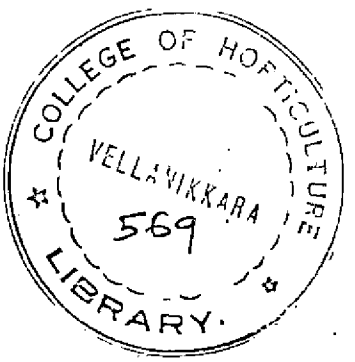
YIELD PREDICTION IN CASHEW BASED ON FOLIAR NUTRIENT LEVELS

By

ROSILY MATHEW



THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

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COLLEGE OF HORTICULTURE

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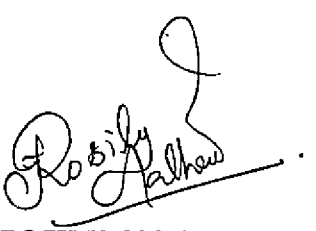
DECLARATION

I hereby declare that the thesis entitled ***"Yield prediction in cashew based on foliar nutrient levels"*** *is a bona fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.*



Vellanikkara,
10th October, 1990

ROSILY MATHEW

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Dated : 10th October, 1990

CERTIFICATE

Certified that this thesis entitled ***"Yield prediction in cashew based on foliar nutrient levels"*** *is a record of research work done independently by* ***Miss Rosily Mathew*** *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.*

A. I. Jose,
Chairman,
Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of ***Miss Rosily Mathew,*** *a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled* ***"Yield prediction in cashew based on foliar nutrient levels"*** *may be submitted by* ***Miss Rosily Mathew,*** *in partial fulfilment of the requirement for the degree.*

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To my Parents

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Introduction

INTRODUCTION

Cashew (*Anacardium occidentale* Linn.) is a native of tropical America stretching from Mexico to Peru and West Indies. It is one of the first fruit trees from the new world to be widely distributed throughout the tropics by early Portuguese and Spanish adventures. It was introduced to India in the sixteenth century.

The crop occupies an area of five lakh hectares in the country with an annual production of two lakh metric tonnes. The annual production is insufficient to meet the processing capacity of five lakh metric tonnes of raw cashew nut. In 1989-90, India exported cashew kernals worth Rs.360 crores. The cashew industry in the country provides employment for three lakhs of people. The crop is mainly cultivated in the states of Kerala, Tamil Nadu, Karnataka, Andra Pradesh, Maharastra, Goa, Orissa and West Bengal.

The cultivation and processing of cashew in India is largely concentrated in the state of Kerala where it occupies an area of 1.3 lakh hectares with an annual production of 88.7 thousand tonnes of raw cashew nut which is sufficient to meet only about one third of the requirement of the processing industry.

The crop is generally grown in areas which are unsuitable for growing other crops. Conventionally the crop is raised under rainfed conditions without the application of fertilizers. But recently more attention is being paid for the better management

of the crop. Studies conducted by earlier workers show that cashew responds well to fertilization. Being a perennial crop, fertilizer recommendation can be made based on tissue analysis of individual plants. Standardisation of tissue as well as period of sampling for evaluating the nutrient level of plant has to be undertaken for evolving suitable foliar diagnostic technique for this crop. Kumar (1985) studied the pattern of N, P and K uptake in seedling progenies of cashew in comparison with air layers. However, he has not made any attempt to standardise the period of sampling and leaf position in relation to yield. Also, studies on the standardisation of leaf tissue for foliar diagnosis in relation to yield as well as on the prediction of yield based on foliar nutrient levels have not been reported.

This investigation was therefore undertaken making use of the experimental plants of NPK trial of the Kerala Agricultural Development Project at Madakkathara, Thrissur in order

1. to standardise leaf position and the period of sampling for the foliar diagnosis in cashew in relation to N,P and K; and

2. to predict the yield of cashew based on the N, P and K status of the plant.

The results of the investigation are presented in the following pages.

Review of Literature

REVIEW OF LITERATURE

1. Foliar diagnosis

Foliar diagnosis is based on the principle that plant behaviour is related to concentration of essential mineral elements in the leaf tissue. Therefore, foliar analysis as a method for assessing the nutrient requirement of a given crop, makes use of the fact that, within certain limits there is a positive relationship between doses of nutrient supplied, leaf nutrient content and yield.

Foliar diagnostic technique was first developed by Lagatu and Maume (1926) in France. They defined foliar diagnosis as the assessment of chemical status, at a given point in time, of suitably selected leaves. It was Loue (1951) in Ivory Coast who first used this technique for Robusta coffee.

Leaf analysis indicates the status of soil fertility, nutrient availability to plants and the critical level of plant nutrients. Critical nutrient concentration is the level of a nutrient below which crop yield, quality and performance are unsatisfactory. Thus for leaf analysis to serve as a guide to crop fertilization, it is essential to standardise the sampling procedures with respect to each nutrient.

1.1 Foliar analysis vs soil analysis

Since leaf is the principal site of plant metabolism, changes in the nutrient supply are reflected in the level of nutrient in

leaf. Analysis of the soil, on the other hand, provides information only on the amount of nutrient available at a given moment, not on the amount actually taken up by the crop.

Soil and tissue tests for predicting olive yields in Turkey were examined by Fox et al. (1964). Leaf nutrient levels were found to be better correlated with yield. In groundnut also, foliar nutrient levels were better correlated with yield than soil nutrient levels (Ollagnier and Giller, 1965). But in banana, both foliar and soil analyses were necessary for determining the fertiliser requirements (Champion, 1966).

The soil may not be able to provide all the time, enough nutrients for optimum plant growth. However, many workers suggested soil tests for monitoring the nutrient requirement of young plants. With regard to NPK nutrition of one year old apple trees, soil analysis gave better results but with two year old trees foliar analysis was better (Klossowski and Czynczyk, 1974). In pineapple, a preplant soil analysis would be sufficient to indicate the P and K requirements (Plessis and Koen, 1983). Hanson (1987) and Hancock and Nelson (1988) suggested soil test for monitoring the K status of young blueberry plant.

Sakshaug (1982) conducted a nutrient survey of strawberry in Norway and Sweden. In many surveys, primary positive correlations between soil nutrients and leaf nutrients were observed.

Significant positive correlations between K values in the soil and in the leaf samples were most frequent.

Although strong relationships between soil nturients and leaf nutrients were observed in many crops, little or no correlation was observed between soil and leaf nutrients in some crops. Bopaiah and Srivastava (1984) reported that there was no significant correlation between soil and leaf nutrient with respect to N, P and K in mango. But in the case of blueberry, weak correlations were noted between soil and leaf nutrient levels of P, K, Ca and Mg (Hanson 1987; Hancock and Nelson, 1988).

1.2. Selection of plant tissue for nutrient diagnosis

The leaf is the centre for physiological activity of plants. It is the site where mineral nutrients are converted into structurally and metabolically active components along with the products of photosynthesis. Consequently, any deficiency or toxicity usually drastically affects the concerned enzyme activity. Nutrient deficiency as well as toxicity is usually expressed by the leaves and thus leaves form an ideal plant part for nutritional diagnosis.

Rogers et al. (1955) showed that leaf was sensitive or even more sensitive than any other plant part for determining the nutrient status of strawberry. For plantains, leaf was found to be the specific tissue for diagnosing N, P, K, Ca and Mg at all stages

of growth (Samuels et al., 1976). According to Quast (1978) leaf was the best for K level determination in apple.

Leaf analysis usually involves the analysis of whole leaf (blade and petiole); but some workers have considered whether separate analysis of petiole could be more informative (Loue, 1968). In grape vines Bergman and Kenworthy (1958) came to the conclusion that when N, P and K were low, these nutrients tended to accumulate more rapidly in the petiole than in the leaf blade. Bertoni and Morard (1982) found that N content of leaf blade was more than double that of petioles. But the effect of locality and season on P and K status of vines was better reflected by petioles. There were also reports that petiole reflected plant P status better than leaf blade (Kovanci and Atalay, 1987). In papaya also, petioles were selected for nutritional diagnosis (Reddy et al., 1988).

Diagnosis on the basis of stem analysis was reported in sugarcane by Humbert (1968). Some investigators notably Marcelle (1976) found that fruit composition was a useful measure of fruit quality. Apples had been the subject of many studies (Perring,1975). According to Quast (1978) fruit analysis was the best for Ca and Mg requirements in apples.

For specific investigations, other plant parts can also be selected. Leaf analysis may give little or no information on the encroaching root toxicities of such elements as Na, Ca, Se, and

Pb. Analysis of rootlets is preferable in such cases (Smith,1962).

1.3 Sampling procedure

A standard sampling procedure should be employed to eliminate all the factors that cause variation in leaf nutrient levels. Steenbjerg (1954) pointed out that neither deficient nor adequate levels of any individual nutrient could be defined, because they were influenced by so many factors, in particular by physical and chemical properties of the soil, water supply, climate and stage of development.

Evans (1979) cited the various external and internal factors affecting leaf nutrient levels. They were climate, season, time of the day, age of the plant, age of the foliage, variation between trees, position in crown, nutrient balance, effect of disease and other factors.

1.4. External factors affecting leaf nutrient levels

1.4.1. Climate and leaf nutrient levels

Certain physiological processes in plants are much affected by climatic variations. Such climatic variations produce appreciable differences in plant nutrient content. Most important climatic factors which influence the chemical concentration of leaves are rainfall and sunshine.

Foster and Chang (1977) examined the influence of rainfall on leaf nutrient content of oil palm. Leaf P and K were found to increase with average level of soil moisture prior to sampling. In a year with inadequate rainfall, a positive correlation was established between leaf N P K content and yield of apple. But in wet years negative or no correlation was found (Dufkova, 1977).

An increase in percentages of macronutrients in the third leaf of sugarcane due to 200 mm rainfall, two months prior to sampling, was noted by Malavolta and Carvalho (1984). Phosphorus content increased by 0.016 - 0.034 per cent and K by 0.017 per cent. According to Yaacob et al. (1985), N and K contents of cashew leaves were higher during dry months than in wet months.

The influence of sunshine and shade on leaf chemical composition was noted by Shorrocks (1961) in rubber and Murray (1961) in banana, as a direct relationship between potassium concentration in leaves and the number of sunshine hours two years earlier. In pepper, De Waard (1969) noted a significant reduction in leaf potassium concentration in the leaves taken from deep shade.

1.4.2. Time of the day

Time of the day has an influence on nitrate level in plants. Nitrate accumulates at night and is utilized during the day as carbohydrates are synthesized. Therefore, rapid test should not be made very early in the morning or late in the afternoon (Tisdale et al., 1985).

According to Ulrich (1952) the best time for taking sample for diagnostic purpose was from 8 a.m. to 12 noon. The N content in the leaves of black pepper was found to decrease from early morning to late afternoon. But K content remained unchanged (De Waard, 1969). Sugiyama et al. (1984) studied the diurnal fluctuation in the nutrient concentrations of spinach leaves in a pot culture experiment. It was found that the concentration of N, P, K and Mg decreased after sunrise, reached a minimum in the late afternoon and then increased to maximum at dawn.

1.4.3. Effect of soil temperature

Soil temperature on the root zone can have a direct effect on nutrient uptake. Many investigators suggested that there was a general relationship between soil temperature and plant nutrient contents. In sugarcane, lower temperature during late growth period was found to depress leaf N (Srinivasan and Morachan, 1980). Franco (1982) observed a reduced growth of coffee bushes at high soil temperature. Okada (1987) found that the N content of citrus leaves increased with soil temperature.

1.4.4. Water Supply

Plants need an adequate and continuing supply of water of suitable quality. Excess or insufficient water or water of poor quality affects root activity and therefore root uptake. At the same time maintaining a satisfactory water regime makes adequate

supply of nutrients. Irrigation during dry season was found to increase the leaf N, P, K, Ca and Mg contents in coffee (Omotoso, 1974). Similar results were also obtained in oil palm (Ataga and Okoye, 1981) and in apple (Lehova and Doichev, 1983).

1.5. Inherent causes of variation in plant composition

1.5.1. Effect of size and thickness of leaves

Steyn (1961) in citrus, found that there was no appreciable effect of leaf size on the leaf nutrient concentration. But Twyford and Couleter (1964) reported a substantial gradient over the length of the banana leaf. The study on foliar diagnosis in pepper by De Waard (1969) revealed that concentration of N and K were higher in the leaves of average size as compared to small sized leaves.

1.5.2. Sample size

According to Bakula et al. (1973) samples of two leaves from each of 18 trees of a 3 ha sampling unit were adequate for the analysis of N, P, K, Ca and Mg in orange trees. In peach, a sample size of 25-30 leaves/tree from 30 trees which included 6 per cent of the test population had been recommended (Rodriguez et al., 1974). A leaf sample size of 30-40 leaves was found to be optimum for nutritional diagnosis in mango (Rajput et al., 1985).

1.5.3. Leaf age and leaf position

Leaf analysis is used as a guide in planning fertilizer programmes. So selection of index tissue is the most important. The

leaf composition depends on age and physiological stage of the tree, position in the crown, age of leaf, season and other conditions of the leaf sampled (Emert, 1954, 1957, 1959, Embleton and Jones, 1964). Therefore, before proposing the index tissue it is essential to determine the manner and extent of influence of these factors on leaf composition.

Leaf sampling technique had been evaluated in many fruits like banana (Hewitt, 1955) citrus (Koo and Sites, 1956; Chandler, 1970) guava (Arora and Singh, 1972; Chadha et al., 1973) mango (Pathak and Pandey, 1976) and papaya (Awada and Long, 1971).

De Waard (1969) studied the leaf nutrient content of black pepper at different leaf positions. A significantly higher leaf N was recorded in the second leaf. The P content of the leaf decreased on aging but K content remained unaffected by the age of the leaf. A negative linear relationship between N, P and K content of rubber leaves with age of the leaf was noted by Guha and Narayanan (1969). But Ca and Mn showed a positive relationship with age of the leaf.

According to Chadha et al. (1973), the N, P and K content of guava leaves decreased with increasing age of the leaf both in fruiting and non-fruiting terminals. Kumar and Grewal (1977) observed a reduction in leaf N content of pear from 2.36 to 1.94 per cent when the age of the leaf advanced from two to nine months.

1.5.4. Fruiting vs. non-fruiting terminals

The proximity of a fruit is likely to affect the composition of mineral elements in nearby leaves. Workers like Harding et al. (1962), Bradford et al. (1963) and Aiyappa et al. (1965) showed that the leaves from the fruiting and non-fruiting terminals did not have the same mineral composition.

Tribulato (1968) observed a significant difference between nutrient status of leaves collected from fruiting and non-fruiting shoots of orange. However, the vegetative branches were richer in N, P, K and Ca. Leaf samples from non-fruiting branches were recommended in mango (Koo and Young, 1972; Thakur et al., 1981) and guava (Singh and Rajput, 1978) since non-fruiting branches had more N, P and K than fruiting branches.

But for some crops, leaf sampling from fruiting terminals has been suggested. De Waard (1969) in Sarawaak recommended leaf sampling from fruit bearing laterals in pepper. A higher content of K in the fruit bearing laterals of pepper was noted by Sushama et al. (1982). Leaf sampling from fruit bearing laterals was also practised in litchi. The leaves should be collected from fruiting branches 2 to 6 weeks after fruitset (Menzel et al., 1987).

1.5.5. Level of yield

In tree fruits, the mineral composition of leaves is influenced by yield level. Cain and Boyton (1948) and Trzcinski (1978)

had shown that in biennially cropping apples, the fruiting year was characterised by a fall in leaf K content and a rise in Ca and Mg content. It was also noted that a high fruit load increased leaf N and decreased leaf K content of apple leaves (Moskal, 1979; Tserling and Egorova, 1979).

Thakur et al. (1983) recorded a high K status in the leaves of mango in the 'off' year than in the 'on' year. The status of N and K of satsuma orange leaves decreased significantly in the 'off' year after fruiting in the 'on' year (Wang, 1985).

1.5.6. Seasonal variation

Variations of rainfall, air temperature, humidity and light intensity are expected to be reflected in the chemical composition of leaves. Closely interacting with this, is the changing demand for nutrients by the plants. So, understanding of this seasonal variation is essential for the choice of a sampling time.

In nutritional studies in citrus, the importance of seasonal changes in nutrient element has been emphasized by various workers (Jones and Parker, 1950; Reuther and Smith, 1955; Stephenson et al., 1986). They have found it desirable to determine the foliar concentration of different nutrient elements at various seasons of the year.

Bataglia et al. (1976) opined that the N levels in the leaves of black pepper rose in the autumn; but declined in winter.

Phosphorus content was highest in summer whereas K content was high in summer and declined in winter. Sushama et al. (1984) reported that the period just prior to flushing was the most suitable one for the collection of leaf sample for diagnostic purpose in Kerala.

Studies conducted by Wahid et al. (1981) in coconut revealed that the leaf N declined with onset of monsoon. But leaf P increased slightly in rainy season whereas leaf K increased until December and thereafter declined. A reduction in the N concentration of the foliar tissue in oil palm during summer months and an increase during rainy season were noted by Nair and Sreedharan (1983). But a reverse trend was observed in the case of P and K.

1.6. Preparation of sample for analysis

There are a few important steps to be taken between sampling and analysis. The sample must be properly cleaned, but no part of it should be under water for more than a few seconds (Chapman, 1964). Studies conducted in apple, citrus and other horticultural crops showed that the leaf washing was essential to get the real nutritional status of the sample (Mason, 1951; Arkley et al., 1960; Labanauskas, 1968).

Studies conducted in pepper by De Waard (1969) revealed that none of the different leaf washing techniques attained significance for any of the nutrients. Mineral composition of mango leaves

prepared by five different leaf washing technique was recorded by Rajput et al. (1987). Variations due to different leaf washing techniques were nonsignificant.

Pushpadas et al. (1978) compared the mineral element content in the leaves of rubber prepared by oven drying immediately after collection or air drying in shade for one or five days. Leaf N content increased by air drying in both the periods and leaf P content increased by air drying for five days.

1.7. Interpretation of the data

Correct interpretation of the data obtained by the analysis of leaves is the most useful and most complex stage of diagnostic technique. Results of leaf analysis can be interpreted either by critical nutrient level (CNL) or balance ratio concept. One of the most recently developed techniques is the Diagnosis and Recommendation Integrated System (DRIS). The DRIS was designed to assess relative nutrient imbalances or deficiency or both in plant tissues (Beaufils, 1973; Sumner, 1977; 1981; 1982). The effectiveness of soil testing and foliar analysis as interpreted by CNL approach and DRIS norms in sugarcane was evaluated by Elwali and Gascho (1984). Fertilization according to DRIS was found to increase both cane and sugar yield. In coconut, DRIS gave more accurate diagnosis of nutrient imbalance or deficiency than CLN approach (Khan et al. 1988).

2.1. Nutritional studies in cashew

Since cashew is a waste land crop, the only maintenance usually accorded is protecting the young plants and later collecting whatever nuts available from the trees. With the recognition of cashew as a paying crop, efforts have been made to study its nutritional requirements.

Addition of wood ash to the planting pits as a practice has been reported (Agnolini and Giuliani, 1977). A minimum of 10 kg of organic manure is mixed with the soil in the pits at the time of planting in Brazil. An NPK mixture of 11:22:16 at 200-300 g per plant annually worked into the surface soil during the first two years has been reported from a field experiment from Majunga in Malagazy (Agnolini and Giuliani, 1977).

Mohapatra et al. (1973) worked out the amounts of nutrients removed by a bearing cashew. Nutrient removal by a 30 year old cashew tree was 20-80 kg N, 0-75 kg P_2O_5 and 120 kg K_2O. A manuring schedule for cashew of different age group has been given by Rai (1969). Results from Tanzania showed that fertilizer application increased cashew yield only in poor soils (Ohler, 1979).

At Vrindhachalam in Tamil Nadu trial with farmyard manure, N, P and K showed that 25 kg farmyard manure and 600 g N per tree gave significant increase in yield (Damodaran et al., 1979). In another trial, initiated at Vengurla in Maharastra, N and P

were found to increase the yield of cashew, but K had no effect on yield. There was a good response to N at 135 kg/ha in the presence of P (50 kg/ha) and K (100 kg/ha) and this response was limited to 75 kg N in the absence of P and K (Sawke, 1980).

In Orissa, old cashew plantations responded only to N and 250 g N per plant was found to be the optimum (Mishra et al., 1980). Kumar et al., (1982a) studied the nutrient uptake pattern during various months in Vittal in South India. It was concluded that half the annual dose of manure should be applied in May-June and the rest in October-November.

The influence of different methods of application of fertilizer on the chemical composition of cashew leaf was tested by Kumar and Nagabhushanam (1981). Among the different methods tested, double ring method enabled quicker absorption of N, P and K. George et al. (1984) found that maximum nutrient accumulation in the leaf occurred when fertilizer was applied in two circular trenches. Foilar spray with urea at 4 per cent has been suggested in cashew in Bapatla since urea spray at 4 per cent and 6 per cent did not differ significantly (Ankaiah and Rao, 1983). Response of cashew to the application of higher levels of N in increasing the yield was significant but there was no significant effect either by the application of P or K on the yield of nuts/tree (Venkataraman, 1979; Ankaiah, 1979; Rao et al., 1984; Veeraraghavan et al., 1985). Reddy et al. (1982) reported that the percentage

of N in the leaf increased with increased dose of N upto 1000 g/plant and thereafter decreased.

Liming was found to increase the N, P and K contents of young leaves and not of mature leaves (Kamal et al., 1985). Response of cashew to the application of lime in increasing the yield was also noted by Badrinath et al. (1987). Application of higher level of N increased flowering duration while in the case of P and K, higher levels decreased it (Ghosh, 1987).

Broadcasting the fertilizers at the rate of 500 g N, 125 g P_2O_5 and 125 g K_2O per tree per annum, has been recommended in Kerala (KAU, 1989).

3. Foliar diagnosis in cashew

Cashew is cultivated on a wide variety of soils and lands, mostly under neglected conditions. So it is difficult to predict its nutritional requirement with certainity. Foliar analysis could be of much use in such situations. Leaf analysis as a method for evaluating the nutritional status of the cashew tree was reported by various workers (Lefebvre, 1973; Falade, 1978; Kumar, 1982).

3.1. Sampling procedure

3.1.1. Leaf position

Leaf sampling technique recommended by IRFA for cashew is to take the youngest fully developed leaf on terminal shoots, situated at medium height and around the periphery (Prevel et al., 1974).

Separate leaf sample size was recommended for sample collection during both pre-fruiting and post-fruiting season. During pre-fruiting season, leaf sample collection at the rate of three composite samples each representing five trees was recommended for an area of one ha while during post fruiting season sample collection at the rate of six composite samples each representing three trees would be enough (Kumar et al., 1982b). Fully matured leaves either from lower or upper branches could be taken for analysis. The lower branches retained higher contents of N, P and K than upper branches (Reddy et al., 1982). Yaacob et al. (1985) opined that the younger leaves contained higher amounts of N, P and K than older leaves.

3.1.2. Sampling stage, date and type of shoots

Experiments in Majunga region of Madagaskar showed that there are two phases of shoot growth per annum, one non-fruiting in December and the other fruit bearing in March. Four to five month old leaves seem to be the most suitable for sampling, i.e., sampling from non-fruiting shoots in March-April and fruiting shoots in July-August (Prevel et al., 1976). Kumar et al. (1985) sampled leaves in January (before fruiting) and in May and found that the leaf N, P and K contents were significantly higher in May than in January. According to Reddy et al. (1982), the best sampling period was November for N, P and K although N showed a major peak in December.

3.2. Leaf nutrient composition

Leaf nutrient composition depends largely on age of genotype, type of soil and management practices in many deep rooted perennial crops.

3.2.1. Nitrogen

Calton (1961) compared the composition of healthy and poorly growing cashew trees and found that healthy trees contained 1.98 per cent and unhealthy trees contained 1.52 per cent leaf N. Marchal and Prevel (1971) made a comparative analysis of leaves of healthy cashew trees and those affected by little leaf in Madagaskar. Leaves from healthy trees contained 1.73 per cent N and normal leaves of the affected trees contained 2.01 per cent N and little leaves (diseased) contained 1.88 per cent N.

For young cashew plants grown in nutrient solutions, 2.4 to 2.58 per cent leaf N was found to be the sufficient range and 0.98 - 1.38 per cent to be the deficient range (Haag et al., 1975). However, the range of hidden hunger was not established. They also established that leaf N content was independent of age of the tree. An increase in leaf N with an increased dose of applied N upto 1000 g per tree has been reported (Reddy et al., 1982). The leaf N content varied between 1.02 - 2.44 per cent. An increase in foliar N content as a result of N application was also reported by Kumar and Nagabhushanam (1981) and Ghosh and Bose (1986).

Reddy and Reddy (1986) estimated the concentration of nutrients in the different plant parts of cashew. Results showed that the concentration of N was higher in the bark (2.03 per cent) and lowest in Wood (1.00 per cent). The leaves and stem had almost the same concentration of N.

3.2.2. Phosphorus

Calton (1961) analysed cashew trees grown under unfavourable physical condition of soil wetness and found that thrifty trees contained 0.21 per cent P and unthrifty trees contained 0.10 per cent P. Haag et al. (1975) recorded a leaf P content of 0.16 to 0.20 per cent under adequate range and 0.11 - 0.14 per cent under deficient range in a pot culture experiment. Maximum growth of cashew in relation to leaf P was at 0.118 per cent (Falade, 1978).

Application of P had a pronounced effect on leaf P and it increased wth higher dose of nutrient (Kumar, 1981a; Reddy et al., 1982; Ghosh and Bose, 1986).

Kumar (1981b) reported that cashew leaves contained about 22.76 per cent of total phosphorus in the plant system while the leaf and stem portion together contributed 50.63 per cent of total P held by the tree (Reddy and Reddy, 1986).

3.2.3. Potassium

Calton (1961) reported that cashew trees grown under ill-drained conditions contained 1.69 per cent leaf K. Lefebvre (1973)

investigated cashew deficiency symptoms in Madagaskar and found that, in general, cashew contained 0.88 per cent leaf K. In the young cashew plants grown in nutrient solution the leaf K content of 1.11 - 1.29 per cent under adequate range and 0.20 - 0.26 per cent under deficient range has been reported (Haag et al., 1975). According to Ghosh and Bose (1986), the percentages of K in the leaf samples taken in different months varied between 0.83 - 1.19 per cent.

3.2.4. Nutrient interaction

Nitrogen and P deficiency symptoms have been reported in Madagaskar by Prevel et al. (1974). He found that combined effect of the two nutrients on growth, flowering and yield was much greater than the sum of responses due to the two nutrients applied separately. Nitrogen application raised leaf N content while it decreased leaf P content. When P fertilizers were applied, leaf P content increased but those of N and K decreased. Potassium fertilizers had little effect on leaf composition. Reddy et al. (1982) opined that the applied N did not influence the leaf P and K content. But the works of Kumar (1985) showed that the leaf P and K were decreased by N application. It was also found that the N application resulted in an increase in leaf Ca, whereas P and K levels significantly reduced the same. Nitrogen and K reduced leaf Mg but P had no effect. A slight increase in leaf N content due to increase in P and K treatment was observed by Ghosh and Bose (1986).

3.3. 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 unlikely to occur (Prevot and Ollagnier, 1957). In cashew, P contents below 0.13 per cent from non-fruiting shoots in April and below 0.07 per cent in fruiting shoots in August are classified as critical values in Madagaskar (Prevel, et al., 1976).

Kumar and Sreedharan (1986) suggested critical levels for N and P at 2.09 per cent and 0.14 per cent respectively. The maximum levels of leaf N and P for maximum response were fixed at 2.84 per cent and 0.17 per cent respectively.

Materials and Methods

MATERIALS AND METHODS

Cashew plants of NPK fertilizer trial of the Kerala Agricultural Development Project (College of Horticulture) at Madakkathara, Thrissur were made use of for the study. The field trial was established in 1979 with newly planted cashew seedlings of variety BLA-39-4. The details of the experiment maintained under this project are as follows.

1.1. Site, climate and soil

The experimental site is situated at 10° 31' N latitude and 76° 13' E longitude, at an altitude of 22.25 m above MSL. This area enjoys typical humid tropical climate.

The soil of the experimental site is deep well drained sandy clay loam (sand 77.5%, silt 5% and clay 17.5%). The pH of the soil is 4.8. The data on the nutritional status of the experimental site are given in Appendix I.

1.2. Design, lay out and treatments (Fig.1)

Design	:	3^3 factorial randomised block
No. of replications	:	2
Total number of treatments	:	27
Total number of plots	:	54
Number of plants/plot	:	2
Spacing	:	8 m x 8 m

Fig.1 Lay out of the field experiment

112	011	121	012	212	120	201	021	020
210	022	022	102	202	000	110	222	010
101	122	100	211	111	200	220	221	001
120	210	200	211	100	221	122	212	121
001	021	022	110	111	002	000	012	202
102	201	011	020	222	220	101	010	112

x Experimental plants

Treatments

Levels of nitrogen

1	n_0	250 g N/plant/year
2	n_1	500 g N/plant/year
3	n_2	1000 g N/plant/year

Levels of phosphorus

1	p_0	125 g P_2O_5/plant/year
2	p_1	250 g P_2O_5/plant/year
3	p_2	500 g P_2O_5/plant/year

Levels of potassium

1	k_0	250 g K_2O/plant/year
2	k_1	500 g K_2O/plant/year
3	k_2	1000 g K_2O/plant/year

Nitrogen, phosphorus and potassium are applied in the form of urea, superphosphate and muriate of potash respectively in accordance with the treatments as a single dose in September-October. No organic manure was given to the experimental plants. The cultural operation and plant protection measures were carried out uniformly irrespective of the fertilizer treatments.

2. Collection of samples for the study

2.1. Selection of plants for sampling

Out of the four plants receiving a single treatment, two plants were taken, one from each plot. The samples were collected separately from 54 plants i.e., 1 plant per plot x 27 treatment x

2 replications. In order to reduce the number of samples involved in chemical analysis, samples from plants of the same treatment of the two replications were pooled to give rise to a composite sample representing a single treatment.

2.2. Collection of soil

Soil samples of depth 0 to 15 cm were collected from different aspects of the basin of the plant within a radius of 2 m.

Samples of two plants receiving the same treatment as detailed above were pooled into a composite sample and thus there were 27 soil samples representing 27 treatments. Soil sampling was done on 15th December, 1989.

2.3. Collection of plant sample

For chemical analysis, leaf samples were collected from all the selected 54 plants separately. Samples of the plants receiving the same treatments were then pooled to give rise to composite samples of the treatment.

2.3.1. Standardisation of leaf position

For this purpose, the leaves of the flowering shoots were serially numbered designating the last fully matured leaf which was not having an inflorescence in the leaf axil as leaf no.1. The leaves were grouped as follows.

Before flushing and flowering of the shoots (old growth), the leaves of the shoots were grouped into

group 1 Top leaves
2 Middle leaves
3 Basal leaves

Each gruop consisted of three leaves thereby covering nine leaves from the tip of the shoots.

After flushing and flowering, the leaves at different leaf positions were grouped into

group 1 Leaf No. 1 and 2 (near to the inflorescence)
group 2 Leaf No. 3 and 4
group 3 Leaf No. 5 and 6
group 4 Leaf No. 7 and 8

Leaf samples were collected from a total of eight shoots drawn from the north, south, east and west aspects of the exposed region of the canopy of each tree. The samples were composited to get samples representing leaf groups 1 to 4 for each treatment combination separately.

2.3.2. Standardisation of period of sampling

In order to standardise the optimum season for the collection of leaf intended for foliar diagnosis, sampling was carried out at different periods as follows :

Period		Date of sampling
1	Prior to flushing and before fertilizer application (old growth)	Ist September, 1989
2	After flushing and flowering but before flower opening	Ist December, 1989
3	At the beginning of flower opening (one month old leaves)	8th December, 1989
4	After the opening of all the flowers of a panicle (just before fruit set)	29th December, 1989
5	Immature nut stage	25th January, 1990
6	Harvesting stage	30th February, 1990
7	Two months after harvesting	30th April, 1990

Stages of sampling of the fruiting shoots are shown in Plate I to V.

3. Analytical methods

3.1. Soil

The particle size analysis of the soil was conducted using hydrometer method (Piper, 1942). The pH of the soil water suspension (1:2.5) was determined using a pH meter. Organic carbon of the soil was determined by Walkley and Black method described by Piper (1942). The Kjeldahl digestion and distillation method was followed for the determination of total nitrogen. Available phosphorus was extracted using Bray No.1 extractant. The phosphorus

Plate I Cashew leaves at the second stage of sampling

Plate II Cashew leaves at the third stage of sampling

Plate III Cashew leaves at the fourth stage of sampling

Plate IV Cashew leaves at the fifth stage of sampling

Plate V Cashew leaves at the sixth stage of sampling

content was determined colorimetrically by the chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958). The available potassium was extracted with 1N neutral ammonium acetate and the potassium content was determined flame photometrically (Jackson, 1958).

3.2. Plant material

The total nitrogen content of the plant sample was determined by using Kjeldahl digestion and distillation method (Jackson, 1958). For the determination of phosphorus and potassium, a known weight of the sample was digested in a mixture of HNO_3, $HClO_4$ and H_2SO_4 (10:4:1). The P content was determined colorimetrically by the vanadomolybdophosphoric yellow colour method in HNO_3 medium and K was determined using a flame photometer (Jackson, 1958).

4. Statistical analysis

The data relating growth and yield characters were analysed by applying the analysis of variance technique (Panse and Sukatme, 1967).

The degree of relationship between yield and N, P and K content of leaf at different leaf positions was estimated by calculating the simple correlation coefficients. The partial correlation coefficients were also calculated in order to find out the degree of association of any two variables, eliminating the effects of other

variables acting in the causal mechanism. The multiple correlation coefficient were also calculated in order to know the joint relationship between the dependent variable and a set of independent variables (Snedecor and Cochran, 1967). The same methods were also used to find the relation between yield and nitrogen, phosphorus and potassium contents of the leaf at different period of sampling.

For predicting the yield corresponding to different levels of nutrients, a simple linear regression equation was fitted by estimating the parameters by the method of least squares (Nigam and Gupta, 1979).

Results and Discussion

RESULTS AND DISCUSSION

One of the prerequisites for the standardisation of foliar diagnosis in crops in relation to yield and nutrient status, is to draw samples from plants maintained at varying fertility gradients especially with respect to the elements in question. This is achieved in the present investigation by drawing samples from the experimental trees of a NPK trial, laid out in 1979 using the cashew seedlings of the variety BLA-39-4 under the erstwhile Kerala Agricultural Development Project (KADP) attached to the College of Horticulture, Vellanikkara, Thrissur. The yield data of this field trial were made use of for establishing precise relationships between the yield and level of nutrients with a view to standardise the tissue and season of sampling and for the prediction of yield based on plant nutrient levels.

Though cashew plants normally commence to bear fruit from the third or fourth year, stabilised yield can be expected only after a period of 10 years. The yield of cashew trees during the initial period of 4 to 10 year may therefore exhibit a high degree of variation synchronising with the early or late bearing nature of the experimental trees, inspite of the uniform cultural and manurial conditions provided under the experiment. Therefore, in this study the mean yields of cashew plants for the last two years namely 1987-88 and 1988-89 as well as the mean yield for

the last four years namely 1985-86, 1986-87, 1987-88 and 1988-89 have been considered separately. In both cases, the values are expressed as mean annual yield instead of cumulative yield.

Influence of NPK treatment on the yield of cashew

The yields of experimental plants as influenced by NPK treatments for the period 1985-89 and 1987-89 are presented in Table 1 and the mean values are given in Table 2. The analysis of variance relating to yield data has been furnished in Appendix II and III.

Nitrogen

Results revealed that the application of increasing levels of N progressively increased the yield of the experimental plants. The yields of nuts at n_0, n_1 and n_2 levels were 4.38, 6.21 and 8.34 kg/plant/year respectively during the period 1987-89. The percentage increases in yield at n_1 and n_2 levels as compared to n_0 level were 41.8 and 90.41 respectively. This shows that the yield of cashew can be almost doubled by increasing the level of N application from n_0 (250 g N/plant/year) to n_2 level (1000 g N/plant/year). The analysis of variance of the yield data furnished in Appendix II and III revealed that the yields at n_0 and n_2 levels differed significantly whereas those between n_0 and n_1 as well as n_1 and n_2 were on par. This is because of the high value of standard error observed, probably due to high genetic

Table 1. Yield of cashew as influenced by NPK treatment

Sl. No.	Treatment NPK	Mean yield kg/plant/year (1985-89)	Mean yield kg/plant/year 1987-89)
1	000	8.260	7.000
2	001	4.940	2.750
3	002	3.940	4.000
4	010	3.290	1.700
5	011	3.310	4.650
6	012	4.300	4.400
7	020	5.200	4.550
8	021	6.650	5.800
9	022	4.780	4.550
10	100	1.850	1.850
11	101	3.860	5.800
12	102	4.210	3.800
13	110	6.270	7.300
14	111	3.480	7.650
15	112	5.180	5.350
16	120	8.290	3.300
17	121	4.790	5.160
18	122	15.390	15.650
19	200	6.060	8.300
20	201	6.450	6.600
21	202	4.530	5.750
22	210	7.540	7.900
23	211	7.020	9.700
24	212	6.400	8.350
25	220	7.950	7.050
26	221	6.450	8.200
27	222	9.660	13.250

Table 2. Effect of NPK treatment on yield of cashew

Summary

Treatment groups	Yield kg/plant/year	
	1985-89	1987-89
n_0	4.96	4.38
n_1	5.92	6.21
n_2	6.89	8.34
F test	NS	S
P_0	4.90	5.09
P_1	5.20	6.38
P_2	7.68	7.50
F test	NS	NS
k_0	6.08	5.44
k_1	5.22	6.26
k_2	6.49	7.23
F test	NS	NS
CD (0.05) for comparing the levels of N, P or K	2.253	2.945

variability and the limited number of experimental trees per plot selected in the study.

An examination of the yield data for the period 1985-89 also revealed that the application of N increased the yield of cashew. The mean values corresponding to n_0, n_1 and n_2 levels were 4.96, 5.92 and 6.89 kg/plant/year respectively. Though the percentage increases in yield at n_1 and n_2 levels were 19.3 and 38.91 over the n_0 level, the differences were not statistically significant.

The yield of cashew trees increases with the increasing age till it reaches the full production potential at about the 10th year of planting. Probably, this may be the reason for the increased response of cashew to higher levels of N application when the yield of 1987-89 was considered. The trend of increasing yield with increasiong levels of N application was also seen in the yield data for the period 1985-89. Nitrogen application results in the increased growth of plant with enhanced production of carbohydrates, proteins, lipids and other metabolites. In two separate studies Rao et al. (1984) and Veeraraghavan et al. (1985) observed that application of N at the rate of 1000 g/tree/year gave the highest yield of nuts compared to the lower levels of application which lends support to the pattern of response to nitrogen observed in this study.

Phosphorus

As in the case of N, increasing levels of P application resulted in progressive increase in yield irrespective of the years of yield considered. For the period 1987-89, the mean annual yields at p_0, p_1 and p_2 levels were 5.27, 6.38 and 7.50 kg/plant/year respectively. The percentage increases in yield at the p_1 and p_2 levels over the p_0 level were 25.34 and 47.34 per cent respectively. However, the differences in yield though conspicuous in terms of percentage increase, were not statistically significant. The same pattern of response was seen when the yield data for 1985-89 were examined. Here, the percentage increases at the p_1 and p_2 levels as compared to p_0 level were 6.12 and 56.73 respectively. The role of phosphorus in the growth and development of plant is well established and the importance of this element becomes more significant in the acid laterite soils of Kerala where the availability of P is usually confronted with heavy rate of phosphate fixation due to the abundance of active Fe and Al in the soil system. In Vengurla in Maharastra, Sawke (1980) also observed good response of cashew plants to phosphatic fertilization.

Potassium

Though cashew plants responded positively to the increasing levels of K application, the increase in yield due to increasing application of K was not as marked as those of N and P. The annual yields of cashew/plant/year at k_0, k_1 and k_2 levels were 5.44,

6.26 and 7.23 kg/plant/year during the period from 1987-89. The percentage increase at k_2 level as compared to k_0 level was 35 per cent. However, the difference in yield due to levels of K applied was not significant. Yield data for the period 1985-89 showed that the differences in yield due to the levels of K application were rather negligible, the mean values corresponding to k_0, k_1 and k_2 being 6.08, 5.22 and 6.49 kg/plant/year respectively. Poor response of cashew to application of K has been observed by several workers (Sawke, 1980; Rao et al., 1984; Veeraraghavan et al., 1985).

NPK interaction

The yield data for the period 1987-89 manifested that the interaction between levels of nutrient applied decisively influenced the yield of plants. While the mean yields at n_2 and p_2 levels were 8.34 and 7.50 kg nuts/tree/year. The highest yield of 9.50 kg was obtained at the treatment combination n_2p_2. Similarly the yield at n_2k_2 was 9.12 kg as compared to the mean yeilds of 8.34 and .7.23 kg at the n_2 and k_2 level. However, the interaction between P and K was not pronounced. When the effect of interaction of the three plant nutrients was considered, the treatment combination $n_1p_2k_2$ recorded the highest yield (15.65 kg nuts/tree/year) closely followed by $n_2p_2k_2$ (13.25 kg nuts/tree/year). However, statistical significance was not observed for the difference in yield probably due to the high heterogeneity of the experimental plants.

Standardisation of season and leaf position for foliar diagnosis in cashew

Under a given set of climatic and cultural conditions the uptake and retention of nutrients in the plant system in relation to the level of nutrient supplied could vary with the season and the type of plant tissue selected for analysis. In cashew, the flushing commences usually with the cessation of the north east monsoon. The process of flushing involves the initiation of new twigs from the existing laterals and the growth of new twigs usually ends in a terminal panicle. These are the flowering shoots. Some of the new shoots continue to grow without the formation of panicle and are referred to as non-fruiting shoots. The whole process of new shoot initiation, tissue development and the emergence of panicle is completed within a period of three weeks. The emergence of leaves of a new flowering shoot is, therefore, at a closer interval of time. The opening of the flowers and setting of the fruits are completed within another period of three weeks whereas the development of nuts to the harvest stage requires a period of two months from the time of fruitset. Normally a flowering twig may have 8-10 leaves. Though the leaf arrangement is said to be alternate, the phyllotaxy is inconsistent with often leaves being clustered around in an irregular manner. However, in the study, the leaves have been numbered taking the last fully matured leaf close to the panicle as leaf No.1. The leaves are categorised into four groups in the order of their decreasing proximity to the panicle.

Thus, leaves of group 4 are those emerged early during the growth of the new bearing shoots. The first stage of sampling was prior to flushing and therefore the leaves sampled at this stage represent previous seasons growth. From the second stage onwards, the leaves are from the new fruiting terminals. While the second stage of sampling corresponds to the formation of new flush, the subsequent stages could be identified only by relating to the development of the panicle and nut development. The sixth stage of sampling was carried out at the time of harvest of nuts whereas the last stage of sampling was at two month after harvest.

Nitrogen

Data on the percentage of N in leaf during the different stages as influenced by the varying levels of nutrients are presented in Tables 3-9 and the mean values in Table 24.

It was revealed that the N content of leaf varied markedly with respect to the position of the leaf and stage of sampling. The extent of the variation was from 1.24 to 2.76 per cent. The minimum value recorded represents the N content of the older leaves collected during the first stage (preflushing) whereas the maximum value corresponds to the N content of the basal leaves (group 4) collected at the time of flower opening.

The distribution of N in the leaves during different stages of sampling manifested a regular pattern. Leaf sample collected during the first period of sampling contained relatively low amount

Table 3. Nitrogen per cent in leaf at the first stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)		
		1	2	3
1	000	1.12	1.26	0.95
2	001	1.34	1.23	1.23
3	002	1.65	1.18	1.06
4	010	1.40	1.26	1.20
5	011	1.26	1.29	1.12
6	012	1.29	1.34	1.40
7	020	1.50	1.23	1.26
8	021	1.23	1.23	1.32
9	022	1.40	1.23	1.34
10	100	1.40	1.32	1.29
11	101	1.57	1.34	1.23
12	102	1.65	1.29	1.43
13	110	1.34	1.12	1.12
14	111	1.51	1.12	1.29
15	112	1.88	1.40	1.57
16	120	1.40	1.06	1.12
17	121	0.98	0.78	0.92
18	122	1.57	1.12	1.12
19	200	1.43	1.23	1.12
20	201	1.57	1.40	1.48
21	202	1.40	1.20	1.26
22	210	1.43	1.32	1.12
23	211	1.40	1.12	1.29
24	212	1.54	1.34	1.28
25	220	2.13	1.23	1.36
26	221	1.82	1.34	1.23
27	222	1.59	1.51	1.40
	n_0	1.35	1.25	1.21
	n_1	1.48	1.17	1.23
	n_2	1.59	1.30	1.28
	CD (0.05)	0.170	0.104	0.113

Table 4. Nitrogen per cent in leaf at the second stage sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	1.99	1.90	1.74	1.69
2	001	2.46	2.18	2.18	1.93
3	002	1.59	1.74	1.74	1.57
4	010	2.24	2.13	2.41	2.41
5	011	1.79	1.93	1.93	2.41
6	012	2.13	1.90	2.04	2.02
7	020	1.99	2.52	2.63	2.62
8	021	1.82	1.99	1.90	1.79
9	022	1.85	1.60	1.79	1.57
10	100	1.88	1.90	1.79	1.46
11	101	2.13	2.07	2.07	2.04
12	102	1.59	1.79	1.79	1.90
13	110	1.85	2.07	1.88	1.90
14	111	2.02	2.24	1.99	1.79
15	112	2.02	1.96	1.96	1.90
16	120	2.07	2.18	1.96	1.96
17	121	1.96	1.90	1.93	1.85
18	122	2.35	2.24	2.18	1.82
19	200	1.85	1.74	1.74	1.46
20	201	2.07	1.93	1.74	1.79
21	202	1.82	1.96	1.96	1.99
22	210	2.41	2.13	2.04	1.85
23	211	1.85	1.96	1.85	1.90
24	212	2.13	2.18	2.35	2.30
25	220	1.74	1.79	1.82	1.77
26	221	1.85	1.85	1.74	1.74
27	222	1.74	1.82	2.25	1.74
	n_0	1.98	1.99	2.04	2.00
	n_1	1.99	2.04	1.95	1.85
	n_2	1.94	1.93	1.94	1.84
	CD (0.05)	0.204	0.199	0.200	0.150

Table 5. Nitrogen per cent in leaf at the third stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.) 1	2	3	4
1	000	1.68	1.79	1.82	2.24
2	001	2.13	2.24	3.08	3.09
3	002	1.73	1.79	1.82	1.74
4	010	2.18	2.12	1.28	2.59
5	011	2.07	1.85	2.07	3.47
6	012	2.07	1.79	1.85	3.64
7	020	2.46	2.35	2.07	3.70
8	021	1.99	1.68	1.46	3.47
9	022	1.68	1.85	2.02	3.19
10	100	1.73	1.60	1.74	1.86
11	101	1.90	1.82	2.04	3.17
12	102	1.90	1.90	1.62	2.88
13	110	1.74	1.79	1.71	1.74
14	111	1.79	1.99	1.90	2.28
15	112	1.76	1.90	1.62	2.91
16	120	2.13	2.41	2.46	2.90
17	121	1.56	1.56	1.65	2.86
18	122	1.90	2.35	2.52	3.64
19	200	1.79	1.90	1.85	2.86
20	201	1.85	1.57	1.90	3.14
21	202	1.68	2.18	1.93	2.43
22	210	2.02	1.68	3.24	3.08
23	211	1.74	1.74	1.96	2.86
24	212	1.90	2.18	2.45	2.52
25	220	1.62	1.85	1.68	2.23
26	221	1.57	1.62	1.71	1.80
27	222	1.62	1.90	2.14	2.24
	n_0	2.00	1.94	2.04	3.01
	n_1	1.82	1.92	1.92	2.69
	n_2	1.75	1.85	2.10	2.57
	CD (0.05)	0.181	0.243	0.388	0.327

Table 6. Nitrogen per cent in leaf at the fourth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	1.90	1.74	1.74	2.13
2	001	2.02	1.79	1.90	2.13
3	002	1.90	1.74	1.74	2.13
4	010	2.69	2.16	1.74	2.13
5	011	2.13	2.07	2.04	2.30
6	012	1.96	1.96	1.96	1.96
7	020	1.96	1.74	2.13	2.18
8	021	1.48	1.60	1.37	1.62
9	022	1.90	1.88	1.99	2.07
10	100	1.79	1.57	2.10	2.07
11	101	2.46	2.13	2.13	2.24
12	102	2.24	2.07	1.74	2.13
13	110	1.85	1.62	1.85	2.18
14	111	1.96	1.96	1.90	2.30
15	112	2.07	2.13	1.90	1.96
16	120	1.99	1.99	2.02	2.41
17	121	1.96	2.02	1.85	1.90
18	122	2.07	1.85	1.85	2.18
19	200	2.04	1.96	2.13	2.04
20	201	1.93	2.12	1.85	2.07
21	202	2.10	2.52	2.13	1.96
22	210	1.96	1.79	2.30	2.24
23	211	2.46	2.32	2.18	1.96
24	212	2.04	2.10	1.96	2.21
25	220	2.16	2.07	1.96	2.02
26	221	2.02	2.02	2.07	2.12
27	222	2.16	2.24	2.16	2.27
	n_0	1.99	1.85	1.85	2.07
	n_1	2.04	1.93	1.93	2.15
	n_2	2.10	2.13	2.08	2.10
	CD (0.05)	0.227	0.189	0.247	0.192

Table 7. Nitrogen per cent in leaf at the fifth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.) 1	2	3	4
1	000	1.54	1.62	1.90	1.90
2	001	1.74	1.74	1.90	1.90
3	002	1.57	1.96	2.10	2.02
4	010	1.79	1.62	1.85	1.85
5	011	2.30	2.41	2.58	2.80
6	012	1.74	1.90	2.04	2.07
7	020	1.90	2.18	2.30	2.18
8	021	1.37	1.40	1.62	1.57
9	022	1.90	1.74	2.13	2.52
10	100	1.85	1.62	1.90	2.02
11	101	2.07	1.96	2.04	2.41
12	102	2.18	1.90	2.04	2.04
13	110	1.85	1.90	2.18	2.02
14	111	1.62	1.79	2.52	1.88
15	112	2.30	2.02	1.93	2.46
16	120	1.56	2.13	2.10	1.96
17	121	1.51	1.62	1.85	2.13
18	122	2.07	1.62	1.90	2.30
19	200	1.51	1.79	1.96	2.07
20	201	1.85	2.07	2.13	2.24
21	202	2.13	1.96	2.52	2.16
22	210	2.07	1.90	1.96	2.30
23	211	1.96	2.07	1.90	2.24
24	212	1.96	2.07	1.90	2.24
25	220	1.85	1.51	1.90	1.93
26	221	2.02	2.02	2.16	1.62
27	222	1.90	1.84	2.07	1.93
	n_0	1.76	1.84	2.05	2.09
	n_1	1.89	1.84	2.05	2.14
	n_2	1.92	1.87	2.10	2.09
	CD (0.05)	0.270	0.348	0.198	0.347

Table 8. Nitrogen per cent in leaf at the sixth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.) 1	2	3	4
1	000	1.79	1.68	1.43	1.40
2	001	1.37	1.17	1.23	1.17
3	002	1.43	1.68	1.40	1.57
4	010	2.02	1.93	1.68	1.70
5	011	1.90	1.79	1.85	1.68
6	012	1.74	1.43	1.43	1.60
7	020	1.93	1.65	1.79	1.54
8	021	1.37	1.40	1.62	1.57
9	022	1.68	1.34	1.48	1.46
10	100	1.68	1.57	1.68	1.40
11	101	1.96	1.62	1.65	1.74
12	102	1.71	1.32	1.57	1.26
13	110	1.62	1.74	1.79	1.60
14	111	1.57	1.62	1.76	1.46
15	112	1.82	1.85	1.40	1.70
16	120	2.16	1.85	1.48	1.68
17	121	1.79	1.79	1.74	1.71
18	122	1.57	1.26	1.18	1.40
19	200	1.74	1.51	1.57	1.29
20	201	1.68	1.43	1.65	1.65
21	202	1.79	1.82	1.68	1.34
22	210	1.57	1.15	1.51	1.18
23	211	1.79	1.68	1.43	1.57
24	212	1.74	1.65	1.68	1.57
25	220	1.51	1.68	1.57	1.51
26	221	1.93	1.82	2.13	1.74
27	222	1.74	1.65	1.51	1.68
	n_0	1.69	1.56	1.55	1.52
	n_1	1.76	1.62	1.58	1.55
	n_2	1.72	1.60	1.64	1.50
	CD (0.05)	0.219	0.223	0.178	0.186

Table 9. Nitrogen per cent in leaf at the seventh stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	1.62	1.74	1.90	1.96
2	001	1.40	1.54	1.29	1.23
3	002	1.20	1.23	1.29	1.34
4	010	1.62	1.34	1.51	1.56
5	011	1.23	1.46	1.51	1.34
6	012	1.57	1.96	1.40	1.40
7	020	1.68	1.79	1.85	1.74
8	021	1.12	1.12	0.98	1.06
9	022	1.40	1.46	1.57	1.51
10	100	1.57	1.68	1.48	1.51
11	101	1.85	1.96	1.65	1.68
12	102	1.57	1.57	1.85	1.54
13	110	1.24	1.37	1.29	1.15
14	111	1.90	1.85	1.68	1.68
15	112	1.48	1.57	1.48	1.40
16	120	1.51	1.57	1.57	1.65
17	121	1.74	1.51	1.43	1.34
18	122	1.46	1.40	1.29	1.23
19	200	1.46	1.60	1.59	1.74
20	201	1.62	1.57	1.48	1.74
21	202	1.85	1.85	1.79	1.85
22	210	1.60	1.74	1.90	1.79
23	211	1.79	1.62	1.60	1.59
24	212	1.57	1.79	1.54	1.57
25	220	1.51	1.62	1.74	1.57
26	221	1.06	1.29	1.34	1.18
27	222	1.90	2.13	1.96	2.07
	n_0	1.43	1.52	1.48	1.46
	n_1	1.59	1.61	1.52	1.46
	n_2	1.60	1.69	1.66	1.68
	CD (0.05)	0.204	0.226	0.224	0.222

of N which increased during the second period and reached a peak during the third stage of sampling. As the stage further advanced, the N content in the leaf decreased. The mean values of N in the first, second, third, fourth, fifth, sixth and seventh stages of sampling were 1.35, 1.96, 2.14, 2.02, 1.97, 1.61 and 1.56 per cent respectively. The increase in N content in the leaves after the first season is quite understandable since the experimental plants received the N fertilizer application in between the first and second stages of sampling. This increase continued upto the third stage of sampling and thereafter decreased. This may be due to the mobilisation of this nutrient from the leaves to the developing inflorescence at a rate exceeding the rate of uptake from the soil. Consequently, the nitrogen percentage gradually declined from fourth to last stage of sampling.

The pattern of variation on the content of N with the varying leaf position was different during different periods of sampling. During the first stage of sampling, maximum content of this element was observed in the first group of leaves which then decreased to a constant level in the second and third groups. Nitrogen being a mobile element, higher content of N in the first group may be due to the translocation of this element from the older leaves. Also, during the second stage of sampling, the N content of the lower leaves (group 4) was comparatively lower as compared to the other groups. But during the third, fourth

and fifth period of sampling the pattern of distribution of N in leaves with respect to leaf position was rather inconsistent. However, it was noticed that during these periods the leaves of the last group invariably retained larger amount of N in them. The relatively low amount of N in leaves of group 1, 2 and 3 may be due to the accelerated removal of this element to the panicles in order to meet the N requirement of the developing fruits. In the sixth and seventh stages, in general, the content of N in leaves decreased with increasing age of the leaves. Perhaps when the demand of N for the developing fruits has been slowed down, the content of this element would have been improved in the younger leaves at the expense of withdrawal of N from the older leaves.

In most of the plants distribution of N in leaves in relation to the age of the leaf shows that the content of N increases with the increasing maturity of the leaf till the leaves become physiologically active and thereafter the N content decreases with the increasing age of the leaf and the minimum amount of this element is reported in leaves approaching senescence. But such a definite pattern of N distribution with respect to the position of the leaf is not observsed in the study. The probable reasosn for this phenomenon may be (1) the whole process of leaf development on the new fruit bearing terminals is completed within a period of three weeks and therefore the age difference between the leaves of different groups is not very much pronounced (2) Most of the stages of sampling synchronsize with the stages of active development

of fruits and the continuous removal of N from the leaves to the developing nuts so that the N level in the leaves could not get stabilized in relation to the age of the leaf.

When the trend of variation in the amount of N retained in leaves of different groups at different stages was examined, it was seen that differences in the levels of N applied do reflect in the level of this element retained in leaves. However, the sensitivity of leaves to respond to increasing levels of N application differed significantly. The maximum differences in the content of N with respect to the levels of N applied was observed in the first, second and third group of leaves collected during the fourth stage in which increasing content of N was observed with progressive increase in the levels of N supplied. An increase in foliar N with increased dose of applied N upto 1000 g per tree has also been reported by Reddy et al. (1982). Similar observations have also been made by Kumar and Nagabhushanam (1981) and Ghosh and Bose (1986).

Phosphorus

Data on the percentage of P in the leaf during different stages as influenced by varying levels of nutrients applied are presented in Tables 10-16 and the mean values in Table 24.

The content of P in leaves at different leaf positions collected during different seasons varied significantly, the range

of variation being 0.063 to 0.316 per cent. The maximum P was observed in the fourth group of leaves at the third stage of sampling, i.e., at the time of beginning of flower opening. In general, the mean content of P in cashew leaves was only 1/20th of that of N and the variation in the content of P showed a regular pattern with the advancing period of sampling. Initially, during the first season, the content of P was relatively low. During the next two stages the P content increased conspicuously and then showed a decline with the increasing period of sampling. The mean values of P in leaf during the second, third, fourth, fifth, sixth and seventh stages of sampling were 0.163, 0.166, 0.103, 0.069, 0.039 and 0.048 per cent respectively. The steep increase in the content of P in the second stage is due to the uptake of P initiated due to P fertilization effected after the first stage of sampling. This increase continued upto the third stage and thereafter P content declined probably due to the withdrawal of this element to meet its demand for the developing nuts. The content of P in leaf during the harvest stage was as low as 0.039 per cent which was only one-fourth of the P retained at the third stage. After the harvest, there was a slight improvement in the build up of P in leaves probably due to gradual and continued uptake of this element. The range of P in the leaves of cashew observed in this study corroborates the reported range of P in cashew leaves observed by Haag et al. (1975) and Reddy et al. (1982).

Table 10. Phosphorus per cent in leaf at the first stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.) 1	2	3
1	000	0.060	0.069	0.052
2	001	0.074	0.072	0.108
3	002	0.076	0.079	0.059
4	010	0.060	0.072	0.072
5	011	0.076	0.048	0.069
6	012	0.079	0.045	0.069
7	020	0.069	0.076	0.043
8	021	0.057	0.067	0.069
9	022	0.069	0.057	0.050
10	100	0.086	0.074	0.084
11	101	0.077	0.084	0.086
12	102	0.062	0.067	0.072
13	110	0.055	0.065	0.060
14	111	0.072	0.079	0.055
15	112	0.081	0.074	0.040
16	120	0.067	0.062	0.076
17	121	0.058	0.050	0.024
18	122	0.053	0.077	0.048
19	200	0.067	0.060	0.043
20	201	0.060	0.065	0.084
21	202	0.074	0.033	0.074
22	210	0.067	0.081	0.024
23	211	0.055	0.062	0.038
24	212	0.074	0.072	0.091
25	220	0.072	0.069	0.086
26	221	0.062	0.072	0.065
27	222	0.067	0.067	0.069
	P_0	0.070	0.070	0.070
	P_1	0.070	0.070	0.060
	P_2	0.060	0.070	0.060
	CD (0.05)	0.0090	0.0130	0.0180

Table 11. Phosphorus per cent in leaf at the second stage of sampling as influenced by the NPK treatment

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	0.165	0.175	0.175	0.160
2	001	0.205	0.210	0.180	0.150
3	002	0.160	0.140	0.135	0.115
4	010	0.210	0.195	0.205	0.185
5	011	0.130	0.170	0.150	0.105
6	012	0.160	0.195	0.185	0.175
7	020	0.195	0.230	0.250	0.220
8	021	0.185	0.205	0.195	0.145
9	022	0.165	0.180	0.205	0.170
10	100	0.175	0.140	0.165	0.120
11	101	0.175	0.180	0.170	0.160
12	102	0.130	0.150	0.075	0.145
13	110	0.180	0.215	0.185	0.085
14	111	0.140	0.180	0.185	0.130
15	112	0.185	0.185	0.160	0.170
16	120	0.185	0.150	0.175	0.160
17	121	0.130	0.150	0.170	0.125
18	122	0.170	0.210	0.170	0.160
19	200	0.160	0.165	0.150	0.135
20	201	0.210	0.165	0.150	0.105
21	202	0.125	0.160	0.170	0.110
22	210	0.170	0.165	0.175	0.145
23	211	0.115	0.165	0.145	0.125
24	212	0.185	0.185	0.200	0.145
25	220	0.135	0.150	0.145	0.145
26	221	0.155	0.165	0.165	0.145
27	222	0.115	0.135	0.125	0.120
	P_0	0.170	0.170	0.150	0.140
	P_1	0.160	0.180	0.180	0.130
	P_2	0.160	0.180	0.180	0.160
	CD (0.05)	0.0220	0.0260	0.0260	0.0270

Table 12. Phosphorus per cent in leaf at the third stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	0.090	0.090	0.125	0.370
2	001	0.105	0.135	0.075	0.365
3	002	0.090	0.085	0.330	0.325
4	010	0.120	0.120	0.130	0.365
5	011	0.135	0.110	0.160	0.155
6	012	0.120	0.110	0.120	0.250
7	020	0.145	0.385	0.145	0.360
8	021	0.140	0.080	0.095	0.265
9	022	0.090	0.095	0.075	0.350
10	100	0.085	0.105	0.100	0.250
11	101	0.090	0.100	0.015	0.325
12	102	0.075	0.075	0.245	0.380
13	110	0.015	0.120	0.375	0.365
14	111	0.110	0.100	0.125	0.280
15	112	0.085	0.070	0.090	0.360
16	120	0.095	0.115	0.090	0.265
17	121	0.075	0.075	0.075	0.350
18	122	0.120	0.150	0.280	0.380
19	200	0.065	0.065	0.075	0.350
20	201	0.080	0.110	0.090	0.330
21	202	0.070	0.095	0.110	0.260
22	210	0.085	0.085	0.250	0.355
23	211	0.085	0.095	0.095	0.275
24	212	0.100	0.110	0.120	0.270
25	220	0.100	0.060	0.065	0.340
26	221	0.125	0.100	0.265	0.320
27	222	0.085	0.090	0.125	0.265
	P_0	0.080	0.100	0.130	0.330
	P_1	0.100	0.100	0.160	0.300
	P_2	0.110	0.130	0.130	0.320
	CD (0.05)	0.0260	0.0690	0.0970	0.0320

Table 13. Phosphorus per cent in leaf at the fourth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	0.075	0.100	0.105	0.090
2	001	0.100	0.065	0.160	0.085
3	002	0.045	0.100	0.105	0.090
4	010	0.070	0.095	0.090	0.090
5	011	0.080	0.095	0.190	0.115
6	012	0.080	0.125	0.150	0.095
7	020	0.070	0.100	0.185	0.110
8	021	0.055	0.085	0.085	0.090
9	022	0.075	0.100	0.140	0.100
10	100	0.065	0.085	0.175	0.085
11	101	0.105	0.120	0.105	0.110
12	102	0.095	0.070	0.145	0.085
13	110	0.070	0.105	0.085	0.175
14	111	0.090	0.110	0.175	0.100
15	112	0.070	0.120	0.110	0.090
16	120	0.100	0.090	0.160	0.090
17	121	0.080	0.115	0.100	0.110
18	122	0.125	0.090	0.190	0.100
19	200	0.070	0.090	0.150	0.075
20	201	0.080	0.065	0.100	0.075
21	202	0.075	0.100	0.170	0.075
22	210	0.120	0.105	0.155	0.090
23	211	0.140	0.090	0.145	0.085
24	212	0.075	0.100	0.085	0.095
25	220	0.050	0.100	0.160	0.080
26	221	0.060	0.085	0.150	0.105
27	222	0.075	0.100	0.210	0.095
	P_0	0.080	0.088	0.136	0.090
	P_1	0.090	0.110	0.132	0.084
	P_2	0.080	0.100	0.153	0.098
	CD (0.05)	0.0190	0.0140	0.0440	0.0250

Table 14. Phosphorus per cent in leaf at the fifth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	0.060	0.080	0.080	0.075
2	001	0.050	0.045	0.065	0.080
3	002	0.075	0.080	0.090	0.050
4	010	0.055	0.060	0.065	0.085
5	011	0.070	0.095	0.095	0.105
6	012	0.070	0.060	0.090	0.110
7	020	0.065	0.070	0.070	0.105
8	021	0.040	0.030	0.065	0.060
9	022	0.050	0.070	0.070	0.080
10	100	0.045	0.060	0.075	0.070
11	101	0.080	0.075	0.100	0.095
12	102	0.060	0.050	0.070	0.070
13	110	0.055	0.045	0.060	0.070
14	111	0.075	0.040	0.085	0.090
15	112	0.080	0.080	0.075	0.095
16	120	0.050	0.070	0.090	0.065
17	121	0.055	0.060	0.090	0.075
18	122	0.075	0.070	0.080	0.100
19	200	0.045	0.045	0.055	0.075
20	201	0.055	0.040	0.080	0.090
21	202	0.075	0.070	0.080	0.090
22	210	0.075	0.060	0.085	0.065
23	211	0.035	0.050	0.075	0.080
24	212	0.065	0.065	0.055	0.085
25	220	0.045	0.035	0.065	0.060
26	221	0.075	0.075	0.080	0.055
27	222	0.065	0.060	0.065	0.050
	P_0	0.061	0.061	0.077	0.075
	P_1	0.058	0.062	0.076	0.087
	P_2	0.058	0.060	0.075	0.072
	CD (0.05)	0.0180	0.0250	0.0150	0.0120

Table 15. Phosphorus per cent in leaf at the sixth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	0.040	0.030	0.025	0.045
2	001	0.025	0.025	0.025	0.020
3	002	0.035	0.040	0.030	0.040
4	010	0.065	0.065	0.045	0.040
5	011	0.055	0.040	0.045	0.060
6	012	0.035	0.055	0.030	0.045
7	020	0.050	0.025	0.040	0.050
8	021	0.025	0.020	0.030	0.035
9	022	0.025	0.045	0.030	0.035
10	100	0.040	0.045	0.035	0.035
11	101	0.050	0.055	0.050	0.045
12	102	0.040	0.060	0.040	0.040
13	110	0.035	0.035	0.025	0.025
14	111	0.030	0.030	0.035	0.030
15	112	0.040	0.050	0.040	0.040
16	120	0.050	0.050	0.040	0.035
17	121	0.070	0.075	0.070	0.095
18	122	0.030	0.045	0.045	0.035
19	200	0.025	0.050	0.025	0.035
20	201	0.025	0.050	0.040	0.035
21	202	0.045	0.040	0.030	0.045
22	210	0.030	0.030	0.025	0.015
23	211	0.030	0.030	0.040	0.040
24	212	0.025	0.040	0.030	0.040
25	220	0.050	0.030	0.025	0.015
26	221	0.030	0.035	0.045	0.065
27	222	0.035	0.040	0.040	0.045
	P_0	0.036	0.043	0.033	0.038
	P_1	0.038	0.042	0.035	0.037
	P_2	0.041	0.041	0.040	0.045
	CD (0.05)	0.0110	0.0110	0.0080	0.1050

Table 16. Phosphorus per cent in leaf at the seventh stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	0.045	0.055	0.050	0.060
2	001	0.035	0.045	0.020	0.075
3	002	0.050	0.030	0.030	0.050
4	010	0.050	0.030	0.025	0.070
5	011	0.050	0.035	0.030	0.050
6	012	0.045	0.060	0.045	0.070
7	020	0.055	0.055	0.055	0.060
8	021	0.040	0.040	0.080	0.060
9	022	0.030	0.050	0.045	0.045
10	100	0.060	0.045	0.050	0.045
11	101	0.045	0.050	0.060	0.050
12	102	0.010	0.045	0.035	0.035
13	110	0.055	0.045	0.045	0.055
14	111	0.045	0.055	0.055	0.050
15	112	0.025	0.055	0.045	0.020
16	120	0.035	0.055	0.045	0.045
17	121	0.070	0.060	0.045	0.050
18	122	0.055	0.050	0.030	0.055
19	122	0.030	0.045	0.035	0.025
20	201	0.045	0.040	0.045	0.050
21	202	0.035	0.040	0.050	0.105
22	210	0.030	0.035	0.045	0.035
23	211	0.035	0.040	0.055	0.040
24	212	0.040	0.045	0.050	0.060
25	220	0.040	0.060	0.050	0.055
26	221	0.060	0.060	0.080	0.070
27	222	0.040	0.040	0.050	0.060
	P_0	0.040	0.043	0.041	0.055
	P_1	0.042	0.044	0.043	0.050
	P_2	0.047	0.051	0.053	0.055
	CD (0.05)	0.0160	0.0080	0.0120	0.0190

The pattern of variation in the content of P in relation to leaf positions showed that the P content decreased with increasing positional groups during the first period of sampling. During the second to fifth stage of sampling variation in the content of P with leaf position was rather inconsistent. However, the mean values showed a tendency to accumulate P in older leaves as comparable to the younger leaves during these periods. This could be, probably, due to the removal of P from the leaves of group 1 and 2 for the development of nuts.

In general, increasing application of P was not resulted in a marked increase in the content of P in leaves, though leaves at p_0 level invariably registered relatively low amount of P. The application of increased levels of P had significantly increased the yield and therefore additional amount of P received by the plant by the enhanced rate of application would have been utilised for the production and development of nuts, without causing its accumulation in the leaves. It is also possible that since the level of P retained in leaf is always low, the expected increase in the content of P in leaf due to higher rate of application will also be negligible.

Potassium

Data on the percentage of K in leaf during different stages as influenced by NPK treatments are presented in Tables 17-23 and the mean values in Table 24.

Table 17. Potassium per cent in leaf at the first stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.) 1	2	3
1	000	0.55	0.58	0.64
2	001	0.50	0.49	0.52
3	002	0.54	0.49	0.54
4	010	0.54	0.56	0.64
5	011	0.42	0.55	0.58
6	012	0.50	0.54	0.59
7	020	0.50	0.56	0.53
8	021	0.72	0.67	0.68
9	022	0.50	0.62	0.68
10	100	0.45	0.46	0.50
11	101	0.52	0.54	0.59
12	102	0.45	0.50	0.53
13	110	0.54	0.62	0.59
14	111	0.70	0.63	0.58
15	112	0.49	0.52	0.59
16	120	0.62	0.76	0.72
17	121	0.64	0.53	0.67
18	122	0.62	0.52	0.52
19	200	0.52	0.50	0.55
20	201	0.46	0.44	0.49
21	202	0.56	0.59	0.61
22	210	0.59	0.50	0.54
23	211	0.48	0.50	0.57
24	212	0.56	0.52	0.63
25	220	0.48	0.49	0.59
26	221	0.50	0.54	0.43
27	222	0.56	0.55	0.47
	k_0	0.53	0.56	0.59
	k_1	0.55	0.54	0.57
	k_2	0.53	0.54	0.57
	CD (0.05)	0.079	0.082	0.090

Table 18. Potassium per cent in leaf at the second stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	2.75	3.00	2.90	2.30
2	001	3.35	3.05	3.00	2.55
3	002	2.35	2.10	2.20	2.20
4	010	2.50	2.65	2.70	2.70
5	011	2.25	2.30	2.25	2.10
6	012	2.30	2.60	2.60	2.70
7	020	2.80	3.10	3.15	2.90
8	021	2.90	3.15	3.20	3.10
9	022	2.70	3.05	2.90	2.70
10	100	3.20	2.85	3.00	2.80
11	101	2.40	3.00	3.00	2.70
12	102	2.20	2.05	2.05	2.10
13	110	2.50	2.60	2.80	1.65
14	111	2.40	2.80	2.65	2.35
15	112	2.60	2.50	1.70	2.70
16	120	3.60	3.20	3.30	3.20
17	121	3.65	3.50	3.70	3.10
18	122	2.65	3.20	3.35	3.30
19	200	2.45	2.20	2.40	2.25
20	201	3.60	2.40	2.35	2.15
21	202	2.95	3.00	3.00	2.85
22	210	2.95	2.70	2.90	2.30
23	211	2.45	2.30	2.05	2.10
24	212	3.40	3.50	3.05	2.80
25	220	1.95	2.00	2.15	2.10
26	221	2.30	2.40	2.50	2.30
27	222	2.75	2.75	2.65	2.50
	k_0	2.74	2.70	2.74	2.47
	k_1	2.81	2.77	2.77	2.49
	k_2	2.66	2.75	2.69	2.65
	CD (0.05)	0.402	0.212	0.392	0.357

Table 19. Potassium per cent in leaf at the third stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	2.25	2.20	2.10	2.40
2	001	2.30	2.30	2.10	2.30
3	002	1.20	1.70	1.40	1.70
4	010	1.90	1.85	2.10	2.15
5	011	2.25	1.95	2.35	2.15
6	012	1.20	1.20	1.90	2.15
7	020	2.45	2.55	2.30	2.55
8	021	2.80	2.60	2.65	2.70
9	022	2.05	2.30	1.50	1.80
10	100	2.10	1.90	1.85	1.95
11	101	2.45	1.50	2.00	2.00
12	102	1.65	1.65	1.70	2.00
13	110	2.10	1.90	1.90	2.00
14	111	2.50	2.30	2.20	2.30
15	112	2.00	2.00	1.90	2.00
16	120	2.50	2.10	2.20	2.30
17	121	2.55	2.10	2.20	2.25
18	122	3.05	2.95	2.80	3.10
19	200	2.10	1.90	1.80	1.85
20	201	2.10	1.95	1.90	2.05
21	202	1.90	1.25	2.20	2.25
22	210	1.80	1.75	1.85	2.05
23	211	1.90	1.90	2.05	1.90
24	212	2.05	2.60	2.40	2.40
25	220	1.65	1.60	1.65	1.90
26	221	2.05	1.75	2.00	1.80
27	222	2.40	1.50	2.40	2.20
	k_0	2.09	1.97	1.97	2.13
	k_1	2.32	2.04	2.23	2.16
	k_2	1.94	1.91	1.96	2.18
	CD (0.05)	0.162	0.370	0.132	0.307

Table 20. Potassium per cent in leaf at the fourth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	1.40	1.60	1.40	1.60
2	001	1.70	1.70	1.80	1.70
3	002	1.40	1.60	1.40	1.50
4	010	1.30	1.50	1.60	1.70
5	011	1.30	1.70	1.90	1.85
6	012	1.65	2.05	1.70	2.00
7	020	1.45	1.60	1.75	1.65
8	021	1.70	1.50	1.60	1.70
9	022	1.40	1.80	1.60	2.05
10	100	1.60	1.35	1.95	1.70
11	101	1.90	1.90	2.00	2.05
12	102	1.70	1.70	1.60	1.80
13	110	1.60	1.80	1.70	2.50
14	111	1.70	1.90	1.70	1.90
15	112	1.60	1.65	1.80	1.80
16	120	1.95	2.30	2.30	2.15
17	121	2.10	1.85	2.05	2.45
18	122	2.50	2.90	2.35	2.40
19	200	1.65	1.70	1.90	1.85
20	201	2.10	1.85	2.05	2.45
21	202	1.60	1.85	1.95	2.00
22	210	1.70	1.40	1.25	1.60
23	211	2.40	1.60	1.40	1.60
24	212	2.00	2.10	2.20	2.30
25	220	1.25	1.70	1.55	1.60
26	221	2.70	1.40	1.40	1.45
27	222	2.30	2.50	2.30	2.20
	k_0	1.54	1.66	1.71	1.82
	k_1	1.96	1.73	1.78	1.85
	k_2	1.79	2.02	1.88	2.01
	CD (0.05)	0.252	0.222	0.147	0.245

Table 21. Potassium per cent in leaf at the fifth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	2.90	2.05	2.25	2.50
2	001	1.60	1.45	1.35	1.30
3	002	1.80	1.80	1.90	1.35
4	010	1.65	1.70	1.95	1.70
5	011	1.50	1.65	1.60	1.90
6	012	1.85	2.00	2.20	2.30
7	020	1.70	1.55	1.90	1.70
8	021	1.75	1.70	1.60	1.80
9	022	2.05	2.05	1.80	2.10
10	100	1.90	1.65	1.75	1.75
11	101	2.00	1.85	1.95	1.85
12	102	2.00	1.70	1.65	1.75
13	110	1.40	1.40	1.35	2.20
14	111	1.90	1.70	1.90	1.90
15	112	1.60	1.30	1.40	1.65
16	120	2.25	1.90	2.20	2.10
17	121	2.20	2.10	2.15	2.70
18	122	2.25	2.05	2.25	2.30
19	200	2.10	2.00	2.05	2.40
20	201	1.90	1.90	1.90	2.10
21	202	1.70	1.90	1.70	1.90
22	210	1.60	1.55	1.60	1.70
23	211	1.85	1.75	1.90	1.70
24	212	2.25	2.00	2.30	2.20
25	220	1.70	1.70	1.70	1.45
26	221	1.45	1.40	1.45	1.70
27	222	2.30	2.10	2.60	2.10
	k_0	1.91	1.72	1.86	1.94
	k_1	1.78	1.73	1.76	1.88
	k_2	1.98	1.88	1.98	1.96
	CD (0.05)	0.300	0.183	0.274	0.351

Table 22. Potassium per cent in leaf at the sixth stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	2.15	2.00	1.95	2.05
2	001	1.30	1.20	1.20	1.30
3	002	1.60	1.80	1.55	1.30
4	010	2.00	1.80	1.80	1.90
5	011	1.35	1.45	1.50	1.45
6	012	1.80	1.80	1.80	1.65
7	020	1.45	1.70	1.55	1.90
8	021	1.40	1.45	1.30	1.35
9	022	2.15	2.05	2.30	2.40
10	100	2.05	1.80	1.70	1.75
11	101	1.85	1.80	1.25	1.65
12	102	1.75	1.55	1.20	1.65
13	110	1.90	1.50	1.60	1.70
14	111	1.90	1.90	1.85	1.70
15	112	1.50	1.60	1.00	2.00
16	120	3.15	2.70	2.30	1.95
17	121	1.10	1.10	1.30	1.40
18	122	2.20	1.90	1.60	1.95
19	200	2.00	1.85	2.00	2.05
20	201	1.90	1.85	1.00	1.95
21	202	1.80	2.00	1.65	2.20
22	210	1.60	1.30	1.40	1.25
23	211	1.80	1.85	1.80	1.50
24	212	1.80	2.40	2.30	2.25
25	220	1.75	1.90	1.70	1.70
26	221	1.45	1.45	1.35	1.40
27	222	2.25	2.20	1.80	1.70
	k_0	2.01	1.84	1.78	1.81
	k_1	1.56	1.56	1.39	1.52
	k_2	1.98	1.92	1.69	1.90
	CD (0.05)	0.490	0.356	0.331	0.273

Table 23. Potassium per cent in leaf at the seventh stage of sampling as influenced by the NPK treatments

Sl. No.	Treatment NPK	Leaf positions (group no.)			
		1	2	3	4
1	000	1.80	1.60	1.70	2.00
2	001	1.60	1.50	1.25	1.40
3	002	1.00	1.10	1.20	1.25
4	010	1.35	1.40	1.35	1.40
5	011	0.95	1.00	1.20	1.20
6	012	1.75	1.75	1.60	1.50
7	020	1.70	1.60	1.70	1.70
8	021	2.30	1.90	2.00	1.90
9	022	1.95	1.85	2.25	1.95
10	100	1.40	1.15	1.25	1.20
11	101	1.85	1.85	1.90	1.75
12	102	1.35	1.35	1.40	1.30
13	110	1.50	1.25	1.35	1.25
14	111	1.45	1.70	1.75	1.70
15	112	1.15	1.15	1.15	1.15
16	120	1.95	2.00	1.65	1.90
17	121	1.70	1.70	1.75	1.85
18	122	2.00	1.95	2.05	2.05
19	200	1.50	1.85	2.70	1.60
20	201	1.60	1.55	1.55	1.45
21	202	1.70	1.45	1.50	1.55
22	210	1.60	1.50	1.50	3.00
23	211	1.45	1.40	1.30	1.25
24	212	1.60	1.50	1.30	1.45
25	220	1.25	1.30	1.30	1.15
26	221	0.75	0.75	0.70	0.65
27	222	2.35	2.40	2.50	1.20
	k_0	1.56	1.52	1.61	1.69
	k_1	1.52	1.48	1.49	1.46
	k_2	1.65	1.61	1.66	1.49
	CD (0.05)	0.418	0.407	0.395	0.410

Table 24. Mean values of N, P and K in cashew leaf at different leaf positions and stages of sampling

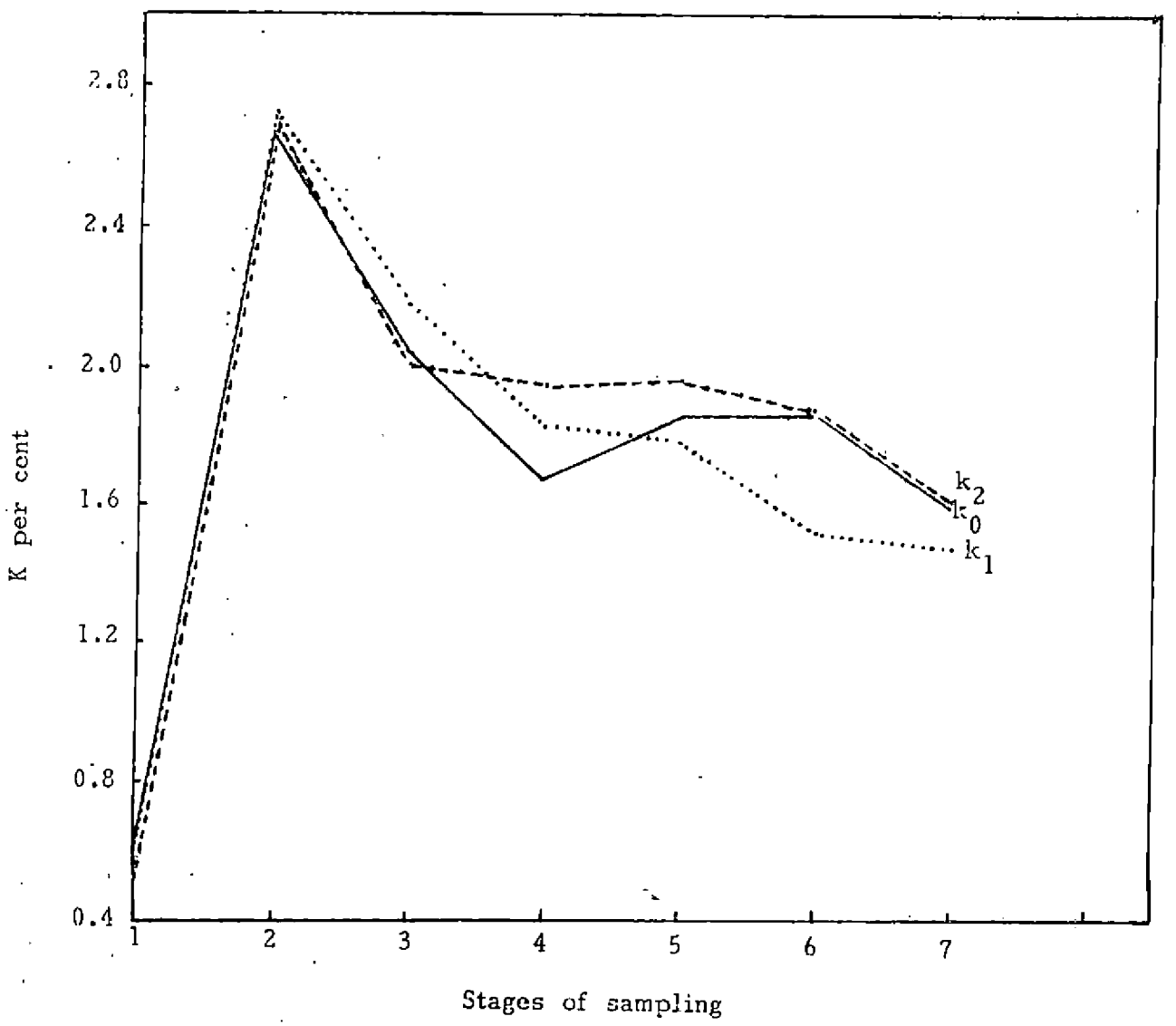
Stages of sampling	Leaf position (group no.)				
	1	2	3	4	Mean
			Nitrogen		
1	1.47	1.24	1.24	x	1.35
2	1.97	1.99	1.98	1.90	1.96
3	1.86	1.90	2.02	2.76	2.14
4	2.04	1.96	1.95	2.11	2.02
5	1.85	1.85	2.07	2.10	1.97
6	1.73	1.60	1.59	1.53	1.61
7	1.54	1.61	1.55	1.53	1.56
			Phosphorus		
1	0.068	0.067	0.063	x	0.067
2	0.164	0.175	0.169	0.140	0.163
3	0.096	0.109	0.142	0.316	0.166
4	0.081	0.096	0.140	0.096	0.103
5	0.061	0.061	0.076	0.079	0.069
6	0.038	0.042	0.036	0.040	0.039
7	0.043	0.047	0.046	0.054	0.048
			Potassium		
1	0.54	0.55	0.58	x	0.55
2	2.74	2.74	2.74	2.54	2.64
3	2.12	1.97	2.05	2.16	2.07
4	1.77	1.80	1.79	1.89	1.81
5	1.89	1.78	1.87	1.93	1.87
6	1.85	1.77	1.62	1.74	1.74
7	1.57	1.54	1.59	1.55	1.56

x During the first stage only three groups of samples were collected.

The content of K in leaf from different positions sampled during different periods exhibited significant variation. The maximum content of K (2.74 per cent) was observed in the younger leaves of the second season whereas the minimum value (0.54 per cent) was noticed in the leaves of the first stage of sampling which represent the leaves of old growth collected prior to flushing. In general, the magnitude of K retained in cashew leaf sampled was similar to that of N, the mean values for N and K in fruit bearing shoots being 1.87 and 1.96 per cent when the seasons and positions were pooled.

The distribution of K in leaves during various stages of plant growth observed a regular pattern of variation. The lowest level of K was seen prior to flushing. With flushing, K content shot upto 2.67 per cent (stage 2) and afterwards gradually declined with advancing stages of growth. The K content in the last stage of sampling (two months after harvest) was 1.56 per cent. The sharp increase in the content of K in newly formed leaves during the second stage of sampling may be the combined effect of K fertilization effected prior to sampling, as well as mobilization of K within the plant to the newly formed leaves during flushing. The subsequent decline during the advancing stages of sampling could be attributed to the withdrawal of the element for the formation and development of nuts. The results are in conformity with findings of Sushama et al. (1984) in pepper.

Fig.2 Relationship between stages of sampling and potassium per cent in leaves



The trend of variation in the content of K with respect to leaf position did not show significant variation eventhough, in general, more K was found in the first group of leaves. Since K is more associated with meristematic and newly formed tissues, the relatively higher content of K in the first group of leaves could be attributed to the active growing nature of this group of leaves when compared to the other groups.

Variation in the levels of K applied resulted in changes in the level of this element retained in leaves. However, the increasing content of leaf K in accordance with increasing level of application was clearly reflected during the fourth stage of sampling (Fig.2). During this stage of sampling, K per cent in leaves at k_0, k_1 and k_2 levels were 1.68, 1.83 and 1.93 respectively. Among the different leaf positions, the increasing level of application was well reflected with an increasing content of K in leaf at the second, third and fourth stages of sampling.

Relationship between leaf nutrient levels and yield

In foliar diagnosis, the optimum content of nutrient for obtaining the maximum yield and the prediction of yield based on the nutrient level retained in the leaf are worked out by establishing precise relationships between yield and the nutrient content of the leaf. With this objective in view, coefficient of simple and partial correlations were estimated between yield and nutrient

status of the selected leaves. Yield prediction is possible with the help of regression equation wherever the correlation coefficients are significant.

Nitrogen

The coefficients of simple and partial correlation between leaf N and yield for both the period from 1985-89 and 1987-89 are given in Tables 25-28.

The coefficients of simple correlation between yield and N content of leaf in relation to different leaf positions and stages of sampling showed that the N content in the leaf failed to give a significant positive correlation with yield, irrespective of leaf position and stages of sampling for both the periods 1985-89 and 1987-89. In fact, a negative correlation between the nitrogen level of the third group of leaves at sixth stage of sampling (at the time of harvest) and yield for the period 1985-89 was observed.

The application of increasing levels of N, as already stated, had increased the yield significantly upto the n_2 level and also that higher leaf N was observed in plants receiving higher levels of this nutrient. Therefore, lack of correlation between yield and leaf N could not be attributed to the lack of response of cashew plants to the application of N. Nitrogen being the most important element for the synthesis of protoplasm, the active growth of plant

Table 25. Coefficients of simple correlation between yield of cashew (1985-89) and nutrient content of leaves at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		Nitrogen		
1	0.1585	-0.0490	-0.1342	x
2	0.2395	0.1585	0.1039	-0.1482
3	-0.1019	0.2788	0.2896	0.1593
4	-0.0629	-0.0114	-0.0060	0.1073
5	0.0057	-0.2121	-0.2535	-0.0675
6	-0.1220	-0.2397	-0.4193*	-0.0775
7	-0.0309	-0.0282	0.0233	0.0553
		Phosphorus		
1	-0.5489**	0.1576	-0.1900	x
2	-0.0427	0.1138	-0.0652	0.0103
3	0.0296	0.0280	0.0223	0.2536
4	0.3530	-0.1184	0.2082	-0.0107
5	0.0049	-0.0503	-0.1429	-0.1287
6	-0.2697	-0.2121	-0.0432	-0.1816
7	-0.0074	0.1536	0.0296	-0.0245
		Potassium		
1	0.3130	0.0856	-0.1179	x
2	0.0738	0.1776	0.2033	0.1975
3	0.4229*	0.3735	0.1688	0.5340**
4	0.5142**	0.6314**	0.2749	0.3302
5	0.3825*	0.3058	0.3788	0.2940
6	0.3406	0.2681	0.1316	0.1267
7	0.4291*	0.4296*	0.3229	0.2882

x During the first stage only three groups of samples were collected.

* Significance at 5% level

**Significance at 1% level

Table 26. Coefficients of partial correlation between yield of cashew (1985-89) and nutrient content of leaves at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		Nitrogen		
1	0.4155*	0.0578	-0.1151	x
2	0.3120	0.0618	0.1678	-0.1807
3	-0.1543	0.2467	0.2790	-0.1215
4	-0.2031	-0.2040	-0.1558	0.0544
5	0.1697	-0.1463	-0.1730	0.0109
6	-0.1499	0.2918	-0.4295*	0.0160
7	-0.2192	-0.2861	-0.0426	-0.0201
		Phosphorus		
1	-0.5672**	0.1857	-0.1612	x
2	-0.2299	0.0130	-0.1546	0.0028
3	0.0159	-0.2261	0.2737	0.2952
4	0.2259	-0.2627	0.2204	-0.1518
5	-0.0453	0.0274	-0.1196	-0.1742
6	-0.0849	-0.1672	0.1274	-0.1555
7	0.0248	0.1849	0.0365	0.0187
		Potassium		
1	0.4869**	0.0751	-0.1594	x
2	-0.0259	0.1158	0.2031	0.2277
3	0.4427*	0.3073	0.1641	0.5469**
4	0.5721**	0.6576**	0.2868	0.3156
5	0.4128*	0.2743	0.3632	0.3066
6	0.4175*	0.3529	0.1081	0.1276
7	0.4727*	0.4919**	0.3249	0.2839

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

beginning with the flushing would have caused an acute demand of this element for the formation and development of new growth. This results in a dilution of this nutrient element with increasing yield so that very often correlation could not be obtained between yield and N content of tissue till the period of active growth ceases. The negative correlation between yield and N content of third group of leaves at the sixth sampling period could be attributed to the maximum cumulative withdrawal of N from these leaves for the development of nuts. In pepper, Sushama et al. (1984) reported that the N content of leaves failed to establish a significant positive correlation with yield irrespective of leaf position and period of sampling.

It is possible that the expression of yield may be a combined effect of the levels of N, P and K and therefore the influence of one element may affect or modify the effect of other element on the yield. In such cases, coefficients of simple correlation cannot describe the type of relationship between the element and yield. In order to find out the effect of one element on the yield, eliminating the effect of others, partial correlations were worked out. The coefficient of partial correlation for N (eliminating the effect of P and K) showed that the N content of the first group of leaves prior to flushing was significantly and positively correlated with yield both for the periods 1985-89 ($r = 0.4155^{*}$) and 1987-89 ($r = 0.4071^{*}$). This indicates that the first group of leaves

collected prior to flushing can serve as the sampling material for foliar diagnosis in relation to N. This particular stage of sampling if utilised for the foliar diagnosis has the additional advantage of adjusting the level of N fertilization, since the collection of sample at this stage preceeds the application of fertilisers to the plants.

The optimum content of N in the first group of leaves in the first stage of sampling (preflushing stage) was found to be 2.00 per cent based on the quadratic model fitted to the yield data of 1987-89. The results are in conformity with the earlier finding of Kumar and Sreedharan (1986). They suggested a critical level of 2.09 per cent.

Phosphorus

The coefficients of simple and partial correlation between P content in the leaf and yield for the period 1985-89 and 1987-89 are furnished in the Tables 25-28.

When simple correlation was examined, it was seen that the yield was not significantly and positively correlated with leaf P. The highest positive value for correlation coefficient obtained was at the fourth stage of sampling for group 1 leaves ($r = 0.3530$) for the period 1985-89 which was not statistically significant. This was true with the yield data for the period 1987-89 also

Table 27. Coefficients of simple correlation between yield of cashew (1987-89) and nutrient content of leaves at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		Nitrogen		
1	0.2049	0.0786	-0.0254	x
2	0.0593	0.0503	0.0677	-0.1944
3	-0.3447	0.0483	0.1302	0.0082
4	0.0369	0.1829	0.1994	0.1091
5	0.1597	-0.1286	0.0264	0.0503
6	-0.1665	-0.1654	-0.16151	-0.0105
7	0.1549	0.1915	0.1261	0.1577
		Phosphorus		
1	-0.4356*	0.1396	-0.2884	x
2	-0.3449	0.0189	-0.1685	-0.2550
3	-0.0699	-0.0729	0.2310	0.0671
4	0.3447	0.0665	0.2710	0.1106
5	0.1843	-0.0711	-0.1414	-0.0676
6	-0.3881*	-0.2300	0.0167	-0.0537
7	0.0452	0.0885	0.1802	-0.0573
		Potassium		
1	0.2720	-0.0961	-0.3409	x
2	-0.1387	0.0416	0.2081	-0.0351
3	0.3575	0.2082	0.1926	0.3432
4	0.6249**	0.5784**	0.2424	0.3528
5	0.2773	0.3219	0.3901*	0.3283
6	0.1970	0.1849	0.0982	0.0784
7	0.2941	0.3618	0.3774	0.1152

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

Table 28. Coefficients of partial correlation between yield of cashew (1987-89) and nutrient content of leaves at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		Nitrogen		
1	0.4071*	0.0295	-0.0170	x
2	0.3494	0.0381	0.1960	-0.1307
3	-0.3940*	0.0459	0.1087	-0.1857
4	-0.0605	0.0584	0.0612	0.0288
5	0.2236	-0.0167	0.1610	0.1192
6	-0.0135	-0.1778	-0.1793	0.0177
7	0.0607	0.0382	0.0652	0.1348
		Phosphorus		
1	-0.4548*	0.1166	-3.3231	x
2	-0.4455*	-0.0172	-0.2568	-0.2160
3	0.0669	-0.1713	0.2904	0.0638
4	0.1085	-0.0234	0.1636	-0.0211
5	0.0949	09.0660	-0.2338	-0.1884
6	-0.2812	-0.1992	0.0983	-0.0492
7	0.0841	0.0469	0.2057	-0.0451
		Potassium		
1	0.4180*	-0.0761	-0.3752	x
2	-0.2009	0.0193	0.2129	-0.0034
3	0.4320*	0.2061	0.1923	0.3867*
4	0.6687**	0.5608**	0.2312	0.3397
5	0.3676	0.3041	0.4015*	0.3273
6	0.2883	0.2411	0.0864	0.0784
7	0.2590	0.3165	0.3689	0.0787

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

(r = 0.3447). A significant negative correlation was noted for the group 1 leaves in the first stage of sampling for both the periods 1985-89 ($r = -0.5489^{**}$) and 1987-89 ($r = -0.4356^{*}$).

The lack of significant positive correlation between yield and P content of leaf could be attributed to the very limited extent of variation in leaf P values observed with increasing levels of P application. As already mentioned, the content of P in leaf was markedly low irrespective of the levels of application.

From the coefficient of partial correlation between leaf P and yield for the period from 1985-89, it was found that leaf P failed to establish a significant positive correlation with yield. In fact a negative correlation was noted in the first stage for the group 1 leaves (r = -0.5672**). For the period 1987-89, the partial correlations were significant at the first leaf position in the first and second stages of sampling. The correlation coefficients were -0.4548* and r = -0.4455* respectively for the first and second stages of sampling. Thus, failure to establish significant positive correlation between yield and leaf P could not be attributed to the interferences of N and K.

Gopi and Jose (1983) reported that the coefficients of correlation, both simple and partial, between leaf P and yield were not significant in coconut.

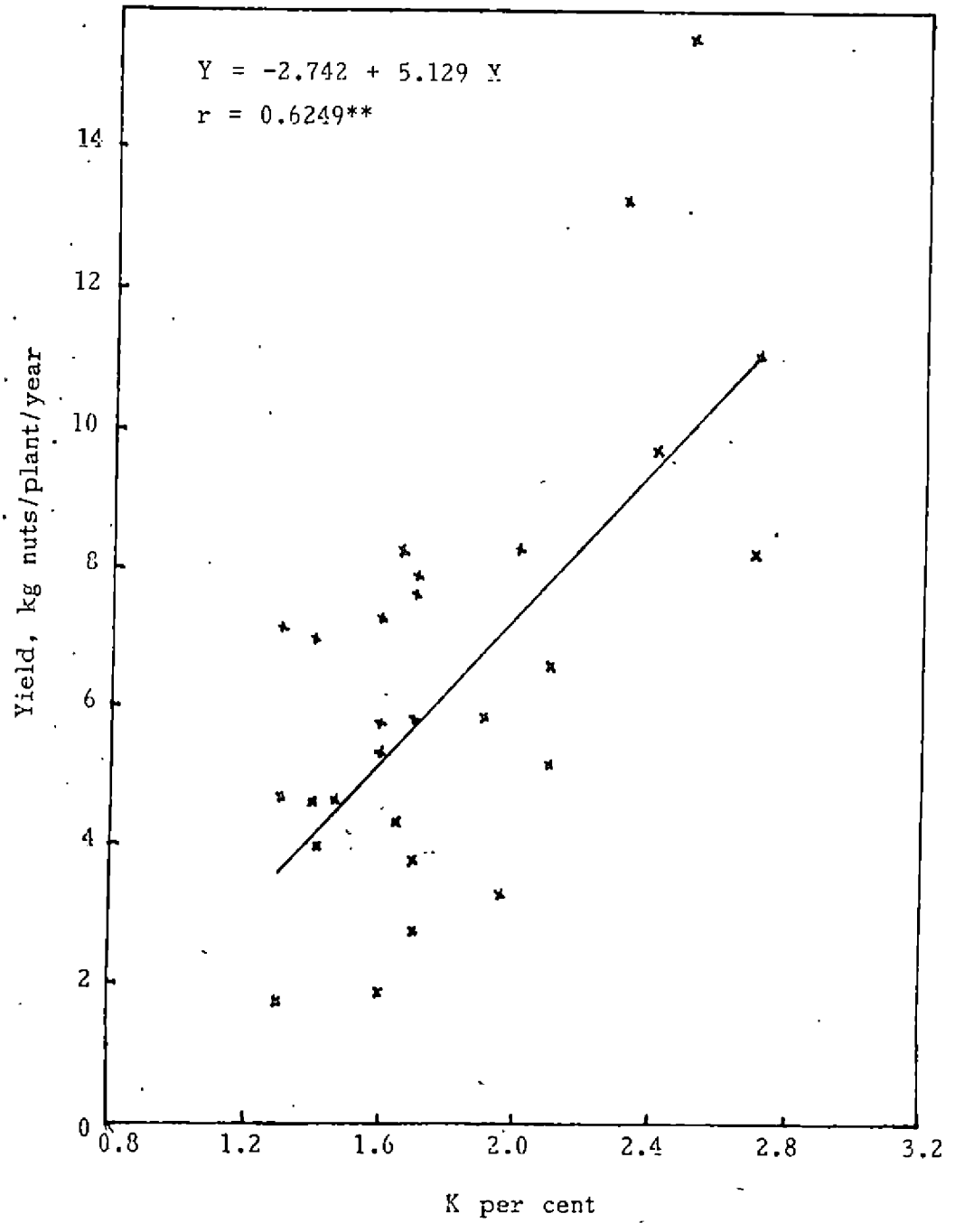
Since no significant positive correlation between P content of leaf and yield was observed, it was not possible to compute the optimum level of P required for the maximum yield, statistically. Also, it is not possible to recommend any specific leaf group for predicting yield of cashew in relation to P. The highest positive value for correlation coefficient was with the P content of the first group of leaves during the fourth stage of sampling, which was not statistically significant.

Potassium

The coefficients of correlation, both simple and partial, are given in the Tables 25-28.

The coefficients of simple correlation revealed that the K content in leaf during different stages of sampling at different leaf positions could serve as a good indicator of the nut yield since the relationships appeared to be more pronounced than those between the yield and the other two plant nutrients, namely N and P. When the yield for 1985-89 was considered, correlation between yield and K content in leaf was significant during the third, fourth, fifth and seventh stages of sampling whereas only the fourth and fifth stages became statistically significant when the yield data for the years 1987-89 were considered. Among the leaf positions, K content of group 1 leaves during the third, fourth, fifth and seventh stages gave significant correlations with the yield for the period 1985-89. The maximum values of simple correlations

Fig.3 Relationship between K per cent of the first group of leaves at the fourth stage of sampling and mean annual yield (1987-89)



are observed for the first and second group of leaves during the fourth stage of sampling. This indicates the suitability of the first and second group of leaves during the fourth stage of sampling for foliar diagnosis and prediction of yield in cashew with respect to the level of K in leaf.

An examination of the coefficients of partial correlation between yield and leaf K eliminating the effects of N and P revealed that the level of K in leaf correlated significantly with yield during most of the stages of sampling. Significant partial correlation was observed between yield and the K content of the first group of leaves collected before flushing (stage 1) whereas simple correlation was not significant at this period of sampling. The coefficients of partial correlation were higher in the case of the first and second group of leaves collected during the fourth stage of sampling as in the case of simple correlation. This again tends to conclude that the first and second group of leaves during the fourth stage of sampling is ideal for the foliar diagnosis and prediction of yield in relation to the K status of plants.

Considering the highly significant simple correlation between K content of the first group of leaves during the fourth stage of sampling, a linear regression was established between the K content of this leaf and the yield for 1987-89. The regression equation was found to be $Y = -2.74 + 5.129\ K$. This relationship shows that for a unit increase in the leaf K per cent, an yield increase

of 5.129 kg nuts could be obtained and for the very expression of yield, the level of K in leaf should be 0.53 per cent. In order to compute the level of K for optimum yield, a quadratic model was fitted to the same group of data and the optimum level of K was found to be 1.307 per cent. In crops like coconut (Gopi and Jose, 1983) and pepper (Sushama et al., 1982) K status of the leaf was found to be significantly correlated with yield.

Nutrient ratios

The ultimate expression of yield very much depends on interaction of nutrients and the overwhelming influence of nutrient interaction very often makes the prediction of yield rather difficult based on the direct effect of nutrient. The concept of nutrient ratios has therefore attained significance in yield prediction based on foliar diagnosis. Therefore, the ratios involving the three major nutrients tried in this investigation were calculated and the influence of these ratios on yield were examined by estimating both simple and partial correlations.

Data on the nutrient ratios are not presented in the text since they could be derived from the data on the nutrient values presented in Tables 3-23. However, the coefficients of simple and partial correlations between the yield and the three nutrient ratios N/P, N/K and K/P are given in Tables 29-32.

Table 29. Coefficients of simple correlation between the leaf nutrient ratios and yield of cashew (1985-89) at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		N/P ratio		
1	0.55003**	-0.19585	0.01090	x
2	0.23319	0.01054	-0.06740	-0.16828
3	-0.13417	0.04767	-0.16700	0.11130
4	-0.23784	0.06168	-0.18728	0.05980
5	0.00189	-0.03089	-0.02666	0.10585
6	0.23472	0.07212	-0.10729	0.20305
7	-0.09597	-0.09258	-0.05068	-0.00768
		N/K ratio		
1	-0.08519	-0.05690	0.00763	x
2	0.09322	-0.09987	-0.13462	-0.21706
3	-0.34840	-0.16506	-0.03535	-0.30662
4	-0.42829*	-0.48169*	-0.03535	-0.30662
5	-0.22480	-0.28918	-0.36945	-0.29310
6	-0.36403	-0.35178	-0.28679	-0.15199
7	-0.13808	-0.39612*	-0.23013	-0.31188
		K/P ratio		
1	0.53466**	-0.12161	0.07677	x
2	-0.00764	0.06050	0.18876	0.02737
3	0.07739	0.14078	-0.02667	0.02675
4	0.08382	0.52736**	-0.04359	0.34363
5	0.20548	0.15268	0.34221	0.34336
6	0.36011	0.23277	0.10093	0.24934
7	0.05965	0.21365	0.25496	0.14403

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

Table 30. Coefficients of partial correlation between leaf nutrient ratios and yield of cashew (1985-89) at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		N/P ratio		
1	0.4105*	-0.0917	0.0861	x
2	0.3467	0.1991	-0.0798	0.1348
3	0.1348	-0.1140	0.0859	-0.1606
4	0.0240	0.1229	-0.6529*	-0.3420
5	-0.1450	-0.0810	-0.0928	-0.1587
6	-0.0837	-0.0614	-0.0177	-0.0005
7	-0.0486	0.0977	-0.1230	-0.3702
		N/K ratio		
1	-0.2799	0.0637	0.0415	x
2	-0.2308	-0.2116	0.0594	-0.1627
3	-0.1627	-0.3261	-0.1223	-0.0173
4	-0.2205	-0.2559	0.5739**	0.2080
5	0.1103	0.0240	-0.0166	0.0946
6	0.0507	-0.0761	-0.2778	-0.1776
7	0.0340	0.2542	-0.1279	0.2061
		K/P ratio		
1	0.5662**	0.0452	-0.0414	x
2	-0.1727	0.0695	0.2012	0.1172
3	°0.1172	0.1159	0.1517	-0.0005
4	0.2056	0.2962	0.7995**	0.2160
5	0.2888	0.2537	0.3148	0.4395*
6	0.3644	0.3283	0.2822	0.2844
7	0.1572	0.4149*	0.4225*	0.4178*

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

Table 31. Coefficients of simple correlation between leaf nutrient ratios and yield of cashew (1987-89) at different leaf positions and stages of sampling

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		N/P ratio		
1	0.5123**	-0.08858	0.20780	x
2	0.47374*	0.0067	0.13171	0.02839
3	-0.14145	0.06735	-0.01600	-0.08481
4	-0.26204	0.01275	-0.14314	0.09084
5	-0.01995	0.02605	0.17703	0.13284
6	-0.3717	0.09185	-0.05659	0.05196
7	-0.09315	0.10095	-0.19589	0.07738
		N/K ratio		
1	-0.0379	0.08860	0.19952	x
2	0.16945	0.02936	0.00256	0.08064
3	0.40936*	-0.11938	-0.16790	-0.37601
4	-0.49393**	-0.33167	-0.01910	-0.24748
5	-0.08768	-0.24689	-0.03117	-0.27699
6	-0.27915	-0.25996	-0.17348	-0.06458
7	-0.17559	-0.18391	-0.18009	-0.14408
		K/P ratio		
1	0.4225*	-0.15741	0.08496	x
2	0.05341	0.00850	0.12630	0.10157
3	0.12759	0.13353	-0.14141	0.08716
4	0.18738	0.38178*	-0.07226	0.16504
5	0.03606	0.17871	0.40132*	0.34077
6	0.41485*	0.18828	0.05576	0.08722
7	-0.02931	0.27740	0.15776	0.07947

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

Table 32. Coefficients of partial correlations between leaf nutrient ratios and yield of cahsew (1987-89) at different leaf positions and stages of samplings

Stages of sampling	Leaf positions (group no.)			
	1	2	3	4
		N/P ratio		
1	0.4737*	0.17913	0.0954	x
2	0.5956**	0.1551	0.0480	0.2287
3	-0.1294	0.0584	-0.0567	0.0580
4	0.0886	-0.4504*	-0.1965	-0.2727
5	0.0722	-0.1017	-0.2799	-0.0295
6	0.0047	0.0300	0.0444	-0.1090
7	0.0330	-0.01971	-0.5107**	0.1399
		N/K ratio		
1	-0.3691	-0.1724	0.0861	x
2	-0.3913*	0.1586	-0.0339	-0.2330
3	-0.3784	-0.0780	-0.1938	-0.2966
4	-0.2361	0.3849*	0.1249	0.2084
5	-0.1079	0.0217	0.2847	0.0061
6	0.0407	-0.2150	0.1449	0.0943
7	-0.0981	0.1479	0.3208	-0.1833
		K/P ratio		
1	0.37%	-0.1406	-0.2073	x
2	-0.2936	0.0056	0.0487	0.1003
3	0.1776	0.1217	-0.1287	0.2844
4	0.4274*	0.5062**	0.0907	0.2993
5	0.0573	0.2759	0.3842*	0.3412
6	0.2047	0.1845	0.1483	0.0925
7	0.1443	0.2947	0.4277*	0.0313

x During the first stage only three groups of samples were collected.

* Significance at 5% level

** Significance at 1% level

The coefficient of simple correlation between N/P ratio of the first group of leaves during the first season and yield was found to be significantly and positively correlated with the yields of both 1985-89 and 1987-89 (Fig.4). This significant relationship was also seen when coefficient of partial correlation was worked out for the same set of data eliminating the influence of other ratios namely N/K and K/P. Making use of the yield data for the year 1985-89 and N/P ratio of the first group of leaves during first stage of sampling a quadratic function was fitted to work out optimum N/P ratio for maximum yield. This was found to be 10.84. The yield decline when the ratio exceeds the limit of 10.84 could be attributed to the excessive vegetative growth resulted by the high content of N or by the growth limiting effect of P when its content becomes below its critical level.

The simple correlation established between N/K ratio and yield showed that the relationship is significant with the first group of leaves of the fourth stage of sampling irrespective of the period of the yield considered. Coefficients of correlation for 1985-89 and 1987-89 yields were -0.4239* and -0.4939** respectively (Fig.5). The relationship which is negative indicates

Fig.4 Relationship between N/P ratio of the first group of leaves at the first stage of sampling and mean annual yield (1985-89)

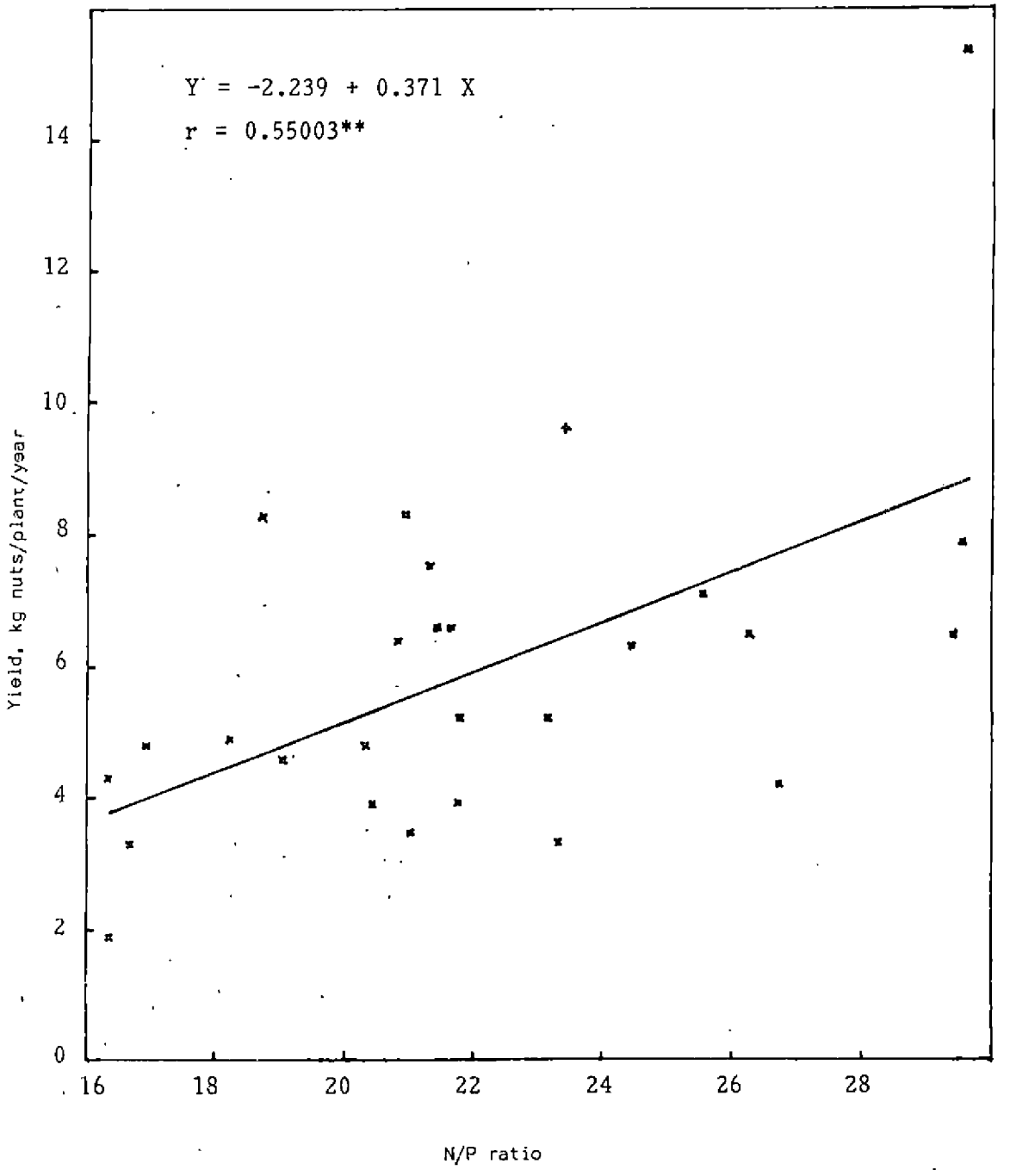


Fig.5 Relatioship between N/K ratio of the first group of leaves at the fourth stage of sampling and mean annual yield (1987-90)

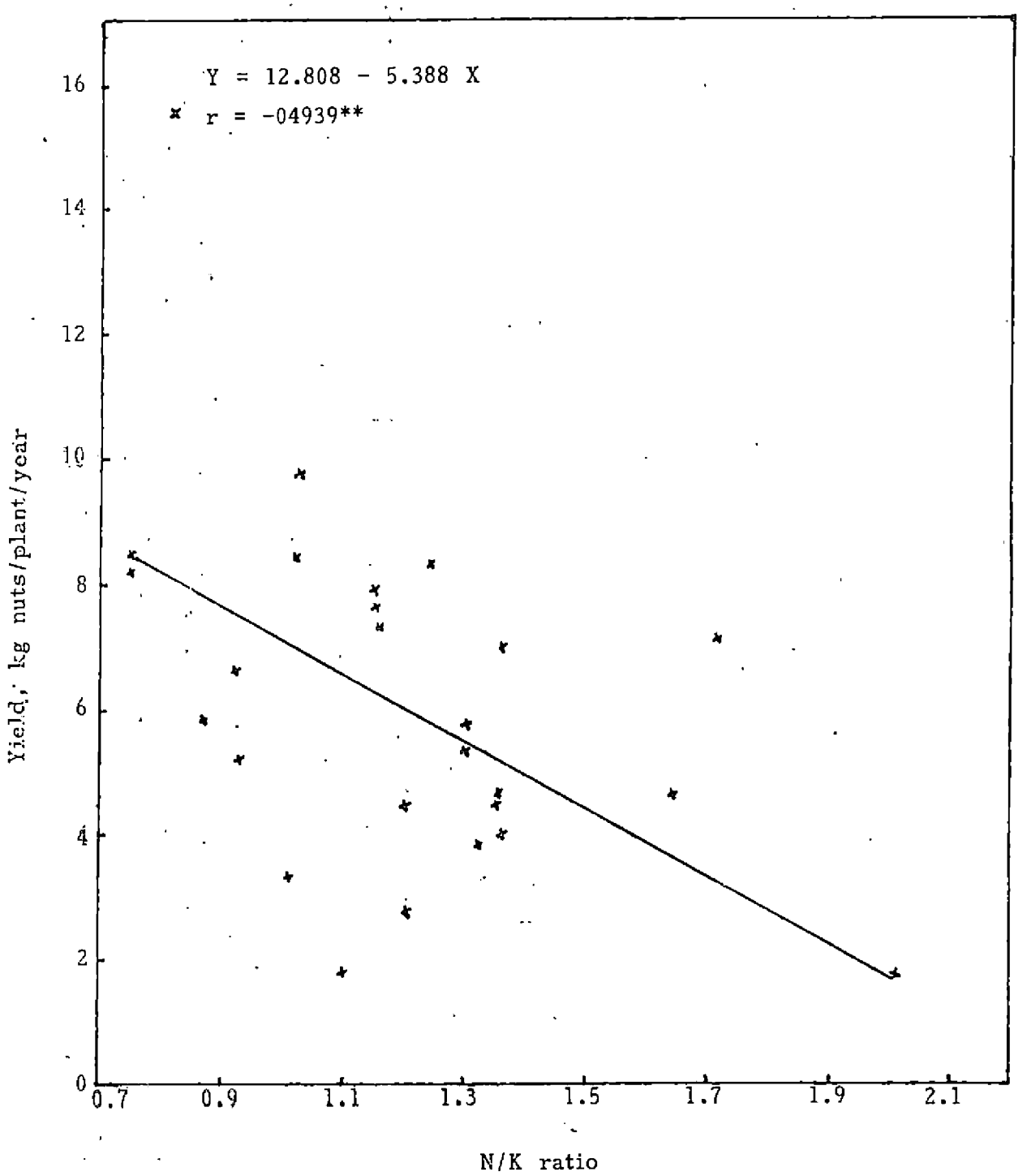
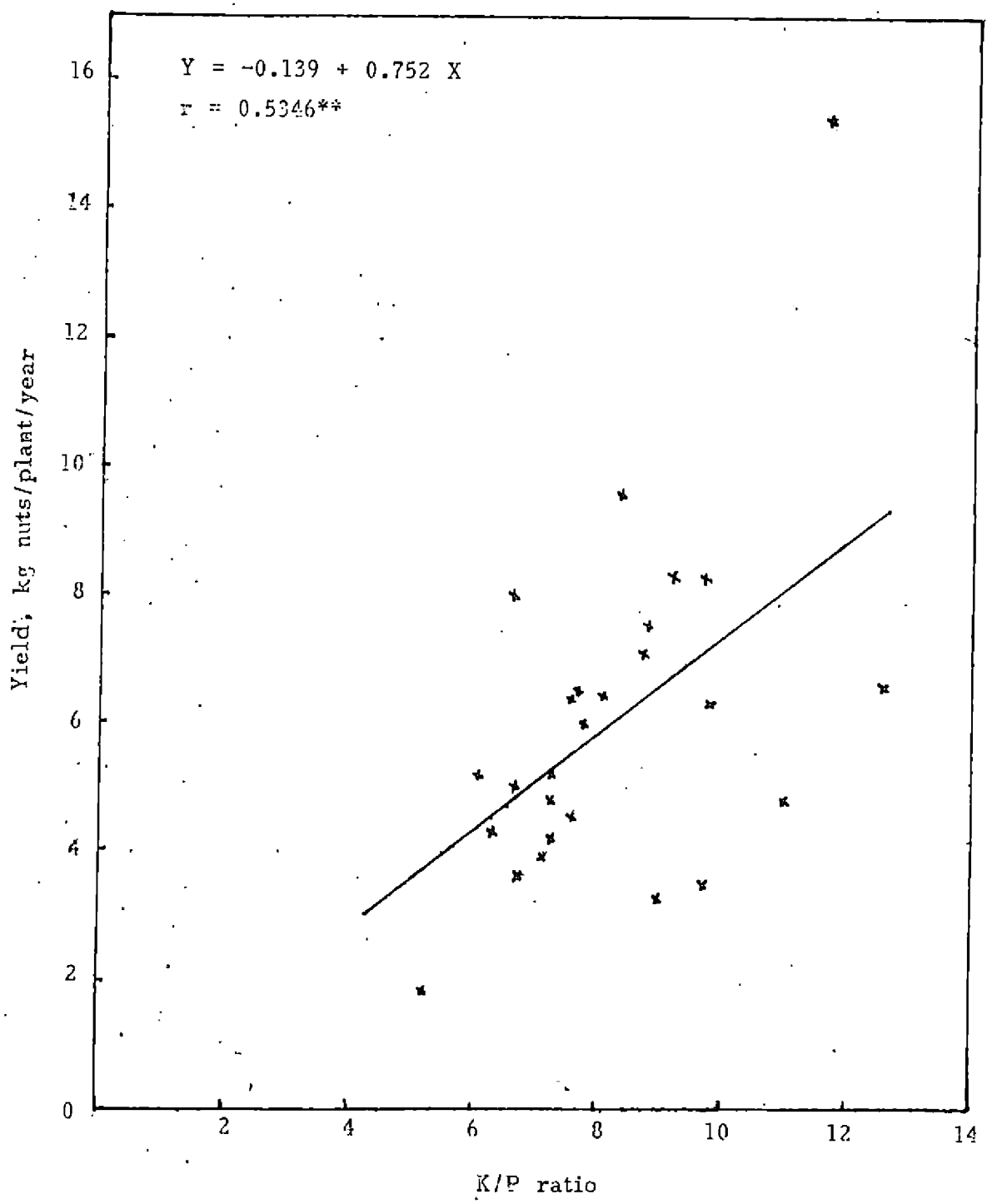


Fig.6 Relationship between K/P ratio of the first group of leaves at the first stage of sampling and mean annual yield (1985-89)



that decrease in ratio could cause an increase in yield and the optimum ratio was found to be 1.99 and 1.70 for the yield data for 1987-89 and 1985-89, respectively. In other words, increasing the N content without a corresponding increase in the content of K could cause a decline in yield which could be attributed to the imbalance in N and K status of the plant. Gopi and Jose (1983) reported that the yield of coconut was considerably reduced by increasing the level of N in the absence of K whereas combined application of N and K increased the yield significantly.

As in the case of N/P ratio, K/P ratio also was significantly correlated with yield. The highest coefficient of simple correlation was observed for the relationship between yield and K/P ratio of the first group of leaves of the first stage of sampling (Fig.6). The optimum ratio worked out with the help of a quadratic model was 14.68 making use of the yield data for the period 1987-89. The significant positive correlation between K/P ratio and yield is indicative of the positive effect of K in increasing the yield upto a critical level when the effect of P becomes limiting. It could also be due to negative relationship observed between the leaf P content and yield observed in this study.

Prediction of yield based on leaf nutrient levels

Since the aim of the foliar diagnosis is to predict yield based on the nutrient levels of leaf tissue, attempts

were made to formulate prediction equation considering the status of nutrients and their ratios. Because of the fact that better relationship between nutrient content of leaf and the yield was observed at the first group of leaves at the first and fourth stages of sampling, only the nutrient values of these samples were adopted for formulating the multiple regression models. Nutrient levels and nutrient ratios of these leaves were considered in different combinations as the independent variables and the maximum prediction was observed with the model

$$Y = -2.227 + 28.542\ X_1 - 0.775\ X_2 + 0.314\ X_3 - 2.466\ X_4 + 0.406\ X_5$$

where X_1 is the P per cent of the first group of leaves during the fourth stage of sampling, X_2 is the K per cent of the first group of leaves at the fourth stage of sampling, X_3 is the N/P ratio of the first group of leaves at the first stage of sampling, X_4 is the N/K ratio of the first group of leaves at the fourth stage of sampling and X_5 is the K/P ratio of the first group of leaves at the first stage of sampling. The R^2 value of this model was 0.5526. The F value of the above regression model was significant at 1 per cent level. The result of the study thus indicated that the yield of cashew can be predicted with a precision of 55 per cent based on the leaf nutrient levels and the ratios. The high genetic variability of the cashew trees raised from seedlings in respect of their yield potential appears to be the important factor which interferes with the establishment of an intense

relationship between the yield and nutrient status of the experimental plants. However, it is presumed that the yield of cashew plants can be monitored and regulated to some extent with the help of the diagnostic technique standardised in this study. Probably, in a less variable population of cashew layers, a better prediction may be possible since the influence of genetic variability on yield would be the minimum.

Summary

SUMMARY

Cashew plants of the NPK fertilizer trial of the Kerala Agricultural Development Project (College of Horticulture) at Madakkathara, Thrissur were made use of for the collection of leaf samples in this study. The field trial was established in 1979 with newly planted cashew seedlings of the vareity BLA-39-4. The experiment was laid out in a 3^3 factorial randomised block design consisting of three levels each of nitrogen (250, 500 and 1000 g N/plant/year), phosphorus (125, 250 and 500 g P_2O_5/plant/year) and potassium (250, 500 and 1000 g K_2O/plant/year).

In order to standardise the leaf position, the leaves of the flowering shoots were serially numbered designating the last fully matured leaf which was not having an inflorescence in the leaf axil as leaf No.1. Before flushing and flowering of the shoots the leaves were grouped into three viz., top leaves, middle leaves and basal leaves. After flushing and flowering, the leaves at different leaf positions were grouped into four groups each consisting of two leaves; they are group 1, group 2, group 3 and group 4. For the purpose of standardising the season best suited for the collection of leaf intended for foliar diagnosis, samples are collected at different stages of plant growth. The patterns of distribution of nitrogen, phosphorus and potassium in leaves of different seasons and positions were examined and regression

models were worked out to predict the yield based on tissue analysis. Attempts were also made to establish the critical levels of nitrogen, phosphorus and potassium to be maintained in the index leaf for getting optimum yield.

1) Application of increased level of N and P resulted in progressive increase in yield irrespective of the years of the yield considered. But increase in yield due to increasing levels of K application was not marked as those of N and P.

2) Among the different levels of N, P and K applied, NP and NK interactions were significant. The highest yield was obtained at n_2p_2 and n_2k_2 combinations. However, the interaction between levels of P and K was not conspicuous. The treatment combination $n_1p_2k_2$ recorded the maximum yield.

3) The nitrogen content of the leaf varied from 1.24 to 2.76 per cent. The distribution of N in the leaves during different stages of sampling showed a regular pattern. Leaf sample collected during the first stage of sampling contained relatively low amount of N which increased during the second stage. This increase continued upto the third stage of sampling and thereafter decreased.

4) Pattern of variation in the content of N with the increasing age of the leaf was different during different stages of sampling. Maximum N accumulation was noted in the first group of leaves

at the first and the last two stages of sampling. Nitrogen distribution at different leaf position in the other stages were rather inconsistent.

5) The differences in the levels of N applied reflected in the level of this element retained in the leaves. Maximum separation with respect to level of applied N was observed only during the fourth stage of sampling.

6) The P content in the leaf varied from 0.063 to 0.316 per cent. Stages of sampling significantly influenced the P content in the leaves. Initially, during the first stage of sampling, the P content in the leaves was very low. Then the P content increased during the next two stages and thereafter it decreased.

7) Mean P content in cashew leaves was only 1/20th of that of N.

8) Distribution of P at different leaf positions was rather inconsistent. However, a tendency to accumulate more P in the basal leaves was noted during different stages of sampling.

9) Increasing application of P was not clearly reflected in the content of P in leaves though the leaf P content at P_0 level was relatively low.

10) The potassium content of the leaf varied from 0.54 to 2.74 per cent. The distribution of K in the leaves during different

stages of sampling observed a regular pattern of variation. The lowest level of K was seen prior to flushing. With flushing, the K content in the leaves increased and thereafter declined with advancing stages of growth.

11) Potassium percentage of the leaves decreased with increasing the age of the leaves. More K was found associated with the first group of leaves.

12) Increasing levels of K application was clearly reflected in the content of this nutrient retained in leaves only during the fourth stage of sampling.

13) Nitrogen content of the leaf failed to establish a significant positive correlation with yield irrespective of leaf position and stage of sampling.

14) The coefficient of partial correlation between yield and N content in the first group of leaves collected prior to flushing was positive and significant and so this sample can serve as a sampling material for foliar diagnosis in relation to N and the optimum level of N for getting maximum yield was found to be 2.00 per cent.

15) The yield of cashew was not significantly and positively correlated with leaf P irrespective of leaf position and stage of sampling. So it was not possible to compute optimum level of P

for getting maximum yield. Also it was not possible to recommend any specific leaf group for determining the P status of the plant.

16) The coefficients of both simple and partial correlation between leaf P and yield were significant and negative in the group 1 leaves during the first stage of sampling.

17) The coefficients of both simple and partial correlation between leaf K and yield were significant and positive in the first and second groups of leaves collected during the fourth stage of sampling. Optimum level of leaf K for getting maximum yield was 1.307 per cent.

18) The first and second groups of leaves collected during the fourth stage of sampling were found to be suitable for diagnostic purpose in relation to K.

19) The N/P ratio of the first group of leaves collected during the first stage of sampling was significantly and positively correlated with yield when compared to other positions and stages tried. The optimum N/P ratio was 10.84.

20) The N/K ratio of the first group of leaves collected during the fourth stage of sampling was significantly and negatively correlated with yield.

21) The K/P ratio of the first group of leaves collected during the first stage of sampling was significantly and positively correlated with yield. Optimum ratio was 14.68.

22) Among the positional groups, the first group of leaves is considered as the best for foliar diagnosis in relation to N and K. As regards the stage of sampling for K, the fourth stage of sampling is recommended as the best season for diagnostic purpose, and for N, preflushing sample is the best.

23) Multiple regression model was fitted with nutrient levels and nutrient ratios of the first group of leaves collected during the first and fourth stages of sampling and yield. Maximum predictability of 55 per cent (R^2 = 0.5526) was obtained for the model $Y = -2.227 + 28.542\ X_1 - 0.775\ X_2 + 0.314\ X_3 - 2.466\ X_4 + 0.406\ X_5$ where Y is the yield (for the period 1985-89), X_1 and X_2 are the P and K content of the first group of leaves collected during fourth stage of sampling. X_3 is the N/P ratio of the first group of leaves at the first stage of sampling. X_4 is the N/K ratio of the first group of leaves collected during the fourth stage of sampling and X_5 is the K/P ratio of first group of leaves collected during first stage of sampling.

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*Originals not seen

Appendices

APPENDIX - I

General characteristics of soil

Sl. No.	Treatment NPK	Organic C(%)	Total N(%)	Available P (ppm)	Available K (ppm)	pH
1	000	1.29	0.179	17.8	150	5.1
2	001	1.08	0.151	25.8	600	5.2
3	002	1.08	0.157	34.0	225	5.2
4	010	1.05	0.148	05.8	150	5.3
5	011	1.11	0.157	31.0	500	4.8
6	012	1.11	0.140	24.4	425	5.1
7	020	1.23	0.174	37.9	400	5.1
8	021	1.26	0.168	59.0	625	5.0
9	022	1.11	0.106	43.0	300	5.0
10	100	0.96	0.154	22.8	250	5.1
11	101	1.02	0.145	12.8	350	5.1
12	102	1.02	0.140	13.8	500	5.0
13	110	1.00	0.162	14.9	375	5.3
14	111	1.05	0.151	27.8	125	5.1
15	112	0.96	0.154	19.9	470	5.1
16	120	0.87	0.143	31.1	150	5.3
17	121	1.11	0.126	43.9	125	5.4
18	122	1.02	0.157	40.0	350	5.3
19	200	1.11	0.140	91.9	150	5.2
20	201	1.02	0.151	6.5	400	5.3
21	202	1.17	0.190	16.9	600	5.4
22	210	1.05	0.160	80.5	175	5.0
23	211	0.93	0.168	32.4	625	5.1
24	212	0.93	0.160	29.2	250	5.2
25	220	1.11	0.160	10.4	400	5.0
26	221	1.23	0.160	81.2	300	5.4
27	222	0.84	0.157	76.8	475	5.2

APPENDIX - II

Effect of NPK treament on yield of cashew 1985-89

Abstract of ANOVA

Source	df	Mean square
Total	26	
N	2	8.398
P	2	21.035*
NP	4	8.900
K	2	3.781
NK	4	5.703
PK	4	5.374
NPK (error)	8	4.295

* Significance at 5% level

Comparison of NP combination

	p_0	p_1	p_2	Mean
n_0	5.71	3.63	5.54	4.96
n_1	3.31	4.98	9.49	5.92
n_2	15.68	6.99	8.03	6.89
Mean	4.90	5.20	7.68	

CD (0.05) = 3.902

Comparison of NK combination

	k_0	k_1	k_2	Mean
n_0	5.58	4.96	4.34	4.96
n_1	5.47	4.04	8.26	5.92
n_2	7.18	6.64	6.86	6.89
Mean	6.08	5.22	6.49	

CD (0.05) = 3.902

Comparison of PK combination

	k_0	k_1	k_2	Mean
p_0	5.39	5.08	4.22	4.90
p_1	5.70	4.60	5.29	5.20
p_2	7.14	5.96	9.94	7.68
Mean	6.08	5.22	6.49	

CD (0.05) = 3.902

APPENDIX - III

Effect of NPK treatment on yield of cashew 1987-89

Abstract of ANOVA

Source	df	Mean square
Total	26	
N	2	35.475*
P	2	13.024
NP	4	3.948
K	2	7.265
NK	4	3.463
PK	4	13.835
NPK (error)	8	7.337

* Significance at 5% level

Comparison of NP combination

	P_0	P_1	P_2	Mean
n_0	4.58	3.58	4.97	4.38
n_1	3.82	6.77	8.03	6.21
n_2	6.88	8.65	9.50	8.34
Mean	5.09	6.33	9.50	

CD (0.05) = 5.100

Comparison of NK combination

	k_0	k_1	k_2	Mean
n_0	4.42	4.40	4.32	4.38
n_1	4.15	6.20	8.27	6.21
n_2	7.75	8.17	9.12	8.34
Mean	5.44	6.26	7.23	

CD (0.05) = 5.100

Comparison of PK combination

	k_0	k_1	k_2	Mean
P_0	5.72	5.50	4.52	5.09
P_1	5.63	7.33	6.03	6.33
P_2	4.97	6.38	11.15	7.50
Mean	5.44	6.26	7.23	

CD (0.05) = 5.100

YIELD PREDICTION IN CASHEW BASED ON FOLIAR NUTRIENT LEVELS

By

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ABSTRACT OF A THESIS

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ABSTRACT

A study was undertaken during 1988-90 with cashew plants of variety BLA-39-4 of the NPK fertilizer trial of the Kerala Agricultural Development Project at Madakkathara, Thrissur to standardise foliar diagnostic technique for cashew in relation to nitrogen phosphorus and potassium content of the leaf and to predict the yield based on leaf nutrient levels. The experiment was laid out in 3^3 factorial randomised block design consisting of three levels each of nitrogen (250, 500 and 1000 g N/plant/year) phosphorus (125, 250 and 500 g P_2O_5/plant/year) and potassium (250, 500 and 1000 g K_2O/plant/year).

For the standardisation of leaf position and period of sampling for diagnostic purpose, the leaves were serially numbered selecting the last fully matured leaf which was not having an inflorescence in the leaf axil as leaf No.1. Before flushing and flowering of the shoots the leaves were grouped into three, viz., top leaves, middle leaves and basal leaves. After flushing and flowering, the leaves at different leaf positions were grouped into four groups each consisting of two leaves; they are group 1, group 2, group 3 and group 4. For the purpose of standardising the season best suited for the collection of leaf intended for foliar diagnosis, samples were collected at different stages of plant growth. The stages of sampling were : (1) Preflushing stage (2) After flushing but before flower

opening (3) After the beginning of flower opening (4) After the opening of all the flowers of a panicle (5) At immature nut stage (6) At the time of harvest; and (7) Two months after harvest. Attempts were also made to establish the critical levels of N, P and K in leaf and to predict yield based on the regression model worked out.

Observations revealed that the N content in the leaf varied from 1.24 to 2.76 per cent. Pattern of variation in the content of N in the leaf at different stages of sampling followed a regular pattern. Prior to flushing, the content of N in the leaf was very low and it increased during the next two stages and thereafter the N content in the leaf declined. The distributions of N in the leaf at different leaf positions at different stages of sampling were rather inconsistent. The P content in the leaf varied from 0.063 to 0.316 per cent when all the leaf positions and stages of samplings were considered. Phosphorus content in the leaves was very low before flushing. With flushing the P content in the leaves increased upto the third stage of sampling and thereafter decreased. Potassium per cent in the leaf varied from 0.54 to 2.74 per cent when all the leaf positions and stages of sampling were considered. Similar to N and P, the K content in the leaves at different stages of sampling also followed a regular pattern with the advancement of stages of sampling. Maximum K was noted in the younger leaves collected during the fourth stage of sampling. During this stage, leaf was

sensitive to levels of applied K. The potassium per cent of the fruiting shoots decreased with increasing age of the leaf.

Results also showed that the nitrogen content of the leaf failed to establish a significant positive correlation with yield irrespective of leaf positions and stages of sampling. But the coefficient of partial correlation was positive and significant in the first group of leaves collected during preflushing stage. So this group of leaves can serve as a sampling material for diagnostic purpose in relation to N. Optimum content of N at this stage was 2.00 per cent. Phosphorus content of the leaf failed to establish a significant positive correlation with yield irrespective of leaf position and stages of sampling. But significant negative correlations were established between P content of the first group of leaves collected during the first stage of sampling and yield when both simple and partial correlations were considered. Potassium per cent of the first and second group of leaves collected during the fourth stage of sampling established significant and positive correlation with yield when both simple and partial correlations were considered. Optimum K content of the first group of leaves at this stage was 1.307 per cent. N/P and K/P ratio of the first group of leaves collected during first stage of sampling was found to be significantly and positively correlated with yield. N/K ratio of the first group of leaves collected during the fourth stage of sampling was significantly and negatively correlated with yield.

Observations revealed that among the positional groups the first group of leaves is ideal for diagnostic purpose in relation to N and K. Regarding the stages of sampling, the fourth stage of sampling is recommended for K. But for N, the first stage of sampling (preflushing sample) was found to be the best.

Multiple regression model fitted with yield and percentage of nutrients in the leaves gave a maximum prediction of 55 per cent (R^2 = 0.5526) when the nutrient content of the first group of leaves collected during the first and fourth stages of sampling were considered.