UPTAKE PATTERN OF MAJOR AND MINOR NUTRIENTS IN SELECTED CASHEW TYPES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **Uptake Pattern of Major and Minor Nutrients in Selected Cashew Types** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or any other similar title, of any other University or Society.

Beena Bhaskar

Vellanikkara,
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BEENA BHASKAR

CERTIFICATE

Certified that the thesis entitled **Uptake Pattern of Major and Minor Nutrients in Selected Cashew Types** is a record of research work done by Ms. Beena Bhaskar under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of Ms. Beena Bhaskar, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled **Uptake Pattern of Major and Minor Nutrients in Selected Cashew Types** may be submitted by Ms. Beena Bhaskar, in partial fulfilment of the requirement for the degree.

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Beena Bhaskar

BEENA BHASKAR

Dedicated to
my loving parents

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Introduction

INTRODUCTION

Cashew (Anacardium occidentale L.), a member of the family Anacardiaceae, is one of the most important commercial crops of our country. This tropical evergreen tree is grown in an area of 5.3 lakh hectares in India, of which 26 per cent is in Kerala (Salam et al., 1991a).

The production of cashew nuts in the country, despite a steady increase in cashew area, has been consistantly low during the last four decades. Several factors were attributed to this dismal situation, of which non-availability of potential genotypes suitable for every agroclimate, is one of the most important ones.

Research on cashew, though started some three decades ago in India, has yet to tackle this production problem. In the recent past, research efforts in cashew have gained momentum, especially to evolve potential genotypes suitable for different agroclimates and also to develop suitable management techniques to increase the productivity of this crop.

In the recent past, although a few high yielding varieties have been evolved from different Cashew Research Centres, attempts are meagre to study their suitability and

adaptability under different agroclimates. Information on the nutritive requirements and nutrient absorption pattern of this crop is also quite inadequate. No attempt seems to have been made so far to study the absorption of nutrients by cashew in relation to its physiological phases. In this context, an investigation was undertaken in the Kerala Agricultural University with the following objectives.

1. To study the varietal variation in the growth and yield of cashew varieties in the oxisols of Kerala

2. To assess the difference in nutrient concentration between harvested parts

3. To estimate the annual removal of nutrients through harvested produce

4. To study the variation in leaf nutrient concentration in relation to physiological phases

5. To assess the relative absorption of soil applied ^{32}P at different physiological phases

REVIEW OF LITERATURE

The literature available on different aspects, relevant to the present investigation is reviewed below.

A. Growth characters

1. Tree height

Differences in growth characters between cashew varieties have been reported by many researchers both in the seedlings as well as in the mature trees of cashew. Gopikumar and Aravindakshan (1979) observed wide differences in plant height between cashew types in the nursery. Variations in tree height between varieties in mature trees were reported by Falade (1981) and Reddy et al. (1989). There exists positive correlation between plant height and nut yield in cashew (Nayar et al., 1981). But Parameswaran et al. (1984) did not observe such a relationship in this crop.

2. Tree girth

The girth of cashew trees vary with variety (Reddy et al., 1989). According to Nayar et al. (1981) there is significant positive correlation between tree girth and yield in cashew.

3. Canopy spread

Canopy spread in cashew differs with varieties (Reddy et al., 1989) ranging from 8.1 m to 25.1 m. Strong positive correlation exists between canopy spread and yield of cashew (Nagabhushanam et al., 1980 and Nayar et al., 1981 and Parameswaran et al., 1984).

B. Physiological aspects

1. Chlorophyll content

Rao et al. (1980) studied the chlorophyll content of 20 cashew types at Cashew Research Station, Bapatla at flowering stage and observed significant differences in chlorophyll a and chlorophyll b contents between cashew types. According to them, the chlorophyll a and chlorophyll b contents of cashew types ranged from 0.165 to 1.792 and 0.438 to 1.416 mg/g respectively. Ankaiah and Rao (1983) observed positive correlation between chlorophyll content in leaves and nut yield.

2. Flowering time

Cashew being andrimonoecious, perfect and staminate flowers occur in the same panicle and the number of flowers

per panicle varies from 200 to 1600 (Damodaran et al., 1965). The duration and season of flowering varies from region to region depending on altitude, temperature, humidity and rainfall (Nambiar, 1974). The duration of flowering in cashew extend for four months, from last week of November to the last week of March (Hanamashetti et al., 1986).

The flowering season in cashew varies with varieties (Nalini and Santhakumari, 1991). They reported that the cashew variety Anakkayam 1 (BLA-139-1) flowers during middle of November (early flowering) while certain other cashew types, for example K-16-1, flowers during the month of February (late flowering).

3. Panicle length and breadth

Panicle length and breadth of cashew vary with types/varieties (Krishnappa et al., 1989); the panicle length ranged from 16.3 to 24.3 cm and the panicle breadth ranged from 17.0 to 23.3 cm in five cashew types studied. There was no correlation between panicle length and yield in cashew (Anitha et al., 1991).

C. Yield components

1. Number of fruits per panicle

Ghosh and Chatterjee (1987) evaluated the performance of 17 cashew types at Jhargram, West Bengal and found that the number of fruits per panicle varied from 1.6 to 4.7 between types. Varietal difference on number of fruits per panicle was also reported by Krishnappa et al. (1989) from Chintamani, Karnataka; Reddy et al. (1989) from Bapatla, Andhra Pradesh and Nalini and Santhakumari (1991) from Cashew Research Station, Anakkayam. There exists significant positive correlation between number of fruits per panicle and nut yield (Anitha et al., 1991).

2. Nut weight

Nandini and James (1984) evaluated 16 cashew types at Cashew Research Station, Anakkayam and found that the nut weight varies from 5.7 to 9.4 g per nut between types. The highest nut weight of 9.4 g was observed with cashew type K-10-2. Aravindakshan et al. (1986) observed the highest nut weight of 7.4 g with the cashew type K-19-1 and the lowest nut weight of 5.1 g with K-25-2. Ghosh and Chatterjee (1987) recorded a nut weight of 6.73 g with the

cashew type H-3-17 at Cashew Research Station, Jhargram. Antarkar and Joshi (1987) observed variation in nut weight from 4.08 to 7.70 g per nut, among five varieties (V1, V2, V3, V4 and V5) tested at Konkan Krishi Vidyapeeth, Dapoli. While evaluating 10 cashew types at Cashew Research Station,Anakkayam, Nalini and Santhakumari (1991) observed variation in nut size from 5.1 to 8.9 g with the highest nut weight (8.9 g) with the cashew type K-16-1. Nut weight varied from 5.80 to 10.85 g in 14 hybrids tested at Cashew Research Station, Madakkathara and the highest nut weight of 10.85 g was noticed with H 1598 (Salam et al., 1991b).

3. Kernel weight

Kernel weight varied from 1.41 to 2.0 g in 13 varieties tested and the highest kernel weight was observed with cashew selection NDR-2-1 (Aravindakshan et al., 1986). George et al. (1991) compared the kernel weight of nine cashew selections (BLA-139-1, BLA-39-4, K-22-1, NDR-2-1, H-3-17, H 1598, H 1608, H 1610 and H 1602) and found that the kernel weight varied from 1.6 g (K-22-1) to 2.76 g (H 1602). Kernel weight varied from 1.64 to 2.76 g in the 14 hybrids tested at Cashew Research Station, Madakkathara and the highest kernel weight of 2.76 g was noticed with the hybrid H 1602 (Salam et al., 1991b).

D. Nut yield

Significant differences in nut yield between cashew varieties have been reported by many researchers (Kologi et al., 1977 and Falade, 1981). Nandini and James (1984) evaluated seven cashew types (BLA-139-1, BLA-273-1, NLR-2-1, BLA-39-4, K-19-1, K-28-2 and UL-21-2) at Cashew Research Station, Anakkayam and the nut yield for ten years was compared. Average yield of these selections ranged from 11.9 kg (UL-21-2) to 34.7 kg (BLA-139-1) per tree per year. Krishnappa et al. (1989) observed yield differences ranging from 1.70 to 6.36 kg per tree per year while comparing five cashew selections (5/23 Coondapur, 8/46 Taliparamba, 9/66 Chirala, 1/11 Ullal and 6/21 Mudabidri) at the sixth year of planting at Agricultural Research Station, Chintamani, Karnataka. Reddy et al. (1989) reported yield differences ranging from 5.3 to 10.08 kg per tree per year between seedling progenies of six Bapatla varieties (BPP 1, BPP 2, BPP 3, BPP 4, BPP 5 and BPP 6) at the tenth year of planting. At Cashew Research Station, Anakkayam, Nalini and Santhakumari (1991) evaluated 10 cashew selections (BLA-139-1, K-19-1, K-25-2, K-10-2, NLR-2-1, K-22-1, K-28-2, K-26-1, K-10-1 and K-16-1) planted during 1960-64 and the yields from 1981-90 were compared. They found that the average yield of these cashew selections ranged from 13.22 kg per tree per year (K-16-1) to 29.29 kg per tree per year

(BLA-139-1). Salam et al. (1991b) reported yield differences ranging from 7.06 to 12.83 kg per tree per year at the 15th year of planting between fourteen hybrids tested at Cashew Reserch Station, Madakkathara. The highest mean yield was noticed with H 1598.

E. Apple weight

The apple weight in cashew differs with varieties (Sawke et al.,1986 and Haldankar et al., 1986). Aravindakshan et al. (1986) observed significant difference in apple weight in 13 types evaluated at Cashew Research Station, Madakkathara. Among these types, the highest apple weight (132.67 g) was observed with the cashew hybrid H-3-13 and lowest (31.33 g) with the cashew type K-28-2. Antarkar and Joshi (1987) evaluated five cashew varieties (Vengurla 1, Vengurla 2, Vengurla 3, Vengurla 4 and Vengurla 5) at Konkan Krishi Vidya Peeth, Dapoli and recorded highest apple weight (60.76 g) with the variety Vengurla 3 and lowest (28.9 g) with Vengurla 5. Krishnappa et al. (1989) observed apple weight to vary from 33.48 to 62 g in five selections tested at Agricultural Research Station, Chintamani. Ghosh and Kundu (1989) recorded variation in apple weight in 17 cashew types tested at Cashew Research

Station, Jhargram. Nalini and Santhakumari (1991) found apple weight to vary from 27 to 80 g in 10 cashew selections evaluated at Cashew Research Station, Anakkayam.

F. Shelling percentage

Shelling percentage of cashew nuts was found to differ with variety (Nandini and James, 1984; Vidyachandra and Hanamashetti, 1984; Nandini and James, 1985; Krishnappa et al., 1989 and Reddy et al., 1989). Aravindakshan et al. (1986) while evaluating 13 cashew selections at Cashew Research Station, Madakkathara observed highest shelling percentage (32.85) with the variety BLA-139-1 and the lowest (20) with the type K-19-1. Ghosh and Chatterjee (1987) observed shelling percentage to vary from 18 (selection 662) to 34.7 (Midnapore red) in 17 cashew types tested at Cashew Research Station, Jhargram. According to Nalini and Santhakumari (1991), shelling percentage of 10 selected cashew types evaluated at Cashew Research Station, Anakkayam varied from 25.8 (K-25-2) to 27.99 (BLA-139-1). Among the 14 hybrids tested at Kerala Agricultural University, the highest shelling percentage of 40.28 was noted with H 1598 (Salam et al., 1991b).

G. Nutrient concentration in plant parts

The leaf nutrient content depends on age of the crop, genotype, soil type and management practices in perennial trees. It can vary with plant part and growth stage. The nutrient concentration in different plant parts of cashew as influenced by age, genotype and growth stages reported by different authors are presented in Tables 1 to 5.

1. Nitrogen concentration (Table 1)

The leaf N concentration varies from 1.20 per cent (Gopikumar et al., 1978) to 3.24 per cent (Gopikumar and Aravindakshan, 1989) in cashew seedlings. In mature trees it ranges from 1.24 per cent (George et al., 1984) to 1.98 per cent (Calton, 1961).

Leaf N concentration varies with variety and it ranges from 1.28 per cent (KAU, 1987) to 2.76 per cent (Sanyal and Mitra, 1991).

The leaf N concentration varies with physiological phases. It was high during "flushing and early flowering" phase (1.85 per cent to 2.16 per cent) and low during

"fruiting and harvesting" phase (1.57 per cent to 1.96 per cent).

According to Gopikumar et al. (1978) kernel N varied from 2.85 per cent to 3.55 per cent between cashew varieties BLA-1 and T-20.

2. Phosphorus concentration (Table 2).

Phosphorus, the second major plant nutrient, occurs in concentrations ranging from 0.14 to 0.4 per cent in most plants (Tisdale et al., 1990).

In cashew, the leaf P concentration varies from 0.12 per cent (Falade, 1978) to 0.81 per cent (Gopikumar et al., 1978). In mature trees, it varies from 0.06 per cent (George et al., 1984) to 0.21 per cent (Calton, 1961).

Varietal difference in leaf P concentration is also traceable in literature and it varies from 0.09 per cent (Reddy and Reddy, 1988) to 0.15 per cent (KAU, 1987).

Variation in P concentration of leaf between physiological phases is also reported. According to

Mathew (1990), leaves of adult cashew contained 0.12 per cent P during flushing stage and it decreased to 0.04 per cent during fruiting and post-harvest phases.

The P content varied from 0.88 per cent to 1.23 per cent in cashew kernels of two varieties (Gopikumar et al., 1978).

3. Potassium concentration (Table 3)

The K concentration in cashew seedlings varies from 0.87 per cent (Gopikumar et al., 1978) to 3.17 per cent (Gopikumar and Aravindakshan, 1989). In mature trees, it ranges from 0.28 per cent (Lefebvre, 1973) to 1.69 per cent (Calton, 1961).

Leaf K content varies with variety ranging from 0.76 per cent in variety BPP 52 (Reddy and Reddy, 1988) to 1.82 per cent in variety Red Hazari (Sanyal and Mitra, 1991).

Leaf K concentration varies with physiological phases (Table 3). Mathew (1990) reported that a 10 year old cashew tree contained 2.45 per cent K during flushing and it decreased to 1.85 per cent during fruiting and it further declined to 1.45 per cent during post-harvest phase.

The K content of kernel ranged from 0.85 to 0.93 per cent in two cashew varieties (Gopikumar et al., 1978).

4. Calcium concentration (Table 4)

Variations in Ca concentration of leaves due to age, variety and physiological phases are reported in literature. The Ca concentration in leaf ranged from 0.15 per cent in BLA-273-1 (KAU, 1987) to 0.38 per cent in Red Hazari (Sanyal and Mitra, 1991).

According to Kumar (1983), Ca concentration of leaf varied with physiological phases and it was high during vegetative phase (0.76 per cent) and low during flowering phase (0.11 per cent).

5. Magnesium concentration (Table 4)

The leaf Mg concentration varies with age of tree and variety. The Mg concentration of leaf was low in mature trees (0.16 per cent; Lefebvre, 1973) and high in seedlings (1.61 per cent; Gopikumar and Aravindakshan, 1989). Between varieties, the leaf Mg concentration ranged from 0.18 to 0.24 per cent (KAU, 1987).

6. Sulphur concentration (Table 4)

The S concentration of the leaves was high in cashew seedlings (0.23 per cent; Gopikumar and Aravindakshan, 1989) and low in mature trees (0.15 per cent; Calton, 1961). It varies between varieties, ranging from 0.09 to 0.12 per cent (KAU, 1987).

7. Iron concentration (Table 5)

Leaf Fe content varies with plant age and varieties. It was high in seedlings (182 ppm; Gopikumar and Aravindakshan, 1989) and low in mature trees (45 ppm; Calton, 1961). Variation in leaf Fe content ranging from 95 to 146 ppm between cashew varieties is also reported (KAU, 1987).

8. Manganese concentration (Table 5)

Leaf Mn concentration in cashew trees ranging from 95 ppm (Calton, 1961) to 174 ppm (Lefebvre, 1973) is reported in literature. Varietal difference in leaf Mn content ranging from 49 to 158 ppm is also reported (KAU, 1987).

9. Zinc concentration (Table 5)

The leaf Zn content was high in seedlings (65.6 ppm; Gopikumar and Aravindakshan, 1989) and low in mature trees (20 ppm, Calton, 1961). Varietal difference in leaf Zn content ranging from 12 to 26 ppm is also reported (KAU, 1987).

10. Copper concentration (Table 5)

Variation in leaf Cu concentration ranging from 5.7 ppm (Lefebvre, 1973) to 16 ppm (Calton, 1961) is reported.

Critical level of nutrients

Critical level of nutrient is defined as the concentration of the element in the leaf above which a yield response from the element in the fertilizer is likely to occur (Prevot and Ollagnier, 1957). Kumar and Sreedharan (1986) suggested critical levels for leaf N and P as 2.09 and 0.14 per cent respectively. Mathew (1990) worked out the critical levels for leaf N and K as 2.00 and 1.03 per cent respectively. Latha (1992) worked out the critical levels of N, P and K at various physiological stages and

Table 1. Nitrogen concentration in different plant parts.

Concentration (per cent)	Remarks	Location	Reference
Leaf N			
2.4 - 2.8	Seedling	--	Haag et al. (1975)
1.53	Seedling	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
1.92	Seedling	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
1.20	Seedling	--	Falade (1978)
3.24	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
1.52 - 1.98	Mature tree	--	Calton (1961)
1.73	Mature tree	Madagascar	Lefebvre (1973)
1.24	Mature tree	CRS, Madakkathara, KAU	George et al. (1984)
	Varietal difference		
1.89	NDR-2-1	COH, KAU	KAU (1987)
1.28	BLA-39-4	COH, KAU	KAU (1987)

(Contd.....)

(Table 1 Contd.....)

2.09	H-4-7	CPCRI, Vittal	Kumar and Sreedharan (1988)
1.74	BPP 52	CRS, Kavali, APAU	Reddy and Reddy (1988)
2.76	Red Hazari	HRS, BCKV, West Bengal	Sanyal and Mitra (1991)
	Variation due to physiological phase		
1.85	Flushing	COH, KAU	Mathew (1990)
1.89	Flushing	COH, KAU	Latha (1992)
2.16	Flowering	CPCRI, Vittal	Kumar (1983)
1.74-2.46	Flowering	COH, KAU	Mathew (1990)
2.16	Flowering	COH, KAU	Latha (1992)
1.96	Fruiting	COH, KAU	Mathew (1990)
1.57	Harvesting	RRS, BCKV, Jhargram	Ghosh and Bose (1986)
1.79	Harvesting	COH, KAU	Mathew (1990)

(Contd....)

(Table 1 Contd.....)

1.71	Post-harvesting	RRS, BCKV, Jhargram	Ghosh and Bose (1986)
1.79	Post-harvesting	COH, KAU	Mathew (1990)
Kernel N			
2.85	BLA-1	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
3.55	T 20	CRS, Madakkathara, KAU	Gopikumar et al. (1978)

APAU - Andhra Pradesh Agricultural University

BCKV - Bidhan Chandra Krishi Viswavidyalaya

COH - College of Horticulture, Vellanikkara

CPCRI - Central Plantation Crops Research Institute

CRS - Cashew Research Station

HRS - Horticultural Research Station

KAU - Kerala Agricultural University

RRS - Regional Research Station

Table 2. Phosphorus concentration in different plant parts

Concentration (per cent)	Remarks	Location	Reference
Leaf P			
0.16-0.20	Seedling	--	Haag et al. (1975)
0.35	Seedling	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
0.81	Seedling	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
0.12	Seedling	--	Falade (1978)
0.34	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
0.21	Mature tree	--	Calton (1961)
0.08	Mature tree	Madagascar	Lefebvre (1973)
0.06	Mature tree	CRS, Madakkathara, KAU	George et al. (1984)
	Varietal difference		
0.12	BLA-273-4	COH, KAU	KAU (1987)
0.15	K-22-1	COH, KAU	KAU (1987)

(Contd.....)

(Table 2 Contd.....)

0.15	NDR-2-1	COH, KAU	KAU (1987)
0.14	H-4-7	CPCRI, Vittal	Kumar and Sreedharan(1988)
0.09	BPP 52	CRS, Kavali, APAU	Reddy and Reddy (1988)
0.10-0.11	Red Hazari	HRS, BCKV, West Bengal	Sanyal and Mitra (1991)
	Variation due to physiological phase		
0.12	Flushing	COH, KAU	Mathew (1990)
0.08	Before flowering	RRS, BCKV, Jhargram	Ghosh and Bose (1986)
0.14	Flowering	CPCRI, Vittal	Kumar (1983)
0.09-0.14	Flowering	COH, KAU	Mathew (1990)
0.12	Flowering	COH, KAU	Latha (1992)
0.04	Fruiting	COH, KAU	Mathew (1990)

(Contd.....)

(Table 2 Contd.....)

0.10	Harvesting	RRS, BCKV, Jhargram	Ghosh and Bose (1986)
0.03	Harvesting	COH, KAU	Mathew (1990)
0.04	Post-harvesting	COH, KAU	Mathew (1990)
Kernel P			
0.88	T 20	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
1.23	K-27-1	CRS, Madakkathara, KAU	Gopikumar et al. (1978)

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KAU - Kerala Agricultural University

RRS - Regional Research Station

Table 3. Potassium concentration in different plant parts

Concentration (per cent)	Remarks	Location	Reference
Leaf K			
0.87	Seedling	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
3.17	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
1.69	Mature tree	--	Calton (1961)
0.28	Mature tree	Madagascar	Lefebvre (1973)
0.50	Mature tree	CRS, Madakkathara, KAU	George et al. (1984)
	Varietal difference		
0.76	BPP 52	CRS, Kavali, APAU	Reddy and Reddy (1988)
1.82	Red Hazari	HRS, BCKV, West Bengal	Sanyal and Mitra (1991)

(Contd.....)

(Table 3 Contd.....)

	Variation due to physiological phase		
2.45	Flushing	COH, KAU	Mathew (1990)
1.14	Flowering	CPCRI, Vittal	Kumar (1983)
1.9-2.4	Flowering	COH, KAU	Mathew (1990)
0.63	Pre-fruiting	CPCRI, Vittal	Kumar et al. (1982)
1.85	Fruiting	COH, KAU	Mathew (1990)
1.80	Harvesting	COH, KAU	Mathew (1990)
1.45	Post-harvesting	COH, KAU	Mathew (1990)
Kernel K			
	Varietal difference		
0.93	K-27-1	CRS, Madakkathara, KAU	Gopikumar et al. (1978)
0.85	Sawantwadi	CRS, Madakkathara, KAU	Gopikumar et al. (1978)

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COH - College of Horticulture, Vellanikkara
CPCRI - Central Plantation Crops Research Institute
CRS - Cashew Research Station
HRS - Horticultural Research Station
KAU - Kerala Agricultural University

Table 4. Calcium, Magnesium and Sulphur concentration in different plant parts

Concentration (per cent)	Remarks	Location	Reference
Leaf Ca			
2.42	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
0.09	Mature tree	--	Calton (1961)
0.29	Mature tree	Madagascar	Lefebvre (1973)
	Varietal difference		
0.25	K-10-2	COH, KAU	KAU (1987)
0.15	BLA-273-1	COH, KAU	KAU (1987)
0.38	Red Hazari	HRS, BCKV, West Bengal	Sanyal and Mitra (1991)
	Variation due to physiological phase		
0.76	Vegetative phase	CPCRI, Vittal	Kumar (1983)
0.11	Flowering	CPCRI, Vittal	Kumar (1983)

(Contd.....)

(Table 4 Contd.....)

Leaf Mg			
1.61	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
0.20	Mature tree	--	Calton (1961)
0.16	Mature tree	Madagascar	Lefebvre (1973)
	Varietal difference		
0.24	BLA-139-1	COH, KAU	KAU (1987)
0.18	H-3-17	COH, KAU	KAU (1987)
0.22	Red Hazari	HRS, BCKV, West Bengal	Sanyal and Mitra (1991)
Leaf S			
0.23	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
0.15	Mature tree	--	Calton (1961)

(Contd.....)

Table 4 Contd....)

	Varietal difference		
0.09	K-22-1	COH, KAU	KAU (1987)
0.12	BLA-39-4	COH, KAU	KAU (1987)
0.10	Red Hazari	HRS, BCKV, West Bengal	Sanyal and Mitra (1991)

BCKV - Bidhan Chandra Krishi Viswavidyalaya

COH - College of Horticulture, Vellanikkara

CPCRI - Central Plantation Crops Research Institute

HRS - Horticultural Research Station

KAU - Kerala Agricultural University

Table 5. Iron, Manganese, Zinc and Copper concentration of different plant parts

Concentration (ppm)	Remarks	Location	Reference
Leaf Fe			
182	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
45	Mature tree	--	Calton (1961)
87	Mature tree	Madagascar	Lefebvre (1973)
	Varietal difference		
95	NDR-2-1	COH, KAU	KAU (1987)
146	H-3-17	COH, KAU	KAU (1987)
Leaf Mn			
95	Mature tree	--	Calton (1961)
174	Mature tree	Madagascar	Lefebvre (1973)

(Contd.....)

(Table 5 Contd.....)

	Varietal difference		
158	H-4-17	COH, KAU	KAU (1987)
49	BLA-273-1	COH, KAU	KAU (1987)
Leaf Zn			
65.6	Seedling	COH, KAU	Gopikumar and Aravindakshan (1989)
20	Mature tree	--	Calton (1961)
	Varietal difference		
12	BLA-273-1	COH, KAU	KAU (1987)
26	K-10-2	COH, KAU	KAU (1987)
Leaf Cu			
16	Mature tree	--	Calton (1961)
5.7	Mature tree	Madagascar	Lefebvre (1973)

COH - College of Horticulture, Vellanikkara
KAU - Kerala Agricultural University

found higher values at flowering. According to her, the critical values for N, P and K at flushing, flowering and fruiting stages were 1.89, 0.069 and 0.51 per cent, 2.16, 0.118 and 0.90 per cent and 2.05, 0.115 and 0.85 per cent respectively.

Nutrient removal

The amounts of nutrients removed from soil by a mature bearing cashew tree per annum has been worked out by Mohapatra et al. (1973). According to them, a bearing cashew tree yielding 24 kg nuts and 155 kg apples remove 2.847 kg N, 0.331 kg P and 1.012 kg K annually through different plant parts (root, stem, nut, apple). The nutrient removal was highest through roots and stem (1.721 kg N, 0.179 kg P and 0.64 kg K per annum) followed by nuts (0.756 kg N, 0.101 kg P and 0.146 kg K per annum) and then by apple (0.370 kg N, 0.051 kg P and 0.226 kg K per annum).

H. Use of ^{32}P in plant nutrition studies

There are reports on the successful use of radioactive isotope of phosphorus in plant nutrition and root activity studies in several crops. The restricted mobility of the

element in soil and its rapid absorption and translocation in the plant paved way for its wide use as a tracer in nutrition studies (Hall et al., 1953).

So far, no work could be traced in literature regarding the use of ^{32}P in the nutrition of cashew. Use of ^{32}P in the nutrition of other crops is traceable in literature; Krakkai and Bardos (1977) in wheat; Brown et al. (1979) in sorghum; Negi (1979) in maize and wheat; Ivanov and Lapa (1980) in potato and Ray (1979) in coconut.

In the present study, ^{32}P has been used to study the differential absorption of phosphorus by cashew varieties at different physiological phases.

Materials and Methods

MATERIALS AND METHODS

The present study was conducted at the Cashew Research Station, Madakkathara and at the Radio Tracer Laboratory, College of Horticulture, Kerala Agricultural University, Vellanikkara. The main objective of the investigation was to study the varietal difference in the growth and nutrition of cashew varieties in the oxisols of Kerala.

The studies undertaken during the course of the investigation were as follows.

Part I Variability in growth and yield of cashew varieties

Part II Nutrient concentration in plant parts and nutrient offtake

Part III Absorption of soil applied ^{32}P at different physiological phases

Location and climate

The experimental site was located at 10°32'N latitude and 76°10'E longitude at an altitude of 22.5 m above mean sea level. The area enjoys a warm humid tropical climate, with 317 cm rainfall *per annum* and mean relative humidity of 68.94 per

cent. The maximum and minimum temperatures ranged from 27.8 to 37.3°C and 19.8 to 25.4°C respectively. The weather conditions during the experimental period are given in Fig. 1 and Appendix 1.

The soil of the experimental site is typical laterite belonging to the soil order oxisols. Texturally the soil is sandy clay loam with a bulk density of 1.34 g/cm^3. The soil is shallow with a hard pan at about 2 m depth. The physico-chemical properties of the soil are as follows.

1. Mechanical composition (Hydrometer method, Bouyoucos 1962).

Coarse sand	:	28.9 per cent
Fine sand	:	21.2 per cent
Silt	:	14.6 per cent
Clay	:	31.3 per cent

2. Chemical properties

Constituent	Content	Rating	Method used for estimation
Organic carbon (per cent)	1.07	Medium	Walkley and Black method (Piper, 1950)
Total nitrogen (per cent)	0.10	Medium	Microkjeldahl distillation method (Jackson, 1958)

Available N (kg/ha)	331.5	Medium	Alkaline permanganate method (Jackson,1958).
Available P (kg/ha)	4.8	Low	Ascorbic acid method (Watanabe and Olsen, 1965)
Available K (kg/ha)	216	Medium	Flame photometry (Jackson, 1958)
pH (1:2.5 soil-water ratio)	5.8	Moderately acidic	pH meter method (Jackson, 1958).
EC (1:2.5 soil-water ratio dS/m)	0.1	Safe	Conductivity bridge method (Jackson,1958)
CEC : meq/100 g soil	4.0	-	Ammonium acetate method (Jackson, 1958)

3. Physical constants

Field capacity (0.3 bars)	18 per cent	Pressure plate method (Richards, 1947)
Wilting co-efficient (15 bars)	11.2 per cent	Pressure plate method (Richards, 1947)
Maximum water holding capacity	30 per cent	Keen Raczhowski box method (Piper, 1950)

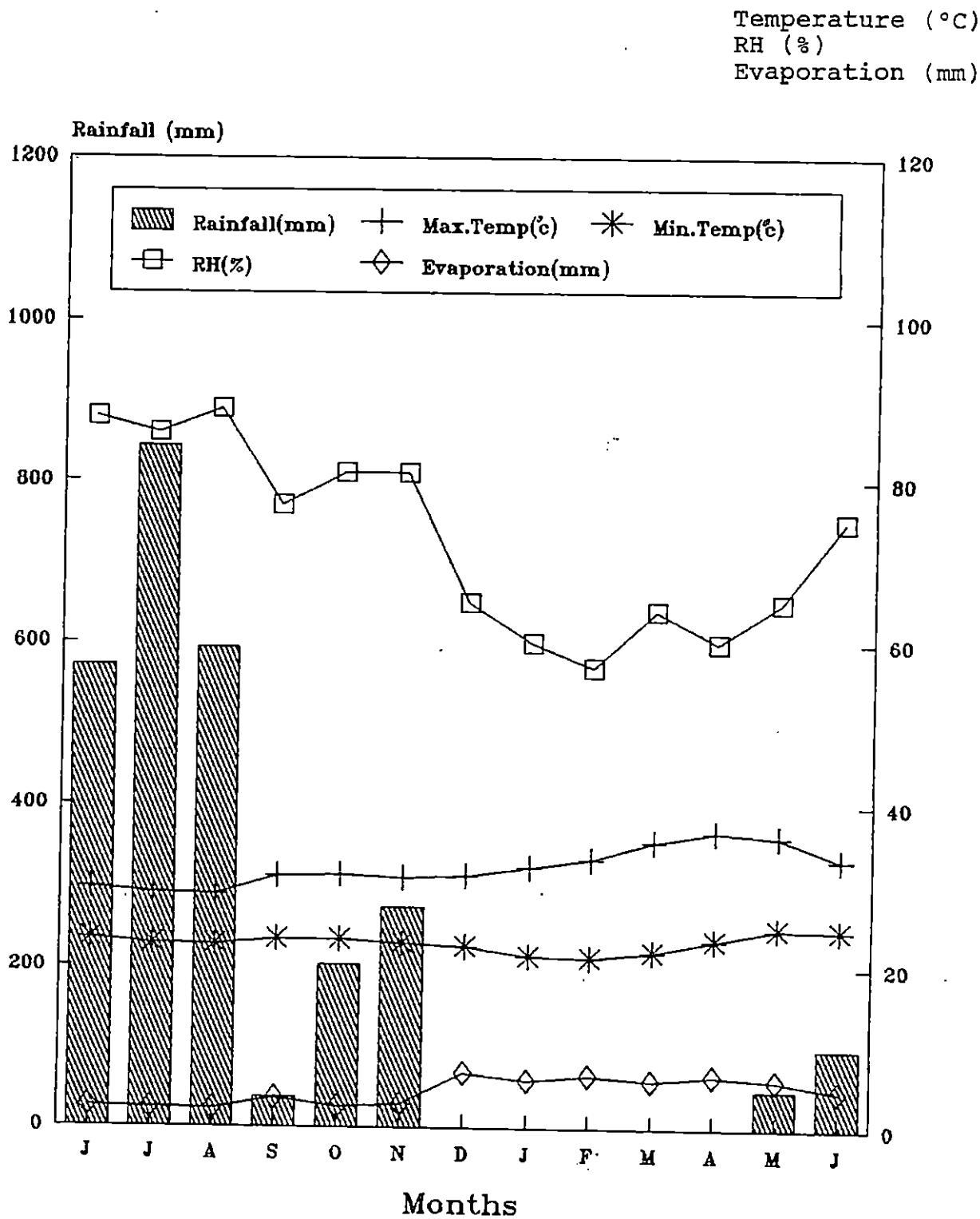


Fig.1 Weather during experimental period

Studies undertaken

Part I: Variability in growth and yield of cashew varieties

The objective of this experiment was to study the variation in the growth and yield of 18 cashew varieties. An existing field experiment started at Cashew Research Station, Madakkathara during 1987, has been adopted for this purpose during 1991. The experiment was conducted in a randomized block design with 18 varieties and 3 replications. There were four trees per variety in each block for evaluation. The lay out plan is given in Fig.2. There was one row of border trees all around the field as indicated in Fig. 2. The particulars of the varieties tested along with their sources are given in Table 6.

The crop was planted with soft wood grafts on 15th June, 1987 with a uniform spacing of 7.5 m x 7.5 m. The plants were raised rainfed and maintained as per the package of practices recommendations of Kerala Agricultural University (KAU, 1989). Fertilization (500 g N, 55 g P and 100 g K per tree), weeding, plant protection operation etc. were done uniformly for all the plants in all the years.

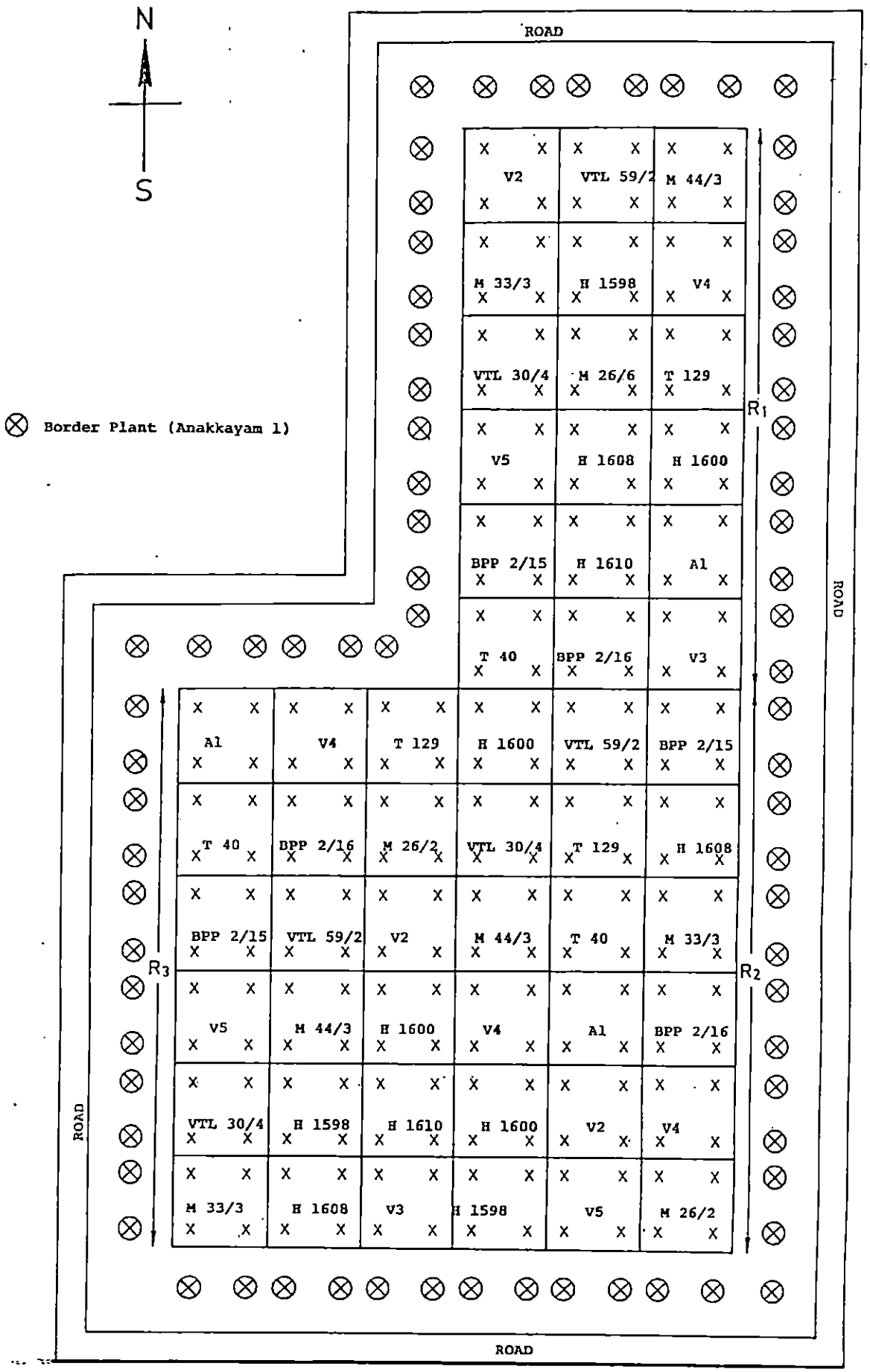


Fig.2. Lay-out plan of field experiment

Table 6. Cashew varieties tested and their sources

Sl.No.	Variety	Source
1.	H 1598	CRS, Madakkathara, KAU
2.	H 1600	,,
3.	H 1608	,,
4.	H 1610	,,
5.	Vittal 30/4 (VTL 30/4)	CPCRI, Vittal
6.	Vittal 59/2 (VTL 59/2)	,,
7.	Bapatla T 129 (T 129)	CRS,Bapatla
8.	Bapatla T 40 (T 40)	,,
9.	Bapatla 2/15 (BPP 2/15)	,,
10.	Bapatla 2/16 (BPP 2/16)	,,
11.	Vengurla 2 (V2)	CRS, Vengurla
12.	Vengurla 3 (V3)	,,
13.	Vengurla 4 (V4)	,,
14.	Vengurla 5 (V5)	,,
15.	Vridhachalam 33/3 (M 33/3)	CRS, Vridhachalam
16.	Vridhachalam 44/3 (M 44/3)	,,
17.	Vridhachalam 26/2 (M 26/2)	,,
18.	Anakkayam 1 (A1)	CRS, Anakkayam, KAU

CPCRI - Central Plantation Crops Research Institute

CRS - Cashew Research Station

KAU - Kerala Agricultural University

Observations recorded

a) Growth and physiological aspects

i. Tree height

The height of the tree was measured from ground level to the point of maximum vegetative growth and was expressed in m.

ii. Tree girth

The girth of the tree was measured at 50 cm height from the ground and was expressed in cm.

iii. Canopy spread

The canopy diameters in East-West and North-South directions were recorded and the mean value was taken as the canopy spread.

iv. Chlorophyll content

The index leaf (last fully matured leaf of the current season flush) as suggested by Mathew (1990) was chosen for chlorophyll analysis. The leaves were collected from four

trees per variety per replication, during the first week of November, 1991 and total chlorophyll, chlorophyll a and chlorophyll b contents were estimated spectrophotometrically (A.O.A.C., 1960) and expressed as milligram of chlorophyll per gram of fresh leaf.

v. Flowering

The date of commencement of flowering as well as the date of termination of flowering were recorded for each variety, to study the difference in the flowering season between varieties. Based on the time of flowering, the varieties were classified as early and mid season flowering varieties.

vi. Panicle length

Ten panicles were selected randomly from each tree, length of each panicle was measured from base to tip and mean value was recorded in cm.

vii. Panicle breadth

The breadth at the widest region of the above selected panicles was measured and the mean value was recorded in cm.

b) Yield components and yield

i) Number of fruits per panicle

The number of fruits per panicle was recorded from 10 randomly selected panicles of a tree and the average of four trees was recorded for each variety.

ii) Nut weight

Twenty nuts were collected randomly from each variety and the mean nut weight was recorded in grams.

iii) Kernel weight

Fifty nuts were randomly selected from each variety, fried and shelled. They were weighed and the mean kernel weight recorded.

iv. Shelling percentage

One kilogram of nuts were fried and shelled and the kernel weight recorded. The shelling percentage was worked out as the ratio of kernel weight to nut weight and expressed as percentage.

v. Apple weight

Ten fully ripe apples were collected randomly from each tree and the mean weight recorded in grams.

vi. Nut yield

During the harvesting period, nuts were collected six times, separately from each tree, by removing the nut from the apple. The collected nuts were sun-dried for three days and the total nut yield from each tree was recorded.

Part II. Nutrient concentration in plant parts and nutrient offtake

a) Nutrient concentration in different plant parts

The objective of the study was to assess the variation in the nutrient concentration in different plant parts (leaves at flushing and apple, kernel and shell at harvest) of selected cashew varieties. For this purpose, six cashew varieties (Anakkayam 1, H 1598, H 1600, V3, V5 and M 26/2) were chosen from the field experiment mentioned above (under Part I). To assess the leaf nutrient status, the index leaf (last fully matured leaf of the current season flush) as

suggested by Mathew (1990) was chosen for chemical analysis. The leaf samples were collected from the above six varieties during November ("flushing and early flowering" phase) from four trees per variety, dried, milled and subjected to chemical assay. At the time of harvest, the total quantity of apple, kernel and shell produced by individual trees of the six varieties was determined on dry weight basis. The dried plant samples (apple, kernel and shell) were also subjected to chemical analysis. The methods of chemical analysis followed are detailed at the end of this section (Part II).

b) Nutrient offtake

The objective of the study was to quantify the annual nutrient removal (nutrient offtake) by a cashew tree through the harvested parts.

For this purpose, using the data on the dry weights of the harvested parts (apple, kernel and shell) and their nutrient concentrations, the nutrient offtake (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) through individual plant parts was worked out first. Then, the annual nutrient offtake by cashew has been estimated as the sum of the nutrient removed by individual plant parts (apple, kernel and shell).

c) Leaf nutrient status in relation to physiological phases

The objective of this study was to assess the variation in leaf nutrient status in relation to physiological phases. For this purpose, a cashew variety viz. Anakkayam 1 was chosen from the field experiment mentioned under Part I. The samples of the index leaves (Mathew, 1990) were collected from four trees each, during four physiological phases viz. post-harvest flushing (July), "flushing and early flowering" (October), "flowering and fruiting" (December) and "maturity and harvesting" (March) phases. The leaf samples were dried and milled and chemically analysed. The methods of analysis followed are detailed below.

Methods of chemical analysis

Total nitrogen content of the plant samples (leaf, apple, kernel and shell) was determined by microkjeldahl digestion and distillation method (Jackson, 1958). For the determination of other nutrient elements (P, K, Ca, Mg, S, Fe, Zn, Mn and Cu), the samples were digested with 2:1 nitric-perchloric acid mixture (Johnson and Ulrich, 1959). Phosphorus in the digest was estimated spectrophotometrically by the vanado-molybdate yellow colour method

(Jackson, 1958). The P content of the shell was determined following the ascorbic acid method (Watanabe and Olsen, 1965). Potassium contents of the digests were estimated by flame photometer method (Jackson, 1958). Calcium and Magnesium contents in the digests were determined by Versonate method (Jackson, 1958). Total S contents in the digests were estimated turbidimetrically (Hesse, 1971) and Fe by thiocyanate method (Jackson, 1958). The estimation of Mn, Zn and Cu were done in an atomic absorption spectrophotometer (Page, 1982).

Part III. Absorption of soil applied ^{32}P at different physiological phases

a) Under rainfed conditions

The objective of this experiment was to study the pattern of absorption of applied ^{32}P by cashew varieties during different physiological phases under rainfed conditions. For this purpose, the ^{32}P soil injection technique was employed. Four cashew varieties (Anakkayam 1, H 1598, H 1600 and V5) from the field experiment mentioned under Part I, were chosen for the study. Six trees of more or less uniform growth and vigour were selected from each variety. The trees were planted at a spacing of

7.5 m x 7.5 m, in a cluster of four trees per variety per block. For the purpose of application of ^{32}P, diagonally opposite trees were selected (Fig. 3) to avoid root interaction between adjacent treated plants.

Based on the growth behaviour of cashew under the agro-climatic conditions prevailing in the state of Kerala, the occurrence of distinct physiological phases of cashew were first identified for the application of ^{32}P. The physiological phases of cashew and the corresponding season of occurrence are given below.

i. Post-harvest phase (June-August)

ii. Flushing and early flowering phase (October-November)

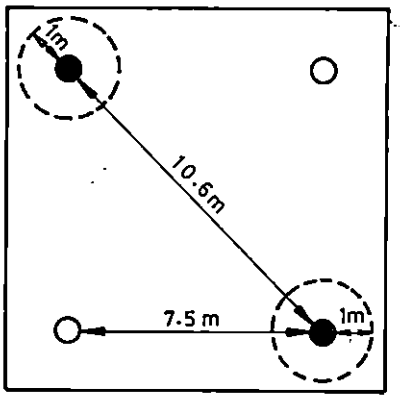
iii. Flowering and fruiting phase (December-February)

iv. Maturity and harvesting phase (March-May)

To study the absorption pattern of ^{32}P, soil injection of ^{32}P was done four times at the four physiological phases. The details regarding the physiological phases, their season of occurrence, time of soil injection of ^{32}P and period of leaf sampling are given in Fig. 5.

Soil injection of ^{32}P

The basins of the selected trees were cleared of weeds over a radial distance of 3 m around the trunk. Equally spaced 16 soil holes (2 cm diameter) were dug with the help of a soil auger to 15 cm depth around the tree at a radial distance of 1 m from the tree trunk (Fig. 4). PVC access tube of about 30 cm length was inserted into each hole so that about 15 cm of the tube would be jutting out above the soil surface (Plate 1). The PVC tubes were closed at the open ends with plastic caps to prevent filling up during rains. At the time of ^{32}P application, the plastic caps were removed from PVC tubes and 2 ml of radioactive solution at a carrier level of 1000 ppm P was applied into each tube using a dispenser (Plate 2) designed for the purpose (Wahid et al., 1988). The amount of radioactivity applied per tree was 1 mCi (37 MBq). The method of application followed is shown in Plate 3. After application, the radioactivity adhered on the inner side of the PVC tube was washed down with a jet of about 15 ml water. The access tube was left as it is for subsequent ^{32}P injections at different physiological phases. The radioactivity in the plant was measured as detailed below.



Spacing 7.5 m x 7.5 m

Fig. 3. Diagram showing ^{32}P treatment allocation to the trees

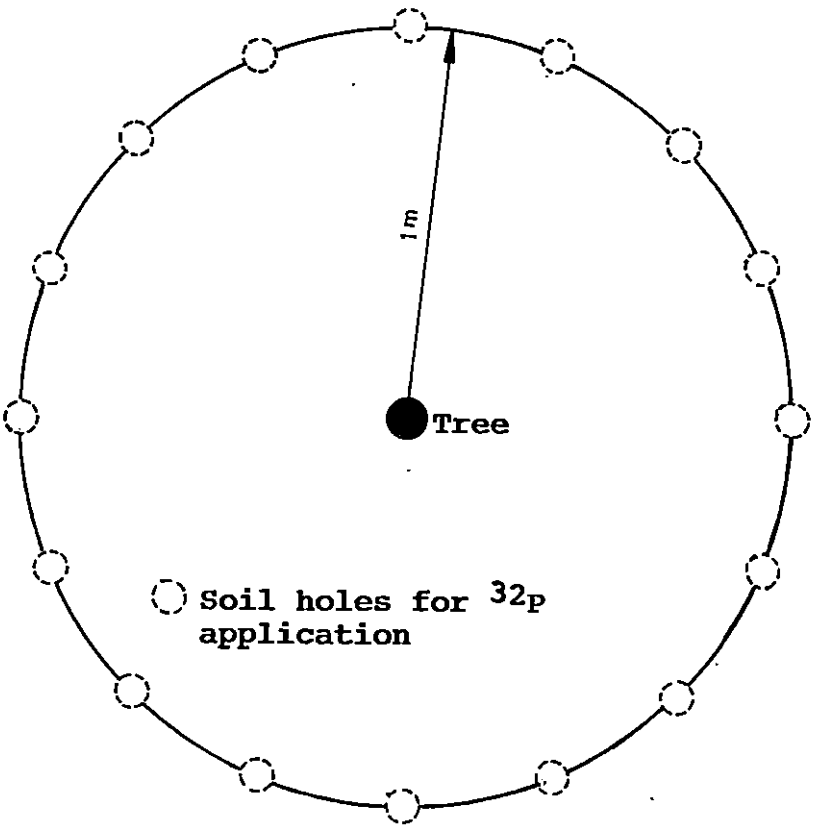


Fig. 4. Method of ^{32}P application around the tree

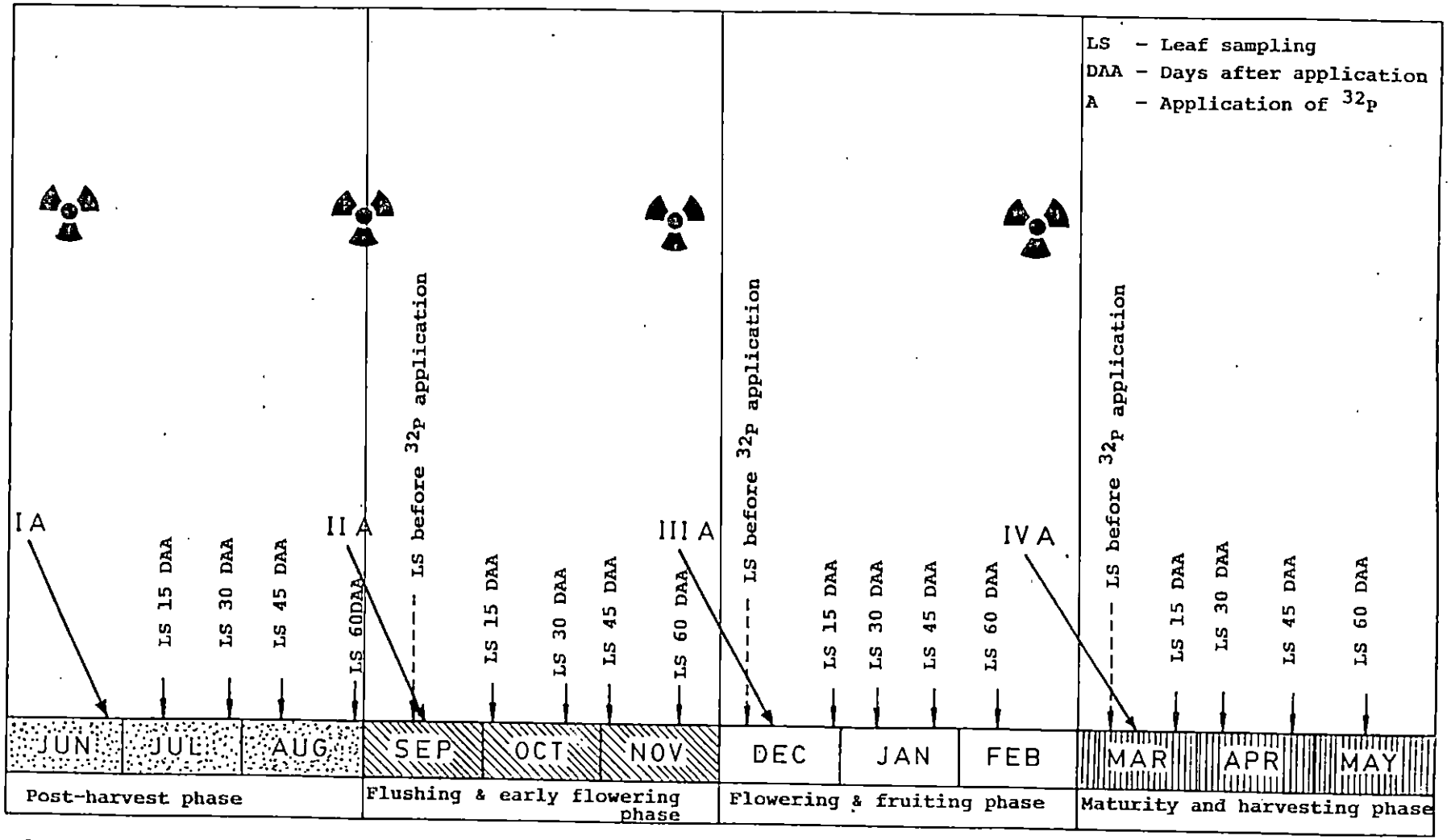


Fig.5. Physiological phases in cashew, their seasons of occurences, times of soil injection of ^{32}P and times of leaf sampling

Leaf sampling

The last fully matured leaf (index leaf) of the current season flush was selected for radioassay. Leaf samples were collected four times at an interval of 15 days after each application. In addition, just prior to the 2nd, 3rd and 4th application of ^{32}P, leaf samples were collected to estimate the pre-treatment level of radioactivity (Fig. 5).

Radioassay

For the determination of ^{32}P activity in the leaves, Cerenkov counting method developed by Wahid et al. (1985) was followed. The method involved wet digestion of 1 g of oven-dried and finely cut leaves with 2:1 nitric-perchloric acid mixture followed by transferring the digest into a scintillation counting vial with distilled water up to a final volume of 20 ml. The vials with the contents were left undisturbed for four hours for the silica in the digest to settle down. Later the radioactivity in the vial containing the acid digest was determined in a microprocessor-controlled liquid scintillation system (Rackbeta of LKB Wallac Oy, Finland) following the programme for the liquid scintillation counting of tritium.

Plate 1

A tree base showing sites of application of ^{32}P. 16 PVC tubes of 30 cm length are inserted to a depth of 15 cm at 1 m radius around the tree

Plate 2

Field dispenser used for soil injection of ^{32}P solution

Plate 3

Application of ^{32}P solution through the PVC tubes using field dispenser

The count rates (cpm) were corrected for background and decay. No attempt was made to present the data in dpm as the counting efficiency of the instrument remained constant (32 per cent) during the period.

b) Effect of irrigation on ^{32}P absorption

This experiment was aimed to study the effect of irrigation during summer on the absorption of applied ^{32}P. For this purpose, six cashew trees(variety Anakkayam 1) from the field experiment mentioned under Part I, of more or less uniform growth and vigour (7.5 m x 7.5 m), were chosen. These trees were left rainfed from June to November and irrigated from December to May. During irrigation, the soil moisture was maintained around 50 per cent of the field capacity. All the trees received uniform management practice as per the package of practices recommendation of Kerala Agricultural University (KAU, 1989). Following the same techniques and procedures explained under Part III (a) above, the ^{32}P absorption was determined at four physiological phases viz. post-harvest phase (June-August), "flushing and early flowering" phase (October-November), "flowering and fruiting" phase (December-February) and "maturity and harvesting" phase (March-May).

Statistical analysis

The data relating to Part I were statistically analysed applying the analysis of variance for randomized block design and that of Part II by employing the analysis of variance for factorial experiment in completely randomized design. In view of the wide variability in cpm values, the data on ^{32}P absorption study (Part III) was subjected to log-transformation prior to statistical analysis (Panse and Sukhatme, 1978).

Results

RESULTS

The results of the experiments conducted during the course of the investigation are presented below.

PART I. Variability in growth and yield of cashew varieties

A. Growth and physiological aspects

The growth performance of 18 cashew varieties was evaluated at the fifth year of planting and the results are presented below.

Tree height (Table 7)

The tree height ranged from 3.55 m (M 33/3) to 4.69 m (H 1610) between varieties. However, this difference did not reach the level of significance.

Tree girth (Table 7)

As in the case of plant height, the tree girth did not differ between varieties though it varied from 42.5 cm (V5) to 58.7 cm (H 1600) between varieties.

Table 7. Growth and physiological characteristics of different cashew varieties

Sl. No.	Name of variety	Tree height m	Tree girth cm	Canopy spread m	Chlorophyll a mg/g of fresh leaf	Chlorophyll b mg/g of fresh leaf	Total chloro-phyll mg/g of fresh leaf	Flowering habit	Panicle length cm	Panicle breadth cm
1	H 1598	4.29	57.7	6.19	0.496^{ab}	0.492^{a}	0.926^{ab}	Mid*	17.2^{defg}	16.8^{g}
2	H 1600	4.14	58.7	5.65	0.284^{efg}	0.202^{c}	0.486^{gh}	Early**	18.8^{abcde}	20.6^{bcd}
3	H 1608	3.80	53.0	5.45	0.468^{abc}	0.353^{b}	0.802^{bcd}	Mid	19.1^{abcd}	20.4^{bcde}
4	H 1610	4.69	55.8	5.83	0.450^{abcd}	0.272^{bc}	0.722^{bcde}	Mid	19.7^{ab}	21.4^{abc}
5	VTL 30/4	4.45	52.2	5.88	0.297^{efg}	0.328^{b}	0.626^{cdefgh}	Early	19.8^{a}	24.4^{a}
6	VTL 59/2	4.44	51.3	6.36	0.271^{efg}	0.280^{bc}	0.551^{efgh}	Mid	17.1^{defg}	20.1^{bcdef}
7	T 129	4.17	53.2	6.24	0.255^{efg}	0.315^{b}	0.570^{efgh}	Mid	17.2^{defg}	20.0^{bcdef}
8	T 40	3.68	51.0	5.46	0.323^{defg}	0.282^{bc}	0.606^{defgh}	Early	16.5^{fgh}	18.5^{cdefg}
9	BPP 2/15	4.38	56.1	6.15	0.357^{bcdefg}	0.344^{b}	0.700^{cdef}	Mid	16.9^{defg}	18.9^{cdefg}
10	BPP 2/16	3.96	49.0	5.83	0.390^{abcde}	0.331^{b}	0.721^{bcde}	Early	17.4^{cdef}	19.9^{bcdef}
11	V2	4.60	46.7	5.45	0.478^{abc}	0.277^{bc}	0.754^{bcde}	Mid	18.0^{abcdef}	19.0^{cdefg}
12	V3	4.44	49.3	5.20	0.528^{a}	0.507^{a}	1.034^{a}	Mid	19.5^{abc}	22.2^{ab}
13	V4	4.36	49.50	5.52	0.338^{cdefg}	0.328^{b}	0.666^{cdefg}	Mid	15.2^{g}	17.5^{efg}
14	V5	3.87	42.50	4.57	0.363^{bcdef}	0.253^{bc}	0.616^{defg}	Early	17.5^{bcdef}	17.9^{defg}
15	M 33/3	3.55	43.6	4.66	0.486^{ab}	0.347^{b}	0.832^{abc}	Mid	18.90^{abcde}	20.50^{bcde}
16	M 44/3	3.83	49.8	5.29	0.456^{abcd}	0.358^{b}	0.814^{bcd}	Early	17.0^{defg}	20.1^{bcdef}
17	M 26/2	3.97	52.0	5.59	0.240^{fg}	0.204^{c}	0.443^{h}	Early	19.6^{abc}	19.9^{bcdef}
18	Anakkayam 1	3.93	46.3	5.31	0.218^{g}	0.277^{bc}	0.496^{fgh}	Early	16.9^{efg}	17.1^{fg}
SE m±		0.26	3.6	0.44	0.05	0.04	0.08		0.80	1.09
CD (0.05)		NS	NS	NS	0.14	0.11	0.21		2.22	3.03

** Early Season Flowering - last week of November to December
* Mid Season Flowering - last week of January to February
Values followed by the same alphabet are not significantly different.

Canopy spread (Table 7)

The canopy spread of the cashew varieties ranged from 4.57 m (V5) to 6.36 m (VTL 59/2) without showing any significant difference between the varieties.

Chlorophyll content (Table 7)

The chlorophyll content of leaves (chlorophyll a, chlorophyll b and total chlorophyll) differed significantly between varieties (Fig. 6). The leaves of the variety V3 contained the highest amount of chlorophyll (1.034 mg/g of fresh leaf). The chlorophyll a content ranged from 0.218 mg/g of fresh leaf (Anakkayam 1) to 0.528 mg/g of fresh leaf (V3). The chlorophyll b content ranged from 0.202 mg/g of fresh leaf (H 1600) to 0.507 mg/g of fresh leaf (V3).

Flowering (Table 7)

Flowering of the varieties commenced from the last week of November and ended by last week of February. The varieties VTL 30/4, T40, BPP 2/16, V5, M44/3, M 26/2, Anakkayam 1 and H 1600 started flowering during the last week of November (early flowering) and ended by December. The other varieties VTL 59/2, T129, BPP 2/15, V2, V3, V4,

M 33/3, H 1598, H 1608 and H 1610 started flowering by the last week of January and ended by February.

Panicle length (Table 7)

The panicle length differed significantly between varieties. It ranged from 15.2 cm (V4) to 19.8 cm (VTL 30/4).

Panicle breadth (Table 7)

The panicle breadth also differed significantly between varieties. It ranged from 16.8 cm (H 1598) to 24.4 cm (VTL 30/4) between varieties.

B. Yield components and yield

Number of fruits per panicle (Table 8)

The number of fruits per panicle did not differ significantly between varieties though the number varied from 5.55 (V3) to 9.38 (M 44/3) between varieties.

Table 8. Yield components, yield and other characteristics of different cashew varieties

Sl. No.	Name of variety	No.of fruits per panicle	Nut weight g	Nut yield kg/tree	Kernel weight g	Apple weight g	Shelling percentage
1	H 1598	8.48	5.46^{g}	3.49^{bc}	2.01^{abcde}	77.8^{bcd}	32.7^{bcd}
2	H 1600	8.04	7.51^{bc}	4.97^{ab}	2.04^{abcde}	72.1^{bcd}	27.0^{g}
3	H 1608	8.14	7.94^{a}	2.70^{bc}	2.02^{abcde}	90.0^{abc}	25.7^{h}
4	H 1610	8.64	6.91^{de}	1.77^{c}	2.37^{ab}	66.0^{bcd}	26.9^{gh}
5	VTL 30/4	7.18	5.39^{g}	3.20^{bc}	1.86^{bcdefg}	70.4^{bcd}	34.4^{ab}
6	VTL 59/2	7.49	6.58^{ef}	3.85^{bc}	2.09^{abcde}	92.2^{ab}	29.5^{ef}
7	T 129	6.23	4.71^{h}	2.98^{bc}	1.46^{fg}	64.9^{bcd}	35.5^{a}
8	T 40	6.42	4.82^{h}	3.16^{bc}	1.93^{bcdef}	61.0^{cde}	34.0^{abc}
9	BPP 2/15	5.83	7.21^{cd}	1.97^{c}	2.31^{abc}	109.4^{a}	32.0^{bcde}
10	BPP 2/16	7.06	7.92^{a}	2.50^{bc}	2.46^{a}	92.3^{ab}	30.5^{def}
11	V2	6.74	6.49^{f}	3.76^{bc}	2.04^{abcde}	75.1^{bcd}	31.6^{cde}
12	V3	5.55	7.27^{cd}	3.84^{bc}	2.18^{abcde}	87.1^{abc}	29.5^{ef}
13	V4	7.51	7.12^{cd}	2.70^{bc}	2.33^{ab}	81.4^{abc}	31.4^{def}
14	V5	8.92	4.72^{h}	3.18^{bc}	1.38^{g}	32.9^{e}	29.1^{fg}
15	M 33/3	6.32	7.85^{ab}	3.66^{bc}	1.67^{efg}	73.7^{bcd}	23.0^{i}
16	M 44/3	9.38	4.92^{h}	6.81^{a}	1.80^{cdefg}	49.6^{de}	30.1^{ef}
17	M 26/2	6.48	6.6^{ef}	6.59^{a}	2.21^{abcd}	75.4^{bcd}	31.4^{def}
18	Anakkayam 1	5.84	5.41^{g}	2.12^{c}	1.71^{defg}	65.8^{bcd}	35.4^{a}
SE m±		0.96	0.14	0.97	0.15	10.6	0.89
CD (0.05)		NS	0.39	2.70	0.52	29.4	2.52

Values followed by the same alphabet are not significantly different

Nut weight (Table 8)

The nut weight differed significantly between varieties (Fig. 7). Among the 18 varieties tested, the nut weight ranged from 4.71 g (H 1608) to 7.94 g (T 129).

Kernel weight (Table 8)

The kernel weight differed between varieties (Fig. 8) and it varied from 1.38 g (V5) to 2.46 g (BPP 2/16). Eleven out of 18 cashew varieties tested (H 1598, H 1600, H 1608, H 1610, VTL 59/2, BPP 2/15, BPP 2/16, V2, V3, V4, M 26/2) had kernel weight more than 2 g.

Nut yield (Table 8)

There was marked difference in nut yield between the 18 varieties tested at the fifth year of planting (Fig. 9). The highest nut yield (6.81 kg/tree) was obtained from the cashew variety M 44/3 and it was on par with that of varieties M 26/2 (6.59 kg/tree) and H 1600 (4.97 kg/tree). The nut yield of the varieties VTL 30/4, VTL 59/2, T 40, V2, V4, V5, M 33/3 and H 1598 ranged from 3 to 4 kg/tree and that of T 129, BPP 2/16, V4, Anakkayam 1 and H 1608 ranged from 2 to 3 kg/tree. The nut yield of the varieties BPP 2/15 and H 1610 was less than 2 kg/tree.

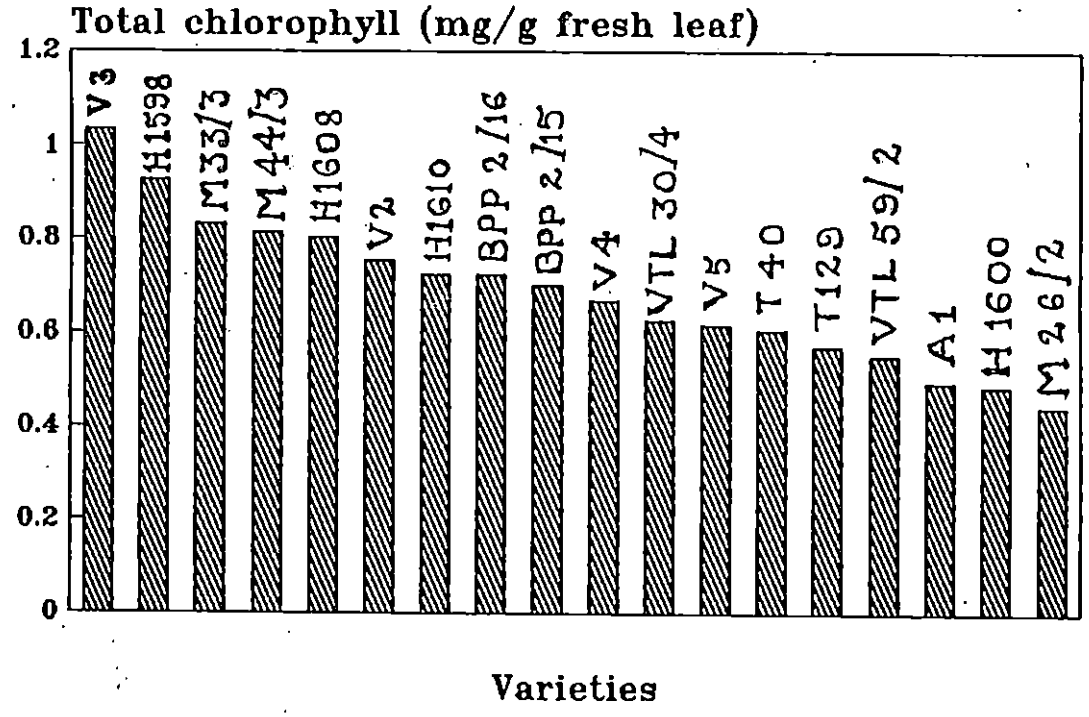


Fig. 6 Varietal variation in total chlorophyll

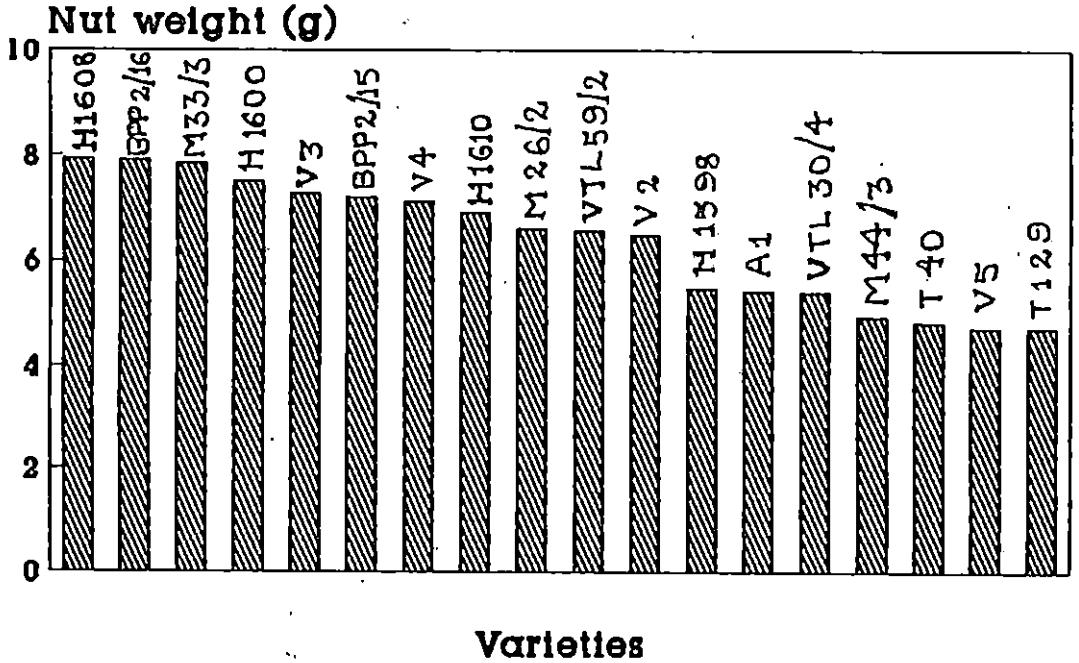


Fig.7 Varietal variation in nut weight

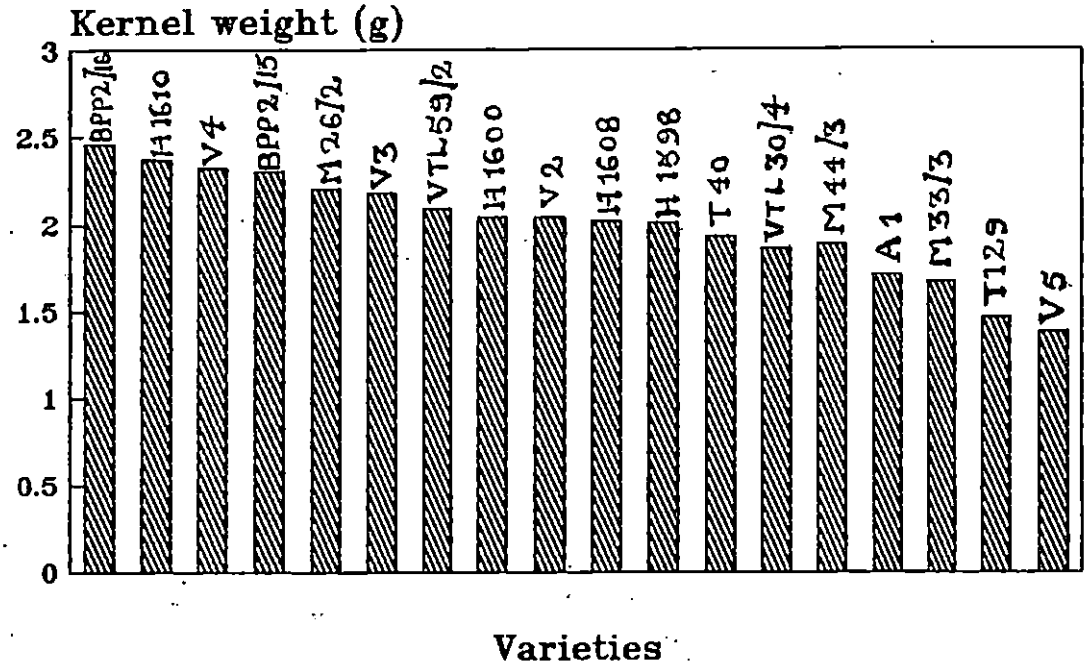


Fig. 8 Varietal variation in kernel weight

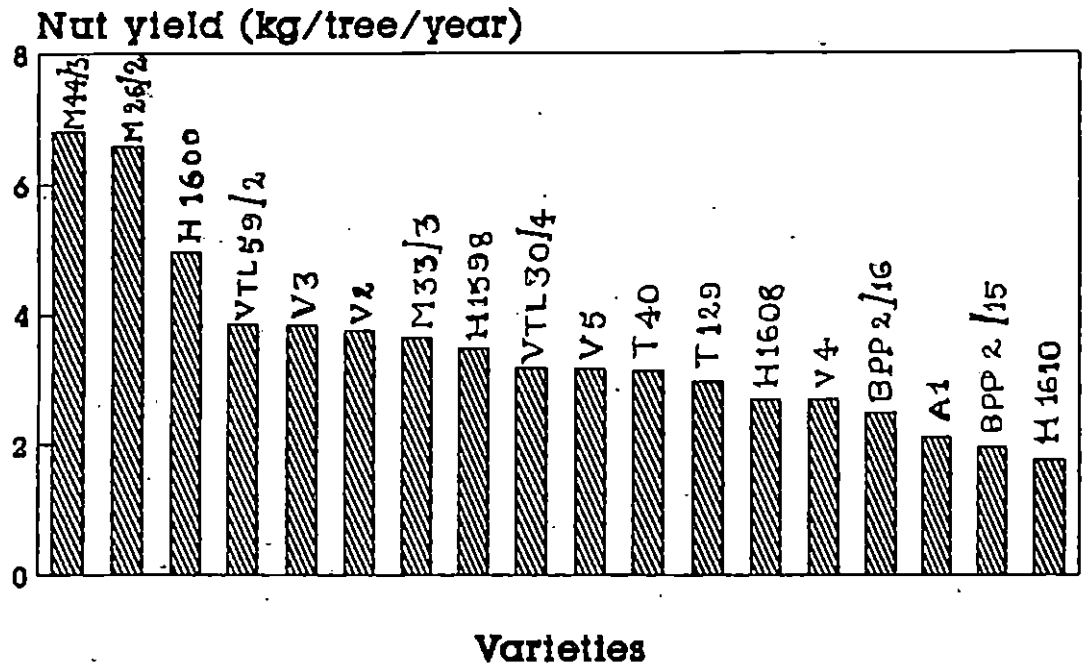


Fig. 9 Varietal variation in nut yield

Apple weight (Table 8)

The apple weight differed between varieties (Fig. 10). The apples of the variety BPP 2/15 had the highest weight (109 g) and the lowest with the variety V5 (32.9 g).

E. Shelling percentage (Table 8)

Shelling percentage differed with varieties (Fig.11) and it was the highest (35.5) with the variety T 129 and lowest (23.0) with the variety M 33/3. Among the varieties tested, eleven of them (H 1598, VTL 30/4, T 129, T 40, BPP 2/15, BPP 2/16, V2, V4, M 44/3, M 26/2 and Anakkayam 1) had shelling percentage more than 30.

PART II. Nutrient status in plant parts and nutrient offtake

a) Nutrient status in plant parts

In this experiment, the concentration of major and minor nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) of leaves at flushing, and apple, kernel and shell at harvesting were determined in six cashew varieties. The annual removal of these nutrients through apple, shell and

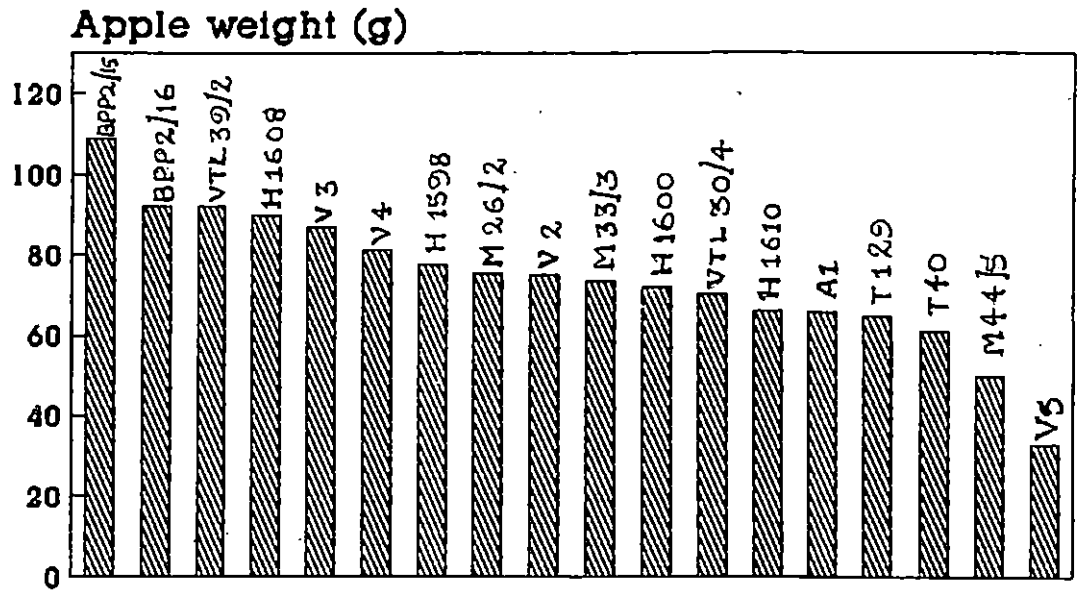


Fig.10Varietal variation in apple weight

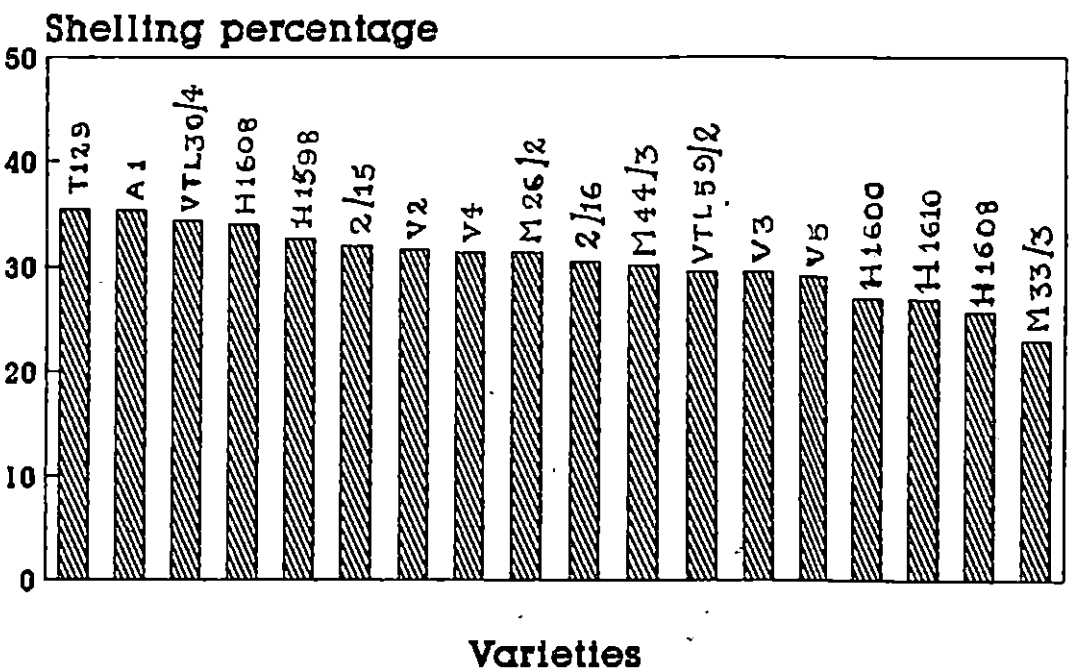


Fig.11Varietal variation in shelling percentage

kernel (nutrient offtake) by these varieties was also estimated. The results of the experiment are presented below.

Nitrogen (Table 9)

The N concentration in cashew varied with variety and plant part. It was high in kernel compared to leaf, apple and shell and it was highest in the kernels of H 1598 (4.78 per cent) followed by M 26/2 and V5 (4.62 per cent).

Phosphorus (Table 9)

The P concentration in cashew varied with variety and plant part. It was high in kernel (0.23 per cent) compared to leaf, apple and shell. The highest P contentration was noted with the kernels of the varieties M 26/2 and V5.

Potassium (Table 9)

The K concentration in cashew differed with variety and plant part. Among the plant parts (leaf, apple, kernel and shell), K concentration was high in apple. The apples of H 1598 (2.54 per cent) and Anakkayam 1 (2.48 per cent) contained more K.

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Calcium (Table 9)

As in the case of N and P, the kernel contained more amounts of Ca. The kernels of H 1598 (0.37 per cent) and Anakkayam 1 (0.35 per cent) contained more Ca than those of the other varieties.

Magnesium (Table 9)

The Mg concentration in cashew differed with plant part and it was high in the apple (0.09 per cent) compared to leaf, kernel and shell. The apples of the varieties Anakkayam 1 and H 1598 contained more amounts of Mg (0.11 per cent) compared to other varieties.

Sulphur (Table 9)

The S concentration in cashew varied with variety and plant part. The S content was high in cashew kernels compared to leaf, apple and shell. The kernels of the varieties V3 (0.18 per cent) and H 1598 (0.17 per cent) contained more S compared to other varieties.

Iron (Table 9)

The Fe concentration in cashew differed with plant part and variety. It was high in the apple compared to leaf, kernel and shell. The apples of H 1600 (295 ppm) and M 26/2 (275 ppm) contained more Fe than those of the other varieties.

Manganese (Table 9)

The Mn concentration in cashew varied with plant part and variety. It was high in the leaf compared to apple, kernel and shell. The highest Mn concentration was seen with the leaves of the variety Anakkayam 1 (166 ppm).

Zinc (Table 9)

The Zn concentration in cashew differed with plant part and variety. The Zn concentration was high in the kernel compared to leaf, apple and shell. The kernels of H 1598 (64.6 ppm) contained more Zn.

Copper (Table 9)

The Cu concentration varied with plant part. It was high (23.3 ppm) in the kernel compared to leaf, apple and shell.

Table 9. Concentration of nutrients in leaf, apple, kernel and shell of six cashew varieties

Nutrient	Plant part	Variety						Mean		SEm±	CD (0.05)
		Al	H1598	H1600	V3	V5	M 26/2				
1	2	3	4	5	6	7	8	9		10	11
N (%)	Leaf	2.94^{ab}	2.68^{b}	2.73^{b}	2.78^{b}	2.68^{b}	3.26^{a}	2.84^{b}	Plant part	0.06	0.17
	Apple	2.89^{b}	2.73^{bc}	2.47^{c}	2.89^{b}	2.84^{bc}	3.41^{a}	2.87^{b}	Variety	0.07	0.19
	Kernel	4.25^{b}	4.78^{a}	4.41^{ab}	4.46^{ab}	4.62^{ab}	4.62^{ab}	4.52^{a}	Interaction	0.14	0.39
	Shell	2.26	2.0	1.94	2.21	2.0	2.05	2.07^{c}			
	Mean	3.08^{b}	3.05^{b}	2.89^{b}	3.08^{b}	3.03^{b}	3.33^{a}				
P (%)	Leaf	0.06	0.07	0.06	0.08	0.08	0.08	0.07	Plant part	0.004	0.01
	Apple	0.10	0.10	0.08	0.09	0.07	0.10	0.09	Variety	0.005	0.014
	Kernel	0.22	0.21	0.22	0.21	0.23	0.25	0.23	Interaction	0.01	NS
	Shell	0.02	0.03	0.02	0.03	0.03	0.03	0.03			
	Mean	0.10^{ab}	0.10^{ab}	0.09^{b}	0.11^{a}	0.10^{ab}	0.11^{a}				

Contd....

Table 9 contd...

1	2	3	4	5	6	7	8	9	10	11
K (%)	Leaf	1.17^{ab}	1.07^{b}	1.15^{ab}	1.34^{a}	1.15^{ab}	1.24^{ab}	1.19^{b}	Plant part 0.04	0.11
	Apple	2.48^{a}	2.54^{a}	1.63^{b}	1.80^{b}	1.74^{b}	2.25^{b}	2.07^{a}	Variety 0.05	0.14
	Kernel	0.74	0.79	0.78	0.79	0.80	0.81	0.79^{c}	Interaction 0.09	0.25
	Shell	0.65	0.57	0.56	0.49	0.58	0.39	0.54^{d}		
	Mean	1.26^{a}	1.24^{b}	1.03^{c}	1.10^{bc}	1.07^{c}	1.17^{abc}			
Ca (%)	Leaf	0.32^{a}	0.23^{bc}	0.28^{ab}	0.22^{bc}	0.22^{bc}	0.18^{c}	0.24^{b}	Plant part 0.01	0.03
	Apple	0.13	0.17	0.17	0.12	0.15	0.17	0.15^{c}	Variety 0.01	NS
	Kernel	0.35	0.37	0.31	0.32	0.34	0.34	0.34^{a}	Interaction 0.02	0.06
	Shell	0.11	0.11	0.12	0.13	0.11	0.13	0.12^{c}		
	Mean	0.23	0.22	0.22	0.20	0.21	0.21			
Mg (%)	Leaf	0.06	0.07	0.06^{ab}	0.09	0.08	0.08	0.07^{b}	Plant part 0.005	0.01
	Apple	0.11^{a}	0.11^{a}	0.10^{ab}	0.07^{b}	0.07^{b}	0.09^{ab}	0.09^{a}	Variety 0.01	NS
	Kernel	0.04^{b}	0.04^{b}	0.06^{ab}	0.08^{a}	0.08^{a}	0.06^{ab}	0.06^{bc}	Interaction 0.01	0.03
	Shell	0.04^{ab}	0.04^{ab}	0.06^{ab}	0.07^{a}	0.04^{ab}	0.03^{b}	0.05^{c}		
	Mean	0.06	0.06	0.07	0.08	0.07	0.06			

Contd.....

Table 9 contd...

1	2	3	4	5	6	7	8	9	10	11
S (%)	Leaf	0.08	0.08	0.07	0.07	0.08	0.07	0.07^{c}	Plant part	0.003	0.01
	Apple	0.09^{ab}	0.12^{a}	0.09^{ab}	0.08^{b}	0.07^{b}	0.10^{ab}	0.09^{b}	Variety	0.003	0.01
	Kernel	0.15^{ab}	0.17^{ab}	0.15^{ab}	0.18^{a}	0.15^{ab}	0.14^{b}	0.16^{a}	Interaction	0.01	0.03
	Shell	0.03	0.02	0.02	0.04	0.02	0.02	0.03^{d}			
	Mean	0.09^{ab}	0.10^{a}	0.08^{b}	0.09^{ab}	0.08^{b}	0.08^{b}				
Fe (ppm)	Leaf	125^{b}	140^{b}	135^{b}	185^{ab}	240^{a}	230^{a}	176^{c}	Plant part	9.52	26.4
	Apple	225^{b}	240^{ab}	295^{a}	245^{ab}	210^{b}	275^{ab}	248^{a}	Variety	11.7	32.4
	Kernel	170^{c}	175^{bc}	175^{bc}	215^{abc}	240^{ab}	265^{a}	207^{b}	Interaction	23.3	64.60
	Shell	200	165	165	205	155	190	180^{c}			
	Mean	180	180	193	213	211	240				
Mn (ppm)	Leaf	166^{a}	70.3^{d}	136^{b}	114^{bc}	123^{b}	99.8^{c}	118^{a}	Plant part	3.28	9.09
	Apple	30.7	26.7	25.6	19.3	29.4	33.5	27.5^{bc}	Variety	4.02	11.1
	Kernel	19.3	18.2	23.4	27.2	33.2	29.6	25.1^{c}	Interaction	8.03	22.3
	Shell	27.2	31.2	35.0	39.9	34.0	37.6	34.2^{b}			
	Mean	60.8^{a}	36.6^{b}	55.1^{a}	50.1^{a}	55.0^{a}	50.1^{a}				

Contd.....

Table 9 contd...

1	2	3	4	5	6	7	8	9	10	11
Zn (ppm)	Leaf	20.3	15.6	22.2	28.9	18.7	16.8	20.4^{c}	Plant part	2.43	6.73
	Apple	41.5^{a}	24.6^{bc}	40.9^{ab}	24.7^{bc}	24.2^{c}	44.0^{a}	33.3^{b}	Variety	2.97	8.23
	Kernel	57.2	64.6	62.6	55.3	52.9	54.5	57.9^{a}	Interaction	5.94	16.5
	Shell	26.9^{b}	15.5^{b}	46.4^{a}	12.5^{b}	12.5^{b}	14.8^{b}	21.4^{c}			
	Mean	36.5^{ab}	30.1^{bc}	43.0^{a}	30.3^{bc}	27.1^{c}	32.5^{bc}				
Cu (ppm)	Leaf	8.2	6.83	7.30	12.2	13.5	12.9	10.1^{c}	Plant part	1.03	2.85
	Apple	16.5	14.2	12.3	10.6	10.6	16.6	13.5^{b}	Variety	1.27	NS
	Kernel	24.6	20.0	22.4	30.1	23.8	19.3	23.3^{a}	Interaction	2.53	NS
	Shell	5.45	3.48	4.15	5.38	4.78	4.83	4.68^{d}			
	Mean	13.7	11.1	11.5	14.6	13.2	13.4				

Values followed by the same alphabet are not significantly different

b) Dry weight of harvested produce

The data on harvested produce (apple and nut) of the six cashew varieties are presented in Table 10 and Fig. 12.

The dry matter yield in terms of apple did not differ significantly between the varieties. But dry matter yield in terms of kernel, shell and total dry weight of harvested produce, differed significantly between varieties. The total dry weight of harvested produce was the highest (13.6 kg/tree/year) with M 26/2 followed by H 1600 (12.0 kg/tree/year). The variety V5 was found to be inferior compared to all other varieties in this respect. The nut yield differed significantly between these six varieties (Fig. 13) and the highest nut yield (6.7 kg/tree/year) was obtained from M 26/2 followed by H 1600 (5.45 kg/tree/year).

c) Partitioning of dry matter between harvested parts

The total dry matter obtained through the harvested produce has been partitioned into apple, kernel and shell and their proportions in relation to the total harvested dry matter were estimated. The data are presented in Table 11 and Fig. 14.

Table 10. Dry weight of harvested produce (kg/tree) of six cashew varieties

Variety	Apple	Kernel	Shell	Total dry weight of harvested produce	Nut yield
Anakkayam 1	3.81	1.1^{bc}	2.33^{bc}	7.24^{abc}	3.38^{bc}
H 1598	3.51	1.03^{bc}	1.92^{c}	6.45^{bc}	3.20^{bc}
H 1600	5.86	1.93^{ab}	4.19^{ab}	12.0^{ab}	5.45^{ab}
V3	3.33	1.14^{bc}	2.61^{abc}	7.08^{abc}	3.65^{abc}
V5	1.74	0.37^{c}	0.85^{c}	2.97^{c}	1.30^{c}
M 26/2	6.66	2.33^{a}	4.63^{a}	13.6^{a}	6.70^{a}
SE m±	1.15	0.36	0.75	2.26	1.08
C.D. (0.05)	NS	1.07	2.23	6.71	3.22

Values followed by the same alphabet are not significantly different

Table 11. Partitioning of dry matter (per cent) between harvested parts

Variety	Apple	Kernel	Shell
Anakkayam 1	52.6	15.2	32.2
H 1598	54.4	15.9	29.7
H 1600	48.9	16.1	35.0
V3	47.0	16.1	36.8
V5	58.7	12.5	28.8
M 26/2	48.9	17.1	34.0
Mean	51.8	15.5	32.8

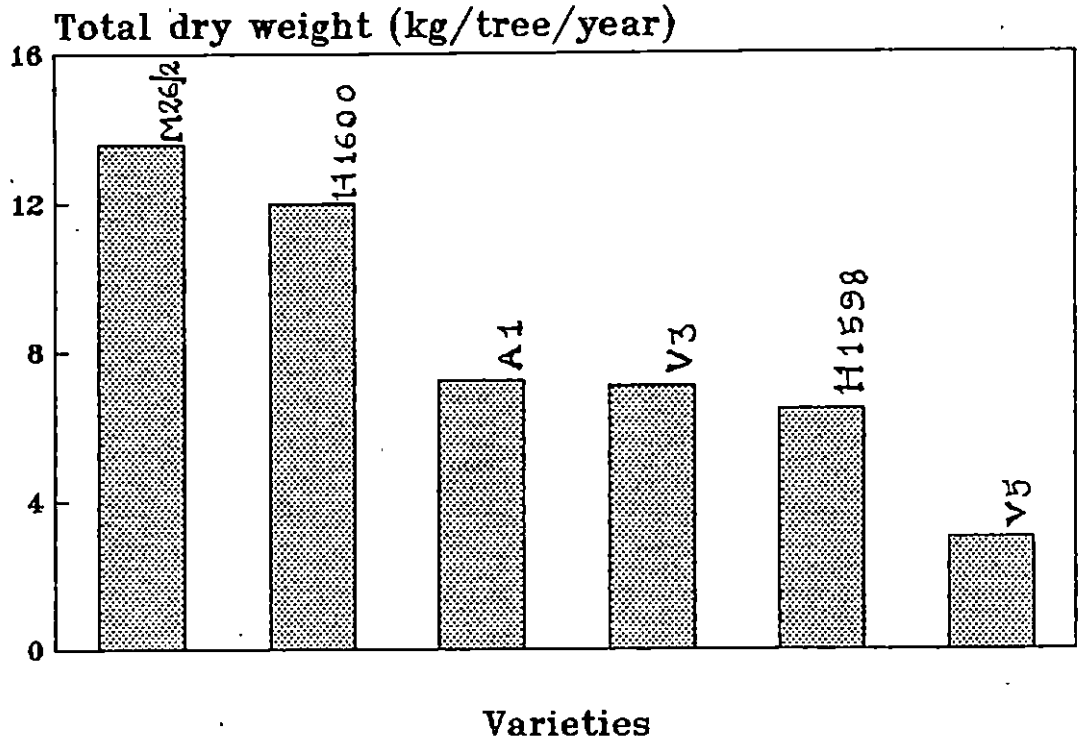


Fig.12Variation in total dry weight of harvested produce (apple, kernel, shell)

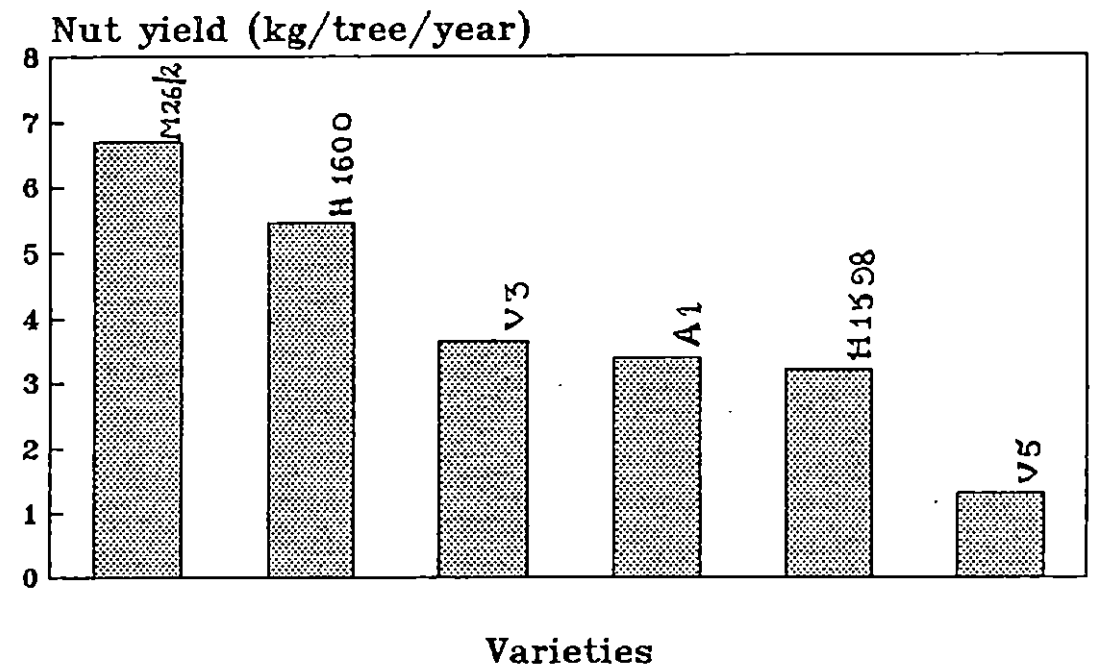


Fig.13Variation in nut yield of cashew varieties

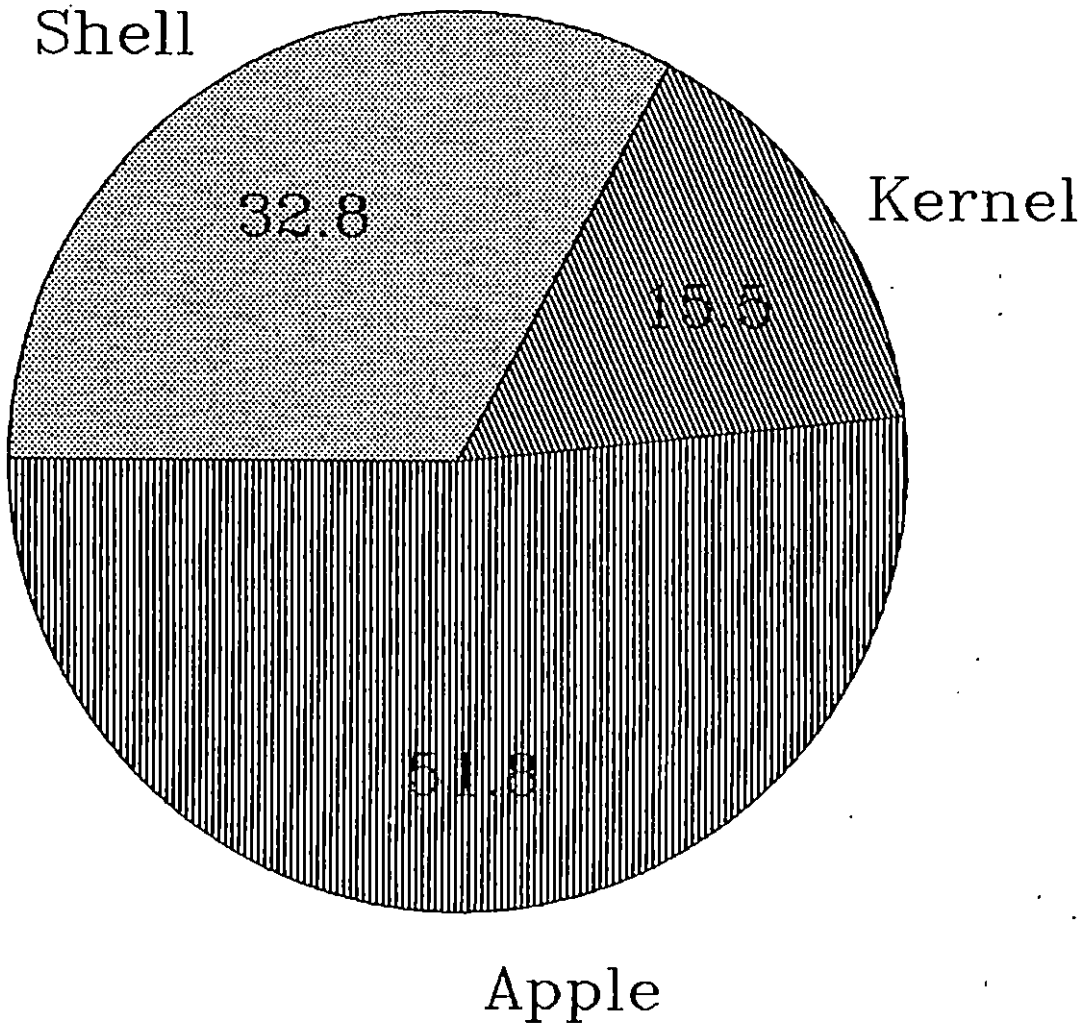


Fig.14 Dry matter (harvested) partitioning in cashew between apple kernel and shell

Among the six varieties, the share of apple to the total dry matter ranged from 47.0 per cent (V3) to 58.7 per cent (V5). The partitioning of the dry matter towards kernel ranged from 12.5 per cent (V5) to 17.1 per cent (M 26/2). The dry matter partitioned towards the shell ranged from 28.8 per cent (V5) to 36.8 per cent (V3). The varieties M 26/2 and H 1600, which were superior in terms of nut yield, expressed more or less similar partitioning of harvested dry matter between apple, kernel and shell. On an average, the partitioning of harvested produce between apple, kernel and shell in cashew was 51.8, 15.5 and 32.8 per cent respectively.

d) Nutrient offtake (Table 12)

i. Varietal difference

The nutrient offtake in cashew varied with variety. The nutrient offtake (N, P,K, Ca, S, Fe, Mn, Zn and Cu) was the highest (439 g N, 13.9 g P, 184 g K, 25.9 g Ca, 10.7 g S, 3356 mg Fe, 418 mg Mn, 511 mg Zn and 181 mg Cu/tree/year) with the variety M 26/2 followed by H 1600. The Mg removal was highest (13.2 g/tree/year) with H 1600 followed by M 26/2. Among the varieties, nutrient removal was lowest with V5.

Table 12. Varietal variation on nutrient offtake (per tree) in six cashew varieties

Variety	N g	P g	K g	Ca g	Mg g	S g	Fe mg	Mn mg	Zn mg	Cu mg	Nut yield kg/ tree	Apple yield (dry wt. basis) kg/tree
A1	212^{bc}	6.91^{bc}	119	10.8^{bc}	5.41^{bc}	5.65^{abc}	1639^{bc}	195^{bc}	322	105	3.38^{bc}	3.81
H 1598	179^{bc}	5.80^{bc}	105	11.7^{bc}	4.63^{bc}	6.30^{abc}	1283^{bc}	168^{bc}	181	78.5	3.20^{bc}	3.51
H 1600	311^{ab}	9.54^{ab}	133	21.3^{ab}	13.2^{a}	8.78^{a}	2685^{ab}	348^{ab}	470	130	5.45^{ab}	5.86
V3	208^{bc}	6.67^{bc}	84.9	6.22^{c}	5.58^{bc}	5.34^{bc}	1708^{abc}	197^{bc}	171	78.6	3.65^{abc}	3.33
V5	82.7^{c}	2.23^{c}	36.1	4.51^{c}	1.77^{c}	1.98^{c}	574^{c}	93.2^{c}	68.3	30.6	1.30^{c}	1.74
M 26/2	439^{a}	13.9^{a}	184	25.9^{a}	8.33^{ab}	10.7^{a}	3356^{a}	418^{a}	511	181	6.70^{a}	6.66
SE m±	71.61	2.15	32.0	3.95	1.84	1.76	570.64	71.17	109.85	14.85	1.08	1.15
CD(0.05)	212.7	6.39	NS	11.7	5.47	5.23	1695.3	211.4	NS	NS	3.22	NS

Values followed by the same alphabet are not significantly different

ii). Variation between plant parts (Table 13)

The nutrient offtake (N, P, K, Ca, Mg, S, Fe, Mn and Cu) through apple, kernel and shell differed between plant parts. The nutrient removal was the largest through apple compared to kernel. A cashew tree yielding 4.08 kg nut and 4.15 kg apple (on dry weight basis) removes through harvested produce 239 g N, 7.51 g P, 110 g K, 14.2 g Ca, 6.4 g Mg, 6.46 g S, 1709 mg Fe, 233 mg Mn, 252 mg Zn and 86 mg Cu/tree/year. In general, the nutrient removal was the lowest through the shell.

e) Partitioning of nutrients between harvested parts

The amounts of different nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) removed annually through harvested parts have been partitioned through different plant parts (apple, kernel and shell) and are presented in Table 14 and Fig. 15 and 16. It is clear from the data that the largest removal of various nutrients takes place through apple. Of the total nutrient offtake, 51 per cent of N, 49.8 per cent P, 78 per cent K, 45.6 per cent Ca, 68.1 per cent Mg, 59 per cent S, 54.5 per cent Fe, 45.5 per cent Mn, 44.8 per cent Zn and 52.2 per cent Cu are through apple. The second major

Table 13. Nutrient offtake (per tree) through different plant parts

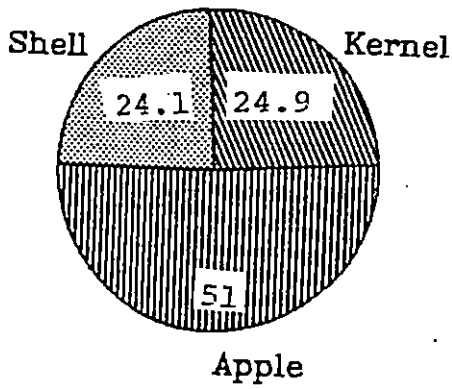
Plant part	N g	P g	K g	Ca g	Mg g	S g	Fe mg	Mn mg	Zn mg	Cu mg
Apple (4.15 kg/tree)	122[a]	3.74[a]	85.8[a]	6.47[a]	4.36[a]	3.81[a]	931[a]	106[a]	113.0	44.9[a]
Kernel (1.32 kg/tree)	59.4[b]	3.05[a]	10.3[b]	4.46[b]	0.70[b]	1.99[b]	274[c]	31.3[b]	75.4	28.0[b]
Shell (2.76 kg/tree)	57.7[b]	0.72[b]	14.0[b]	3.26[b]	1.34[b]	0.66[c]	504[b]	95.5[a]	63.9	13.1[c]
Total (8.23 kg/tree)	239	7.51	110	14.2	6.40	6.46	1709	233	252	86
SE m±	10.88	0.34	6.18	0.61	0.35	0.29	79.1	10.3	19.4	4.47
CD (0.05)	30.15	0.94	17.1	1.69	0.97	0.80	219	28.5	NS	12.40

* Figures in parentheses refer to the yield per tree on dry weight basis

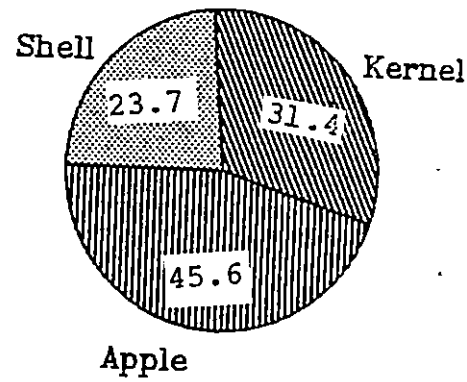
Values followed by the same alphabet are not significantly different

Table 14. Partitioning of nutrients (per cent) between harvested parts

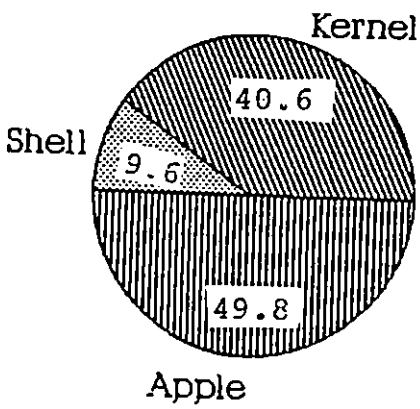
Plant part	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Apple	51.0	49.8	78.0	45.6	68.1	59.0	54.5	45.5	44.8	52.2
Kernel	24.9	40.6	9.4	31.4	10.9	30.8	16.0	13.4	29.9	32.6
Shell	24.1	9.6	12.7	23.0	20.9	10.2	29.5	41	25.4	15.2



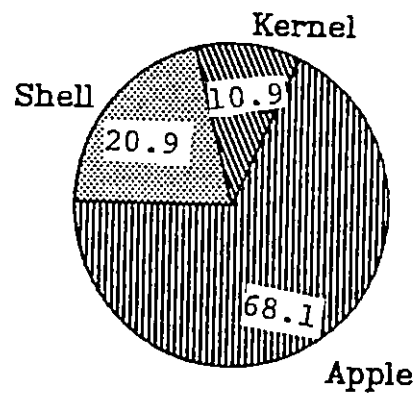
Nitrogen partitioning



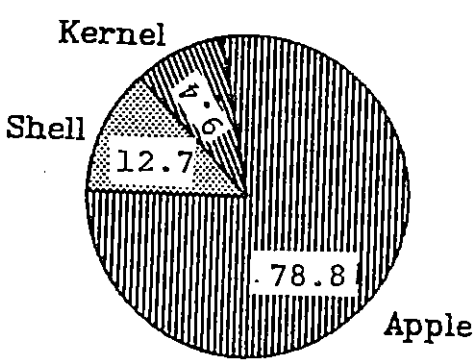
Calcium partitioning



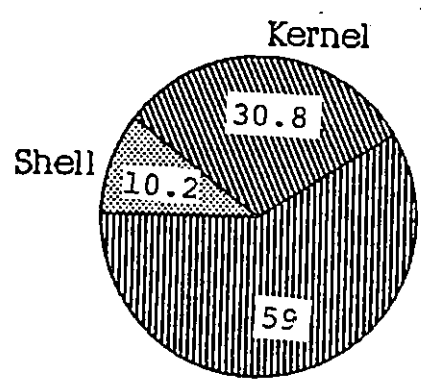
Phosphorus partitioning



Magnesium partitioning

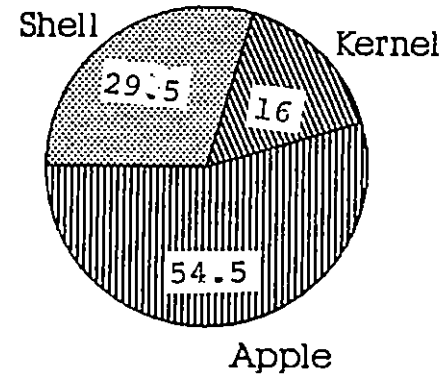


Potassium partitioning

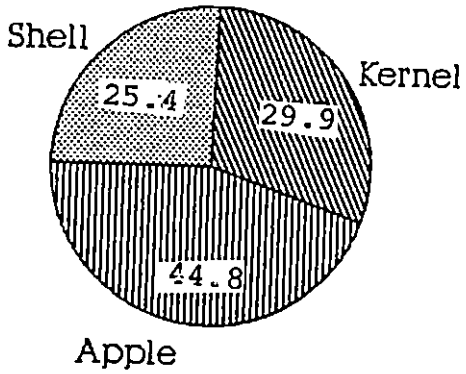


Sulphur partitioning

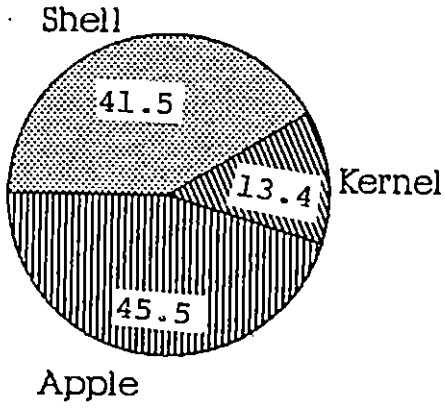
Fig.15 Nutrient (harvested) partitioning -N,P,K,Ca,Mg,S- in cashew between apple,kernel and shell



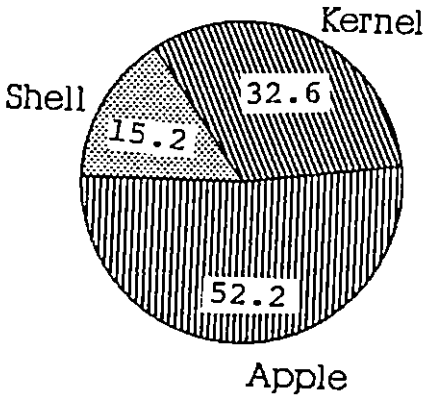
Iron partitioning



Zinc partitioning



Manganese partitioning



Copper partitioning

Fig.16 Nutrient (harvested) partitioning - Fe,Mn,Zn,Cu - in cashew between apple, kernel and shell

share of nutrient removal (N, P, Ca, Zn and Cu) was through kernel. The removal of K, Mg, Fe and Mn was more through shell than kernel.

f) Prediction models for nutrient requirements

The data on nut yield and nutrient offtake (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) of cashew varieties were regressed and the best fitting models are presented in Table 15 and Fig. 17 to 19. There was significant positive correlation between nut yield and nutrient removal in cashew. The relationship between nut yield and nutrient removal (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) was positive and linear. The relationship between nut yield and Mg removal was quadratic. The higher R^2 values (Table 15) indicate the greater predictability of the models.

g) Leaf nutrient status in relation to physiological phases

The data on leaf nutrient status of cashew (variety Anakkayam 1) in relation to different physiological phases are given in Table 16 and Fig. 20 to 22. The leaf nutrient status varied with physiological phases. The leaf N content was high during "flushing and early flowering" phase and it

Table 15. Prediction models for nutrient requirement

Nutrient removed	Regression equation	R^2	SE of b	SE of c
N	$y = -14.4 + 64.1\ x$	0.977	4.89	-
P	$y = -0.58 + 2.05\ x$	0.973	1.71×10^{-1}	-
K	$y = 12.8 + 24.7\ x$	0.891	4.33	-
Ca	$y = -3.15 + 4.19\ x$	0.873	8.01×10^{-1}	-
Mg	$y = -3.46 + 3.65x - 0.24x^2$	0.704	3.02	3.61×10^{-1}
S	$y = 0.27 + 1.57\ x$	0.965	1.49×10^{-1}	-
*Fe	$y = -200.6 + 525.7\ x$	0.989	2.74×10^{1}	-
*Mn	$y = -14.5 + 63.6\ x$	0.975	5.05	-
*Zn	$y = -59.2 + 87.8\ x$	0.873	1.68×10^{-1}	-
*Cu	$y = -3.82 + 26.5\ x$	0.944	3.24	-

y = nutrient requirement (g/tree/year, *mg/tree/year)

x = nut yield (kg/tree)

Table 16. Leaf nutrient concentration of cashew variety Anakkayam 1 at different physiological phases

Physiological phase	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
	per cent						ppm			
1. Post-harvest phase	2.36^{b}	0.04	0.85^{b}	0.41	0.06^{b}	0.10^{b}	215^{b}	527	43.6	7.15
2. Flushing and early flowering phase	2.94^{a}	0.06	1.17^{a}	0.32	0.06^{b}	0.08^{a}	125^{c}	166	20.3	8.20
3. Flowering and fruiting phase	2.21^{b}	0.04	1.00^{ab}	0.35	0.15^{a}	0.09^{a}	225^{ab}	382	36.7	8.25
4. Maturity and harvesting phase	2.42^{b}	0.06	0.90^{b}	0.33	0.08^{b}	0.08^{a}	255^{a}	236	23.4	5.83
SE m±	0.10	0.007	0.07	0.04	0.01	0.01	10.4	89.9	6.63	0.93
CD (0.05)	0.31	0.02	0.22	NS	0.03	0.03	0.32	NS	NS	NS

Data presented are means of four trees.
Values followed by the same alphabet are not significantly different

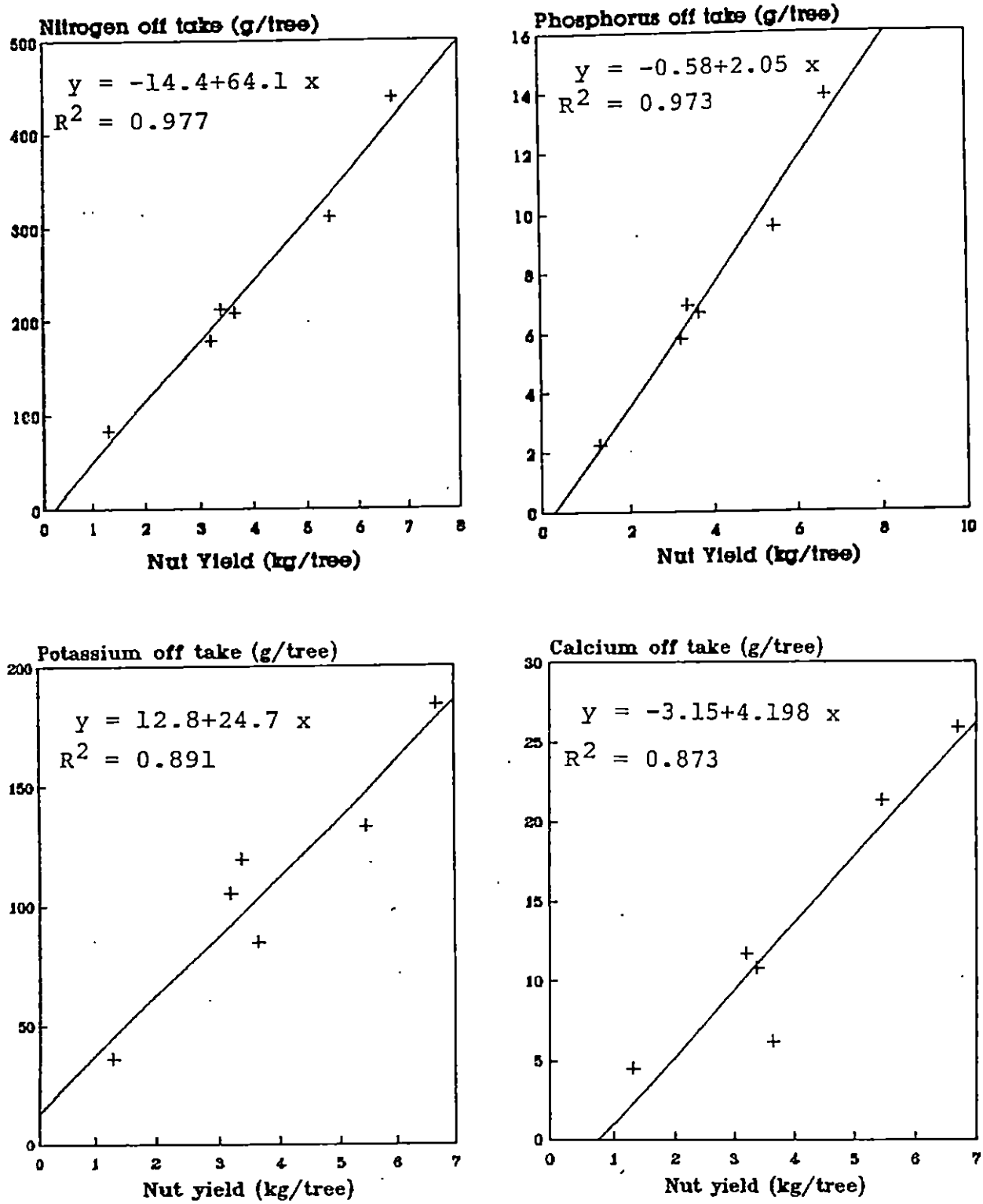


Fig.17 Nutrient offtake (N,P,K,Ca) by cashew in relation to nut yield

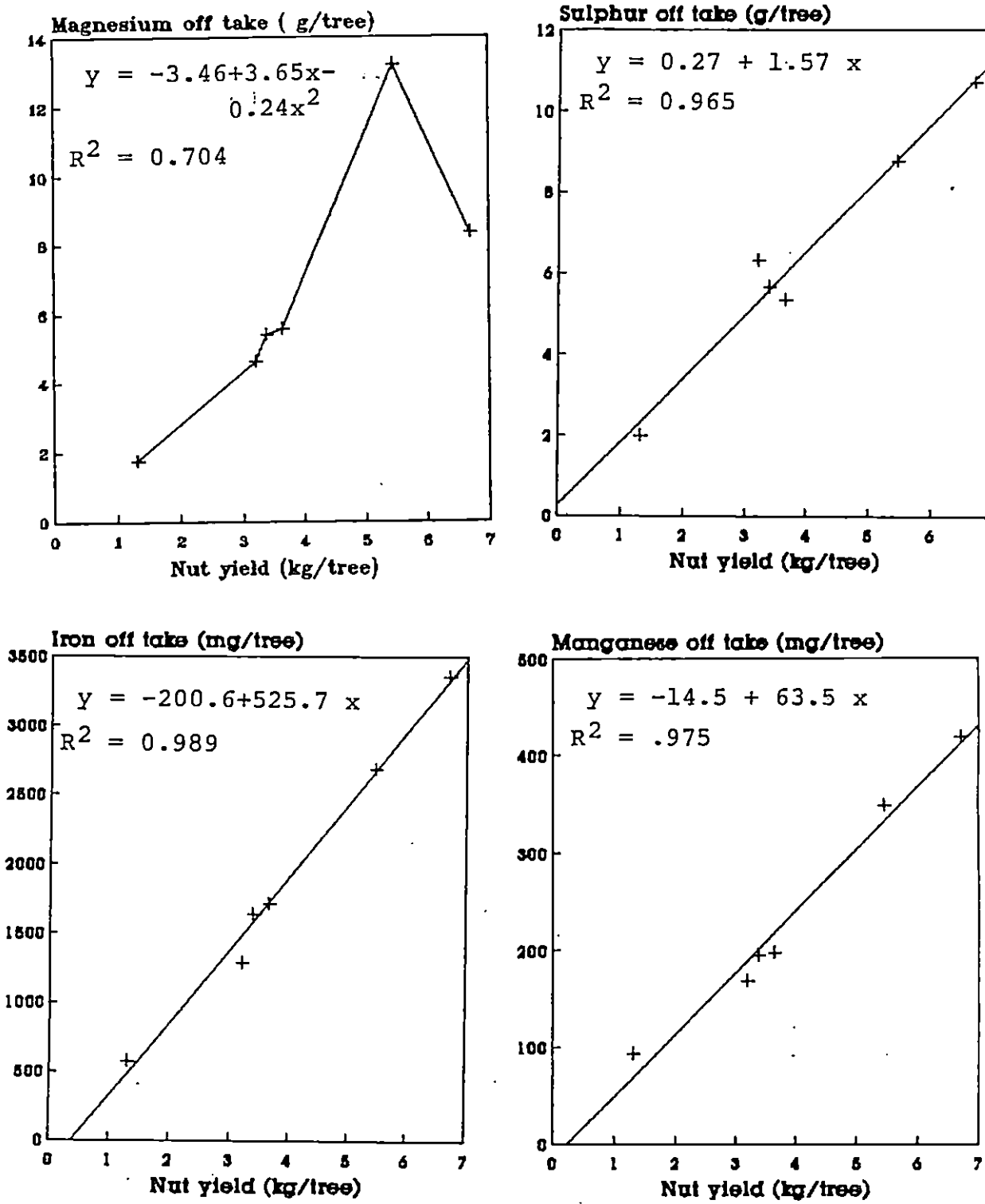
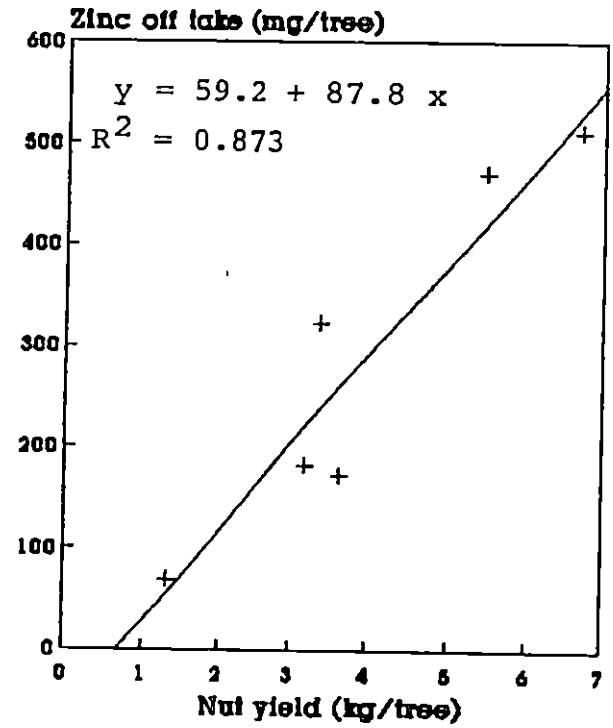


Fig. 18 Nutrient offtake (Mg,S,Fe,Mn) by cashew in relation to nut yield



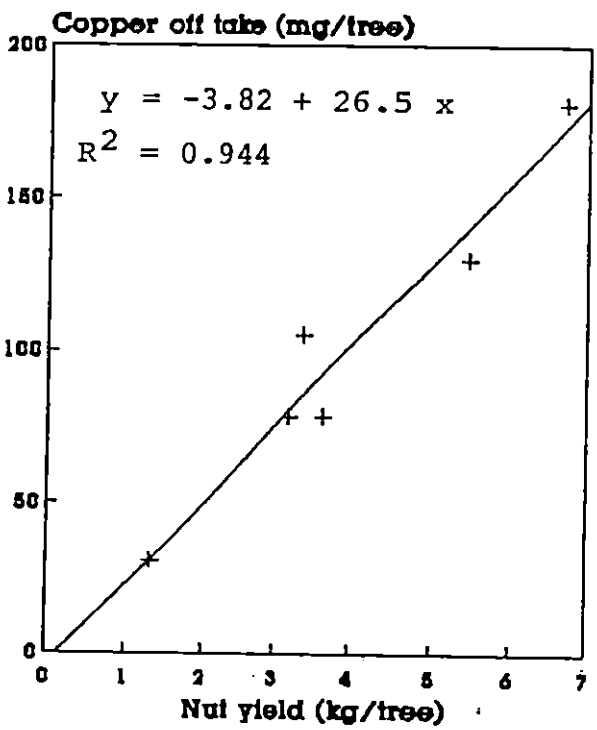
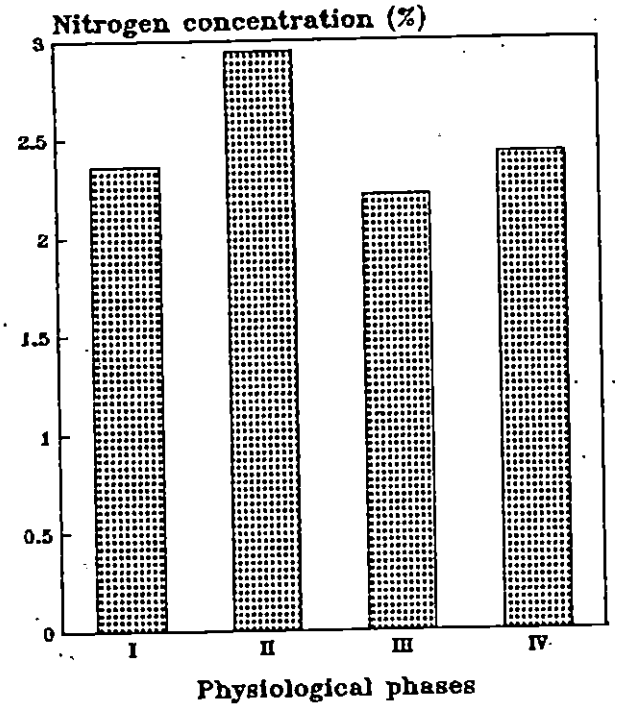
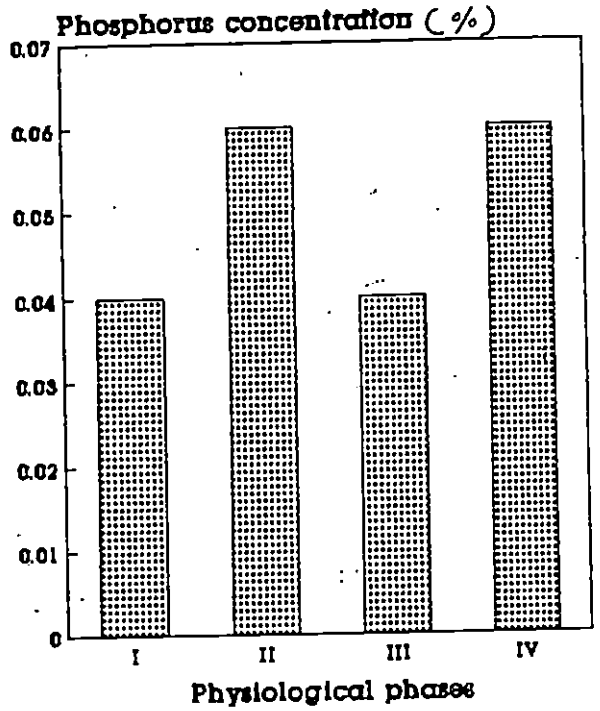
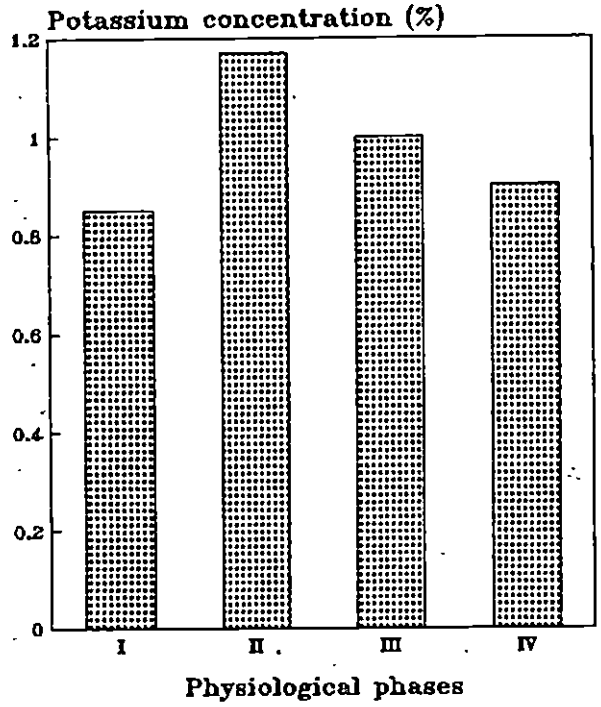
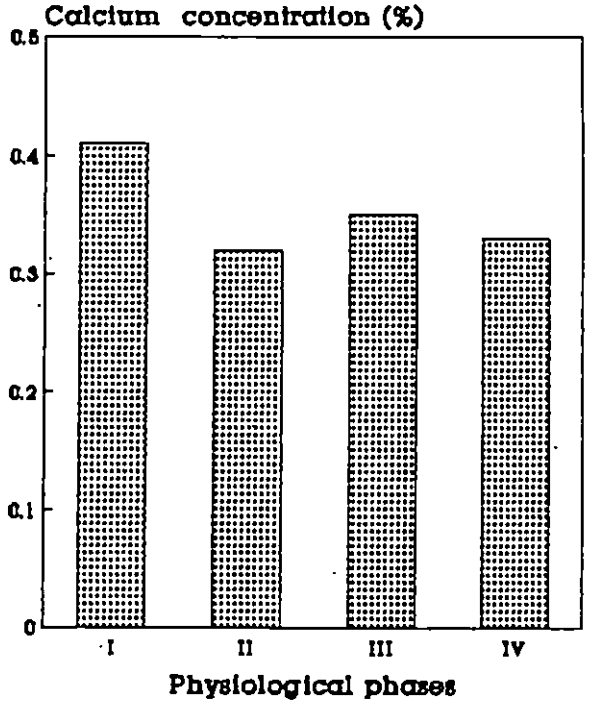


Fig. 19 Nutrient offtake (Zn,Cu) by cashew in relation to nut yield









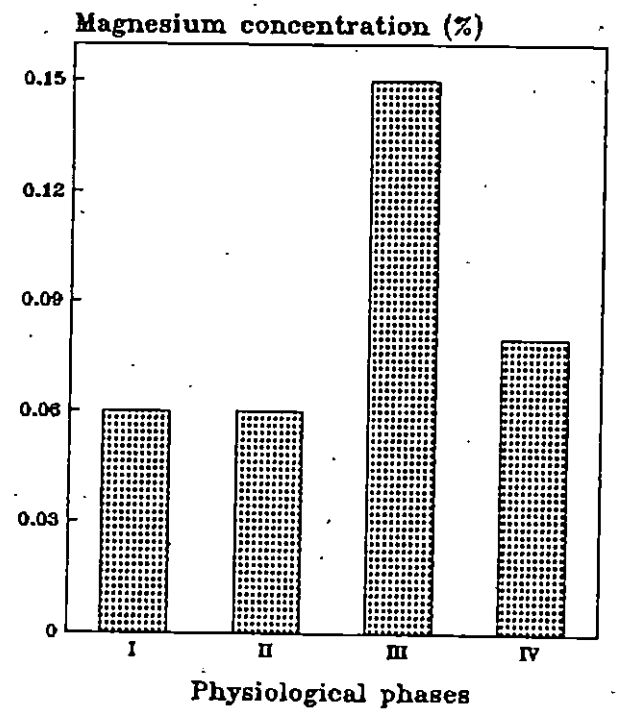
I Post-harvest phase

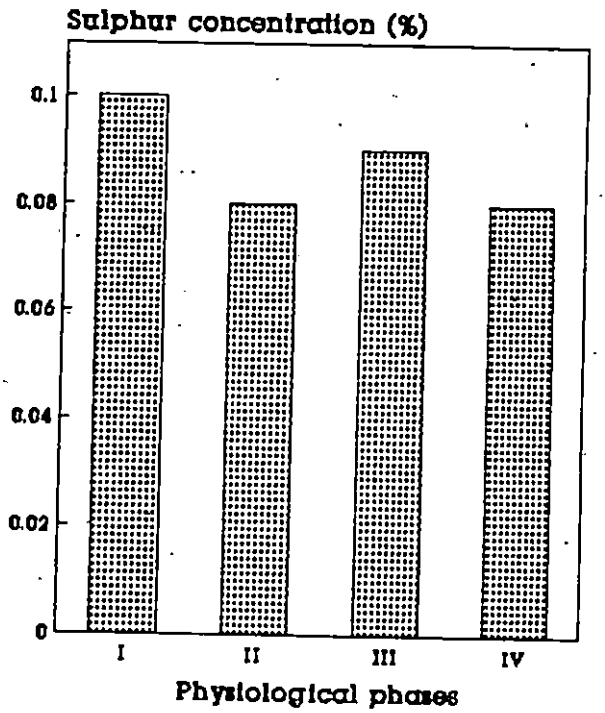
II Flushing and early flowering phase

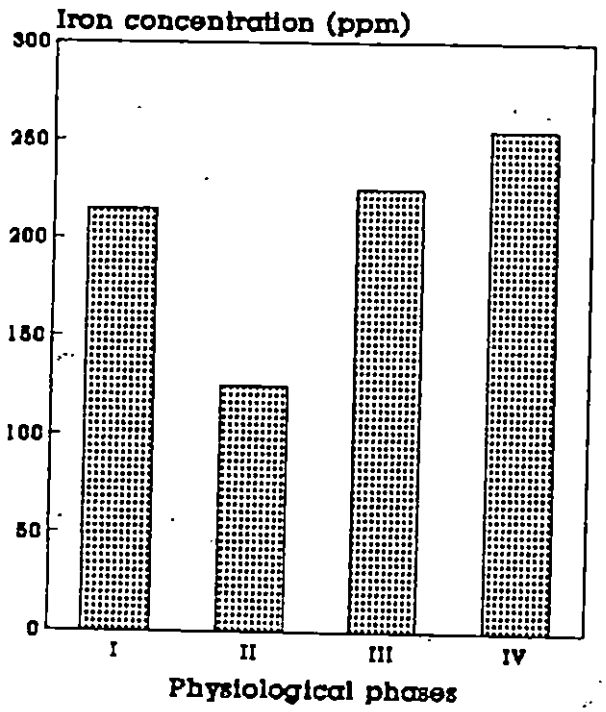
III Flowering and fruiting phase

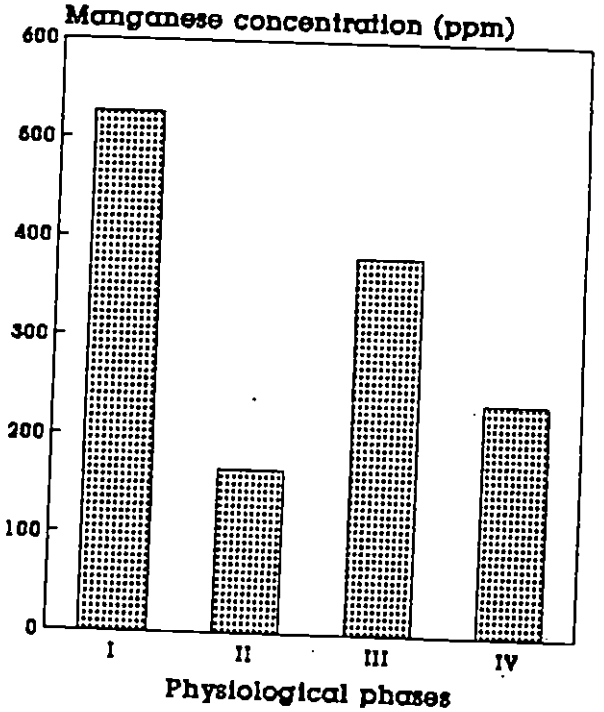
IV Maturity and Harvesting phase

Fig.20 Variation in leaf nutrient concentration (N,P,K,Ca) in relation to physiological phases in cashew variety Anakkayam 1









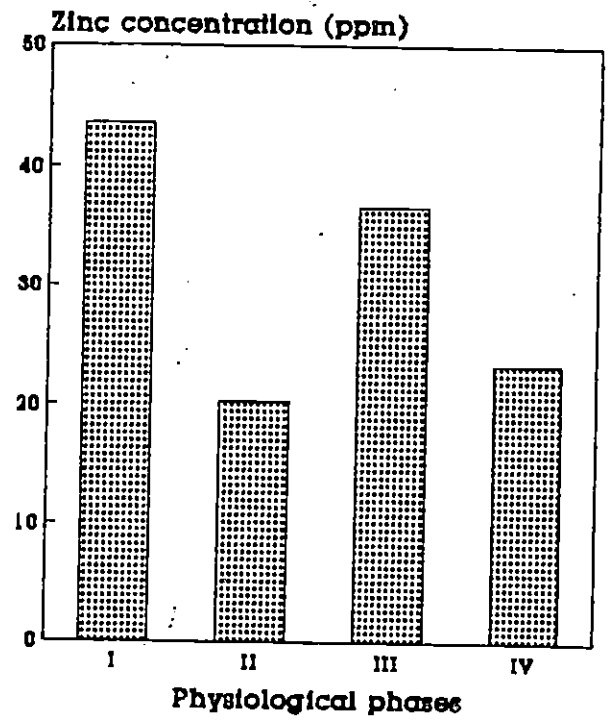
I Post-harvest phase

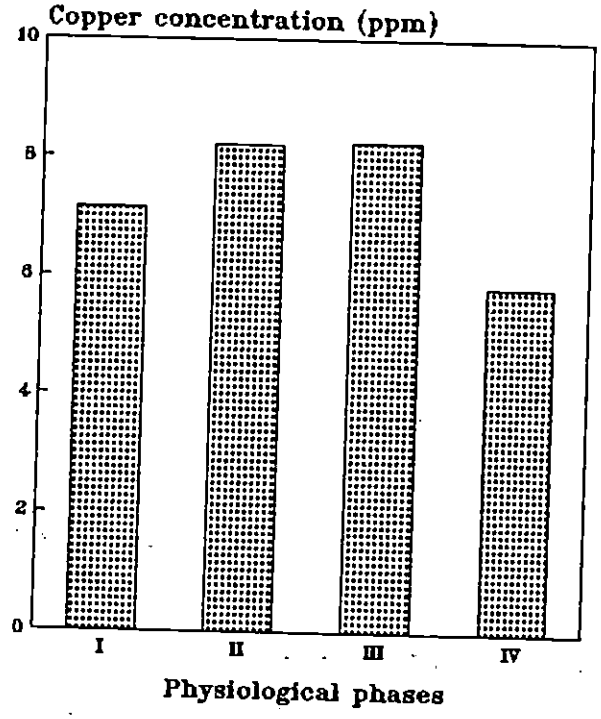
II Flushing and early flowering phase

III Flowering and fruiting phase

IV Maturity and harvesting phase

Fig.21 Variation in leaf nutrient concentration (Mg,S,Fe,Mn) in relation to physiological phases in cashew variety Anakkayam 1





I Post-harvest phase

II Flushing and early flowering phase

III Flowering and fruiting phase

IV Maturity and harvesting phase

Fig.22 Variation in leaf nutrient concentration (Zn,Cu) in relation to physiological phases in cashew variety Anakkayam 1

decreased in the fruiting and maturity phases. The leaves during post-harvest phase contained comparatively low amounts of N.

The P and K concentrations of leaves were high during "flushing and early flowering" phase and low during post-harvest phase. Unlike N, P and K, the concentrations of Ca, S, Mn and Zn concentration in leaf were high during post-harvest phase. The leaf Mg and Cu content was high during "flowering and fruiting" phase. The Fe concentration in leaf was more during "maturity and harvesting" phase.

PART III. Absorption of soil applied ^{32}P at different physiological phases.

a) Under rainfed condition

The data on the recovery of soil-applied radiophosphorus in the leaves of cashew varieties during different physiological phases are presented in Tables 17 and 18. There was no significant difference in the absorption of ^{32}P among the four varieties (Anakkayam 1, H 1598, H 1600 and V5) tested. But the absorption of ^{32}P in the four physiological phases (post-harvest phase, "flushing and early flowering" phase, "flowering and fruiting" phase

Table 17. Recovery of soil applied ^{32}P in the leaves (log cpm/g leaf) of four cashew varieties

Variety	Recovery of ^{32}P
Anakkayam 1	2.324 (211)
H 1598	2.137 (137)
H 1600	2.139 (138)
V5	2.193 (156)
SE m±	0.06
CD (0.05)	NS

Table 18. Recovery of soil applied ^{32}P in the leaves (log cpm/g leaf) of cashew at different physiological phases

Physiological phase	Recovery of ^{32}P
Post-harvest phase	2.505^{b} (320)
Flushing and early flowering phase	2.852^{a} (711)
Flowering and fruiting phase	2.157^{c} (144)
Maturity and harvesting phase	1.279^{d} (19)
SE m±	0.06
CD (0.05)	0.17

Parentheses denote cpm/g leaf
NS - Not significant

and "maturity and harvesting" phase varied significantly (Fig. 23). The recovery of radiophosphorus was the highest (711 cpm/g) at the "flushing and early flowering" phase and it was lowest (19 cpm/g) at "maturity and harvesting" phase. The interaction between variety and physiological phase on ^{32}P absorption was not significant and as such the data are not presented.

b) Effect of irrigation on ^{32}P absorption

The recovery of soil-applied ^{32}P in cashew variety Anakkayam 1 at different physiological phases as influenced by irrigation during summer (December-May), is given in Table 19 and Fig. 24.

Among the four physiological phases, the recovery of ^{32}P was the highest (711 cpm/g) during the "flushing and early flowering" phase (October-November). The second highest absorption peak (320 cpm/g) was noticed at the post-harvest phase (June-August). Absorption of ^{32}P was much less in "flowering and fruiting" phase and the lowest in "maturity and harvesting" phase.

During summer months (December-May), the trees were irrigated to maintain the soil moisture around 50 per cent

Table 19. Recovery* of soil applied ^{32}p (cpm/g leaf) in cashew variety Anakkayam 1 as influenced by irrigation

	Post-harvest phase (June - August)				Flushing and early flowering phase (October-November)				Flowering and fruiting phase (December-February)				Maturity and harvesting (March - May)			
	Time of sampling (DAA)				Time of sampling (DAA)				Time of sampling (DAA)				Time of sampling (DAA)			
	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
Rainfed	60	378	738	1060	394	920	839	1364	239	211	355	294	5	6	24	75
Irrigated	**	**	**	**	**	**	**	**	474	704	602	752	13	36	110	329

Mean recovery of ^{32}P during the phase

Rainfed	559	879	275	28
Irrigated	**	**	633	122

DAA - Days after application
* - Average from six trees
** - Irrigation was not given during these phases

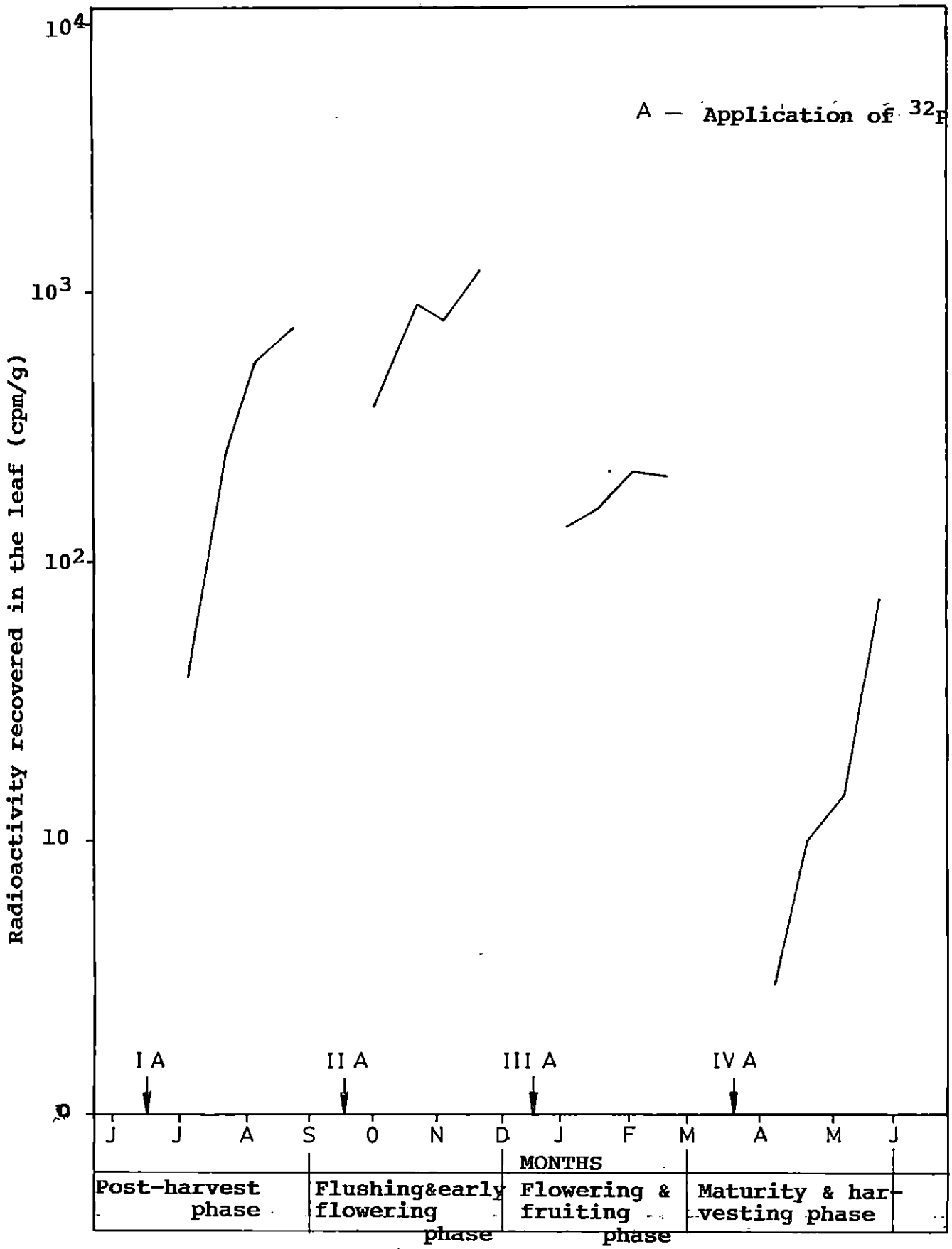


Fig.23. Absorption of soil applied ^{32}P under rainfed conditions at different physiological phases.

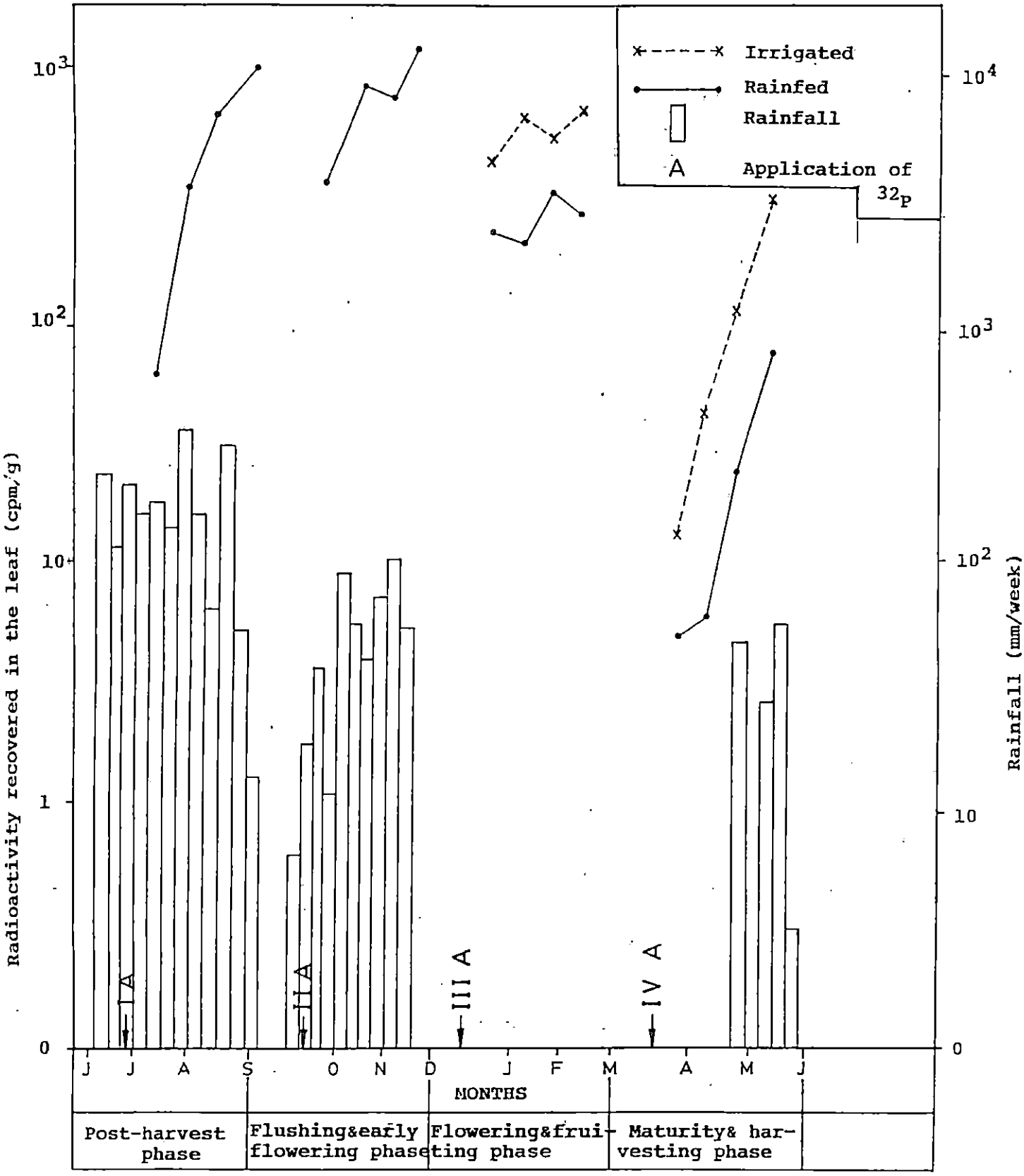


Fig.24. Variation in the absorption of soil applied ^{32}P at different physiological phases between rainfed and irrigated trees

depletion from field capacity. Considerable increase in the absorption of soil applied ^{32}P by irrigation of trees during "flowering and fruiting" phase as well as during "maturity and harvesting" phase was noticed. The ^{32}P contents of the leaves of rainfed and irrigated trees were 275 and 633 cpm/g leaf respectively during "flowering and fruiting" phase. The corresponding values during "maturity and harvesting" phase were 28 and 122 cpm/g leaf respectively.

Discussion

DISCUSSION

PART I. Variability in growth and yield of cashew varieties

This experiment was undertaken to study the varietal difference in growth and yield of 18 cashew varieties evolved from different Cashew Research Stations in the country. The results obtained from this study are discussed below.

The growth measurements in terms of tree height, tree girth and canopy spread (Table 7) as at the fifth year of planting did not differ significantly. This might be due to considerable tree to tree variation inherent to this tree crop. The standard error of the means was also high. Varietal differences on tree height (Falade, 1981), tree girth (Reddy et al., 1989) and canopy spread (Reddy et al., 1989) are reported in literature.

The chlorophyll content of the leaves (at "flushing and early flowering" stage) differed significantly between varieties and the variety V3 contained more chlorophyll (Fig. 6). The amount of chlorophyll in the leaves of a variety indicates its high photosynthetic ability and better productivity. Though the variety V3 contained the highest amount of chlorophyll, its effect was not reflected on nut

yield (Table 8). The correlation between leaf chlorophyll content and nut yield also did not reach the level of significance. Rao et al. (1980) observed significant difference in chlorophyll content of leaves between cashew types.

The flowering time in cashew is a varietal character and it differed with variety. Flowering commenced from the last week of November and ended by February. Based on flowering time, the varieties were classified as early and mid season flowering varieties (Table 7). The varieties VTL 30/4, T 40, BPP 2/16, V5, M44/3, M 26/2, Anakkayam 1 and H 1600 which started flowering during the last week of November and ended by December are the early flowering varieties. These varieties completed their reproductive phase earlier than the other varieties, and the harvesting was over by March. Other varieties (VTL 59/2, T 129, BPP 2/15, V2, V3, V4, M 33/3, H 1598, H 1608, H 1610) which started flowering by the last week of January and ended by February are the mid season flowering varieties and the harvesting was over by May. None of the 18 varieties evaluated in this experiment appeared to be late flowering at Madakkathara conditions. This indicates that the harvesting of all the 18 varieties can be completed before

the onset of South West monsoon in the state. Variation in flowering between cashew varieties has been reported by Nalini and Santhakumari (1991).

Panicle length and breadth differed between varieties (Table 7). The variety VTL 30/4 had the largest panicles. Varietal difference on panicle length and breadth is reported by Krishnappa et al. (1989). There was no correlation between panicle size and nut yield.

The number of fruits per panicle did not vary between varieties (Table 8). This can be attributed to the higher tree to tree variability as evidenced from the standard error of means. Correlation between number of fruits per panicle and nut yield was also weak. There are reports on varietal difference on number of fruits per panicle (Ghosh and Chatterjee, 1987; Krishnappa et al., 1989; Reddy et al., 1989 and Nalini and Santhakumari, 1991).

Eleven out of 18 varieties tested had nut weight exceeding 6 g. (Table 8). Seven varieties (H 1608, BPP 2/16, M 33/3, H 1600, V3, BPP 2/15 and V4) had nut weight exceeding 7 g and four varieties (M 44/3, T 40, V5 and T 129) had nut weight less than 5 g (Fig. 7). Nut weight is a varietal character and it varies with varieties. Varietal

difference in nut weight is reported in literature (Nandini and James, 1984; Aravindakshan et al., 1986; Ghosh and Chatterjee, 1987; Antarkar and Joshi, 1987 and Nalini and Santhakumari, 1991). Chadha (1991) opined that a nut weight of 7 g is the minimum standard for a good cashew variety. As such, seven out of 18 varieties evaluated, qualify this minimum standard.

Kernel weight (Table 8) varied from 1.38 g (V5) to 2.46 g (BPP 2/16) between the varieties. Eleven (H 1598, H 1600, H 1608, H 1610, VTL 59/2, BPP 2/15, BPP 2/16, V2, V3, V4 and M 26/2) out of 18 varieties had kernel weight over 2 g (Fig. 8). A kernel weight of 2 g was fixed as a minimum standard for a good cashew variety (Chadha, 1991). Kernel weight is a varietal character. Varietal difference on kernel weight in cashew is reported by Aravindakshan et al. (1986) and George et al. (1991).

The nut yield of the cashew varieties at the fifth year of planting (Table 8) showed considerable difference between varieties. Nut yield ranged from 1.77 kg/tree/year (H 1610) to 6.81 kg/tree/year (M 44/3). Two varieties (M 44/3 and M 26/2) had nut yield over 6 kg/tree/year and three varieties (H 1600, M 44/3 and M 26/2) had nut yield over 4 kg/tree/year (Fig. 9). Eleven (M 44/3, M 26/2,

H 1600, VTL 59/2, V3, V2, M 33/3, H 1598, VTL 30/4, V5, T 40) out of 18 varieties yielded nuts over 3 kg/tree/ year. Two varieties (BPP 2/15 and H 1610) yielded less than 2 kg/tree/year. It may be noted that the experimental trees did not attain yield stability and it is too early to make a judgement on yield performance at this stage. However, the results as at the fifth year of planting indicate the superiority of the varieties M 44/3, M 26/2 and H 1600 over the rest. Cashew, being a perennial crop, it is absolutely essential to continue the evaluation of these varieties over a period of yield stability. As such the experiment is being continued. Nut yield is a varietal character. Several workers have reported varietal difference on the yield of cashew (Kologi et al., 1977; Falade, 1981; Nandini and James, 1984; Krishnappa et al., 1989; Reddy et al., 1989 and Nalini and Santhakumari, 1991).

Chadha (1991) opined that a cashew tree yielding not less than 8 kg/tree/year can be a good variety. Of the 18 varieties evaluated, two varieties viz. M 44/3 and M 26/2 from Cashew Research Station, Vridhachalam yielded nearly 7 kg/tree as at the fifth year of planting. A few more varieties from this lot are also expected to show better performance on yield stabilisation ie., after 7-10 years of

growth. The results indicate that the two varieties M 44/3 and M 26/2 are adaptable under the agroclimatic conditions prevailing at Madakkathara. It was surprising that Anakkayam 1, an important variety released from Kerala Agricultural University showed poor performance in this experiment, compared to Vridhachalam varieties (M 44/3 and M 26/2). A correct judgement on this can be made only on yield stabilisation of the varieties.

The apple size differed between varieties (Table 8). Six varieties (BPP 2/15, BPP 2/16, VTL 59/2, H 1608, V3 and V4) had apple weight exceeding 80 g (Fig. 10). The variety V5 had the smallest apple (32.9 g). Apple weight is a varietal character. Varietal difference on the apple weight of cashew is reported by many researchers (Haldankar et al., 1986; Sawke et al., 1986; Aravindakshan et al., 1986; Antarkar and Joshi, 1987; Krishnappa et al., 1989; Ghosh and Kundu, 1989 and Nalini and Santhakumari, 1991).

Shelling percentage differed with varieties and eleven (H 1598, VTL 30/4, T 129, T 40 , BPP 2/15, BPP 2/16, V2, V4, M 44/3, M 26/2 and Anakkayam 1) out of 18 varieties had shelling percentage exceeding 30 (Fig. 11). Chadha (1991) opined that a variety with shelling percentage not less than 28 per cent can be considered as a good variety. The

varieties H 1598, VTL 30/4, VTL 59/2, T 129, T 40, BPP 2/15, BPP 2/16, V2, V3, V4, V5, M 44/3, M 26/2, Anakkayam 1 satisfy this standard. Shelling percentage is a varietal character. Varietal difference on shelling percentage in cashew is reported in literature (Nandini and James, 1984; Vidyachandra and Hanamashetti, 1984; Ghosh and Chatterjee, 1987; Krishnappa et al., 1989 and Nalini and Santhakumari, 1991).

PART II. Nutrient concentration in plant parts and nutrient offtake

The experiment was undertaken to study the nutrient concentration in plant parts and to assess the nutrient offtake by six cashew varieties (Anakkayam 1, H 1598, H 1600, V3, V5 and M 26/2). The results obtained are discussed below.

a) Nutrient status in plant parts

The concentration of major and minor nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) differed between plant parts (leaf, apple, kernel and shell) in all the six varieties tested (Table 9). The cashew kernel contained the highest amount of N (4.52 per cent), P (0.23 per cent), Ca

(0.34 per cent), S (0.16 per cent), Zn (57.9 ppm) and Cu (23.3 ppm) compared to leaf, apple and shell. This means, kernel acts as the major sink for the accumulation of two major nutrients (N and P), two secondary nutrients (Ca and S) and two micronutrients (Zn and Cu). The K (2.07 per cent), Mg (0.09 per cent) and Fe (248 ppm) concentrations were high in the apple indicating the preferential accumulation of these nutrients in apple compared to kernel. Among the plant parts, the concentration of various nutrients was generally low in the shell. Gopikumar et al. (1978) reported variation in kernel N ranging from 2.85 to 3.55 per cent between cashew varieties.

The concentrations of N, P, K, S, Fe, Mn and Zn in leaf, apple, kernel and shell of cashew differed with variety also (Table 9). The N, K, Ca and Mn concentrations were more in Anakkayam 1 whereas the P concentration was more in varieties V3 and M 26/2. The Mg concentration was more with variety V3 and S concentration was more with variety H 1598. The variety M 26/2 contained more Fe. The Zn concentration was high in H 1600 and Cu concentration was high in V3. Considerable varietal difference on nut and apple yields of cashew is reported in literature (Reddy et al., 1989 and Nalini and Santhakumari, 1991) and as such

The mean K content of leaf was 1.19 per cent (Table 9) which was above the critical level of these nutrients reported by Mathew (1990). The leaf K status indicates that the trees are well supplied with K.

The leaf Ca concentration (0.24 per cent) observed in the experiment was low (Table 9) compared to the values (0.76 per cent) reported by Kumar (1983). The low Ca concentration in the experimental trees suggests that the trees may respond to Ca nutrition.

Calton (1961) and Lefebvre (1973) reported leaf Mg concentration ranging from 0.16 to 0.20 per cent in mature cashew trees. Earlier studies at Kerala Agricultural University (KAU, 1987) also indicate similar values with five year old cashew trees. In the experimental trees, the leaf Mg concentration was found to range from 0.06 to 0.09 per cent in the six varieties (Table 9). The low leaf Mg concentration (0.07 per cent) in the trees suggests that the trees may respond to Mg nutrition.

The S concentration of leaf (Table 9) was also low (0.07 to 0.08 per cent) compared to the values reported by Calton (1961). The results suggest that the trees may respond to S nutrition.

the nutrient requirement of trees would also differ with variety. Such a difference in yield potential between varieties would thus cause differential nutrient demand and thus different nutrient concentration in the plant parts of different varieties. Kumar and Sreedharan (1988) worked out the critical values as 2.09 per cent and 0.14 per cent for leaf N and P for cashew. Mathew (1990) worked out the critical levels for leaf N and K as 2.0 and 1.03 per cent respectively. The mean leaf N content (2.84 per cent) observed in this study is well above the critical levels suggested by the above authors. The results indicate that the trees are well supplied with N and any further increase in application of N in the experimental field may not yield any response from the trees. Variation in leaf N concentration ranging from 1.28 per cent (KAU, 1987) to 2.76 per cent (Sanyal and Mitra, 1991) is reported in literature.

The leaf P concentration of cashew was found to range from 0.06 to 0.08 per cent in the six varieties (Table 9). The mean leaf P content observed in the experimental trees (0.07 per cent) was far below from the values reported by Kumar and Sreedharan (1988). The results indicate that trees are starved of P and there is possibility for getting response from trees to P nutrition.

The Fe concentration in the leaf (176 ppm) was more compared to the values reported earlier (KAU, 1987).

The leaf contained the highest amount of Mn (118 ppm) compared to apple, kernel or shell (Table 9). The leaf Mn concentration was about four times more than that in apple or kernel. In an earlier work conducted at the Kerala Agricultural University (KAU, 1987) a leaf Mn level ranging from 49 to 158 ppm is reported.

The leaf contained 20.4 ppm Zn (Table 9) and the values are comparable with the earlier reports of Calton (1961).

The leaf Cu concentration was observed to be 10.1 ppm in the present study (Table 9). Calton (1961) reported a leaf Cu concentration of 16 ppm while Lefebvre (1973) observed 5.7 ppm of leaf Cu in mature trees.

b) Dry weight of harvested produce

As a pre-requisite for estimating the nutrient offtake, the dry matter of the harvested produce (apple and kernel) was estimated for the six varieties included in this experiment (Table 10). The dry matter of the harvested produce (Fig. 12) differed with variety. Of the six

varieties evaluated, the dry matter of M 26/2 and H 1600 exceeded 8 kg/tree/year. The nut and apple yield were also highest with these varieties (Fig.13). Varietal differences in nut yield and apple yield are reported by many workers (Reddy et al., 1989 and Nalini and Santhakumari, 1991).

c) Partitioning of dry matter between harvested parts (Table 10)

Of the total harvested dry matter, partitioning towards apple ranged from 47 per cent (V3) to 58.7 per cent (V5) and partitioning towards kernel ranged from 12.5 per cent (V5) to 17.1 per cent (M 26/2) and partitioning towards shell ranged from 28.8 per cent (V5) to 35 per cent (H 1600). On an average, the shares of harvested produce between apple, kernel and shell were in the order of 51.8, 15.5 and 32.8 per cent (Fig. 14). The results indicate that about half of the harvested dry matter is in the form of apple and about one third in the form of shell. The share towards economic produce (kernel) is only to the tune of 15.5 per cent. It is clear that at the same productivity level any effort to decrease the partitioning of dry matter towards apple and shell may cause an increase in the kernel yield.

d) Annual nutrient offtake

The annual nutrient offtake through harvested produce differed with variety (Table 12) and plant parts (apple, kernel and shell). The nutrient offtake increased with increase in dry matter in terms of harvested produce. The variety M 26/2 and H 1600 which produced the highest amount of apple and kernel, removed the largest amount of nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu). The variety V5 which produced the lowest amount of apple and shell removed the lowest amount of nutrients. Nutrient removal was largest through apple compared to kernel (Table 13). It is to be noted that the experimental trees are at the fifth year of planting and did not attain yield stability. As such, the yield level was also low.

It is estimated that a four year old cashew tree yielding 4.08 kg nut and 4.15 kg apple on dry weight basis, removes 239 g N, 7.51 g P, 110 g K, 14.2 g Ca, 6.40 g Mg, 6.46 g S, 1709 mg Fe, 233 mg Mn, 252 mg Zn and 86 mg Cu. Mohapatra et al. (1973) reported that a bearing cashew tree yielding 155 kg apple and 24 kg nut removes 1.126 kg N, 0.152 kg P and 0.372 kg K annually through apple and nut (0.37 kg N, 0.05 kg P, 0.23 kg K and 0.756 kg N, 0.10 kg P, 0.15 kg K respectively). This works out to 31.5 g N, 4.17 g

P and 6.25 g K (per kg of nut). In the present study, the corresponding values were found to be 28.5 g, 0.92 g, and 5.96 g. The N and K removal by cashewnuts observed in this study on per kg basis were comparable with that reported by Mohapatra et al. (1973). But the P offtake was found to be very low. The leaf P concentration (Table 9) in the trees was also considerably low. From the results it appears that the trees are not adequately supplied with P and they may respond well to P application.

e) Partitioning of nutrients between harvested parts

An attempt has been made to estimate the proportion of nutrient removed through apple, kernel and shell (Table 14 and Fig. 15 and 16). It was found that the nutrient (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) removal was largest through apple. Of the total annual nutrient offtake, 51 per cent N, 49.8 per cent P, 78 per cent K, 45.6 per cent Ca, 68.1 per cent Mg, 59 per cent S, 54.5 per cent Fe, 45.5 per cent Mn, 44.8 per cent Zn and 52.2 per cent Cu were through apple. The data on dry matter of harvested produce (Table 10) explain this. Though the concentration of nutrients in the apple (Table 9) was less compared to kernel, this difference was more than compensated by the increased partitioning (Table 11) of dry matter of the harvested produce towards

apple (51.8 per cent). The second major share of nutrient removal was through kernel. About 24.9 per cent N, 40.6 per cent P and 9.4 per cent K were removed through the kernel. There is a practice to remove apple from the plantation for the preparation of certain cashew apple products. The results suggest that any attempt to recycle the cashew apple waste back to the plantation would minimise the outflow of nutrients from the system.

f) Prediction models for nutrient requirement

Based on the data on nutrient offtake and nut yield per tree, an attempt has been made to develop models to predict the annual nutrient requirement (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) of cashew. The prediction models and their coefficient of determination (R^2) are presented in Table 15. The relationship between nutrient removal and nut yield was linear and positive in respect of N, P, K, Ca, S, Fe, Mn, Zn and Cu while that with Mg was quadratic (Fig. 17 to 19). The higher values on coefficient of determination indicate the greater predictability of the model.

The model would enable us to predict the nutrient requirement of cashew trees based on the yield level. The positive linear relationship indicates that the nutrient

requirement greatly depends on the nut yield of cashew. As per the models, to produce a kg of nut, the tree requires 64.1 g N, 2.05 g P, 24.7 g K, 4.19 g Ca, 1.57 g S, 525.7 mg Fe, 63.6 g Mn, 87.8 mg Zn and 26.5 mg Cu. These values refer to the quantity of nutrients that is removed through apple and nut while producing a kg of nut. Normally in cashew plantations there exist considerable heterogenity in the population especially in those originated from seedling progenies. The open pollinated nature of cashew is responsible for this. Many of the existing cashew plantations in the country are of seedling origin with greater variability in nut yield between trees. The present practice is to go in for a uniform fertilizer dose for all the trees without considering the production potential of individual tree. The results of the present study clearly suggest that it is essential to evolve suitable fertilization schedules based on yield level.

No attempt to predict nutrient requirement based on nut yield in cashew seems to have been made so far and as such the models developed are new. It is to be noted that the requirement worked out here represents the actual physiological requirement to produce a certain amount of nuts. As such the amount of nutrient to be applied in the

form of fertilizer would be more than the value predicted by the model which would depend on specific soil and climatic factors.

g) Leaf nutrient concentration in relation to physiological phases

The leaf nutrient status of cashew varied with physiological phases (Table 16 and Fig. 20 to 22) The concentration of N, P and K in the leaf was high at "flushing and early flowering" phase. Variations in leaf N, P, K and Ca concentrations due to change in physiolgical phases have been reported by Kumar (1983). The growth phase viz."flushing and early flowering" is physiologically most active during which the trees putforth new flushes and initiate flowering. A higher leaf concentration of N, P and K at this stage indicate the greater demand of these nutrients by the tree during this phase. The results thus suggest that "flushing and early flowering" phase is a very important physiological phase with peak nutrient demands and the trees should be well supplied with nutrients at this stage.

The concentrations of Mg and Cu were high at "flowering and fruiting" phase, while the leaf Fe concentration was

high during "maturity and harvesting" phase and the concentration of Ca, S Mn and Zn were high at post-harvest phase. Information on the micronutrient status of leaf in relation to physiological phase is not traceable in literature, as such the information generated is new.

PART III. Absorption of soil applied ^{32}P under rainfed conditions

This experiment was conducted to study the varietal difference on the absorption pattern of radiophosphorus under rainfed conditions in relation to physiological phases. Radioassay of leaf samples collected at 15 days interval (Table 19) revealed that detectable amount of ^{32}P was absorbed by the tree upto 60th day after application (DAA). The data revealed differences in the absorption of radiophosphorus between physiological phases (Table 18 and Fig. 23) but not between the four varieties tested (Table 17). The radioactivity in the leaves showed an increasing trend from 15 DAA to 60 DAA at all the four physiological phases. The absorption peak was noticed at "flushing and early flowering" and it was lowest at the "maturity and harvesting" phase.

During October, trees start flushing and enter the next reproductive phase. The data on leaf analysis indicate that the period October-November (flushing and early flowering phase) is physiologically more active demanding greater amount of nutrients, especially major nutrients (Table 9). The highest absorption of radiophosphorus noticed at this phase further confirms this.

The second highest absorption peak was noted during post-harvest phase. After completing a production cycle, the tree may be recouping its nutritional status slowly and preparing again for the next production cycle.

As the trees enter the "flowering and fruiting" phase (December-February) the absorbed nutrients may start flowing into the reproductive sink. The decline in ^{32}P activity in the leaves during "flowering and fruiting" phase compared to the previous phase subscribes to the view. The trees on entering the "maturity and harvesting" phase (March-May), further accumulate the nutrients in the apple and nut. The ^{32}P activity in the leaves at this stage was the lowest. Perhaps, more mobilisation of P from the leaves to the fruit occur at this phase.

It is very clear from the data that ^{32}P absorption by cashew varies with physiological phase without much variation among the four varieties. It was also clear that "flushing and early flowering" is the most physiologically active phase with peak nutrient demands and root activity. To sustain productivity of this crop, it is essential to bestow more attention during "flushing and early flowering" phase. The trees should not be allowed to starve at this phase.

No information regarding the differential absorption of radiophosphorus at different physiological phases is traceable in literature as such the information generated is new.

b) Effect of irrigation on ^{32}P absorption

During summer, the trees were irrigated to maintain the soil moisture regime around 50 per cent depletion from the field capacity. Radioassay of leaves of trees irrigated during summer (December-May) revealed that there was considerable increase in the absorption of ^{32}P due to irrigation compared to rainfed trees (Table 19). Irrigation has caused about 130 per cent increase in ^{32}P absorption compared to the unirrigated control during "flowering and fruiting" phase. During "maturity and harvesting" phase, the

corresponding increase was to the tune of 340 per cent. However, the amount of absorption of ^{32}P during this phase was low compared to the former. It was also clear from the data that peak absorption was during "flushing and early flowering" phase (Fig. 24). The ^{32}P activity in the leaves during "flowering and fruiting" phase, even by irrigation, did not reach the level observed at "flushing and early flowering" phase. The results further confirm that "flushing and early flowering" is the phase of peak physiological activity and nutrient demand. The results suggest the possibility of increasing cashew yields by summer irrigation as it would enhance greater absorption of nutrients by the tree.

Summary

SUMMARY

An investigation was undertaken at Cashew Research Station, Madakkathara and at the Radio Tracer Laboratory, Kerala Agricultural University during the period 1990-92 to study the varietal difference in growth and nutrition of cashew. The following studies were undertaken during the course of the investigation.

I Variability in growth and yield of 18 cashew varieties

II Nutrient concentration in plant parts and nutrient offtake

III Absorption of soil applied ^{32}P at different physiological phases

The salient results of the investigation are summarised below.

The tree height, tree girth and canopy spread did not differ between varieties.

The leaves of the varieties V3, H 1598 and M 33/3 contained higher amounts of chlorophyll.

The cashew varieties H 1600, VTL 30/4, T 40, BPP 2/16, V5, M 44/3,M 26/2 and Anakkayam 1 were early flowering

and the varieties H 1598, H 1608, H 1610, VTL 59/2, T 129, BPP 2/15, V2, V3, V4 and M 33/3 were mid season flowering.

Seven varieties (H 1600, H 1608, BPP 2/15, BPP 2/16, V3, V4 and M 33/3) had nut weight exceeding 7 g.

Eleven varieties (H 1598, H 1600, H 1608, H 1610, VTL 59/2, BPP 2/15, BPP 2/16, V2, V3, V4 and M 26/2) had kernel weight over 2 g.

As at the fifth year of planting, the varieties M 44/3 and M 26/2 gave the highest nut yield.

Six varieties (H 1608, VTL 59/2, BPP 2/15, BPP 2/16, V3 and V4) had apple weight exceeding 80 g and the variety V5 had the smallest apple.

Eleven varieties (H 1598, VTL 30/4, T 129, T 40, BPP 2/15, BPP 2/16, V2, V4, M 44/3, M 26/2 and Anakkayam 1) had shelling percentage exceeding 30.

The concentration of major and minor nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) differed between plant parts (leaf, apple, kernel and shell) and between varieties. The cashew kernel had the highest concentration of N, P, Ca, S,Zn and Cu compared to leaf, apple and shell. The concentrations of K, Mg and

Fe were high in apple. The Mn concentration was high in leaf. The nutrient concentration was low in the shell.

The harvested dry matter is being shared between apple, kernel and shell @ 51.8, 15.5 and 32.8 per cent respectively.

The nutrient offtake in cashew through harvested produce differed with variety and plant parts (apple, kernel and shell). The cashew varieties M 26/2 and H 1600 removed the largest amount of nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu).

A four year old cashew tree yielding 4.08 kg nut and 4.15 kg apple on dry weight basis removed 239 g N, 7.51 g P, 110 g K, 14.2 g Ca, 6.40 g Mg, 6.46 g S, 1709 mg Fe, 233 mg Mn, 252 mg Zn and 86 mg Cu.

Between apple, kernel and shell the nutrient removal was largest through apple. Of the total annual nutrient offtake, 51 per cent N, 49.8 per cent P, 78 per cent K, 45.6 per cent Ca, 68.1 per cent Mg, 59 per cent S, 54.5 per cent Fe, 45.5 per cent Mn, 44.8 per cent Zn and 52.2 per cent Cu were through apple.

The relationship between nutrient removal and nut yield was linear and positive in respect of N, P, K, Ca, S, Fe, Mn, Zn and Cu while that of Mg was quadratic.

Leaf nutrient status of cashew varied with physiological phases. The concentration of N, P and K in the leaf was high at "flushing and early flowering" phase. The concentrations of Mg and Cu in leaf were high during "flowering and fruiting" phase, that of Fe, was high during "maturity and harvesting" phase and the concentrations of Cu, S, Mn and Zn were high at post-harvest phase.

The absorption of soil applied ^{32}P differed with physiological phases but not between the varieties tested. The absorption peak was noticed at "flushing and early flowering" phase and lowest at "maturity and harvesting" phase.

Irrigation of cashew trees during summer increased ^{32}P absorption compared to the unirrigated trees.

Future line of work

From the studies on the leaf nutrient concentration, it was observed that the concentrations of P and Mg in the leaf are extremely low. These results suggest that the trees are not adequately supplied with these nutrients. It would be worthwhile to investigate on the effect of P and Mg on cashew under the agroclimatic situation of Madakkathara.

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Appendices

Appendix 1. Weather data (weekly average) for the experimental period (from 11-6-1991 to 3-6-1992).

Standard week No.	Month and date	Total rainfall mm	No. of rainy days	Temperature		Relative Humidity		Sunshine hours	Evaporation mm/day
				Maximum ° C	Minimum °C	Forenoon %	Afternoon %		
24	Jun.11-17	239.8	7	30.6	24.2	92	81	4.0	2.7
25	Jun.18-24	115.6	5	30.2	23.2	94	83	3.6	2.7
26	Jun.25-Jul.1	216.0	6	28.4	23.1	93	83	0.6	2.3
27	Jul.2-8	161.4	5	29.3	22.8	93	78	2.8	2.6
28	Jul.9-15	179.4	5	28.4	23.2	94	79	2.1	2.1
29	Jul.16-22	140.9	7	29.5	22.7	94	77	2.4	2.6
30	Jul.23-29	361.6	7	29.3	22.6	92	79	3.2	2.3
31	Jul.30-Aug.5	160.8	6	29.3	23.3	95	84	1.9	1.4
32	Aug.6-12	65.2	6	29.5	23.1	95	79	2.3	2.7
33	Aug.13-19	313.9	7	27.8	22.0	95	84	1.8	2.5
34	Aug.20-26	53.0	5	29.1	22.3	96	79	3.5	2.5
35	Aug.27-Sep.2	12.5	2	30.4	23.3	94	66	6.5	3.3
36	Sep 3-9	0	0	31.4	23.2	90	59	9.1	4.5
37	Sep 10-16	6.4	1	31.6	24.6	90	65	6.1	3.8
38	Sep 17-23	18.3	3	31.5	22.4	92	59	6.8	3.3
39	Sep 24-30	36.8	3	31.7	24.0	90	70	6.5	3.2
40	Oct 1-7	11.4	3	31.2	23.5	92	77	4.1	2.5
41	Oct 8-14	97.3	3	30.6	23.2	91	75	4.3	2.0
42	Oct 15-21	57.6	3	32.1	23.0	87	66	6.4	2.6
43	Oct 22-28	40.0	3	30.8	23.1	87	72	3.9	2.7
44	Oct 29-Nov 4	75.4	4	29.8	23.0	96	76	3.0	2.8
45	Nov 5-11	105.0	5	32.1	22.5	89	62	7.4	2.6
46	Nov 12-18	53.4	3	32.4	22.8	94	69	5.0	3.4
47	Nov 19-25	0.5	0	31.0	24.4	76	58	7.7	6.9
48	Nov 26-Dec 2	0	0	31.9	20.9	79	58	8.6	5.5
49	Dec 3-9	0	0	31.3	21.4	78	45	9.7	6.3
50	Dec 10-16	0	0	30.9	23.5	69	56	8.0	8.9
51	Dec 17-23	0	0	31.9	23.2	75	49	7.9	6.4
52	Dec 24-30	0	0	33.2	19.9	91	45	8.6	4.0
1	Jan 1-7	0	0	32.5	21.8	80	39	7.0	5.9
2	Jan 8-14	0	0	32.1	20.6	66	35	9.3	7.6
3	Jan 15-21	0	0	32.5	22.3	72	40	9.4	7.9
4	Jan 22-28	0	0	33.2	19.8	60	28	9.7	9.4
5	Jan 29-Feb 4	0	0	33.1	20.4	80	44	9.3	4.4
6	Feb 5-11	0	0	34.6	22.1	90	41	9.1	5.1
7	Feb 12-18	0	0	24.5	21.6	91	44	8.9	5.3
8	Feb 19-25	0	0	34.4	21.6	88	44	9.3	5.4
9	Feb 26-Mar 4	0	0	36.7	22.2	81	36	9.4	7.2
10	Mar 5-11	0	0	36.3	22.3	90	37	9.3	5.9
11	Mar 12-18	0	0	37.1	21.9	71	23	10.0	8.4
12	Mar 19-25	0	0	37.3	23.6	85	38	9.7	6.2
13	Mar 26-Apr 1	0	0	36.4	23.9	86	49	9.1	5.7
14	Apr 2-8	0	0	36.1	24.0	84	44	9.2	6.4
15	Apr 9-15	0	0	36.1	24.8	82	45	9.1	5.7
16	Apr 16-22	0	0	36.6	24.6	80	52	8.1	6.2
17	Apr 23-29	48.6	2	36.2	24.2	80	48	8.4	5.9
18	Apr 30-May 6	0	0	35.9	25.5	80	52	9.3	6.7
19	May 7-13	28.4	3	35.0	24.2	87	61	8.8	6.2
20	May 14-20	58.0	3	30.9	24.1	88	73	3.7	3.8
21	May 21-27	3.0	1	33.6	25.3	86	59	9.1	4.9
22	May 28-Jun 3	11.4	1	34.0	24.9	86	59	6.3	4.4

Source: Meteorological Observatory, Vellanikkara.

Appendix 2. Abstract of Anova

Growth and Physiological characters of different cashew genotypes

Source	df	Mean square							
		Tree height	Tree girth	Canopy spread	Chloro-phyll a	Chloro-phyll b	Total chloro-phyll	Panicle length	Panicle breadth
Replication	2	0.17	103.35	0.50	0.003	0.008	0.003	18.08	168.48
Treatment	17	0.33	60.57	0.73	0.029**	0.019**	0.074**	5.27**	10.46**
Error	34	0.21	38.83	0.59	0.008	0.005	0.017	1.93	3.58

Appendix 3. Abstract of Anova

Yield component, yield and other characteristics of different cashew genotype

Source	df	Mean square					
		No.of fruit per panicle	Nut weight	Kernal weight	Nut yield	Apple weight	Shelling percentage
Replication	2	15.44	0.09	0.008	3.14	52.32	1.83
Treatment	17	4.00	4.16**	0.24**	5.83*	901.34**	102.36**
Error	34	2.76	0.06	0.017	2.85	377.25	2.54

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

Appendix 4. Abstract of Anova
Concentration of major and minor nutrients in leaf, apple, kernal and shell of six cashew varieties

Source	df	Mean square									
		N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Plant part	3	25.58**	0.18**	10.85**	0.23**	0.009**	0.069**	26682**	48154**	7283**	14.76**
Variety	5	0.34**	0.001**	0.14**	0.002	0.001	0.001**	8624**	1078**	522**	28.0
Interaction	15	0.15*	$4x10^{-4}$	0.19**	0.004**	0.001**	0.001**	4535*	1152**	250	33.8
Error	72	0.075	$3.6x10^{-4}$	0.03	0.001	0.001	$1.7x10^{-4}$	2174	258	141	25.7

Appendix 5. Abstract of Anova
Dry weights of harvested produce in six cashew varieties

Source	df	Mean square				
		Apple	Kernal	Shell	Total dry weight of harvested produce	Nut yield
Treatment	5	12963359NS	1965513*	8088094*	61011392*	14.04*
Error	18	5331232	513847	2247825	20381853	4.7

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

Appendix 6. Abstract of Anova

Varietal variation on annual removal of nutrients through harvested produce (per tree)

Source	df	Mean square									
		N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Treatment	5	59720*	61.9*	9774	288**	60.488	36.2*	3980709*	59184*	125945	10542
Error	18	20514	18.5	4096	62.4	13.5	12.4	1302529	20260	48270	3835

Appendix 7. Abstract of Anova

Annual nutrient removal per tree through different plant parts

Source	df	Mean square									
		N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Plant part	2	37877**	59.9**	43496**	62.9**	91.8**	60.1**	2665117**	39402**	16057	6064**
Variety	5	19883**	20.6**	3275**	83.0**	20.4**	12.1**	760624**	17715**	27605*	1480*
Intera-ction	10	1859	2.90	1662	5.98	8.42**	2.82	206548	2114	7409	790
Error	54	2840	2.82	915	9.06	2.98	1.96	150298	2548	9044	479

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

Appendix 8. Leaf nutrient content of cashew variety Anakkayam 1 at different physiological phases

Source	df	Mean square									
		N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
Treatment part	3	0.41**	0.001*	0.08*	0.006	0.007**	0.003*	12533**	103146	487	5.2
Error	12	0.04	0.00017	0.02	0.005	0.0008	0.0008	433	32298	176	3.43

Appendix 9. Recovery of soil applied ^{32}P in the leaves of cashew

Source	df	Mean square
Replication	5	0.023
Variety	3	0.185
Physiological phase	3	10.95**
Interaction	9	0.16
Error	75	0.085

UPTAKE PATTERN OF MAJOR AND MINOR NUTRIENTS IN SELECTED CASHEW TYPES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

An investigation was undertaken at the Kerala Agricultural University during 1990-92 to study the varietal difference in growth and nutrition of 18 cashew varieties. The study was also aimed to assess the variability in nutrient concentration in plant parts and the nutrient offtake. The variation in the absorption of soil applied ^{32}P at different physiological phases was also assessed. The experimental trees were at the fifth year of planting. The most important findings are abstracted below.

Two cashew varieties viz. M 44/3 and M 26/2 originated from Cashew Research Station, Vridhachalam gave higher nut yield.

The concentrations of major and minor nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu) differed between plant parts (leaf, apple, kernel and shell) and between varieties. The cashew kernel had the highest concentration of N, P, Ca, S, Zn and Cu compared to leaf and apple. The concentrations of K, Mg and Fe were high in apple. The Mn concentration was high in leaf. The nutrient concentration was low in the shell.

A four year old cashew tree yielding 4.08 kg nut and 4.15 kg apple on dry weight basis removed 239 g N, 7.51 g P, 110 g K, 14.2 g Ca, 6.40 g Mg, 6.46 g S, 1709 mg Fe, 233 mg Mn, 252 mg Zn and 86 mg Cu.

Among Between apple, kernel and shell, the nutrient removal was largest through apple.

Leaf nutrient status of cashew varied with physiological phases. The concentrations of N, P and K in the leaf were high at "flushing and early flowering" phase.

Absorption of soil applied ^{32}P differed between physiological phases but not between the varieties and the absorption peak was noticed in the "flushing and early flowering" phase. Irrigation of cashew trees during summer increased the absorption of soil applied ^{32}P.