ROOT DEVELOPMENT AND ACTIVITY STUDIES IN ASHGOURD

By

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THESIS

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the requirement for the degree

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Department of Agronomy
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that this thesis entitled "Root development and activity studies in ashgourd" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any University or Society.

Roselin Sebastian

Vellanikkara,
Feb., 1987.

ROSELIN SEBASTIAN

CERTIFICATE

Certified that this thesis entitled "Root development and activity studies in ashgourd" is a record of research work done independently by Kum. Roselin Sebastian under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of Kum. Roselin Sebastian, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Root development and activity studies in ashgourd" may be submitted by Kum. Roselin Sebastian in partial fulfilment of the requirement for the degree.

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C O N T E N T S

LIST OF TABLES

14 Effect of methods and stages of fertilizer application on growth and yield.

a) Vine length

b) Leaves/plant

c) Leaf area index

d) Dry matter production

15 Effect of methods and stages of fertilizer application on the content of NPK

a) Content of N

b) Content of P

c) Content of K

16 Effect of methods and stages of fertilizer application on the uptake of NPK

a) Uptake of N

b) Uptake of P

c) Uptake of K

LIST OF APPENDICES

LIST OF FIGURES

Introduction

INTRODUCTION

Roots play an important role in the growth and life of a plant. They are the means by which plants come in contact with soil and absorb major part of the nutrients and water and as such deserve great attention. The complex branching of the root system and their concealment in soil make them perhaps the most inconvenient of the plant organs for detailed study. The behaviour of the root system in soil depends on different soil factors such as texture, nutrients, aeration, moisture content, temperature and the management practices followed.

An understanding of the rooting habits like their density, lateral and vertical spread are useful in determining the exact site of fertilizer application for the effective and economic utilisation of the nutrients and to develop proper cultural practices. Information on the root development with age and distribution pattern will also help in scheduling irrigation. The extent of spread with advancing age will decide the volume of soil from which plants can extract water. Knowledge of the rooting pattern of a crop can also be usefully employed for evaluating suitability of crops for the dry condition. Studies on the root distribution pattern of different crops can provide much information on the potential for multiple cropping and crop sequences.

Ashgourd is one of the vegetable crops cultivated in relatively large areas under irrigated conditions in the state. Traditionally the crop is sown in pits and irrigated by pot watering. Consequent to the increase in labour cost and the larger use of other surface methods of irrigation, it has become necessary to modify the methods of planting and irrigation. With the introduction of methods of irrigation involving larger quantities of water it has become necessary to modify the traditional daily pot watering. Information on the extent of root spréad becomes relevant then in deciding on the quantity of water to be applied and the frequency of applying it. A probable change in the method of planting may also become necessary to suit this modified method of irrigation.

The present study was undertaken with the following objectives:

1. To find out the extent of vertical and horizontal root spread with advancing age.

2. To study the distribution of ^{32}P in different plant parts.

3. To compare the root development pattern in rainfed and irrigated conditions.

4. To arrive at zones of active nutrient absorption.

Review of Literature

REVIEW OF LITERATURE

Root systems are of particular importance to plants as they are responsible for the uptake of water and nutrients besides providing anchorage to the plant. A knowledge of the root density, their lateral and vertical spread are essential for developing scientifically sound and efficient method of fertilizer use in crop gardens. The interest in root studies started early in eighteenth century with studies of Hale in 1727 on the root systems of cultivated crops as reported by Bohm (1979). Increased fertilizer use necessitated a better understanding of the root systems and consequently Weaver (1926) developed scientific excavation techniques. Later the discoveries of profile wall method (Oskamp and Batjer, 1932) and monolith method (Pavlychenko, 1937) led to more studies concerning roots.

The use of radiotracer method in root research by Hall et al. (1953) was an important land mark in the field of root studies. Construction of modern root laboratories and rhizotrones (Kernok and Kucharaki, 1982) facilitated more reliable and easy methods for studying root systems.

1. Root distribution pattern of annual crops

The direct methods of root study provide a clear picture of the entire root system of the plant. Weaver and Burner (1927) reported that cucurbits develop a strong tap root system which may penetrate the soil at a rate of 2.5 cm per day up to a depth of 90 to 120 cm in cucumbers and 180 cm in gourds. Burner (1932) observed rooting depth of groundnut and found that it reached a depth of 90 to 120 cm. Mohammed et al. (1933) studied the root system of three groundnut forms grown under irrigation and found that spreading form had much more vigorous growth of roots than the bunch forms. Doneen and Mac Gillivray (1943) classified vegetable crops into three groups based on the extent of vertical penetration of roots as shallow rooted (upto 90 cm), moderately deep rooted (90 to 120 cm) and deep rooted (more than 120 cm). Cucumber was classified as moderately deep rooted and pumpkin, deep rooted.

Inforzato and Alvarez (1957) described the root system of sugarcane variety Co-290. The roots reached a depth of 2.1 m at six months age and 3.3 m at maturity. Pumphery and Koehler (1958) in their studies on sweet clover found that nearly 90 per cent of the roots were in the top 30 cm. A study on the root development of groundnut by

Seshadri *et al.* (1958) revealed that on 10th day after sowing, when germination was complete the tap roots attained a length of 19 to 30 cm with a rate of development of one to 1.5 cm per day. Maximum root development was attained at flowering and thereafter there was little increase in length of tap root. At final stages tap root had a length of 50 cm to 124 cm with a penetration of 53 cm to 80 cm.

Akiya *et al.* (1960) examined the root systems of different varieties of watermelon and found that clay soil variety had shallow, spreading, slender roots while the volcanic ash type had deep thick roots. Hybrids and polyploids had vigorous root system with deep thick roots with much branching.

Whitaker and Davis (1962) reported that the root system of all the economic cucurbits is extensive but shallow. They had found that lateral root growth often equals or exceeds vine growth and is very rapid and attain a rate of 12.5 cm per day. Vittum and Flocker (1967) pointed out that cucurbits are with medium or deep root system. Pearson and Lund (1968) observed the root growth of cotton and found that under favourable chemical and physical conditions of soils primary roots of cotton elongated 3.3 times as fast as stems and reached a maximum depth of 170 cm. The period of maximum root proliferation coincided with the period immediately following initiation of the reproductive cycle.

Borisov (1969) revealed that early varieties of squashes developed the root system more rapidly and had larger actively absorbing surface than others. Ghildyal and Satyanarayana (1969) found that in the rice variety 'Rupsail' most of the roots were concentrated in the upper seven cm soil layer in sandy, silty and clayey soils. A study of root system of tomato plants by Inforzato _et al_. (1970) revealed that 63 per cent of roots occurred in the upper 10 cm layer of soil. Within 25 days, the root system reached a depth of 1.3 m and 2.5 m within 75 days.

In soybean, Mitchell and Russell (1971) found that dry weight of root was concentrated in the upper portion of soil profile, 90 per cent or more in the upper 7.5 cm early in the season and in the 15 cm during remainder of the season. Studies on the root system of legumes by Naimark (1976) showed that growth rate was high during pre-emergence period. It slowed at flowering and stopped after that. About 70 to 80 per cent of the root mass of all legumes was in plough-depth layer. Loomis and Crandall (1977) indicated that cucumber extracted 50 per cent of the total amount of water consumed from the upper 30 cm of profile, 30 per cent from the next 30 cm and 10 per cent from the next 30 cm. Doorenbos and Kassam (1979) reported that watermelon has deep and extensive root system up to a depth of 1.5 to 2 m. The active root zone from where most of the water is extracted under adequate water supply is limited to the upper one to 1.5 m.

Peterson et al. (1979) studied the rooting depth of Kentucky blue grass as measured by nitrogen absorption. They found that the roots penetrated to 7.5 cm and 15 cm shortly after sodding and developed to 30, 37.5 and 45 cm by the third, fourth and fifth growing seasons. Paz-Vergara et al. (1980) recorded 80 per cent of sugarcane roots within 60 cm of soil layer. Lakshmanan (1985) studied the root system of cucurbits by excavation at the time of harvest and reported that in ashgourd the maximum lateral spread was 285 cm and vertical penetration was up to 71 cm. In oriental pickling melon, lateral spread of 152 cm and depth of 71 cm and in pumkin lateral spread of 235 cm and depth of 85 cm was noted.

2. Root activity patterns of annual crops by radiotracer technique

Tracer methods provide a precise, quick and easy means of evaluating the underground parts. Lott _et al._ (1950) and Hall _et al._ (1953) used tracer techniques to study the development and activity of plant root systems in a natural soil profile. Following these, considerable work has been done to study the root activity of plants.

Burton _et al._ (1954) found that after three months of planting the roots reached a depth of 240 cm in coastal burmuda, 180 cm in pangola, 120 cm in common burmuda and dalhis, and 60 cm in common bahia, pansola bahia, tall fescue and carpet grass. Root activity studies in alfalfa by Lipps _et al._ (1957) revealed three zones of root activity viz. surface root where activity was high in the spring but decreased during the dry weather of summer and fall, zone of minimum activity in unfavourable environment between two and four feet and zone of secondary activity in moist soil above the water table.

Mc Clure and Harvey (1962) used radiophosphorus to measure the rate and extent of root growth of sorghum hybrid throughout the growing season under field condition and found significant root growth after flowering up to fifth week and little growth afterwards. Nakayama and van Bavel (1963) revealed that in sorghum 90 per cent of root activity occurred in top 90 cm and lateral 37.5 cm. Root growth rates were from 1.9 cm to 6 cm per day. Hammes and Bertz (1963) showed that in carrots the roots were active to a depth of 75 cm and showed deeper rooting in a loam than in a muck. In snap bean the root development was rapid between blossom and harvest. In onion and pepper 80 per cent of the activity of absorbing roots was in the upper 20 cm of soil. Using stable strontium and ^{32}P as tracers Fox and Lipps (1964) observed three zones of activity in alfalfa. 1. A zone of high root activity in the surface horizons which received intermittant moisture from rainfall. 2. A zone of moderate activity associated with ample capillary moisture above the water table. 3. Low activity associated with poor chemical environment and or inadequate moisture between zones 1 and 2.

Hallstead and Rennie (1965) evaluated the root distribution of wheat in different soils up to 120 cm depth and found that only eight to 10 per cent of the roots were present in 60 to 120 cm of soil depth. Kafkafi *et al.* (1965) studied the root activity of dryland sorghum and found that 70 per cent of total activity in the plants was taken up from the 25 cm distance and 90 per cent of the total activity from the upper 90 cm of soil. Dejong and Otinkarang (1969) revealed that in irrigated tomato, 75 per cent or more of the active roots were present in a core of 25 cm diameter and 45 cm depth.

Virmani and Dhaliwal (1969) found that the extent of active roots distributed in different soil depth varied at different physiological stages of the corn plant except towards maturity. In the initial stages almost 40 per cent of the total active roots were concentrated in the upper 40 cm of the soil out of which 73 per cent were in the upper 20 cm of soil. About 30 days after germination, 20 to 40 cm soil depth was the important feeding zone. Towards maturity 28 per cent of the total feeding roots were below 40 cm layer.

Bassett _et al._ (1970) reported that under irrigated conditions the tap root of cotton grew at an average rate of 2.5 cm per day to a depth of 153 cm as evidenced by ^{32}P uptake. The lateral roots grew at half this rate. The basic frame work of the root system was established by the onset of flowering and it was found that two-third of the total activity at flowering was confined to the top 30 cm. Root activity at lower depths intensified as the season progressed and resulted in relatively uniform activity down to 183 cm at the end of 130 days. Reddy and Venketeswaralu (1971) studied the active root distribution of two castor varieties by ^{32}P soil injection and found that the high yielding mutant NPH-1 had more extensive root system than the long duration local variety HC-8.

Root development studies of two tall and two semidwarf varieties of wheat by Virmani (1971) using ^{32}P plant injection showed that about 90 to 95 per cent were located within zero to 60 cm of soil. A stuay by Ellis and Burns (1973) using ^{86}Rb in barley revealed that 82 per cent of the living roots of barley grown on sandy loam soil of Oxford were concentrated in the upper 2.5 to 22.5 cm layer of soil. Kumaraswamy *at al.* (1977) studied the root distribution pattern of high yielding rice varieties by ^{32}P plant injection technique at Tamil Nadu Agricultural University, Coimbatore. The results revealed that 80 to 85 per cent of roots were concentrated in the soil zone of 15 cm distance at 24 cm depth and about 55 to 75 per cent of roots were concentrated at 10 cm lateral distance at 16 cm depth. Marykutty (1978) from her study on root activity pattern of wheat grown in loamy soil of Udaipur reported that varieties Heera and 1577 are shallow rooted with 62 to 68 per cent of root system confined to a depth of eight cm while HDM 1593 was deep rooted with only 43.2 per cent of roots in the eight cm soil layer.

Srinivas (1980) determined the root activity and soil feeding zones of five bajra hybrids at Udaipur by ^{32}P placement and found that more than 44 per cent of root activity occurred in the soil layer of zero to 15 cm depth at a lateral distance of zero to 10 cm. Subramanian et al. (1980) studied root distribution pattern of Bengal gram variety Co-1 using ^{32}P soil injection technique at Coimbatore and found that it was a deep, medium spreading type with roots extending to a lateral distance of about 15 cm and to a depth of about 25 cm. Singh et al. (1982) on rice noted that maximum of roots were present at zero to 15 cm and minimum roots at 45 to 60 cm depth while distribution of roots at lateral distance of zero to 15 cm and 15 to 30 cm was not much different.

3. Root distribution as affected by different soil conditions and cultural practices

Rogers (1952) stated that the age and variety of a plant and various soil factors like texture, nutrients, aeration, moisture and temperature influence behaviour of the root system which in turn largely controls the performance of the plant. Soil management practices affect plant growth through its effect on rhizosphere.

3.1 Root distribution under moisture stress

A knowledge on the root system helps to explain the difference in drought resistance exhibited by crop plants (Cook, 1943). Doss *et al.* (1960) reported that relatively dry soil condition induced the plants to develop a more extensive root system. The distribution of roots of spring wheat in the various horizons of highly leached caucasian chernozem was studied by Gubanova (1952) and he found that it varied with soil moisture. According to Burton *et al.* (1954) 93.6 per cent of the roots of drought susceptible carpet grass was confined to the upper 60 cm of soil whereas 65.1 to 65.8 per cent of tolerent coastal and suwannee bermudas occurred in this layer. Gingrich and Russell (1956) reported that an increase in soil moisture tension from one to 12 atmospheres brought about progressively smaller increase in the radicle elongation, fresh weight and dry weight of roots in corn. Komch *et al.* (1957) found that roots developed in wheat with limited moisture supply were finer and had more and longer branches than roots developed under favourable soil moisture conditions. Bloodworth *et al.* (1958) studied the root distribution of some irrigated crops like cotton and tomatoes and found that in irrigated areas large percentage of plant roots occupied the first 30 cm of soil and especially first 15 cm.

Effective rooting depth decreased as soil moisture increased in warm season forage crops (Doss, 1960) and also in cool season forage crops (Bennett and Doss, 1960). Salim et al. (1965) found that the extent of root growth in cereals is highly correlated with soil moisture level, with oats, wheat or barley little penetration of soils occurred at or below permanent wilting point, but penetration by side-oats grama and sandlove grass under the same condition was fairly extensive. Leaf growth continued after root extension has ceased in drought susceptible oat and wheat varieties. Hurd (1968) reported that in the drought resistant wheat variety 'Thatcher', roots penetrated more quickly in dry soils than in wet soil and more quickly than other varieties.

Thorup (1969) studied the root development and phosphorus uptake of tomato plants under controlled soil moisture conditions and found that root growth was very restricted at a soil moisture level well below permanent wilting point attaining a maximum of 20 mm. At the level slightly below permanent wilting point, roots grew to a length of 90 mm with substantial secondary root development. Maximum growth was attained at the moisture level maintained above permanent wilting point and reached a length of 150 mm and showed extensive secondary branching. In all the cases a portion of the root system was supplied with readily available water. At all soil moisture level, phosphorus was taken up by the plants and a significant increase in uptake followed each increase in soil moisture.

Malinina (1971) reported that watermelon growing in arid conditions and showing drought resistance was characterised by a short main root and numerous long side roots. Soni et al. (1972) studied the root distribution pattern of wheat varieties in the medium black soils of Madya Pradesh under irrigated and rainfed conditions and found that there was less proliferation under unirrigated condition. Reicosky et al. (1972) showed that in presence of watertable, water uptake was not related to root distribution and that a small amount of root near the capillary fringe absorbed most of the water in soybean. A study made in eight strains of sorghum by Bhan et al. (1973) revealed that in drought resistant strains root penetrated deeper giving rise to a difference of 14.9 cm at 40 days and six cm at harvest. Also in drought resistant strains the breadth of root system was less. Lupton *et al.* (1974) studied the root system of normal and semidwarf cultivars of winter wheat in England and found that soil and climatic conditions had a major influence on rooting depth and distribution than the genetic make up of the plant.

Mayaki *et al.* (1976) observed that in soybean 67 per cent of the roots were distributed in zero to 15 cm layer and 89 per cent in the zero to 90 cm in irrigated crop and 83 per cent in the zero to 90 cm layer in unirrigated soils. Ellis *et al.* (1977) found that in barley majority of the roots were confined to the top 12.5 cm soil when rainfall was more, but a higher percentage of roots were distributed in deeper soil layers when the rainfall was limiting. In a laboratory study Nour and Weibel (1978) found that drought resistant cultivars of sorghum had heavier root weight, greater root volume and higher root to shoot ratios. The findings of Sivakumar *et al.* (1977) and Boyer *et al.* (1980) indicated that under drought condition the soybean root profile was characterised by a low root density in the dry surface layer and a maximum proliferation in the deeper and wetter soil layer.

Garay and Wilhelm (1983) studied the root characteristics of two soybean isolines under water stress

18

condition in Nebraska and found that at 47 days after planting (full bloom) the roots were concentrated on the surface 15 cm layer especially under the row. Eighty per cent of the roots were within 30 cm. By 78 days after planting and 30 days of drought, root length and density were greatest in 90 to 120 cm layer and 80 per cent of roots were within zero to 120 cm layer. In a laboratory study Jodari-Karimi et al. (1983) found that root production of nonirrigated alfalfa was lower under conditions of high evaporational demand but was higher than irrigated ones in low evaporational demand condition.

3.2 Root development affected by fertilizers

Fox et al. (1953) reported limited root development in grasses on the surface horizon due to low exchangeable calcium and low nitrogen content. Komch et al. (1957) reported that in winter wheat nitrogen fertilization increased root weights and moisture utilization. Duncon and Ohlrogge (1958) found that in young corn growth stimulation of that part of the root system in soil fertilized with both nitrogen and phosphorus was not produced by nitrogen fertilizer alone and to a limited degree by phosphorus fertilizer alone. Haas (1958) revealed that N and P fertilizers increased root weights of three spices of grass and K had no effect.

Holt and Fisher (1960) reported that in coastal burmuda grass root weight per acre increased as application of N fertilizer increased. Hanson and Juska (1961) found that the pattern of root development in kentucky blue grass was modified by N application. Wright (1962) reported that root weight of blue panic grass was significantly increased by fertilisation with N and P. Bolaria and Mann (1964) reported that in wheat the dry weight of roots increased up to heading stage and then decreased at maturity. The decrease in dry weight was less when N or NPK were applied.

Mc Neill and Frey (1969) reported that in oats root and shoot growth responded better to fertilizer application when moisture was adequate than when deficient. Panchal <u>et al</u>. (1972) studied the growth and distribution of roots of two sorghum genotypes under different levels of N and found that the total dry weight of roots increased with increasing levels of N. Warsi and Wright (1973) reported that in sorghum application of N consistently increased the root growth at all stages and the application had more effect in the early stages than in the later stages.

20

From a study Gupta and Dev (1982) revealed that in wheat variety Kalyansona, HD 2009 and WH-157 the application of P reduced root density in upper zero at 40 cm while it increased in WH-147 and S-308. Emanuelsson (1984) reported that in barley the root growth was enhanced by increased calcium concentration.

3.3 Root development affected by soil bulk density

De Roo and Waggoner (1961) reported that root penetration of potatoes was inhibited at plough depth by the hard pan which was induced by normal tillage and shattering of this favoured a deep and well developed root system. Meredith and Patrick (1961) reported that root penetration into soils decreased as soil compaction was increased. Phillips and Kirkhan (1962) found that rate of corn seedling root elongation decreased linearly with increased bulk density. Barber (1971) noted that tillage influenced the root growth of corn and found that when the soil was ploughed annually corn roots developed more extensively to a greater depth.

Singh et al. (1971) found that with increase in bulk density of sod the length and dry weight of soybean roots decreased. Reddy and Dakshinamurthi (1971) revealed

21

that under deep ploughing root penetration was better because of improvement in soil structure. Kar and Varade (1972) reported that in rice maximum root growth occurred at a bulk density of 1.6 g cm^{-3} and the root growth decreased both at low and high bulk densities. Khanna et al. (1974) found that soil compaction reduced both phosphorus uptake and root activity of maize particularly in the lower layers of soil. Shierlaw and Alston (1984) found that in corn the total root length was slightly affected by compaction of soil, but distribution was greatly affected. Compaction decreased root length in that layer but increased in the overlying layer.

Materials and Methods

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MATERIALS AND METHODS

The experiments were conducted at the College of Horticulture, Vellanikkara, which is situated at an altitude of 22.25 m above mean seal level, at a longitude of 76° 10'E and at a latitude of 10° 32' N, which enjoys typical warm humid climate.

The physico-chemical characteristics of the soil of the experimental area are furnished in Table 1. The soil is acidic laterite with medium organic carbon and available phosphorus and potassium. The rainfall data for the experimental period are furnished in Appendix I.

1. Experimental techniques

Present study constituted three field experiments to find out the root development and distribution pattern in rainfed and irrigated ashgourd. The variety of ashgourd used was 'KAU Local' identified promising for cultivation. Experiment No.1 included placement of ^{32}P at varying vertical and lateral distances prior to sowing and studying the ^{32}P activity in leaf tissue. This was conducted on rainfed ashgourd. Experiment No.2 was similar with some

Table 1. Soil characteristics of the experimental area

1. Mechanical composition

Fraction	Per cent composition	Procedure adopted
Coarse sand	23.6	Robinson's international pipette method (Piper, 1950)
Fine sand	28.1	
Silt	21.3	
Clay	29.7	
Textural class	Sandy clay loam	ISSS system

2. Physical constants

Bulk density (g cm^{-3})	1.54	Core method (Blake, 1965a)
Particle density (g cm^{-3})	2.49	Pycnometer method (Blake, 1965b)

3. Chemical properties

Constituent	Content in soil	Rating	Method employed
Organic carbon (%)	0.7	Medium	Walkley and Black Method (Piper, 1950)
Total nitrogen (%)	0.126	Medium	Macro Kjeldhal (Jackson, 1958)

(Contd.)

21

Table 1 (Contd.)

Constituent	Content in soil	Rating	Method employed
Available phosphorus ($kg\ ha^{-1}$) (Bray I extract)	22.4	Medium	Chlorostannous reduced molybdo-phosphoric blue colour method (Jackson, 1958)
Available potassium ($kg\ ha^{-1}$) (Neutral normal ammonium acetate extract)	168	Medium	Flame photometry (Jackson, 1958)
pH (1:2.5 soil water suspension)	5.2	Acidic	Elico pH meter (Jackson, 1958)

modification in the distances of placement of the radio label. It was conducted on irrigated crop during summer season. The third experiment had treatments of application of NPK fertilizers at varying lateral distances at varying periods after germination and growth, yield and uptake of nutrients by the crop were studied. Further experimental details are given below.

1.1 Experiment No.1 Root development in rainfed ashgourd

The rainfed crop of ashgourd was raised from May 1985 to September 1985. The treatments included factorial combinations of four depths (25, 50, 75 and 100 cm) and four lateral distances (50, 100, 150 and 200 cm) of placement of ^{32}P. The combinations were the following.

Notation	Depth (cm)	Lateral distance (cm)
T_1	25	50
T_2	25	100
T_3	25	150
T_4	25	200
T_5	50	50
T_6	50	100
T_7	50	150

26

T_8	50	200
T_9	75	50
T_{10}	75	100
T_{11}	75	150
T_{12}	75	200
T_{13}	100	50
T_{14}	100	100
T_{15}	100	150
T_{16}	100	200

Layout:

Design	:	Randomised block
Replications	:	3
Treatments	:	16
Number of treatment plants	:	48
Spacing	:	3 m x 1.5 m Every 4th plant in alternate row was selected as treatment plant.

1.2 Experiment No.2 Root development in irrigated ashgourd

The irrigated crop was taken from December 1985 to March 1986. Here the treatments included factorial

27)

combinations of three depths (25,50 and 75 cm) and four lateral distances (0, 15, 30 and 60 cm) of placement of labelled P. The treatment combinations were the following.

Notation	Depth (cm)	Lateral distance (cm)
T_1	25	0
T_2	25	15
T_3	25	30
T_4	25	60
T_5	50	0
T_6	50	15
T_7	50	30
T_8	50	60
T_9	75	0
T_{10}	75	15
T_{11}	75	30
T_{12}	75	60

<u>Layout</u>

Design	:	Randomised block
Replications	:	3
Treatments	:	12
Number of treatment plants	:	36
Spacing	:	3m x 1.5 m Every 4th plant in alternate row was selected as treatment plant

1.3 Experiment No.3 Fertilizer experiment

This consisted of four sets of experiments with fertilizers applied at different periods viz. at germination 15, 30 and 45 days after germination and studying the growth, yield and uptake of nitrogen, phosphorus and potassium one month after the application of fertilizers. The experimental plants of the above sets were thus harvested 30, 45, 60 and 75 days after germination. Treatments consisted of a control receiving no fertilizers, and full dose of fertilizers applied in bands at lateral distance of 0-20 cm, 20-40 cm and 40-60 cm.

Notation	Treatments
T_1	No fertilizers
T_2	Full dose of fertilizers applied around the plant in a band at 0-20 cm lateral distance.
T_3	Full dose of fertilizers applied around the plant in a band at 20-40 cm lateral distance.
T_4	Full dose of fertilizers applied around the plant in a band at 40-60 cm lateral distance

Layout

Design	:	Randomised block
Replications	:	5
Treatments	:	4
Number of treatment plants	:	20
Spacing	:	3 m x 1.5 m
		Alternate plants in each row were selected as the treatment plants

2. Cultural practices

2.1 Land preparation

Pit followed by mound method was used for the rainfed crops and pit method for the irrigated crop. Pits of 60 cm diameter and 30 cm depth were made and they were filled with cowdung and top soil.

2.2 Manurial application

Cowdung was applied at the rate of 10 kg per pit as basal dose, at the time of land preparation. Fertilizers were applied at the rate of 63: 22.5: 22.5 of N :P_2O_5: K_2O per plant. Full dose of P_2O_5 and K_2O and 1/2 N were applied as basal dose at the time of planting.

1/4 N at the time of vining and the rest at the time of full blooming in the case of experiments 1 and 2. In the fertilizer experiment, 10 kg cowdung was applied per pit and the fertilizers were applied as a single dose according to the treatments.

2.3 Sowing

Four seeds were sown per pit and after germination, all the plants except one were removed.

2.4 After cultivation

The basins were kept free of weeds. When the plants started to vine, the space in between the basins was mulched with dry twigs and coconut leaves.

2.5 Plant protection

Phorate was applied just before sowing as a prophylatic control measure against the attack of red pupkin beetle. In the rainfed crop leaf spot was noted and Dithane M-45 was applied to control it.

3. Experimental details

3.1 Root development studies

The ^{32}P application was done just before sowing. For the application of ^{32}P the area around the selected pits was cleared and auger holes were taken around the pits in a ring to the desired depth which varied according to the treatment. For the rainfed crop, 16 equidistant holes were taken around each pit. In the irrigated crop, one hole for the vertical placement, eight holes for the 15 cm lateral distance and 16 holes for the 30 cm and 60 cm lateral distances were taken. Holes were made using a 2 cm diameter auger in advance. PVC pipes were placed in the holes and the exposed ends were covered with polythene covers to prevent entry of rain water.

3.1.1 Injection of radioactive ^{32}P in the soil

Injection of the desired volume of ^{32}P into the soil was done with a dispenser fabricated for this purpose (Sankar, 1985).

The radioactivity used per plant was 0.5 mCi in the rainfed crop. A carrier solution of 1000 ppm P (as potassium dihydrogen orthophosphate) was added to the supplied stock which was transferred to the reservoir bottle. This was done to reduce the fixation of ^{32}P by soil through isotope exchange. Finally enough carrier solution was added to give 7.8 μCi of ^{32}P per ml of the solution. Four ml of the active solution was added per hole thus making the total volume of the active solution per plant, 64 ml.

In the irrigated crop the supplied stock was diluted to give 16 μCi of ^{32}P per ml of the solution. The plants with only one hole (vertical application) received 8 ml of the active solution. Other plants received four ml of the active solution per hole thus giving an activity of 0.5 mCi per plant with eight holes and one mCi for those with 16 holes. Immediately after injection, the PVC tubes were washed with a jet of distilled water (about 5 ml) to drain off any radioactivity sticking to the tubes. The PVC tubes were removed carefully and the holes were filled with soil.

3.1.2 Analysis of leaf samples

Last fully opened leaf was used for analysis. First sample was taken 15 days after germination and subsequent samples were taken at 15 days intervals. For analysis the entire leaf was dried in an oven at 70°C for 48 hr. Dried samples were made into small pieces and digested in diacid mixture containing equal proportions of nitric acid and perchloric acid. Radio assay of ^{32}P was done in a liquid scintillation counter employing Cerenkov counting technique (Wahid et al., 1985). The count rates were corrected for decay to a common reference time after background correction.

3.2 Root excavation

The untreated healthy plants were used for taking root observations at biweekly intervals. The rooting patterns were studied by the excavation method (Bohm, 1979). The primary roots were traced out by removing the surface layer of soil beginning at the stem. The entire root system was dug out. The maximum lateral spread and depth upto which the roots were found and the number of roots/tap root were noted. The dry weight of the roots was determined after careful washing to remove the adhering soil, by drying in an oven at 70°C for 48 hr.

3.3 Distribution of ^{32}P in different plant parts

In order to study the distribution of the absorbed ^{32}P in different plant parts, the three plants which received radiolabel at 50 cm depth and 15 cm lateral distance in the irrigated condition were taken. All these plants had recorded presence of ^{32}P from 30 days after germination. Two months after germination, the plants were removed from the base and cut into six portions along the length of main vine. From each portion, leaves, petioles, stem and fruits and flowers were separated. The tendrils were collected together. After separation, they were dried at 70°C for 48 hr and the dry weights were recorded. Radioassay of the samples was done as described earlier. The counts after background and decay corrections were used for finding out the relative distribution of ^{32}P in the various plant parts.

3.4 Fertilizer experiment

Fertilizers (NPK) were applied 0, 15, 30 and 45 days after germination in the four sets of experiments as bands at four lateral distances of 0.20 cm, 20-40 cm and 40-60 cm in each set. One month after the application of fertilizers, the plants were cut at the base and the fresh weight was recorded. Harvesting of the first set which received fertilizers at the time of germination was done 30 days after germination, the second set which received fertilisers 15 days after germination was harvested 45 days after germination, the third set which received fertilizers 30 days after germination was harvested on 60th day after germination and the fourth set which received fertilizers 45 days after germination was harvested 75 days after germination. After harvesting, the plants were dried in an oven at 70°C and the dry matter production was recorded. The fourth set was separated into fruits and vegetative parts and the others were dried as whole plants.

35

Chemical analyses

Nitrogen, phosphorus and potassium contents of plants

The plant samples were ground and the nitrogen content was determined using micro kjeldhal method (Jackson, 1958). The phosphorus and potassium contents were determined after diacid digestion of the sample with equal proportion of nitric and perchloric acids. Phosphorus was determined colorimetrically by Vanadomolybdophosphoric yellow colour method (Jackson, 1958). Potassium content was determined using flame photometer (Jackson, 1958).

Uptake of nitrogen, phosphorus and potassium

Total uptake of nitrogen, phosphorus and potassium by the plants was calculated from the nutrient contents and dry weights of the plants and expressed as g plant^{-1}.

3.5 Biometric observations

3.5.1 Vine length

Length of the main vine of all the experimental plants were recorded at the time of sampling. Length of the vine was measured from the base to the growing tip.

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3.5.2 Leaves/plant

Total number of leaves from all the experimental plants was recorded at the time of sampling.

3.5.3 Leaf area index

Since destructive sampling was not possible, on the spot measurement of leaf area was done. For the determination of leaf area, the regression equation developed by Lakshmanan (1985) was usea. For this the average leaf diameter of 20 leaves from each plant was measured randomly at different points along the vine length. This was then converted to average leaf area values using the equation

$$A = 25.45\,x - 230.2 \qquad A = \text{Leaf area in cm}^2$$
$$x = \text{leaf diameter in cm}$$

The average leaf area values were multiplied by the total number of leaves, to get the total leaf area which when divided by the land area to give the leaf area index (Watson, 1947). The leaf area index values were worked on all sampling days.

3.5.4 Dry matter production

Dry matter production was recorded at the time of harvest. The plants were dried in an oven at 70°C for

48 hr and the dry weight was expressed as g plant^{-1}.

3.5.5 Yield and harvest index

The fruits were harvested from all the experimental plants. The fresh weight of the fruits was recorded and the yield/plant was calculated. From the total dry matter production and dry weight of fruits harvest index was calculated using the formula

$$\text{Harvest index} = \frac{\text{Y econ}}{\text{Y biol.}}$$

where,

Y econ = dry weight of fruits

Y biol = total dry weight of plants (excluding roots)

3.6 Statistical analysis

The data of the fertilizer experiment was subjected to statistical analysis by using analysis of variance technique (Panse and Sukhatme, 1967).

Results

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RESULTS

1. Root development in rainfed ashgourd

The experiment was conducted with 16 treatments being the combinations of four lateral distances and four depths with three replications. Considerable temporal difference in the development and extension of roots were observed among the replicates of the same treatment. Very rarely the root development in more than one plant of the three replicates exhibited more or less similar trend. The detection of radioactivity in the leaves of a plant under a given treatment is considered here as an indication of the root extension to that particular soil zone. Similarly the extent of absorption of ^{32}P varied among the three plants of the same treatment. In as much as these trends reflect the inherent variability among the plants in root development, the data generated from this experiment can only be discussed plant wise as the discussion based on mean values will not bring out the true picture of root development. The mean values for the three replicates will under estimate ^{32}P absorption as in most cases, only one plant of the three replicates in a treatment had absorbed the applied label at any samping interval.

9

1.1 Root development at 30 days after germination

At this stage (Table 2 and Fig.1) root development was seen up to a lateral distance of 150 cm and to a depth of 50 cm.

Among the three plants which received ^{32}P at a depth of 25 cm at 50 cm lateral distance, the radioactivity could be detected in two plants (26.2 cpm g^{-1} of leaf). Among the plants receiving ^{32}P at the same depth but 100 cm away from the plant, only one plant was found to absorb the applied radioactivity (46.8 cpm g^{-1} of leaf). None of the plants absorbed radioactivity from the same depth at lateral distances of 150 cm and 200 cm, indicating that the roots did not develop to that distances at this stage.

In the case of 50 cm depth, two plants were found to absorb ^{32}P from 50 cm lateral distance (34 cpm g^{-1} of leaf) and all the three plants from 150 cm lateral distance (22.4 cpm g^{-1} of leaf). However none of the plants was found to absorb ^{32}P from the same depth at 100 cm and 200 cm lateral distances.

None of the plants was found to derive radioactivity from 75 and 100 cm depth, indicating that the roots did not reach these depths at this stage.

40

Table 2. Recovery of ^{32}P in the leaves of rainfed ashgourd ($cpm\ g^{-1}$) 30 days after germination

Depth (cm)	Plant number	Lateral distance (cm)			
		50	100	150	200
25	1	-	-	-	-
	2	28.44	46.75	-	-
	3	24.00	-	-	-
50	1	-	-	21.18	-
	2	25.71	-	27.69	-
	3	42.35	-	18.37	-
75	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-
100	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-

1.2 Root development at 45 days after germination

The root development was seen up to a lateral distance of 200 cm and to a depth of 100 cm at this stage (Table 3 and Fig.1).

All the three plants which received ^{32}P at 25 cm depth at a lateral distance of 50 cm were found to absorb the activity (65.4 cpm g^{-1} of leaf). In the case of plants receiving ^{32}P at a lateral distance of 100 cm at the same depth, radioactivity was detected within the leaves of two plants (61.3 cpm g^{-1} of leaf). In the case of plants which received ^{32}P at 25 cm depth, all the three plants were found to absorb ^{32}P (26.4 cpm g^{-1} of leaf) from a lateral distance of 150 cm and two plants were found to absorb ^{32}P from a lateral distance of 200 cm (46.2 cpm g^{-1} of leaf).

All the three plants which received ^{32}P at a depth of 50 cm and at a lateral distance of 50 cm showed absorption of the radioactivity (161 cpm g^{-1} of leaf). At the same depth and a lateral distance of 100 cm two plants showed absorption of the radio label (58.8 cpm g^{-1} of leaf). In the case of plants receiving ^{32}P at a lateral distance

Table 3. Recovery of ^{32}P in the leaves of rainfed ashgourd (cpm g^{-1}) 45 days after germination

Depth (cm)	Plant Number	Lateral distance (cm)			
		50	100	150	200
	1	129.06	85.99	24.23	33.94
25	2	35.10	36.62	23.27	58.39
	3	31.85	-	31.73	-
	1	42.06	-	65.28	42.36
50	2	355.67	54.83	27.63	-
	3	85.46	62.76	-	50.43
	1	56.16	69.39	94.13	114.93
75	2	-	53.77	35.55	-
	3	56.16	31.15	32.39	-
	1	69.57	72.41	-	-
100	2	-	-	-	-
	3	48.40	-	-	-

93

of 150 cm at a depth of 50 cm radioactivity was detected in the leaves of two plants (22.6 cpm g^{-1} of leaf). From a lateral distance of 200 cm, two plants showed absorption of the radioactivity at the same depth (46.4 cpm g^{-1} of leaf).

In the case of plants receiving ^{32}P at a depth of 75 cm at a lateral distance of 50 cm, two plants showed absorption of the radioactivity (56.2 cpm g^{-1} of leaf). On the other hand all the plants which received ^{32}P at 100 cm and 150 cm lateral distances at the same depth were found to take up the radioactivity. Among the plants which received ^{32}P at a depth of 75 cm at a lateral distance of 200 cm, only one plant was found to absorb ^{32}P (114.9 cpm g^{-1} of leaf).

Among the plants which received ^{32}P at a depth of 100 cm, two plants were found to absorb ^{32}P from a lateral distance of 50 cm (59 cpm g^{-1} of leaf) and one plant was found to take up ^{32}P from 100 cm lateral distance (72.4 cpm g^{-1} of leaf). From the same depth at lateral distances of 150 cm and 200 cm none of the plants was found to absorb ^{32}P.

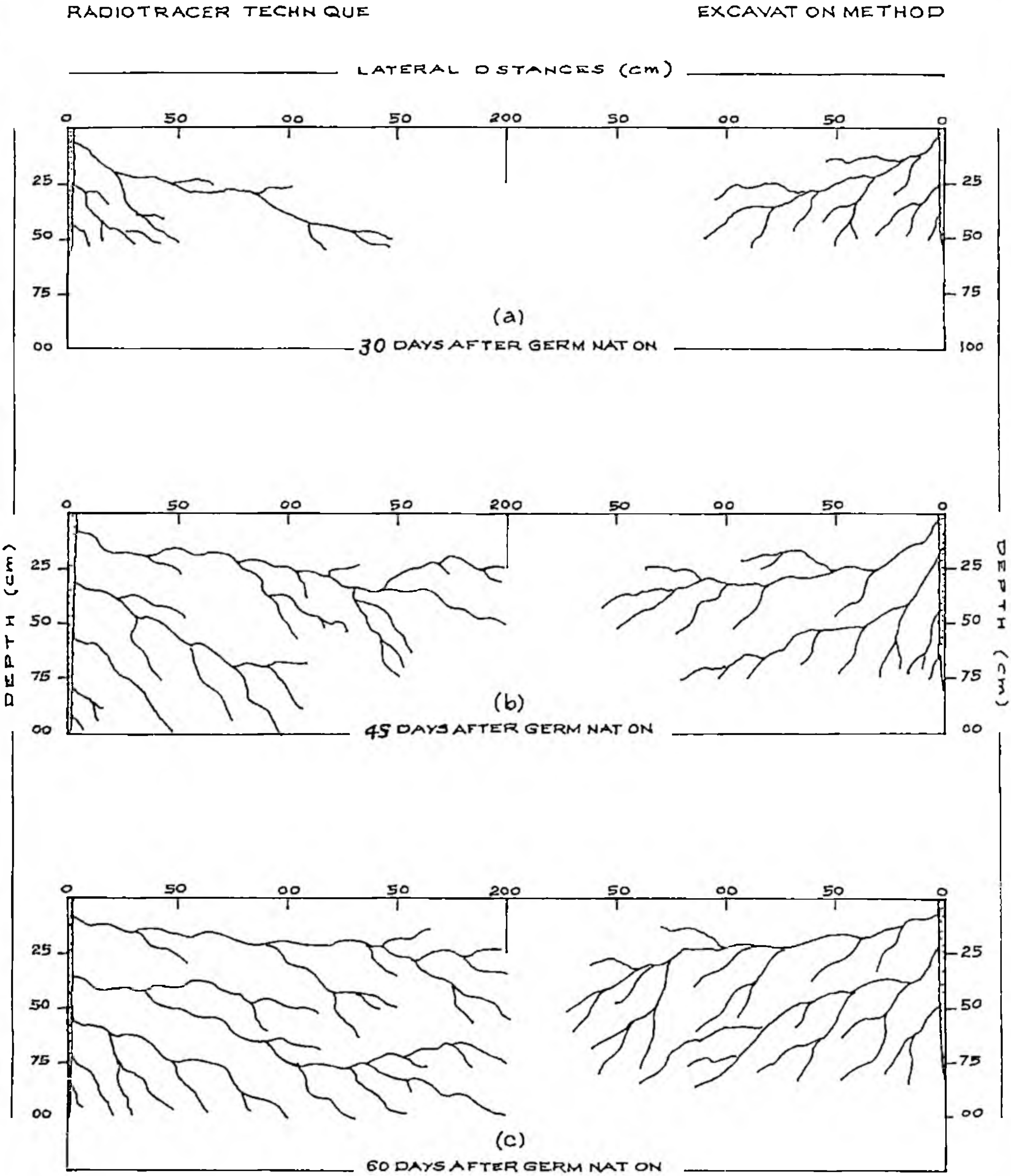

FIG 1 SCHEMATIC REPRESENTATION OF ROOT DEVELOPMENT IN RA NFED ASHGOURD

1.3 Root development at 60 days after germination

At this stage (Table 4 and Fig.1) the root development was seen up to a lateral distance of 200 cm and a depth of 100 cm.

Plants which received ^{32}P at a depth of 25 cm at a radial distance of 50 cm showed absorption of ^{32}P (179.3 cpm g^{-1} of leaf). Two plants which also received radio-phosphorus at the same depth, but 100 cm away from the plant were also found to absorb the radiolabel (65 cpm g^{-1} of leaf). In the case of plants receiving ^{32}P at a lateral distance of 150 cm at the same depth radioactivity was detected in the leaves of only one plant (80 cpm g^{-1} of leaf). On the other hand all the three plants which received ^{32}P at a distance of 200 cm were found to take up the radioactivity (88.5 cpm g^{-1} of leaf).

Among the plants receiving ^{32}P at 50 cm depth, all the three were found to absorb ^{32}P from a radial distance of 50 cm (163.9 cpm g^{-1} of leaf) and one plant was found to absorb ^{32}P from a radial distance of 100 cm (242.6 cpm g^{-1} of leaf). In the case of plants receiving ^{32}P at a lateral distance of 180 cm at the same depth radioactivity was detected in the leaves of only one plant (55.3 cpm g^{-1}

Table 4. Recovery of ^{32}P in the leaves of rainfed ashgourd (cpm g^{-1}) 60 days after germination

Depth (cm)	Plant Number	Lateral distance (cm)			
		50	100	150	200
	1	265.71	48.95	80.17	74.13
25	2	95.47	81.06	-	80.48
	3	176.70	-	-	110.97
	1	48.52	-	-	136.76
50	2	386.19	242.61	95.25	-
	3	57.01	-	-	70.29
	1	45.27	100.36	120.90	119.04
75	2	-	57.64	70.85	-
	3	261.05	68.61	75.00	-
	1	123.67	70.19	-	48.44
100	2	200.65	-	81.60	53.65
	3	-	-	-	-

of leaf). Two plants showed absorption of the applied radio label from 50 cm depth and 200 cm lateral distance (103.5 cpm g^{-1} of leaf).

Among the plants receiving ^{32}P at a depth of 75 cm at a radial distance of 50 cm radioactivity was detected in the leaves of two plants (153.2 cpm g^{-1} of leaf). All the three plants which received ^{32}P at the same depth and a lateral distance of 100 cm showed absorption of the radioactivity (75.5 cpm g^{-1} of leaf). In the case of plants receiving radio-phosphorus at a lateral distance of 150 cm at a depth of 75 cm, radioactivity was detected in all the three plants (88.9 cpm g^{-1} of leaf). Only one plant showed absorption of ^{32}P from a depth of 75 cm at a lateral distance of 200 cm (119 cpm g^{-1} of leaf).

Among the plants receiving ^{32}P at 100 cm depth, two plants showed absorption of radiolabel from 50 cm radial distance (162 cpm g^{-1} of leaf) and one plant showed absorption of the applied activity from 100 cm radial distance (70.2 cpm g^{-1} of leaf). From the same depth, one plant absorbed radioactivity from 150 cm lateral distance (81.6 cpm g^{-1} of leaf) and two plants absorbed radioactivity from 200 cm lateral distance (51.1 cpm g^{-1} of leaf).

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2. Root development in irrigated ashgourd

This experiment was conducted with 12 treatments being the combinations of four lateral distances viz. 0, 15, 30 and 60 cm and three depths viz., 25, 50 and 75 cm with three replications. The plants which received ^{32}P vertically below, received 8 ml of the ^{32}P solution containing activity of 16 $\mu Ci\ ml^{-1}$. The total radioactivity applied to the plant was therefore, 0.128 mCi. For the plants which received ^{32}P at 15 cm lateral distance, the total volume per plant was 32 ml and the total activity per plant was 0.5 mCi. For the plants which received ^{32}P at 30 cm and 60 cm lateral distances, the volume of the solution per plant was 64 ml and the activity per plant was 1 mCi.

2.1 Root development at 15 days after germination

At this stage (Table 5 and Fig.2) root development was seen up to a depth of 50 cm and a lateral distance of 30 cm.

Among the plants which received ^{32}P at a depth of 25 cm, two plants were found to absorb ^{32}P from zero cm lateraldistance (3416.7 cpm g^{-1} of leaf) and all the three plants were found to absorb ^{32}P from 15 cm lateral distance

42

Table 5. Recovery of ^{32}P in the leaves of irrigated ashgourd (cpm g^{-1}) 15 days after germination

Depth (cm)	Plant number	Lateral distance (cm)			
		0	15	30	60
25	1	-	22506.3	164.5	-
	2	6126.2	3626.7	1209.3	-
	3	707.1	19245.9	-	-
50	1	85.5	-	-	-
	2	-	-	-	-
	3	-	145.6	-	-
75	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-

(15126.5 cpm g^{-1} of leaf). In the case of plants receiving ^{32}P at a lateral distance of 30 cm at the same depth, radioactivity was detected in the leaves of two plants (687 cpm g^{-1} of leaf). None of the plants was found to absorb ^{32}P from a radial distance of 60 cm at a depth of 25 cm.

Among the plants which received ^{32}P at a depth of 50 cm, one plant each was found to absorb ^{32}P from 0 and 15 cm lateral distances. From 30 and 60 cm lateral distances at the same depth, none of the plants was found to absorb the radioactivity.

None of the plants was found to absorb ^{32}P from 0, 15, 30 and 60 cm lateral distances at 75 cm depth.

2.2 Root development at 30 days after germination

At this stage (Table 6 and Fig.2) root development was seen up to 60 cm lateral distance and 75 cm depth.

Two plants which received ^{32}P at 25 cm depth at zero cm lateral distance were found to take up the radioactivity (6142.9 cpm g^{-1} of leaf). All the plants which received ^{32}P at 15 and 30 cm lateral distances at the same depth were found to absorb ^{32}P (22904.4 and

Table 6. Recovery of ^{32}P in the leaves of irrigated ashgourd ($cpm\ g^{-1}$) 30 days after germination

Depth (cm)	Plant number	Lateral distance (cm)			
		0	15	30	60
	1	-	21573.2	537.1	-
25	2	3600.1	29189.6	844.0	-
	3	8685.6	17950.2	173.6	90.75
	1	-	11668.9	-	-
50	2	-	16144.8	-	-
	3	110.6	2530.9	-	-
	1	-	-	-	-
75	2	-	-	-	-
	3	4491.9	11098.9	-	-

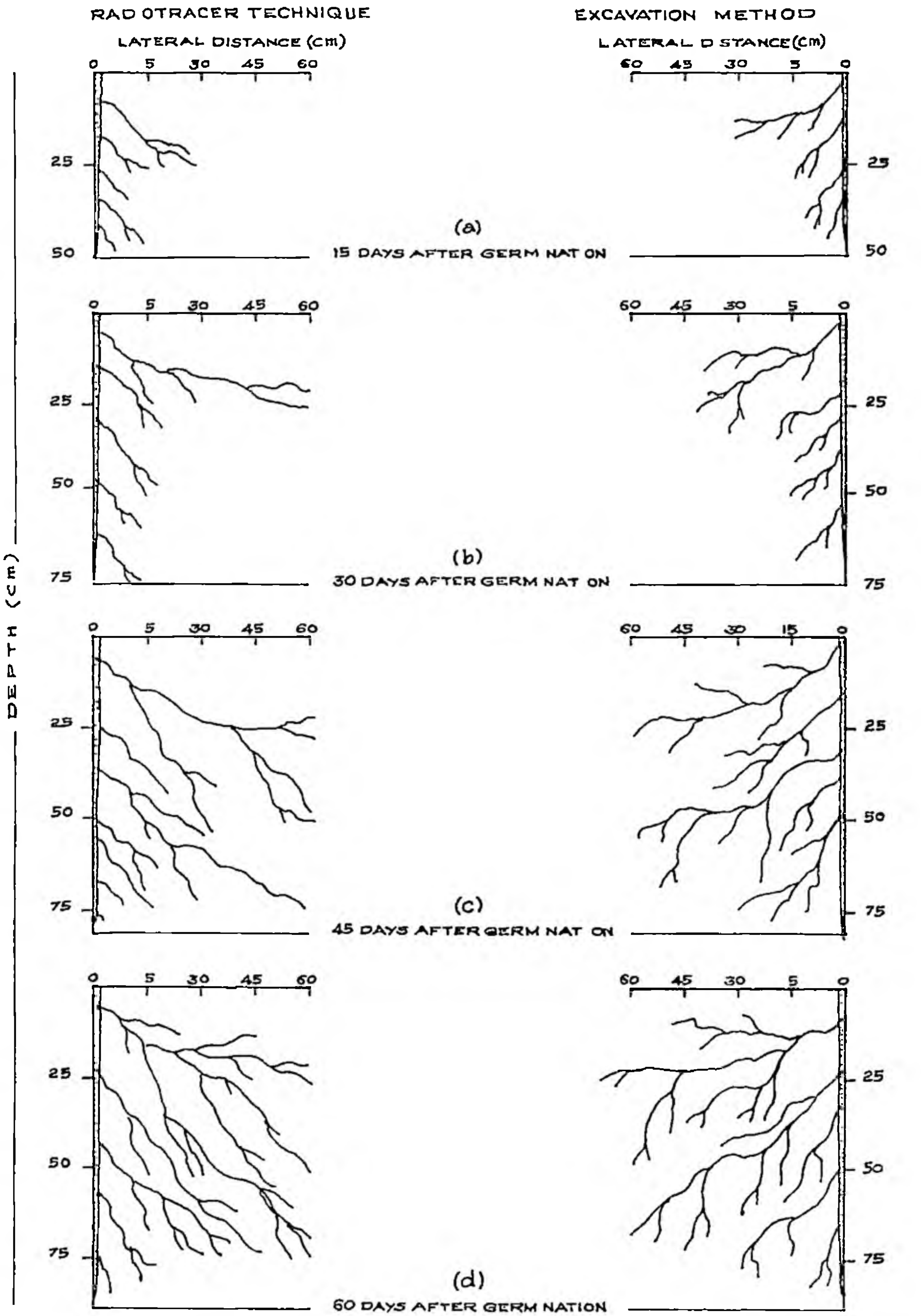

FIG 2 SCHEMATIC REPRESENTATION OF ROOT DEVELOPMENT IN IRRIGATED ASHGOURD

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518.2 cpm g^{-1} of leaf respectively). Only one plant showed absorption of ^{32}P from 60 cm lateral distance at 25 cm depth (90.8 cpm g^{-1} of leaf).

Among the plants receiving ^{32}P at 50 cm depth, one plant was found to take up the radioactivity from zero cm lateral distance (110.6 cpm g^{-1} of leaf) and all the three plants from 15 cm lateral distance (10114.9 cpm g^{-1} of leaf). None of the plants was found to take up ^{32}P from 30 and 60 cm lateral distances at the same depth.

In the case of plants receiving ^{32}P at 75 cm depth, radioactivity was detected in the leaves of one plant, each from 0 and 15 cm radial distances. None of the plants was found to take up ^{32}P from 30 and 60 cm lateral distances at the same depth.

2.3 Root development at 45 days after germination

At this stage (Table 7 and Fig.2) root development was seen up to 75 cm depth and 60 cm lateral distance.

Two plants were found to take up ^{32}P from 25 cm depth at zero cm lateral distance. All three plants which received ^{32}P at the same depth and at 15 cm radial distance were found to absorb radioactivity. Similarly

Table 7. Recovery of ^{32}P in the leaves of irrigated ashgourd (cpm g^{-1}) 45 days after germination

Depth (cm)	Plant Number	Lateral distance (cm)			
		0	15	30	60
	1	-	12943.8	876.4	829.8
25	2	3350.0	13661.8	3918.7	193.7
	3	6507.9	11981.7	2234.9	221.1
	1	70.0	7472.4	277.5	93.7
50	2	95.3	9774.2	1446.6	1092.4
	3	150.5	5499.2	8339.2	288.1
	1	58.1	-	112.5	-
75	2	576.8	1649.5	-	162.0
	3	59.9	7063.1	1671.7	340.2

52

all the plants absorbed ^{32}P from 30 and 60 cm lateral distances.

All the three plants which received ^{32}P at 50 cm depth at zero cm lateral distance were found to take up the radioactivity (105.3 cpm g^{-1} of leaf). From the same depth all the plants were found to take up the radio-label at 15, 30 and 60 cm radial distances.

Plants which received ^{32}P at 75 cm depth at zero cm lateral distance were found to take up the radio label. In the case of plants which received ^{32}P at the same depth, two plants each were found to take up the radioactivity from 15, 30 and 60 cm lateral distances.

2.4 Root development at 60 days after germination

At this stage (Table 8 and Fig.2) root development was seen up to 75 cm depth and 60 cm lateral distance.

Two plants which received ^{32}P at 25 cm depth and zero cm lateral distance absorbed the radio-label (1962.7 cpm g^{-1} of leaf). All the plants which received ^{32}P at 25 cm depth at 15, 30 and 60 cm radial distances showed absorption of radio-label.

56

Table 8. Recovery of ^{32}P in the leaves of irrigated ashgourd (cpm g^{-1}) 60 days after germination

Depth (cm)	Plant Number	Lateral distance (cm)			
		0	15	30	60
	1	-	11620.6	1293.2	1647.6
25	2	1980.6	50045.0	2040.0	390.8
	3	1944.7	13214.4	3069.3	534.3
	1	206.8	2374.6	434.4	410.8
50	2	153.2	11190.0	802.3	1792.6
	3	724.5	4617.9	4686.1	261.3
	1	-	184.1	183.8	-
75	2	296.6	985.2	245.1	72.9
	3	3354.0	3655.5	2632.3	1808.2

55

As in the above treatments, all the plants which received ^{32}P at 0, 15, 30 and 60 cm radial distances at 50 cm depth were found to take up ^{32}P.

In the case of plants receiving ^{32}P at 75 cm depth, radioactivity was detected only in two plants at zero cm lateral distance (1825.3 cpm g^{-1} of leaf). All plants which received ^{32}P at 15 and 30 cm lateral distances at the same depth were found to take the radioactivity. However only two plants absorbed ^{32}P from 75 cm depth 60 cm away from the plant (940.5 cpm g^{-1} of leaf).

3. Root excavation studies

3.1 Roots/tap root

The data on number of roots/tap root are presented in Table 9. The number primary roots per tap root increased rapidly up to beginning of flowering (45 days after germination) in both rainfed and irrigated condition (Fig.4). The number of roots per tap root was less under rainfed condition the maximum being 14, while it was 18 under irrigated condition.

3.2 Lateral spread of roots

The data presented in Table 9 and Fig.4 indicated that as growth advanced, the lateral spread of the roots

Table 9. Root development under rainfed and irrigated conditions

Days after germination	Primary roots/ tap root		Lateral distance (cm)		Depth of penetration (cm)		Dry weight (g)	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainred	Irrigated	Rainfed	Irrigated
15	7	12	35.8	32.4	33.6	47.2	0.12	0.20
30	9	14	108.6	57.5	54.3	67.6	1.05	1.58
45	12	17	162.4	62.0	82.5	83.4	6.35	8.95
60	13	17	175.0	69.5	84.8	86.0	15.40	18.37
75	13	16	179.5	69.0	86.0	87.5	24.50	28.60
98	14	18	188.2	74.5	87.0	90.3	29.08	34.70

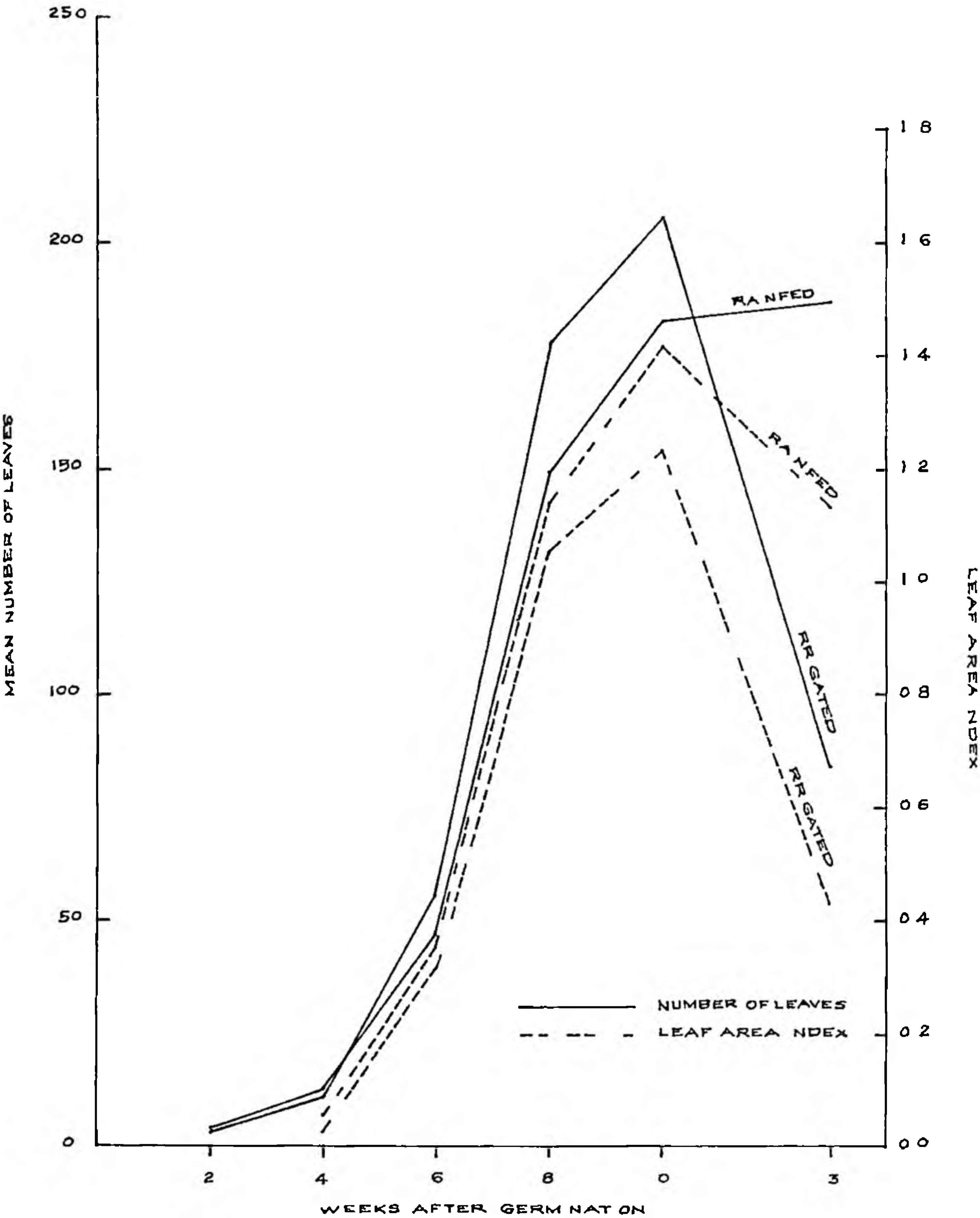

FIG 3 MEAN NUMBER OF LEAVES AND LEAF AREA NDEX AT WEEKLY NTERVALS

increased up to flowering and thereafter the increase in lateral spread was not much. There was difference between rainfed and irrigated ashgourd in the lateral extension of roots, it being more in the rainfed condition. The lateral extension was seen up to 188 cm in rainfed condition, while it was only 75 cm in the irrigated condition.

3.3 Depth of penetration of roots

As growth advanced, the depth of penetration of roots increased as shown by the data presented in Table 9 and Fig.5. There was rapid penetration by the roots in both conditions up to flowering and thereafter, the increase in depth of penetration was not rapid. There was not much difference between rainfed and irrigated crops in the depth of penetration of roots, the maximum depths recorded being 87 and 90 cm respectively.

3.4 Dry weight of roots

The data relating to dry weight of roots are given in Table 9. The dry weight of roots increased as growth advanced and the maximum was attained at harvest in both the cases (Fig.6). The dry weight was more in irrigated crop at all stages.

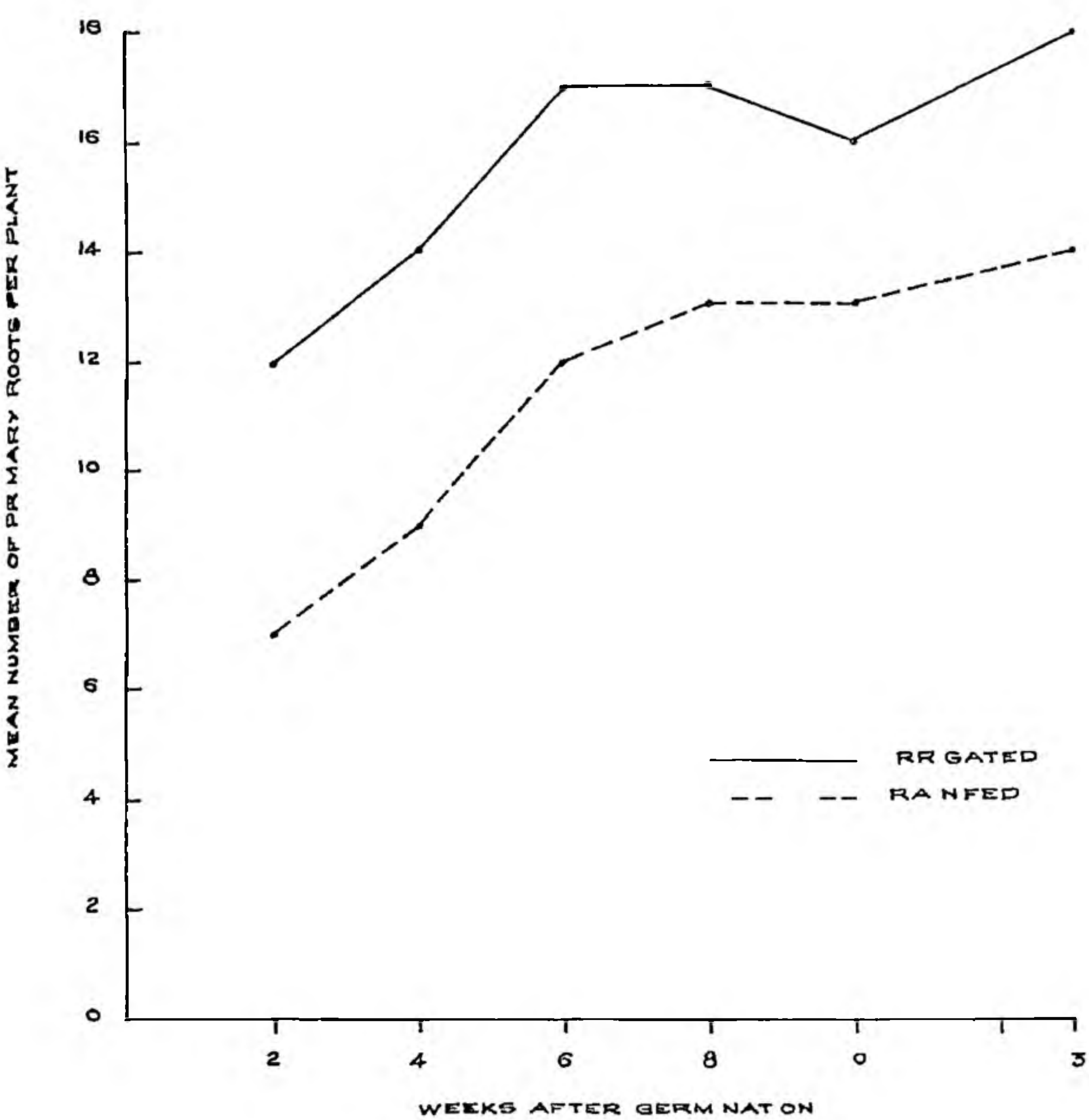

FIG 4 NUMBER OF PRIMARY ROOTS PER PLANT AT WEEKLY INTERVALS

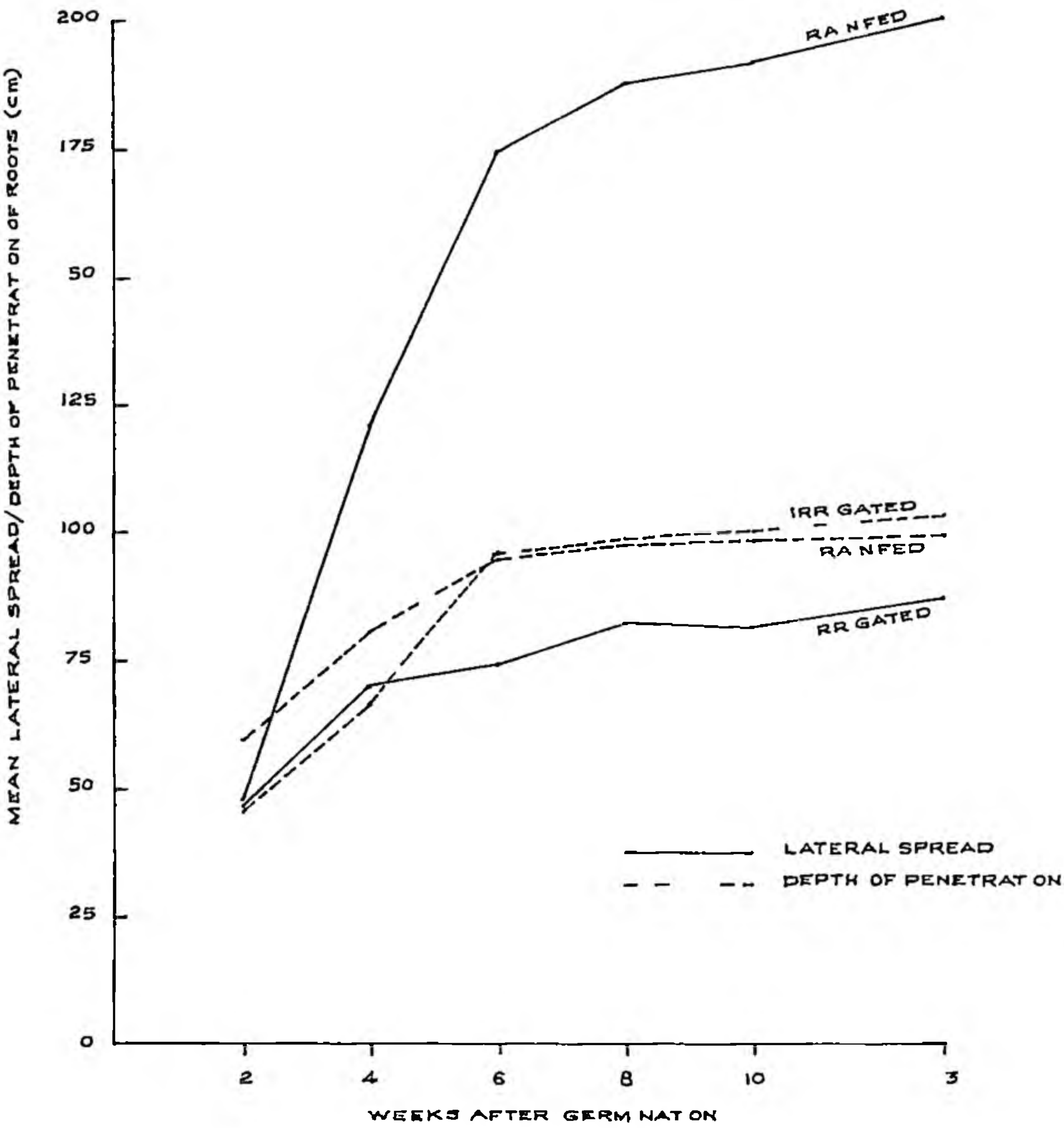

FIG 5 MEAN LATERAL SPREAD AND DEPTH OF PENETRATION OF PRIMARY ROOTS AT WEEKLY INTERVALS (EXCAVATION STUDY)

4. Distribution of ^{32}P in different plant parts

The data relating to the distribution of ^{32}P in different plant parts are given in Table 10. The data indicated that accumulation of absorbed ^{32}P was maximum in fruits followed by stem, petioles, tendrils and leaves. Nevertheless when total dry matter content of each part was taken into consideration, it was seen that the leaves accounted 31.1 per cent of the total absorbed ^{32}P followed by stem, fruit, petioles and tendrils (Fig.9) comparing the different portions (Table 11) it has been found that in general the ^{32}P content was more in the growing tip and it decreased towards the base or the plant.

5. Biometric observations of rainfed and irrigated ashgourd

5.1 Vine length

The data relating to the length of main vine are given in Table 12 and Fig.8. The length of the main vine increased as the growth of the crop proceeded in both the conditions. The length of the main vine was more in the rainfed condition at all stages with a maximum of 1039 cm, while for the irrigated crop it was only 653 cm.

Table 10. Distribution of absorbed ^{32}P in ashgourd

Plant part	cpm g^{-1}	Dry matter (g)	Total radio-activity recovered (cpm)	Relative distri-bution (%)
Leaf	2715.5	203.7	553032.8	31.08
Petiole	3002.6	81.9	245895.0	14.32
Stem	3551.8	145.8	517788.7	29.10
Fruit	4498.2	86.2	387863.9	21.80
Tendril	2922.3	25.7	74968.3	4.21

60

Table 11. ^{32}P content in different sections of the main vine

* Portion of the vine starting from the upper most	^{32}P content (cpm)			
	Leaf	Petiole	Stem	Fruit
1	3749.6	3804.2	4425.4	5401.7
2	3265.7	3507.5	4208.7	4508.0
3	2553.8	3056.0	3791.2	4411.2
4	2350.4	2614.57	3450.2	4315.2
5	2387.3	2852.9	3191.9	3854.7
6	1986.4	2180.4	2243.5	-

*Indicates the portion of the plant which was devided into six equal parts. The numbers are given from the top one-sixth of the plant (youngest) to the last one-sixth (oldest) portion of the plant.

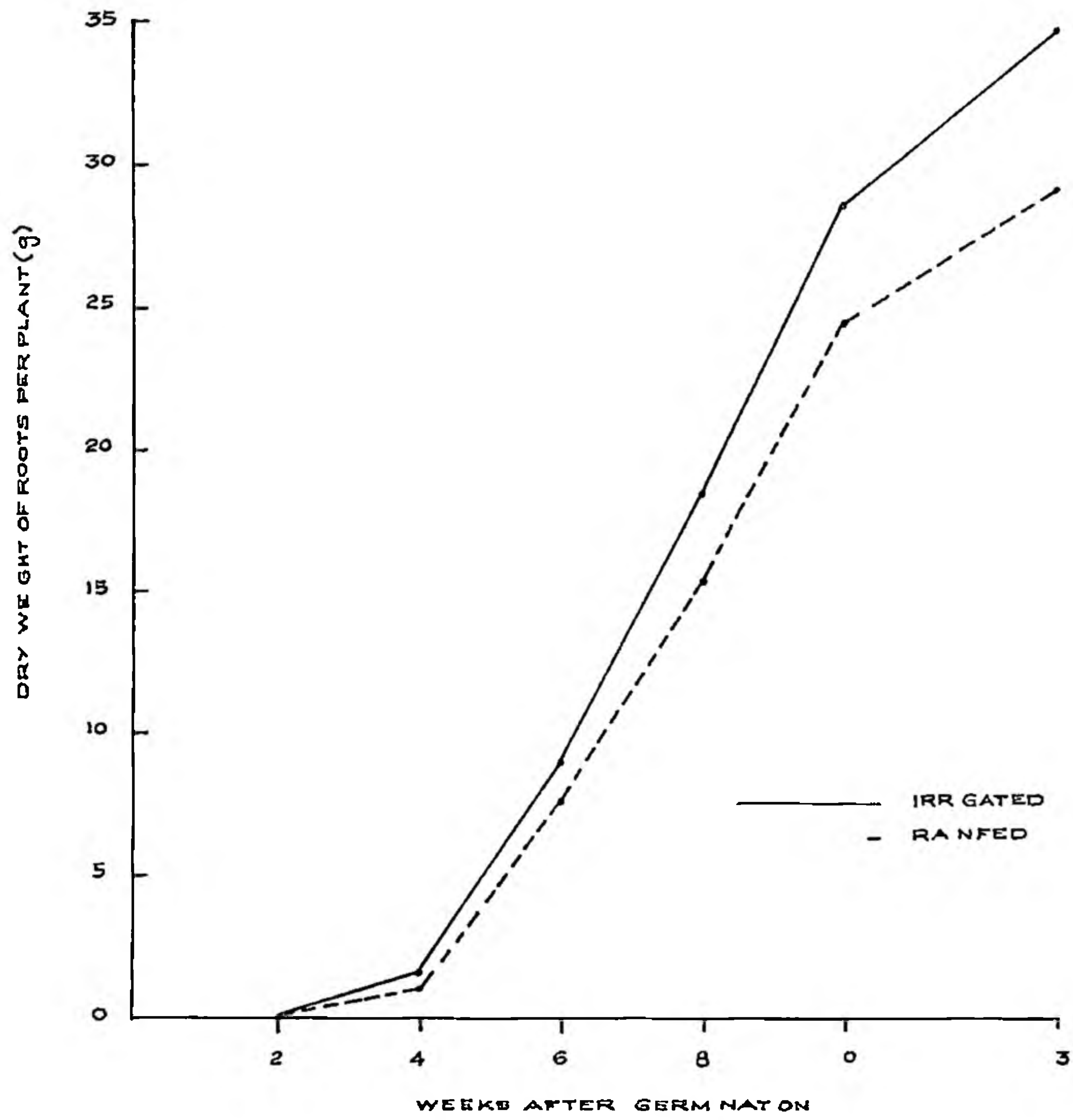

FIG 5 DRY WEIGHT OF ROOTS AT WEEKLY INTERVALS

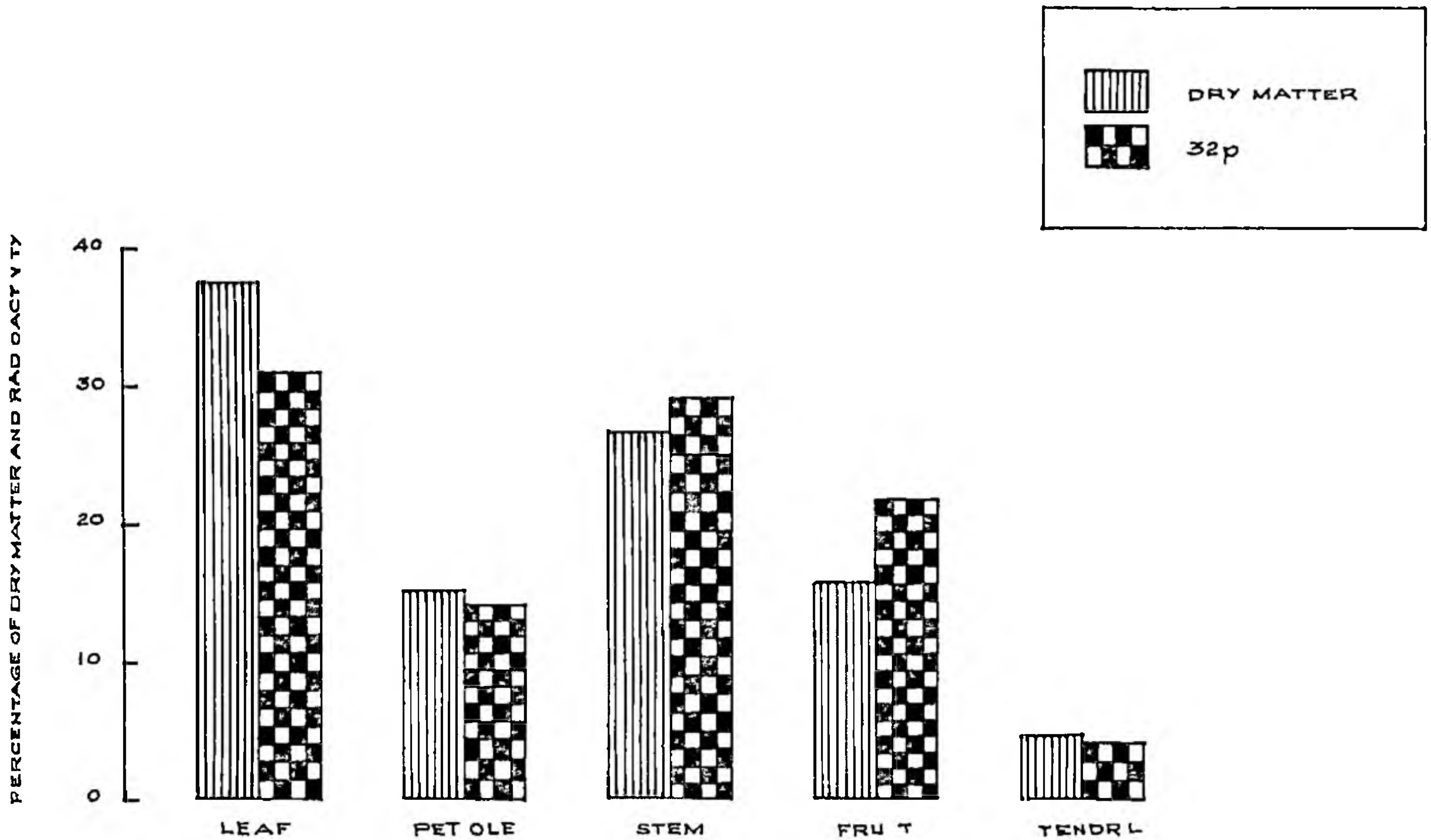

FIG 7 RELATIVE DRY MATTER ACCUMULATION AND 32p DISTRIBUTION N PLANT PARTS

61

5.2 Leaves/plant

The number of leaves increased till harvest in the rainfed crop (Table 12 and Fig.8), while for the irrigated crop the number of leaves attained a maximum at 75 days after germination and thereafter there was a drastic decrease. Up to 30 days after germination, the number of leaves was more in the rainfed crop and after that in the irrigated crop excepting at the last stage, 98 days after germination.

5.3 Leaf area index

The data relating to leaf area index of both the crops are given in Table 12 and Fig.8. In both the crops the leaf area index increased up to 75 days after germination and then it decreased. The leaf area index was more in the rainfed crop than the irrigated crop at all stages.

5.4 Dry matter production

The data relating to dry matter production at harvest are given in Table 13. There was not much difference in dry matter yield between the rainfed and irrigated crops of ashgourd.

Table 12. Growth observations of rainfed and irrigated ashgourd at different stages

Days after germination	Vine length (cm)		Leaves/plant		Leaf area index	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
15	11.0 ± 0.4	4.6 ± 0.3	4.0 ± 0.1	3.5 ± 0.1	-	-
30	181.6 ± 7.2	65.9 ± 7.1	12.9 ± 0.7	10.6 ± 0.7	0.06 ± 0.003	0.03 ± 0.003
45	465.4 ± 13.9	280.1 ± 12.9	46.7 ± 2.4	55.9 ± 4.9	0.36 ± 0.02	0.32 ± 0.03
60	735.4 ± 11.1	509.6 ± 21.4	149.0 ± 5.7	177.7 ± 4.7	1.143 ± 0.04	1.05 ± 0.05
75	909.4 ± 17.5	633.0 ± 21.6	182.7 ± 6.7	206.3 ± 7.6	1.42 ± 0.06	1.23 ± 0.06
98	1039.0 ± 21.2	653.4 ± 19.9	186.9 ± 11.0	84.6 ± 11.34	1.14 ± 0.08	0.43 ± 0.07

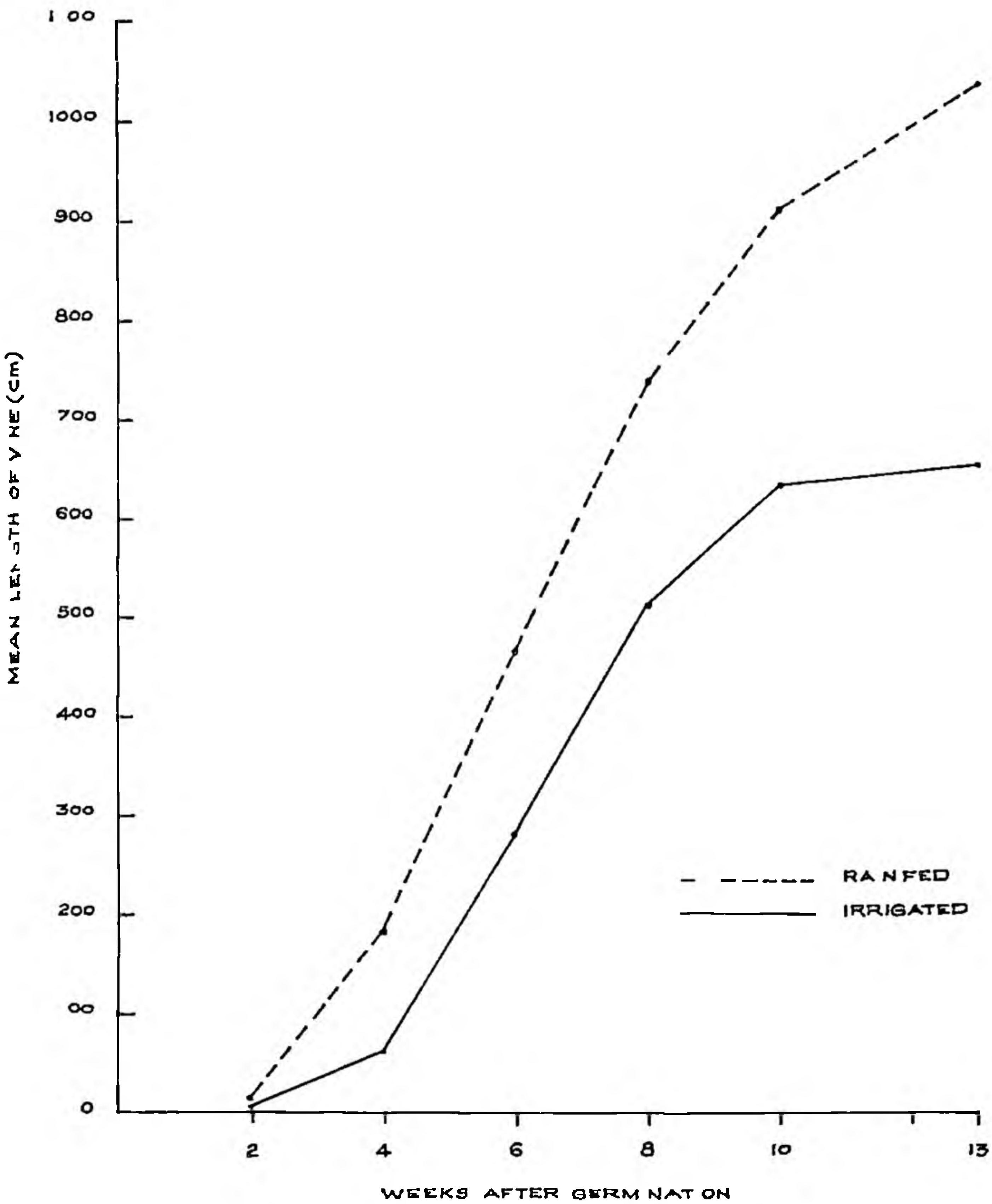

FIG 8 LENGTH OF VINE AT WEEKLY INTERVALS

5.5 Yield and harvest index

The data on yield and harvest index are given in Table 13. The yield and harvest index were more in the irrigated condition. The yield in irrigated condition was 16.8 kg plant^{-1} and that in the rainfed, 14.4 The corresponding harvest index values were 0.75 and 0.58 respectively.

6. Fertilizer experiment

6.1 Vine length

The data on length of main vine of the different sets are given in Table 14 and their analysis of variance in Appendix II.

There was significant difference among the treatments with respect to the length of main vine only in the first set harvested 30 days after germination. The treatment T_2, receiving fertilizers at 0-20 cm, had maximum length of vine in the first set which was on par with T_3, receiving fertilizers at 20-40 cm. The treatments T_3, T_1 (control) and T_4 (40-60 cm) were on par. In the second set, harvested 45 days after germination, also T_2 had maximum length of vine while T_3 had maximum length for the main vine in the third set (harvested 60 days after germination) and fourth set (harvested 75 days after germination).

Table 13. Dry matter production at harvest, harvest index and yield of rainfed and irrigated ashgourd

	Rainfed	Irrigated
Dry matter production (g $plant^{-1}$)	1161.2 ± 54.2	1120.2 ± 85.5
Yield (kg $plant^{-1}$)	14.4 ± 0.75	16.8 ± 1.1
(t ha^{-1})	31.9	37.3
Harvest index (%)	57.75 ± 1.6	75.31 ± 3.7

Table 14. Effect of methods and stages of fertilizer application on growth and yield

a) Vine length (cm)

Treatments	Harvest (days after germination)			
	30	45	60	75
T_1 (Control)	100.0	381.0	586.0	638.0
T_2 (0-20 cm)	144.0	507.0	685.0	664.0
T_3 (20-40 cm)	103.2	477.0	731.0	691.0
T_4 (40-60 cm)	89.0	406.0	680.0	619.0
CD (0.05)	37.9	NS	NS	NS
SE $\pm$	12.3	39.2	46.7	41.7

(Contd.)

NS Not significant

66

6.2 Leaves/plant

The data relating to the number of leaves are given in Table 14b and their analysis of variance in Appendix II.

There was significant difference among the treatments with respect to number of leaves per plant only in the third set harvested 60 days after germination. The treatment T_3 which received fertilizers at 20-40 cm had maximum number of leaves in this set which was on par with T_2 (0-20 cm) and T_4 (40-60 cm).

6.3 Leaf area index

The data on leaf area index are given in Table 14c and their analysis of variance in Appendix II.

There was significant difference between treatments in the first, second and third sets harvested 30, 45 and 60 days after germination. The treatment T_2 (0-20 cm) recorded maximum leaf area index in first set which was on par with T_3 (20-40 cm). In the second set T_2 recorded maximum leaf area index and was on par with T_3 and T_4 (40-60 cm). In fourth set also T_2 had recorded maximum leaf area index but the difference was not

Table 14 (Contd.)

b) Leaves/plant

Treatments	Harvest (days after germination)			
	30	45	60	75
T_1 (Control)	12.0	58.6	94.2	91.6
T_2 (0-20 cm)	14.0	107.4	197.2	125.8
T_3 (20-40 cm)	12.2	100.2	221.8	110.6
T_4 (40-60 cm)	11.4	85.6	188.4	107.4
CD (0.05)	NS	NS	63.8	NS
SE ±	0.8	11.9	20.7	13.5

(Contd.)

NS Not significant

Table 14 (Contd.)

68

c) Leaf area index

Treatments	Harvest (days after germination			
	30	45	60	75
T_1 (Control)	0.051	0.381	0.628	0.559
T_2 (0-20 cm)	0.073	0.867	1.663	0.871
T_3 (20-40 cm)	0.054	0.731	1.816	0.780
T_4 (40-60 cm)	0.637	0.605	1.455	0.752
CD (0.05)	0.022	0.272	0.546	NS
SE ±	0.007	0.088	0.177	0.100

(Contd.)

NS Not significant

statistically significant. In the third set the treatment T_3 recorded maximum leaf index which was on par with T_2 and T_4.

6.4 Dry matter production

The data relating to dry matter yield are given in Table 14a and their analysis of variance in Appendix III.

There was significant difference between treatments in all the sets with respect to dry matter production. In the first set harvested 30 days after germination, T_2 (0-20 cm) recorded maximum dry matter, while all others were on par. In the second set harvested 45 days after germination T_2 recorded maximum dry matter yield which was on par with T_3 (20-40 cm), while T_3 and T_4 (40-60 cm) were on par. In the third set harvested 60 days after germination T_3 recorded maximum dry matter production which was on par with T_2 and T_4. In the fourth set harvested 75 days after germination T_2 recorded maximum dry weight of the vegetative parts and the fruits which was on par with T_3 and T_4.

6.5 Chemical analysis

6.5.1 Nitrogen content

The data relating to the nitrogen content are given in Table 15a and their analysis of variance in Appendix IV.

70

Table 14 (Contd.)

d) Dry matter production (g $plant^{-1}$)

Treatments	Harvest (days after germination)				
	30	45	60	75 Vegetative	Fruits
T_1 (Control)	12.40	86.2	208.2	163.9	218.6
T_2 (0-20 cm)	18.34	190.9	396.2	306.9	550.8
T_3 (20-40 cm)	12.62	161.0	512.1	296.7	423.2
T_4 (40-60 cm)	10.16	138.5	474.1	281.7	441.0
CD (0.05)	4.87	65.3	139.8	95.13	193.0
SE ±	1.58	21.2	45.4	30.9	62.6

(Contd.)

)/

There was no significant difference between treatments with respect to nitrogen content in any sets. The nitrogen content was more in the initial stages and it decreased with age of the crop. Fruits had less nitrogen content compared to the vegetative parts.

6.5.2 Phosphorus content

The data on phosphorus content of the different sets are given in Table 15b and their analysis of variance in Appendix IV. There was no significant difference between treatments with respect to phosphorus content of the plant in any set. The phosphorus content decreased with age of the plant. Fruits had more phosphorus content to the vegetative parts.

6.5.3 Potassium content

The data on potassium content are given in Table 15c and their analysis of variance in Appendix IV.

There was no significant difference between treatments with respect to potassium content in any set. The potassium content decreased with age of the plant and comparing fruits and vegetative parts fruits had higher content of this nutrient.

Table 15. Effect of methods and stages of fertiliser application on the content of NPK

a) Content of N (%)

Treatments	Harvest (days after germination)				
	30	45	60	75 Vegetative	Fruits
T_1 (Control)	4.38	4.0	3.17	2.79	1.80
T_2 (0-20 cm)	4.65	4.65	3.43	2.99	2.40
T_3 (20-40 cm)	4.89	4.53	3.54	3.16	2.40
T_4 (40-60 cm)	4.72	4.67	3.40	3.01	2.30
CD (0.05)	NS	NS	NS	NS	NS
SE ±	0.15	0.17	0.11	0.11	0.24

(Contd.)

NS Not significant

Table 15 (Contd.)

b) Content of P (%)

Treatments	Harvest (days after germination)				
	30	45	60	75 Vegetative	Fruits
T_1 (Control)	0.70	0.54	0.33	0.26	0.35
T_2 (0-20 cm)	0.84	0.57	0.35	0.27	0.46
T_3 (20-40 cm)	0.80	0.54	0.28	0.26	0.41
T_4 (40-60 cm)	0.64	0.55	0.28	0.27	0.40
CD (0.05)	NS	NS	NS	NS	NS
SE $\pm$	0.09	0.044	0.03	0.02	0.06

(Contd.)

NS Not significant

Table 15 (Contd.)

c) Content of K (%)

Treatments	Harvest (days after germination)				
	30	45	60	75 Vegetative	Fruits
T_1 (Control)	4.9	4.5	3.0	2.0	2.6
T_2 (0-20 cm)	5.2	4.7	3.1	2.1	3.3
T_3 (20-40 cm)	4.7	4.7	3.0	2.0	2.9
T_4 (40-60 cm)	5.2	4.5	2.9	2.1	3.1
CD (0.05)	NS	NS	NS	NS	NS
SE $\pm$	0.23	0.32	0.22	0.10	0.37

NS Not significant

6.5.4 Uptake of nitrogen

The data on uptake of nitrogen are given in Table 16a and their analysis of variance in Appendix V.

There was significant difference between treatments with respect to uptake of nitrogen in all the sets. In the first set harvested 30 days after germination T_2 (0-20 cm) recorded maximum uptake of nitrogen and all the other treatments were on par. In the second set harvested 45 days after germination T_2 recorded maximum uptake and this was on par with T_3 (20-40 cm) and T_4 (40-60 cm). In the third set harvested 60 days after germination T_3 recorded maximum uptake of nutrient and T_4 was on par with this. T_4 and T_2 were also on par. In the fourth set harvested 75 days after germination T_3 recorded maximum uptake of nitrogen for the vegetative parts which was on par with T_2 and T_4, while T_2 recorded the maximum uptake in fruits which was on par with T_4 and T_3.

6.5.5 Uptake of phosphorus

The data relating to the uptake of phosphorus are given in Table 16b and their analysis of variance in Appendix V.

Table 16. Effect of methods and stages of fertilizer application on the uptake of NPK

a) Uptake of N (g $plant^{-1}$)

Treatments	Harvest (days after germination				
	30	45	60	75 Vegetative	Fruits
T_1 (Control)	0.55	3.6	6.7	4.6	4.8
T_2 (0-20 cm)	0.85	8.9	13.5	9.1	11.0
T_3 (20-40 cm)	0.61	7.4	18.1	9.2	9.0
T_4 (40-60 cm)	0.48	6.5	15.8	8.3	10.1
CD (0.05)	0.22	3.2	4.4	2.7	4.1
SE $\pm$	0.07	1.0	1.4	0.9	2.3

(Contd.)

There was significant difference between treatments in all the sets. In the 1st set harvest 30 days after germination T_2 (0-20 cm) recorded maximum uptake of phosphorus. The treatments T_3 (20-40 cm) and T_4 (40-60 cm) were on par with T_1 (control). In the second set harvested at 45 days after germination also T_2 recorded maximum uptake. T_3 and T_4 were on par with T_2 but T_4 was also on par with control. In the third set harvested 60 days after germination T_3 recorded maximum uptake and was on par with T_2 and T_4. In the fourth set harvested 75 days aftor germination T_2 showed maximum uptake for both fruits and vegetative parts. This was on par with T_4 and T_3.

6.5.6 Uptake of potassium

The data relating to uptake of potassium are given in Table 16c and their analysis of variance in Appendix V.

There was significant difference between treatments in all the sets. In the first set harvested 30 days after germination T_2 (0-20 cm) recorded maximum uptake and T_3 (20-40) and T_4 (40-60) were on par with T_1 (control). In the second set harvested 45 days after germination also T_2 recorded maximum uptake of potassium. T_2 was on par

Table 16 (Contd.)

b) Uptake of P (g plant^{-1})

Treatments	Harvest (days after germination)				
	30	45	60	75 (Vegetative)	Fruits
T_1 (Control)	0.09	0.45	0.68	0.42	0.93
T_2 (0-20 cm)	0.16	1.15	1.36	0.85	2.54
T_3 (20-40 cm)	0.10	0.92	1.40	0.75	1.75
T_4 (40-60 cm)	0.70	0.84	1.33	0.76	1.95
CD (0.05)	0.05	0.42	0 50	0.26	0.82
SE $\pm$	0.02	0.16	0.16	0.08	0.27

(Contd.)

with T_3 and T_4, but T_4 was on par with control. In the third set harvested 60 days after germination T_3 recorded maximum uptake of potassium and was on par with T_4 and T_2. In the fourth set harvested 75 days after germination T_4 recorded maximum uptake by vegetative parts which was on par with T_2 and T_3. For the fruits, T_2 recorded maximum uptake which was on par with T_4. T_4 and T_3 were also on par.

80

Table 16 (Contd.)

c) Uptake of K (g plant^{-1})

Treatments	Harvest (days after germination)				
	30	45	60	75 (Vegetative)	Fruits
T_1 (Control)	0.62	3.59	6.40	3.20	7.0
T_2 (0-20 cm)	0.96	9.71	12.54	6.21	17.65
T_3 (20-40 cm)	0.62	7.68	15.46	6.02	12.20
T_4 (40-60 cm)	0.52	6.13	13.23	7.27	13.35
CD (0.05)	0.32	4.08	4.71	2.03	4.53
SE ±	0.10	1.32	1.52	0.66	1.47

Discussion

DISCUSSION

81

The information on the extent of root development and activity in any crop will be useful in deciding on the method of fertilizer application and scheduling of irrigation. There is an optimum and active root profile that is particularly responsible for the absorption of larger part of nutrients and water from soil. Proper understanding of the activity and distribution pattern of roots is, therefore, necessary for proper and economic utilisation of fertilizers and water.

Root development in rainfed and irrigated ashgourd

Isotope techniques now make it comparatively easy to determine the root distribution without disturbing the root system. The root activity pattern of different crops have been reported in different annual crops (Lott *et al.*, 1950; Hall *et al.*, 1953; Burton *et al.*, 1954; Lipps *et al.*, 1957; Mc Clure and Harvey, 1962; Nakayama and Van Bavel, 1963; Hammes and Bertz, 1963; Fox and Lipps, 1964; Halltead and Rennie, 1965; Kafkafi *et al.*, 1965; Dejong and Ontinkarang, 1969; Virmani and

Dhaliwal, 1969; Bassett *et al.*, 1970; Reddy and Venkateswaralu, 1971; Virmani, 1971; Ellis and Burns, 1973; Kumaraswamy *et al.*, 1977; Marykutty, 1978; Srinivas, 1980; Subramanian *et al.*, 1980; Singh et al., 1982).

In the present study, recovery of radioactivity from a given soil depth and lateral distance as indicated by leaf assay was taken as the evidence for the presence of root in that soil zone. As had been indicated earlier, a statistical comparison of the magnitude of ^{32}P absorption from various soil zones was not attempted because of the differences in applied activity, variability in root extensions etc. Therefore, only a qualitative comparison of the individual plant data was made. However, as the data on radioactivity in leaves showed that the results were not always consistent and in several instances, varying number of plants of the same treatment showed presence of activity in foliage (Tables 2 to 8). Such a trend was more conspicuous in the early stages especially under rainfed conditions. With advancing age, larger number of plants of a treatment recorded activity. In the irrigated condition, the results were more consistent with nearly all the experimental plants of a treatment recording activity simultaneously.

8?

As will be evident from the results of the root excavation studies, the lateral roots of ashgourd were few and there was, a high probability of the roots not coming in contact with the ^{32}P placed. The differences between treated plants of a set were probably arising out of this. Assuming such a variability in root spread as the factor responsible for the inconsistency, presence of radioactivity in the foliage of any one of the three experimental plants is reckoned as indicative of the spread of the roots upto that point of placement.

In the rainfed crop, the roots were found to spread upto a lateral distance of 150 cm one month after germination. The vertical extension at this stage was upto 50 cm at nearly all the lateral distances. The vines at this stage spread upto a comparable distance of 180 cm. At the next stage, 45 days after germination, the maximum lateral spread of roots was up to 200 cm at a vertical distance of upto 75 cm and 100 cm upto vertical distance of 100 cm. At this stage, the vines spread to a distance of 465 cm. Root spread was noticed upto 200 cm laterally and 100 cm vertically at the next stage, 60 days after germination. The vines spread upto 735 cm by this stage. The roots developed upto a soil volume of radius of at least 200 cm and depth of

100 cm by the time the crop reaches half its total field duration. It is also possible that there are further extensions of roots beyond these distances with further growth. It also appears that in a crop planted at a spacing of 4.5 x 2 m, the roots cover the plant to plant distance in a row in less than a month after germination and row to row distance in atleast two months. The soil that can be exploited by the crop roots can be up to a depth of 50 cm one month after germination and up to not less than 100 cm by the second month. Such a vertical spread will qualify this crop to be grouped as 'moderately deep rooted' (Doneen and Mac Gillivray, 1943).

Since the absorption of the radiolabel was very less in the rainfed crop and as the root system of the crop was found to be sparse in the root excavation study, treatments were modified for the study under irrigated conditions. Since the chances for interception and absorption of radiolabel was less, the treatments were modified with 0, 15, 30 and 60 cm lateral distances and 25, 50 and 75 cm vertical distances in the irrigated crop instead of 50, 100, 150 and 200 cm lateral distances and 25, 50, 75 and 100 cm vertical distances in the rainfed crop.

In the irrigated crop, the roots reached a lateral distance of 30 cm at 25 cm depth and 15 cm at 50 cm depth by 15 days after germination. The vine length at this stage was only 5 cm. At the next stage 30 days after germination, the maximum lateral spread of roots was up to 60 cm to a depth of 25 cm and the maximum depth of penetration was 75 cm at the base. At this stage, the vines spread to a distance of 66 cm. By 45 days after germination, the roots reached a lateral distance of 60 cm at a depth of 75 cm by which time the vines attained a length of 280 cm. These were the maximum lateral distance and depth tried and by 45 days after germination root extension was seen up to these points. It is possible that there are further extension of the roots beyond these with further growth in the irrigated condition.

Comparing the root system or rainfed crop with irrigated, it was found that lateral root development was more in rainfed crop at comparable periods after germination. One month after germination, the root development was seen up to a lateral distance of 150 cm at 50 cm depth in rainfed crop, while it was only 60 cm at 25 cm depth in the irrigated crop. By 45 days after germination, root development was seen up to a lateral distance of 200 cm at 75 cm depth in rainfed crop, while it was only 60 cm distance at

75 cm depth in irrigated crop. In the rainfed condition, the soil moisture was distributed uniformly in the soil and the high rainfall received in the season probably maintained the soil near field capacity. In the irrigated condition, the basins were irrigated and the space in between had less available water. Restriction of root development in the wetted zone is attributable to this trend of lesser root spread in the irrigated condition.

Root excavation

The excavation studies were conducted at intervals of 15 days to 100 days after germination. The maximum lateral and vertical extensions of primary roots were measured at all the above stages (Table 9). The total number of roots in each excavated plant was counted and total dry weight of roots estimated. Data on extent of spread showed that the maximum spread of the primary roots which was noted at the last stage (100 days after germination) was up to a lateral distance of 188 cm and a depth of 87 cm in rainfed crop while it was up to a lateral distance of 75 cm and a depth of 90 cm in the irrigated crop. The excavation studies also thus showed that the lateral spread of the roots was more in rainfed crop while the depth of penetration of the roots was almost same in both the conditions. In both the cases, there were progressive increases in the root extensions both vertically and laterally with advancing age. However, the rates of growth were markedly different between the stages, the bulk of extensions being upto 45th day in the case of lateral spread in the rainfed crop and upto 30 days in the irrigated. Expressed as percentages of the spread at the last stage (100 days) the values at the above stages were 86.3 and 77.2 per cent, respectively. In the case of vertical spread, the peak rates of root growth were upto 45 days in both rainfed and irrigated situations. The percentage extension values at this stage were 94.8 and 92.4 respectively. A comparison with the data on root development using ^{32}P under rainfed conditions would indicate that there were rapid extension of root upto 30 and 45 days both laterally and vertically in this study also. The absolute values were however, much higher in the ^{32}P study, apparently as rootlet growth also is accounted in this. The root development values in the irrigated condition are strictly not comparable as ^{32}P studies were limited to only much shorter distances. Based on the excavation studies also the crop can be classified as moderately deep rooted (Domen and Mac Gillivray, 1943).

Root proliferation as measured in terms of number of primary roots on the tap root and the root dry weight was more in the irrigated condition at all stages. However, such a better root growth in the irrigated condition is not accompanied by a corresponding shoot growth which was generally better in the rainfed condition. A tendency for enhanced root proliferation in this crop under moisture restrictions is thus indicated. Presumably, there would be better utilisation of applied nutrients from the zone of placement in the irrigated conditions because of this. Another factor that may contribute to better utilisation of applied nutrients by the irrigated crop is the tendency of root restriction to the area in and around the planting pits. Exploitation of inherent soil fertility, on the other hand, should be expected to be better in the rainfed situation as indicated by the greater vertical and horizontal root spread.

The excavation studies also revealed that the root system of the crop was sparse with a few primary roots on the tap root with a maximum of around 14 to 18. It was found that the two or three roots formed on the tap root near the soil surface developed laterally without much branching and penetration into the soil. The roots produced on the tap root in the deeper layers usually had less lateral spread.

Distribution of ^{32}P in different plant parts

The distribution of ^{32}P in different plant parts was studied two months after germination in the irrigated crop. Three plants which received ^{32}P at 50 cm depth and 15 cm lateral distance were removed 60 days after germination and devided into six equal portions along the length of main vine and each portion was ranked from 1 to 6 with youngest portion as 1st and the oldest as 6th. From each portion, leaves, petioles, stem and fruits were separated and the activity was determined. Fruits recorded maximum ^{32}P activity (4498 cpm g^{-1}) followed by stem, petioles, tendrils and leaves (Table 10). The dry matter accumulation was the highest in leaves (37.5%) followed by stem (26.8%), fruits (15.9%), petioles (15.1%) and tendrils (4.7%). The relative distribution of ^{32}P (expressed as percentage of the total radioactivity in the plant) was maximum in leaves (31%) followed by stem (29.1%), fruits (21.8%), petioles (14.3%) and tendrils (4.2%). As the pattern of accumulation of ^{32}P follows the same pattern as the relative dry matter accumulation, it appears that the nutrient distribution is primarily decided by the dry matter yields of the different plant parts. In general, the ^{32}P activity decreased from the top one-sixth (youngest) to the bottom one-sixth (oldest) portion in all the parts viz. leaves, petioles, stem and fruits (Table 11).

Biometric observations

The biometric observations were taken at intervals of 15 days upto 100 days to find out the general performance of both rainfed and irrigated ashgourd. The length of main vine was more in the rainfed condition on all stages compared to the irrigated crop. In both cases, there was increase in length of vine with age. The rates of growth were markedly different between stages, the bulk of extension being upto 60 days in irrigated crop while it continued upto 100 days in the rainfed crop. The rainfed crop had a maximum length of 1039 cm at 100th day while it was only 653 cm in irrigated (Table 12).

The number of leaves was almost same in both the crops, upto 45 days after germination. In the irrigated crop, the number of leaves increased upto 75 days after germination (206) and after that, there was a drastic decrease (85) while the rainfed crop continued to produce leaves upto the last stage, the rate, however, decreasing with age. The leaf area index values were generally low with a maximum of 1.42 in the rainfed and 1.23 in the irrigated condition (Table 12). The maximum leaf area index values were recorded at 75 days after germination in both conditions and thereafter it decreased. At all stages, the leaf area index values were more in the rainfed crop. The reason for higher leaf area index values in the rainfed crop at 45, 60 and 75 days after germination, during which periods the irrigated crop had more number of leaves is attributable to the higher leaf size in the rainfed crop.

Total dry matter production values at harvest were almost same in both the crops. Yield and harvest index values were more in the irrigated condition (Table 13). The irrigated crop recorded a fruit yield of 37.3 t ha^{-1} while it was 32 t ha^{-1} in the rainfed crop. The corresponding harvest index values were 75 and 58 per cent, respectively.

Fertilizer experiment

In the root excavation studies, it was noted that the roots reached upto a lateral distance of 108 cm by 30 days after germination and 162 cm by 45 days after germination in the rainfed crop while it reached 57 cm by 30 days and 62 cm by 45 days after germination in irrigated. This fertilizer experiment was conducted with the primary objective of confirming the results of the ^{32}P and excavation studies. Another ancillary objective was to have an assessment of the relative root activities in the various lateral distances. The treatments involved application of full dose of fertilizers around the plant in bands at 0-20, 20-40 and 40-60 cm lateral distances and an unfertilized control. These treatments were given to four sets of plants i.e. at germination, 15, 30 and 45 days after germination. The growth of the crop upto one month after fertilizer application and the total uptake of nutrients were used as measures of root activity.

Different methods of fertilizer application tried did not exert a significant influence on the length of main vine and number of leaves while leaf area index and dry matter production were significantly affected (Tables 14a to 14d). In the initial stage, 30 days after germination only the treatment which received fertilizers at 0-20 cm band showed significant difference in leaf area index and dry matter production as compared to unfertilized control. All others were on par with control indicating very little absorption of nutrients from the applied fertilizers. By 45 days after germination, the treatment which received fertilizers at 20-40 cm lateral distance also started recording high leaf area index and dry matter which was significantly superior to unfertilized control. By 60 days after germination, leaf area index and dry matter in all the treatments which received fertilizers were significantly superior to the unfertilized control. Similar was the case with uptake of nutrients. The contents however did not change with the treatments (Tables 15a to 15c). By 30 days after germination, only the treatment which received the fertilizer near the base recorded statistically significant difference in nutrient uptake as compared to control while by 45 days the treatment which received fertiliser at 20-40 cm also recorded higher uptake than control. By 60 days after germination, the uptake of nutrients from distance of 0-20, 20-40 and 40-60 cm were comparable and superior to the unfertilized control (Tables 16a to 16c). By excavation studies, it was found that the roots reached a lateral distance of 108 cm in rainfed and 57 cm in irrigated crop by 30 days after germination. The results of the fertilizer experiment showed that there was active absorption only from the

0-20 cm lateral distance though the roots extended much more by 30 days after germination. By 45 days the extensions were 162 cm and 57 cm respectively while the actively absorbing roots extended upto 40 cm distance only. By 60 days after germination, the absorption of nutrients was nearly the same from 0-20, 20-40 and 40-60 cm distances. The corresponding lateral root extension values at this stage were not less than 200 cm in the rainfed crop in ^{32}P study and upto 175 cm in the excavation study. The corresponding value in the irrigated condition was 70 cm in excavation study.

As indicated by the large differences between root extension zone and root activity zone, it appears that there was a tendency for the actively absorbing roots to got concentrated around the planting pits. It is also to be noted that organic manures were applied in the planting pits in all cases including the crop of the fertilizer experiment. The tendency for concentration of roots around the plants is attributable to such a placement of manures. It is also logical to conclude that when left unmanured and unfertilised, there may be exploitation of much larger volumes of soil perhaps at least all the interspace available in the normal method of planting. It also appears that more effective absorption of water may occur from nearly all the space available after the crop has grown for about 45-60 days as the exten~~d~~t of root density required for substantial water absorption is established to be much less than for nutrients.

Summary

SUMMARY

The investigations were carried out in the Department of Agronomy, College of Horticulture, Vellanikkara on ashgourd during 1985-'86 with the following objectives. (1) To find out the vertical and horizontal root spread of rainfed and irrigated ashgourd with advancing age (2) to study the distribution of absorbed ^{32}P in different plant parts, (3) to compare the root development pattern in the rainfed and irrigated conditions and (4) to arrive at zones of active nutrient absorption. The following conclusions were drawn based on the present investigations.

1. Root development studies with ^{32}P showed that rainfed crop had more lateral development of roots compared to irrigated crop. By 30 days after germination it reached a lateral distance of 150 cm in rainfed crop while it was only 60 cm in irrigated condition. The root excavation studies also revealed that the lateral spread was more in rainfed condition with a maximum of 188 cm while it was only 75 cm in irrigated condition. The depth of penetration was almost same in both rainfed and irrigated conditions, values being 87 and 90 cm respectively. The crop can be classified as moderately deep rooted.

97

2. The ^{32}P distribution studies showed that radioactivity was maximum in fruits (4498 cpm g^{-1}) followed by stem, petioles, tendrils and leaves. The relative distribution (expressed as percentage of the total radioactivity in plant) was maximum in leaves (31%) followed by stem (29.1%), fruits (21.8%), petioles (14.3%) and tendrils (4.2%) which showed almost the same pattern of dry matter accumulation.

3. The root excavations also revealed that the root system of the crop was sparse with only a few primary roots (ranging from 14-18). The few roots produced near the surface developed laterally without much branching and penetration. Those produced in the deeper layers did not have much lateral spread. It was found that the number of primary roots and the dry weight of roots were more in the irrigated condition.

4. Fertilizer experiment with fertilizers placed at various lateral distances showed that the zones of active uptake of nutrients were upto 20 cm by 30 days, 40 cm by 45 days and 60 cm by 60 days.

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* Original not seen

Appendix

Appendix I. Weekly rainfall during the crop periods

I Crop 1.6.1985 to 14.9.1985				II Crop 21.12.1985 to 5.4.1986				III Crop 21.6.86 to 6.9.1986			
Week	Dates		Rainfall (mm)	Week	Dates		Rainfall (mm)	Week	Dates		Rainfall (mm)
22	25-5 to	1-6	137.1	51	15-12 to	21-12	54.6	25	15-6 to	21-6	198.7
23	2-6 to	8-6	147.2	52	22-12 to	28-12	0.0	26	22-6 to	28-6	337.2
24	9-6 to	15-6	131.7	1	29-12 to	4-1	0.0	27	29-6 to	5-7	84.6
25	16-6 to	22-6	132.6	2	5-1 to	11-1	0.0	28	6-7 to	12-7	30.2
26	23-6 to	29-6	393.7	3	12-1 to	18-1	0.0	29	13-7 to	19-7	152.5
27	30-6 to	6-7	245.7	4	19-1 to	25-1	1.2	30	20-7 to	26-7	89.0
28	7-7 to	13-7	139.9	5	26-1 to	1-2	0.0	31	27-7 to	2-8	0-5
29	14-7 to	20-7	100.8	6	2-2 to	8-2	0.0	32	3-8 to	9-8	179.2
30	21.7 to	27-7	49.7	7	9-2 to	15-2	0.7	33	10-8 to	16-8	106.5
31	28-7 to	3-8	164.9	8	16-2 to	22-2	1.2	34	17-8 to	23-8	0
32	4-8 to	10-8	95.1	9	23-8 to	1-3	0	35	24-8 to	30-8	0
33	11-8 to	17-8	125.0	10	4-3 to	8-3	0	36	31-8 to	6-9	22.5
34	18-8 to	24-8	24.7	11	9-3 to	15-3	0				
35	25-8 to	31-8	25.0	12	16-3 to	22-3	8.4				
36	1-9 to	7-9	0.0	13	23-3 to	29-3	0				
37	8-9 to	14-9	40.3	14	29-3 to	5-4	0				

Appendix II. Abstract of analysis of variance of growth characters

Source	df	Mean squares							
		Length of vine				Number of leaves			
		I	II	III	IV	I	II	III	IV
Block	4	725	11245	24808	18117	1.5	1480	7865	560
Treatment	3	2899*	17441	18501	4910	6.3	2325	15651**	983
Error	12	755	7676	10900	8693	3.3	708	2140	904

Source	df	Mean squares			
		Leaf area index			
		I	II	III	IV
Block	4	0.00	0.09	0.62	0.03
Treatment	3	0.001*	0.21*	1.40*	0.09
Error	12	0.000	0.04	0.16	0.05

* Significant at 5% level
** Significant at 1% level

Appendix III. Abstract of analysis of variance for dry matter production

Source	df	Mean squares				
		I	II	III	IV	
					Fruits	Vegetative parts
Block	4	7.5	5804	28613	24106.8	10828
Treatments	3	60.9*	9758*	91374**	95923*	22047*
Error	12	12.5	2247	10296	18238	4765

* Significant at 5% level
** Significant at 1% level

Appendix IV. Abstract of analysis of variance for content of NPK

Source	df	Mean squares									
		N content					P content				
		I	II	III	IV Veg.	IV Fruit	I	II	III	IV Veg.	IV Fruit
Block	4	0.04	0.07	0.06	0.06	0.24	0.004	0.007	0.004	0.012	0.004
Treatment	3	0.22	0.5	0.12	0.12	0.42	0.004	0.016	0.007	0.002	0.001
Error	12	0.12	0.15	0.15	0.06	0.3	0.042	0.01	0.004	0.002	0.017

Source	df	Mean squares				
		K content				
		I	II	III	IV Veg.	IV Fruit
Block	4	0.53	0.40	0.13	0.78	0.83
Treatment	3	0.13	0.15	0.04	0.39	0.40
Error	12	0.26	0.52	0.26	0.15	0.70

Appendix V. Abstract of analysis of variance for uptake of NPK

Source	df	Mean squares									
		N uptake					P uptake				
		I	II	III	IV Veg.	IV Fruit	I	II	III	IV Veg.	IV Fruit
Block	4	0.02	13.2	26.6	5.2	34.4	0.001	0.2	0.2	0.1	0.2
Treatment	3	0.13*	25.2*	122.2*	23.7*	37.1*	0.007**	0.4*	0.6*	0.2**	2.2**
Error	12	0.03	5.5	10.4	4.0	9.7	0.001	0.1	0.1	0.02	0.3

Source	df	Mean squares				
		K uptake				
		I	II	III	IV Veg.	IV Fruit
Block	4	0.04	18.6	29.4	6.4	21.7
Treatment	3	0.18*	33.4*	75.1**	15.1**	96.0**
Error	12	0.05	8.8	11.7	2.1	12.7

* Significant at 5% level
** Significant at 1% level

ROOT DEVELOPMENT AND ACTIVITY STUDIES IN ASHGOURD

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

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ABSTRACT

Experiments were conducted at College of Horticulture, Vellanikkara during 1985-86 to study the root development and distribution pattern of rainfed and irrigated ashgourd. In the rainfed crop, there were 16 treatments involving placement of ^{32}P at 16 places being the combinations of four lateral and four vertical distances. In the irrigated crop, there were only 12 treatments being the combinations of four lateral and three vertical distances. In the fertilizer experiment there were four treatments viz. no fertilizers and full dose of fertilizer applied at 0-20, 20-40 and 40-60 cm. These were conducted at 0, 15, 30 and 45 days after germination. Growth and uptake of nutrients were studied one month after application. The field experiments were laid out in randomised block design.

The root development was very fast in ashgourd. By 30 days, it reached 150 cm in rainfed and 60 cm in irrigated conditions. The excavation studies also revealed that the lateral development of roots were more in rainfed reaching a maximum of 182 cm while it was only

75 cm in irrigated, by 100 days. The depth of penetration was almost same in both cases, the values being 87 cm in rainfed and 90 cm in irrigated crop. The crop can be classified as moderately deep rooted.

The crop had a sparse root system with only a few primary roots (14 to 18). The primary roots near surface grew laterally without much penetration whereas others developed without much lateral spread.

The ^{32}P distribution studies revealed that ^{32}P content was more in fruits. The relative distribution followed the same pattern of dry matter accumulation with maximum in leaves (31%).

The fertilizer experiments revealed that the zone of active absorption of nutrients were upto 20 cm by 30 days, 40 cm by 45 days and 60 cm by 60 days.