GROWTH AND YIELD OF CASHEW IN RELATION TO FOLIAR AND SOIL NUTRIENT LEVELS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur

1992

DECLARATION

I hereby declare that this thesis entitled "**Growth and yield of cashew in relation to foliar and soil nutrient levels**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship of any other similar title, of any other University or Society

Vellanikkara
31 7 1992

LATHA, A.

CERTIFICATE

Certified that the thesis entitled "Growth and yield of cashew in relation to foliar and soil nutrient levels" is a record of research work done independently by **Ms.Latha,A.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of Ms.Latha,A. a candidate for the degree of Master of Science in Agriculture, agree that the thesis entitled "Growth and yield of cashew in relation to foliar and soil nutrient levels" may be submitted by Ms.Latha,A. in partial fulfillment of the requirement for the degree.

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ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude to my guide, Dr.P S.John, Associate Professor, Department of Agronomy, whose never ending encouragement, perpetual support and unfailing help influenced me considerably in the execution of research work and early submission of thesis. Inspite of his busy schedule, he had conscientiously gone through each and every bit of my work and offered searching comments and suggestions throughout my course of investigation. I owe enormous debt to him.

I am happy to acknowledge with gratitude, Dr.E.Tajuddin, Professor and Head, Department of Agronomy for the valuable guidance.

My heartfelt thanks are due to Dr.A I.Jose, Professor and Head, Department of Soil Science and Agricultural Chemistry for the suggestions and generous help accorded to me during the course of this study

Let me place on record my sincere thanks to Dr.Mercy George, Assistant Professor, Department of Agronomy for the timely help, valuable suggestions and whole-hearted co-operation towards the satisfactory fulfillment of this endeavour

I am deeply obliged to Dr N Neelakantan Potty, Professor, Department of Agronomy who had made a critical appraisal of the manuscript and offered constructive suggestions for it's betterment.

It is with pleasure, I express my sincere gratitude to Mr.Krishnan,S., Assistant Professor, Department of Agricultural Statistics and Mr.Sunny, K.L., Associate Professor, Department of Agricultural Statistics for their estimable help in the statistical analysis.

My abiding gratitude will remain with the staff members of Department of Agronomy especially Dr.K.E Savithri for their whole-hearted co-operation.

My profound thanks are due to Dr.A.V Kesava Rao, Deparıment of Agricultural Meteorology for his valuable help.

The assistance and co-operation rendered to me by Mr.K.M Varghese, Farm Assistant, KADP, Madakkathara and the labourers of KADP are very much appreciated I thank them profusely.

My heartfelt thanks are also due to Mrs.Joicy,T J , Technical Assistant, Computer Centre, College of Horticulture and Mrs.Mercy, K.A., Assistant Professor, Department of Agricultural Statistics for their help in the analysis of data.

It is with immense pleasure that I thank all my friends who have contributed in some way or other towards the completion of my research work.

I will always remain beholden to my parents for their boundless affection, maximum help and inspiration throughout my course. At this juncture, I remember my sisters and cousins whose affection helped me in the successful completion of this work

I am deeply indebted to my husband, for the encouragement, sincere help and co-operation.

The award of Junior Research Fellowship by ICAR during the period of my study is gratefully acknowledged

Last but not the least, I bow my head before God Almighty whose blessings enabled me to undertake this venture successfully

LATHA,A

To my parents

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Introduction

INTRODUCTION

Introduced over three centuries ago mainly for the purpose of soil protection, cashew has come to occupy an area of 5 lakh ha of marginal lands in India. Cashew constitutes the basis of an export oriented agro-industrial system, catering to the needs of about 1.5 lakh families in our state. Despite the importance of cashew among other tree crops, it remains still as a little attended crop with the average productivity remaining about 0.5 kg/tree against a reported 8 to 10 kg/tree under good management. Our internal production is only 47 per cent which necessitated the import from other states to maintain the industry which calls for all our efforts in improving the productivity of cashew.

Plant improvement techniques for production enhancement in perennial crops can only be seen in a long term perspective. An improvement in the management techniques alone forms the practical answer to improve the productivity. The response of cashew to management practices has been emphasized by Ankaiah (1980). The productivity of cashew is as high as 8-10 kg/tree/annum under good management (Singh, 1991). Hence, formulation of objective oriented management system of cashew and its judicious application in the field will enable us not only to meet the entire requirements as envisaged at present, but also boost the industry to still further height,.

Continuous application of fertilizers tends to develop scientific nutritional environment which determines the nature and extent of productivity in perennial crops. The management techniques need to be standardised based on such specific nutritional environment Any management system of cashew in our state should take into account all the major nutrients as they are deficient in laterite soil, in which the cashew cultivation is concentrated.

The response behaviour of crop in relation to application of these nutrients has to be studied in the context of utilization pattern since the time separation between application of nutrients and the reflection in productivity is relatively long. The efficacy of management techniques should be examined on the basis of absorption, translocation and transformation of nutrients applied either directly or by biometric or metabolic expression, for different agroclimates, separately. The metabolic expressions in terms of leaf nutrient contents could be served as an indicator to supply needs of nutrients to perennial crops (Mathew, 1990). Insufficient informations on these aspects of scientific management of cashew necessitates the comprehensive experimentation, which has been attempted here.

The objectives are

to establish the relationship between the levels of N, P and K in soil and leaf, and growth and yield of cashew, to work out the optimum level of nutrients as reflected from the current fertilization,

to determine the critical level of major nutrients in leaf as a basis for prediction of economic yield,

to test the available prediction equation for yield in relation to the major nutrient status of plants and to modify if necessary, and

to work out the production function and economic optimum dose of major nutrients.

Review of Literature

2. REVIEW OF LITERATURE

Nutritional management is the main means of improving productivity of existing perennial crop plants. Being introduced mainly for the purpose of soil conservation, cashew had not received any scientific attention in the past and information on its nutritional behaviour has been meagre and management technology has been arbitarary to high degree. This calls for renewed efforts on these lines based on information already generated in the field. Literature on nutritional aspects of cashew in India and else where has been reviewed here.

2.1. Response of cashew to mineral fertilization

Conflicting results on the response of cashew to mineral fertilization has been reported. Lefebvre (1973), Ankaiah (1980), and Kumar (1983) found that cashew manifests significant positive effects due to mineral fertilization. But experiments in Tansania (Ohler, 1979) suggested that the response is governed by soil fertility. Response to fertilization by cashew need be expected only in poor soils. Adi and Kurnea (1983) observed greater response in young cashew trees than older ones to mineral fertilization.

2.1.1 Effect of nitrogen

2 1 1 1. Growth

Out of the three major nutrients nitrogen has the most marked effect on the growth and development of cashew. The nature and extent of response was found to be affected by nature of generation of the plant - clone, layers etc. in addition to the soil type. Nambiar (1983) reported an increase in the number of leader shoots produced per plant due to the application of 1000 g N/tree/year in sandy loam soils of Bapatla. He also reported significant linear increase in height of the trees with 500 and 1000 g N/tree/year over control. However, in the laterite soils of West Bengal application of 400 g N/tree/year resulted in higher growth especially the number of lateral branches. In a study of the Madakkathara laterite soil of Kerala; significant increase in height and girth of plants were observed by application of 1000 g N/tree/year over the lower doses of 500 or 250 g N/tree/year (Anon., 1980). Investigating the differential response of layers and seed progenies at Cashew Seed Farm, Shantigodu, Kumar (1985) found that seed progeny and layers recorded maximum heights at 450 and 300 g N/tree/year, respectively.

2.1.1.2. Yield

Veeraraghavan et al. (1985) and Ghosh (1988) had shown that application of nitrogen had definite advantage in increasing cashew yield. Lefebvre (1973) reported that response to applied N in cashew was enhanced in the presence of phosphorus. Response to N was limited to 75 kg/ha in the absence of P and K but response upto 125 kg N/ha was obtained in the presence of applied P and K. On the contrary Rao et al. (1984) found that N application alone had increased the tree yield significantly. Pujari (1979) reported differential response to graded fertilizer levels and maximum cashew yields were obtained by application of 500 g ammonium sulfate and 1250 g of single super phosphate per tree per year on sandy loam soil. Reddy et al. (1982) recorded 42, 80 and 90 per cent yield increase over control with N application at 500, 1000 and 1500 g/tree/year, respectively. Nambiar (1983) reported that application of 1000 g N sufficiently out yielded (6.82 kg) the treatments with 500 g N(5 03kg)and control (3.83 kg) in coastal sandy soils of Bapatla.

Nair et al. (1972) found that response of cashew to fertilization was goverened by level of application and suggested that no additional advantage will be obtained if the level of N was limited to 220 g or below per plant per year. A fertilizer trial at Kasaragod also revealed that very low N application was not sufficient for higher yields. Significant linear yield increases were obtained with 300 and 500 g over 100 g N/tree/year (Anon., 1974). However, Kumar (1985) reported that there was substantial yield increase from 2.92 kg to 4.27 kg when N application was increased from 150 to 300 g N/tree/year and beyond which the increase was marginal.

Mathew (1990) studying the pattern of N response of crop receiving constant levels over a period of 10 years found that the gap between 250 and 1000 g N/tree/year will be very wide. At 250 g the nut yield was 6.91 kg as against 8.34 kg for 1000 g after 10 years of the fertilizer application in seed progenies.

High level of chlorophyll in any plant system by and large has been reported to be associated with high productivity. Investigating the comparative performance of low and high yielders of casnew in relation to chlorophyll content, Ankaiah and Rao (1983) from Cashew Research Station, Bapatla reported that the chlorophyll content ranged between 8.58 to 11.77 mg/g tissue in case of high yielders and 6.61 to 8.46 mg/g tissue in case of poor yielders. In the experiments at Cashew Seed Farm, Shantigodu, Vittal, Kumar (1985) observed significant increase in chlorophyll 'a' and chlorophyll 'b' with every increment of N from 150 to 450 g/tree/year. The increase in both chlorophyll 'a' and 'b' was about 14 and 26 per cent at 300 and 450 g N application, respectively over application of 150 g N/tree/year.

2.1.1 3. Nut and apple characters

Kumar (1985) related the apple characters such as fruit volume, fruit weight and total soluble solids (TSS) of juice with mineral fertilization and found that these characters are differentially influenced by N fertilization. Progressive increase in nitrogen levels did not affect fruit weight but decreased fruit volume and tended to increase TSS of juice at lower levels. The decrease in fruit volume by increasing the fertilizer level from 150 to 450 g/tree/year was 24 per cent and the decrease in TSS was 10 per cent.

Ghosh (1990) reported that N application at medium levels increased the yield through the improvement in the number of nuts as well as individual nut weight in laterite soils of West Bengal. In sandy soils of Bapatla Kumar (1983) found that the effect of N in improving the productivity especially with higher levels of N application will be confined to increasing the number of nuts per plant.

The quality of kernel is decided by its protein and lipid contents. Mahapatra et al. (1972) analysed cashew kernels and reported that kernels of different genotypes varied from 13.13 to 25.03 per cent in their protein content. Ankaiah (1980) reported an increase in protein content of kernels from 22.3 per cent in contrast to 27.4 per cent due to application of fertilizers to cashew trees. Kumar (1985) found about 8 per cent increase in orotein content of cashew kernels over control with application of 450 g N/tree/year.

2.1.1.4. Nitrogen content in leaf

Leaf nutrient content largely depend on age, genotype, soil type and management practices in perennial trees. It can vary in different plant parts and at different growth stages. Calton (1961) reported N content of 1.52 to 1 98 per cent in cashew leaf. Lefebvre (1973) from Medagascar reported 1.73 per cent leaf nitrogen. Hagg et al. (1975) suggested from pot culture studies that 2.4 to 2.58 per cent leaf N to be sufficient range and o.98 to 1.38 per cent leaf N to be deficient range in cashew trees. They further stated that leaf N content was independent of age of the trees. Falade (1978) suggested from a sand culture experiment that 1.24 per cent leaf N was essential for maximum growth. Reddy et al. (1982) reported that application of N from 0 to 1500 g/tree/year increased leaf N content from 1.02 to 1.15 per cent during August and from 1.73 to 1.99 per cent during December. Increasing levels of N application in cashew decreased leaf P content from 0.149 to 0.124 per cent during August and from 0.187 to 0.171 per cent during December while it decreased leaf K content from 0.660 to 0.575 per cent.

Kumar and Nagabhushanam (1981) and Ghosh and Bose (1986) observed higher concentration of nitrogen in leaf and shoot when higher levels of nitrogen was applied to cashew trees. Kumar (1985) found an increase in leaf N from 2.04 to 2.53 per cent by application of 300 g N/tree/year. While leaf P decreased with increase in N application from 150 to 450 g N/tree/year and leaf K content showed a significant decline from 0.99 to 0.90 per cent when N level was raised from 150 to 300 g/tree/year.

Mathew (1990) reported that the extent of variation in leaf N content with respect to the position of leaf and stage of sampling was from 1.24 to 2.76 per cent. The minimum value recorded represented the N content of the older leaves collected during preflushing where as the maximum value corresponded to the N content of basal leaves collected at the time of flowering.

2.1 2. Effect of phosphorus

2 1.2.1. Growth

The role of P in height and vegetative development of cashew in early stages has been well documented.

Nambiar (1983) reported that application of 200 and 400 g P_2O_5/tree/year resulted in linear increase in plant height over no phosphorus application in sandy loam soils of Bapatla. However, the increase was not marked as that of nitrogen application. He also found increase in the number of leader shoots produced per plant due to higher levels of phosphorus. Kumar (1985) observed about 12 per cent increase in height when phosphorus application was increased from 50 to 150 g P_2O_5/tree/ year. Phosphorus application increased tree canopy volume (Sawke et al., 1985). Ghosh (1988) reported that higher levels of phosphorus decreased flowering duration.

Kumar (1985) found that P application increased chlorophyll a, chlorophyll 'b' and total chlorophyll content in cashew leaves Chlorophyll a and b increased by 23 and 20 per cent, respectively, when P application was increased from 50 to 100 g P_2O_5/tree/year.

2 1.2.2. Yield

There are conflicting reports of the effect of P application on yield.

Anon (1974) in sandy loam of Kasaragod, Venkataraman (1979) and Rao et al (1984) in sandy loam soils and Veeraraghavan et al. (1985) in laterite soil of Madakkathara failed to observe any increase in yield due to P application. Sawke et al. (1985) found that the effect of P by itself increasing the yield was limited upto 25 kg/ha level. But when supplemented with N this P influenced the yield upto 75 kg/ha level of application

Kumar (1985) reported that the nut yield in seed progenies increased significantly from 1.49 kg/tree at P application level of 50 g P_2O_5/tree to 2 kg/tree at 150 g P_2O_5/tree/year However, in airlayers the significant yield increase occurred even with 100 g P_2O_5/tree/year. The yield at 50 and 100 g P_2O_5/tree/year were 3 25 to 4.97 kg/tree, respectively. Mathew (1990) recorded an yield increase of 73 per cent when P application was raised from 125 to 500 g P_2O_5/tree/year in Madakkathara laterite soil

2.1.2 3. Nut and apple characters

Nature and extent of response in respect of volume and weight of fruits were identical with that of nitrogen application. However, in the case of total soluble solids, P tended to increase, while N had decreased it as reported by Kumar (1985).

Nambiar (1983) and Ghosh (1988) reported increase in the number of nuts per plant with P application that contributed to higher yield in sandy loam soils. Kumar (1985) noticed that nut volume was decreasing with increasing levels of P application, while it did not cause any variation in nut density. Since there was significant yield increase per tree this also implicate little change in individual nut weight but marked response in number of nuts per plant with higher levels of P application.

P application influenced the protein content of kernels. Kumar (1985) observed an increase of 10.5 per cent protein when P application was increased from 100 to 150 g/tree/year.

2.1.2.4. P content in leaves

Calton (1961) analysed cashew trees grown under unfavourable physical condition of soil wetness and found that thrifty and unthrifty trees contained 0.21 and 0.1 per cent leaf phosphorus content, respectively. Lefebvre (1973) investigating deficiency symptoms in Madagascar observed cashew containing 0.082 per cent leaf phosphorus. Haag et al. (1975) reported adequate and deficient range for leaf phosphorus to be 0 16 to 0.2 and 0 11 to 0.14 per cent, respectively. From sand culture experiments to study the effect of macro and micro nutrients on growth, Falade (1978) reported leaf phosphorus concentration of 0.118 per cent in relation to maximum growth.

Ghosh and Bose (1986) has reported that application of fertilizer will soon be reflected in leaves. Kumar (1985) reported that leaf P content increased with increasing levels of P application and reached the highest value of 0.16 per cent with 150 g P_2O_5/tree/year Mathew (1990) observed leaf P content varying from 0.063 to 0.316 per cent. The maximum P content was observed at 7 and 8 leaves from the inflorescence at flower opening stage. Before flushing the leaf P content was relatively low.

2 1.3. Effect of Potassium

Research results on the response of cashew to the mineral fertilizers have been contradictory.

2.1 3.1. Growth

Nambiar (1983) recorded positive effects of K on cashew, but suggested that higher levels of K may be ineffective. Kumar (1985) observed increase in height of cashew due to K application. But Lefebvre (1973) failed to register any effect of K on growth of cashew Experiments at CPCRI, Kasaragod suggested that K need not be applied to young cashew (Anon , 1979), since the young cashew did not respond to K application

Kumar (1985) reported that application of K increased the total chlorophyll and the constituent components, and the percentage increase of chlorophyll a, b and total chlorophyll at 150 g K_2O/tree/year application were worked out to be 18, 15 and 30 respectively over 50 g K_2O/tree/year

2 1.3 2 Yield

Lefebvre (1973) reported that application of K had significant effect in increasing the production particularly in the presence of N. Ghosh (1988) and Ghosh (1990) recorded significant yield increase with 200 g K_2O/tree/year over no K application The yield increase was obtained due to greater number of nuts/tree. Venkataraman (1979), Mishra et al. (1980), Rao et al (1984) and Veeraraghavan et al (1985) couldn't observe yield increase due to K application in cashew Nambiar (1983) reported that potassium application did not show any significant effect on cashew yield at Bapatla and Vengurla and the effect of K was more pronounced only at Jhagram in Midnapur tracts of West Bengal. Kumar (1985) obtained linear response for K upto 150 g K_2O/tree, the highest level tried by him. Mathew (1990) observed that the increase in yield due to increasing application of K was not marked as that of N and P The yield increased from 5.44 to 7.23 kg/tree with increasing K application from 250 to 1000 g K_2O/tree/year.

2 1.3.3 Nut and apple characters

Potassium appeared to counter balance the negative influences of N and P on the volume and weight of fruit. Application of K increased the fruit weight and decreased the fruit volume and total soluble solids remained unaffected by K application (Kumar, 1985). He also observed that the kernel protein content was unaffected by K application.

2.1 3.4. K content of leaves

Calton (1961) observed leaf potassium content varied from 1.69 per cent in thrifty trees grown in unfavourable physical conditions of soil wetness. Lefebvre (1973) studied the deficiency symptom of cashew in Madagascar and reported that cashew contained 0.88 per cent of leaf potassium. Haag et al. (1975) established that leaf potassium content was a concomitant variable with age of the trees and reported the adequate and deficient range to be 1.11 to 1.29 and 0.20 to 0.26 per cent, respectively. Falade (1978) reported maximum growth at 0.342 per cent leaf potassium concentration. Kumar (1985) reported that application of higher rate of K increased the leaf N content, but decreased the leaf P content. The leaf K content of 0.85 per cent was increased to

0 98 per cent when the K application level was increased from 50 to 150 g/tree/year. Mathew (1990) observed that leaf K content varied from 0 54 to 2.74 per cent. The maximum content was observed in leaves in the stage where the opening of flowers in panicle are completed and the lowest level of K was seen prior to flushing.

2.2. Nutrient interaction

Lefebvre (1973) reported significant interaction of nitrogen and potassium in relation to cashew yield. Application of K had significant effect only in the presence of N and N application increased yield linearly with higher K levels.

Prevel et al. (1974) while studying the N and P deficiency symptoms of cashew in Madagascar 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. N application raised leaf N content while it decreased P content. When P fertilizer was applied, leaf P content increased but those of N and K decreased.

Sawke et al. (1985) observed differential response to N by cashew with varied P and K levels. Trees responded to N upto 125 kg/ha at 50 kg P_2O_5/ha and 100 kg K_2O/ha but the N response was brought down to 75 kg/ha when P and K levels were brought to zero. The response of P was also found raised with different levels of N and was as low as 25 kg/ha with low N levels.

Kumar (1985) found that P and K content of leaf were decreased with increased N application levels. Ghosh and Bose (1986) reported that P and K in combination with higher levels of N increased N, P and K content of leaf and shoot. Mathew (1990) observed higher N application rate decreasing P content of leaf even with higher rates of P application.

A fertilizer trial conducted at Cashew Research Station, Vengurla (Anon., 1981) revealed that without P and K application the response to N application was only upto 75 kg/ha. There was response to P application without K application at all levels of N and there was response to K application at higher levels of N eventhough there was no response due to K application alone. Lefebvre (197_) from experiments conducted on already bearing cashew trees reported that the application of K had a significant effect on increasing production in presence of N. He also observed a response in cashew to applied N especially in presence of K. Nutritional studies in cashew conducted by KADP, Madakkathara (Anon., 1980) reported that the maximum yield of nuts were obtained from plots receiving 500 g N : 500 g P_2O_5 : 250 g K_2O/ tree/year

2.3. Effect of other nutrients

Lefebvre (1973) reported that the best response of NPK fertilizers were masked due to zinc deficiency in the experimental plots He observed that 20 ppm of zinc on oven dry weight basis to be optimum level in cashew.

Response of cashew to the application of lime in increasing yield was noted by Badrinath et al. (1987). In another study Badrinath et al (1989) reported beneficial effects due to application of soil amendments and zinc oxide to cashew grown in coastal soils of Karnataka. Based on root activity studies, Veeraraghavan (1990) revealed that cashew is mainly a surface feeder under laterite soil conditions. Kamal et al. (1982) revealed that different levels of organic matter in the soil significantly affected both tree height and canopy surface area in cashew. He also reported that increased lime application increased the leaf N, P and K content of young cashew leaves but not that of mature leaves.

2.4. Diagnostic technique

Analysis of soil for nutrient levels has been practiced to diagnose nutrient need by plants. Now a days tissue analysis is also widely used as a tool to identify the nutrient needs of plant Soil and tissue tests for predicting olive yields in Turkey were examined by Fox et al. (1964). In many surveys primary positive correlation between soil nutrients and leaf nutrients were observed.

Leaf nutrient levels were found to be better correlated with yield than soil nutrient levels (Ollagnier and Giller, 1965). But in banana both foliar and soil analysis were necessary for determining fertilizer requirements (Champion, 1966).

Leaf being the major metabolic organ, is an ideal choice for sampling to ascertain fertilizer requirements. A standard sampling procedure should be employed to eliminate all the factors that cause variation in leaf nutrient levels. Several workers tried to standardise leaf sampling for NPK analysis Kumar et al. (1982) opined that 3 composite samples consisting of 5 trees/sample taken before fruiting or 6 composite samples consisting of 3 trees/sample taken after fruiting were sufficient. Mathew (1990) standardised the leaf position for sampling. The last fully matured leaf which was not having an inflorescence in leaf axil was found to be the best for foliar diagnosis in relation to N and K. As regards the stage of sampling, the stage after the opening of all the flowers of a panicle was recommended as the best season for diagnostic purpose of K and for N, preflushing sample was the best.

2.5. Climate and leaf nutrient content

Most important climatic factors that influence the chemical concentration of leaf are rainfall and sunshine. According to Yaacob et al. (1985) N and K contents of cashew leaves were higher during dry months than in wet months. Okada (1987) found that the N content of citrus leaves increased with soil temperature.

Reddy *et al.* (1982) studying the growth in relation to cashew nutrition reported that application of N from 0 g to 1500 g N/ tree/year increased leaf N from 1.02 to 1.15 per cent during August and from 1.73 to 1.99 per cent during December. According to Ghosh and Bose (1986) percentage of K in leaf sample taken in different months varied between 0.83 to 1.19 per cent

2.6. Critical level of nutrients

Critical level of nutrient is defined as the concentration of the element in the leaf above which a yield response from the element in the fertilizer is likely to occur (Prevot and Ollagnier, 1957). Kumar and Sreedharan (1986) suggested critical levels for N and P at 2.09 and 0.14 per cent, respectively. They estimated the critical level of 1.96 to 2.53 per cent in the case of N and 0.14 to 0.17 per cent for P but failed to work out the critical concentration for K in view of linear response to K application.

2.7. Optimum dose of fertilizer

Optimum doses of fertilizers are applied for maximum net return. In an experiment conducted for 6 years, it was observed that 666 g N, 266 g P_2O_5 and 533 g K_2O/tree/year were optimum doses for the highest net return of Rs.7.40/tree/year (Anon , 1976). Results of fertilizer trial conducted at Madakkathara, Thrissur recommended optimum dose of 250 g N, 125 g P_2O_5 and 125 g K_2O/tree/year for cashew in laterite soil (KAU, 1989). Kumar (1985) observed that optimum doses of N and P in cashew were 430 and 130 g/tree/year and expected yields were 4.71 and 4.5 kg/tree. The optimum dose for K was not worked out due to the linear response to K application.

2.8. Effect of nutrient application on nutrient removal and soil nutrient levels

According to Mahapatra et al. (1973) annual nutrient removal by a mature cashew tree was 2.84 kg N, 0.752 kg P_2O_5 and 1 265 kg K_2O.

Venugopal and Abdul Khader (1989) suggested a deep well drained laterite soil with high water holding capacity and organic matter content as an ideal soil type for cashew. Based on root activity studies using ^{32}P, Veeraraghavan (1990) concluded that cashew forged mainly from 2 m radius area. Kumar (1985) reported that N application of 450 g N/tree/year increased soil N from 0.15 to 0.17 per cent while it reduced soil P from 0.11 to 0.07 per cent and it increased soil K from 248 ppm to 290 ppm. P application increased soil N from 0.15 per cent to 0.16. When P was increased from 50 to 150 g P_2O_5/tree/year soil K was increased from 144 ppm to 372 ppm while it failed to bring about any effect on soil P. Kumar also reported that K application increased soil N and soil K while when K was applied at 100 g K_2O /tree/year the soil P content was decreased.

Materials and Methods

3. MATERIALS AND METHODS

An experiment on the growth and yield of cashew in relation to foliar and soil nutrient levels was carried out for two years during 1990-91 and 1991-1992. Cashew trees of NPK fertilizer trial of Keralu Agricultural Development Project (College of Horticulture) at Madakkathara, Thrissur were made use for this study. The field trial was established in 1979 with newly planted cashew seedlings of variety BLA-39-4 and still continuing. The details on experimentation are as follows.

3.1. Location

The experimental site is located at 10°31' N latitude and 76°13' E longitude at an altitude of 22.25 m from MSL.

3.2. Climate

The area enjoys typical humid tropical climate. The data on rainfall, maximum and minimum temperature for 1990-'91 and 1991-'92 are given in Fig. 1.

3.3. Soil

The soil of the experimental site is laterite. The textural class of the same is sandy clay loam. The average physico-chemical properties of the soil are given in Table 1.

FIG 1

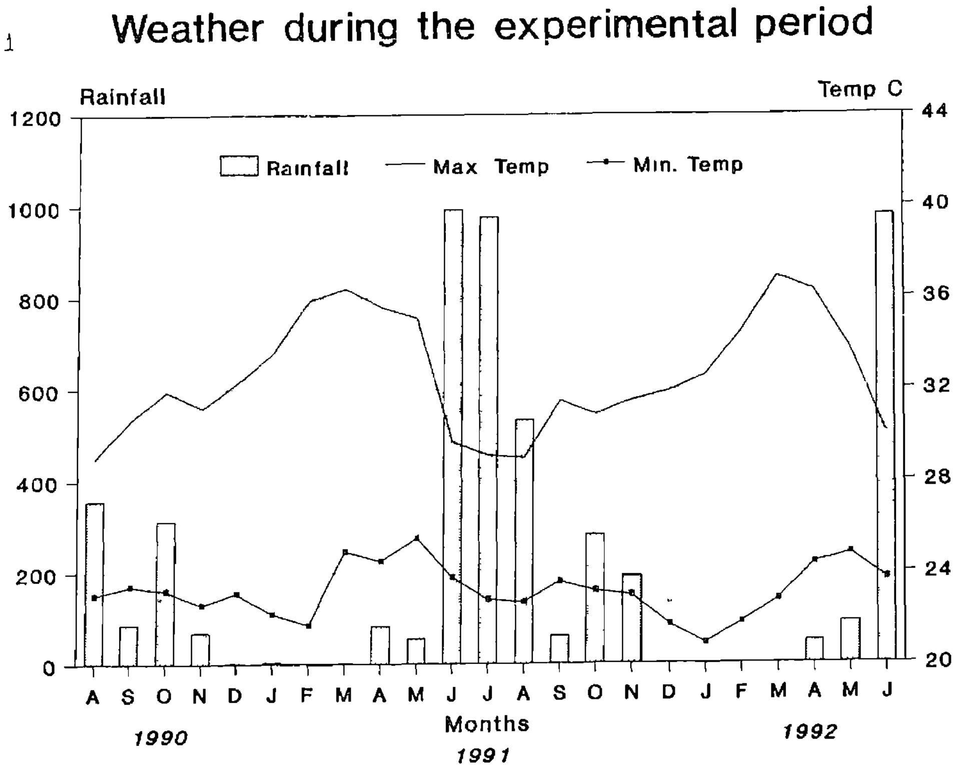
Weather during the experimental period
Rainfall
Temp C
Rainfall
Max Temp
Min. Temp
1200
1000
800
600
400
200
0
44
40
36
32
28
24
20
A S O N D J F M A M J J A S O N D J F M A M J
Months
1990
1991
1992

Table 1. The physical and chemical properties of soil in the experimental field

Sand	- 77.5 per cent	(Piper, 1942)
Silt	- 5 per cent	
Clay	- 17.5 per cent	
pH	- 4.8	
Total nitrogen	- 0.179 per cent (Sankaran, 1966)	
Available phosphorus	- 17.8 ppm (Jackson, 1958)	
Available potassium	- 150 ppm (Jackson, 1958)	

3.4. Experimental details

3.4 1. Treatments

The treatments consisted of N, P and K at 3 levels of each and an absolute control. Absolute control treatment was added in the ongoing experiment through unfertilized dummy plots.

The total treatments are as follows.

Absolute control : 1 (without NPK application)

Levels of N : 3 (250, 500, 1000 g N/tree/year)

Levels of P : 3 (125, 250, 500 g P_2O_5/tree/year)

Levels of K · 3 (250, 500, 1000 g K_2O/tree/year)

3 4.2. Design and lay out

Design : 3^3 + 1 Factorial RBD

Replication : 2

Number of plants/plot : 2

Spacing . 8 x 8 m^2

Total number of plots · 28

The plan of lay out is shown in Fig. 2.

3.4.3. Application of treatments

N, P and K were applied in the form of urea, super phosphate and muriate of potash in both the years. The fertilizers were applied in accordance with treatments in single dose during tail end of south west monsoon in the basin taken at a radius of 2 m from the trunk. No organic manure was applied to the experimental plots. The cultural operations and plant protection measures were carried out uniformly irrespective of the fertilizer treatments.

3.5. Observations

The following observations were made from whole plant or by drawing samples or by computation. The samples were collected separately from 112 plants ie. 2 plants/plot x 28 treatments x 2 replications.

3.5.1. Height of the plant

Plant height was recorded only in 1991-'92. The height was measured from ground level to the point where maximum growth was observed.

Fig. 2. Lay out of the field experiment

	123	122	232	123	323	231	312	132	131
000	321	113	133	213	313	111	221	333	121
	212	233	211	322	222	311	331	332	112
	231	321	311	322	211	332	233	323	232
000	112	132	133	221	222	113	111	123	313
	213	312	122	131	333	331	212	121	223

* Experimental plants

3.5.2. Number of flushes/unit area

This was determined in both years by using 1 m^2 quadrat from five locations around the tree canopy.

3.5.3. Number of panicles/unit area

The observation was made by adopting the same technique in 3.5.2.

3.5.4. Nut yield

Ripened nuts were collected either from the tree or fallen nuts from the basins two times daily. The collection started from the day of observing the first ripened apple and nut till the last apple and nut ripened in the experimental plot. The nuts were cleaned, dried and the weight expressed in kg/tree.

3.5.5. Test weight of nuts

Hundred nuts were selected randomly from each treatment and weight was expressed in grams.

3.5.6. Nut volume

The nuts used for taking test weight were used for determining the nut volume by water displacement method and expressed as cubic centimetre per nut.

3 5 7 Protein content of kernels

Nitrogen content of raw kernels was estimated and multiplied by 6.25. The product was expressed as per cent protein on dry weight basis of kernel.

3 5 8 Fruit weight

Fifty uniformly matured cashew apples were collected from each tree and the mean weight was recorded and expressed in gram/fruit.

3 5 9. Fruit volume

Volume of the same fruits were determined by water displacement method and expressed as cc/fruit.

3 5.10 Total soluble soild of juice

Fruit juice was extracted from 20 randomly selected ripened fruits and TSS was recorded immediately using refractometer (Erma Optical Instruments, Japan).

3.5.11. Analysis of leaf sample

3 5.11.1. Collection of sample

The first pair of leaves from the inflorescence was collected (Mathew, 1990) for analysis of leaf nutrient content and chlorophyll They were collected from 20 shoots drawn randomly from all sides of the exposed region of the canopy of each tree.

The stages and date of sampling is given as follows.

Stage	Date of sampling	
50 per cent flushing	1991-'92	6-11-1991
50 per cent flowering	1990-'91	28-11-'90
	1991-'92	30-12-'91
50 per cent fruiting	1990-'91	24-12-'90
	1991-'92	6-2-'92

3.5.11.2. Chlorophyll content

Chlorophyll 'a' and chlorophyll 'b' were estimated from leaf samples collected at 50 per cent flushing in 1991-'92 only by the method described in AOAC (1970) and expressed in mg/g leaf tissue. Total chlorophyll was computed using the standard formula.

3.5.11.3. Leaf nutrient content

The total nitrogen content of the leaf 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 nitric acid, perchloric acid and sulphuric acid (10:4.1) The phosphorus content was determined colorimetrically by vanadomolybdophosphoric yellow colour method in nitric acid medium and potassium was determined using a flame photometer (Jackson, 1958).

3 5.12 Analysis of soil sample

Soil samples of depth 0 to 15 cm were collected from different sides of the basin of the plant within a radius of 2 m Soil sampling was done on 22-3-1991 ie. after harvesting in 1990-'91 and on 15-9-'91 ie. one month after fertilizer application in 1991-'92.

The kjeldahl digestion and distillation method using sulphuric acid - salicylic acid mixture was made use of for the determination of total nitrogen (Sankaram, 1966). Phosphorus was determined colorimetrically using chlorostannous reduced molybdo-phosphoric blue colour method in hydrochloric acid system (Jackson, 1958) The available potassium was extracted with 1N neutral ammonium acetate and potassium content was determined flame photometrically (Jackson, 1958).

3.5 13. Critical concentration of nutrients

Critical concentrations of N, P and K in leaf were worked out by fitting a quadratic function between levels of fertilizer and leaf nutrient concentration. From the second order regression equation the critical level of nutrients were calculated from the formula

$$y = a + bx + cx^2$$ where

y = critical leaf nutrient content

x = level of fertilizer

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y = critical leaf nutrient content

x = level of fertilizer

3.5 14. Production function and optimum dose

Production function and economic optimum dose of fertilizer was calculated by fitting a second order regression equation. The economic optimum dose was worked out from the equation

$$x_{Econ.opt} = \frac{q - p.b}{2\ p.c}$$

where $x_{Econ.opt}$ - Economic optimum dose of fertilizer

q - input price/kg

p - output price/kg

3 5 15 Economics

Economics of cultivation was worked out taking into account the cost of all the cultural operations, fertilizer application, plant protection and harvest.

3 5 16 Statistical analysis

The data recorded for different parameters were compiled and tabulated and were subjected to analysis of variance technique (Panse and Sukhatme, 1985).

Independent contrasts were worked out between absolute control and different levels of nutrients. The influence of elemental composition of leaves at various stages on yield and other parameters were studied by working out correlation coefficients (Snedecor and Cochran. 1967). Possible relationship between soil and foliar nutrients were also examined similarly

Results

4. RESULTS

The results of the experiment on growth and yield of cashew in relation to foliar and soil nutrient levels conducted during 1990-'91 and 1991-'92 are presented in this chapter. The main effects of treatments alone are presented in cases where significant and consistent interactions were not obtained.

4.1. Effect on growth

4 1.1. Height of tree

Effect of N

N application effected a significant increase in the height of tree by 1.2 m over no nitrogen application (Table 2a). Even application of lowest dose (N_1 = 250 g N/tree/year) resulted in significant height increase (Appendix I).

The effect of different levels of N in the height of trees showed significant variation. However, a linear increase was not observed with increase of N rate. When N rate increased from N_1 level to 500 g N/tree/year (N_2) the height decreased and at the highest dose of 1000 g N/tree/year (N_3) the height increased (Table 2b).

Effect of P

Phosphorus application significantly increased the height of tree by 31 per cent over no P application (Table 2a) and the

Table 2. Effect of fertilizer management on height (m) of tree

	1991-92
a. Control vs treatment	
Control	4.8
Effect due to nitrogen	6.0**
Effect due to phosphorus	6.3**
Effect due to potassium	6.4**
b N levels	
N_1	6.03
N_2	5.43
N_3	6.5
CD (0.05)	0.124
c. P levels	
P_1	5.92
P_2	6.11
P_3	5.94
CD (0 05)	0.124
d K levels	
K_1	5.89
K_2	6.07
K_3	6.01
CD (0.05)	NS

** Denotes significant difference with control at 1 per cent level

increase was noticed from the lowest dose (P_1) of 125 g P_2O_5 per tree per year (Appendix 1)

The comparison of different levels of P showed significant effect on the height of tree (Table 2c). Increase in the level from P_1 to P_2 (250 g P_2O_5 per tree per year) resulted in significant increase in height. However, further increase in the level to P_3 level (500 g P_2O_5 per tree per year) effected the similar response as that of the lowest level of P (Table 2c).

Effect of K

Similar to N and P, application of K also produced significant effect on the height of tree over control (Table 2a) from lowest level of K (Appendix 1). However, levels of K failed to bring about any significant variation in the height of tree (Table 2d).

Interaction effect of nutrients

Significant interaction between the nutrients was observed. All the interactions i.e., NP, NK, PK and NPK were found to be significant (Table 3). At the lowest levels of N, there was no response for the highest levels of P and K, but only for their lowest levels in increasing the height. However, when N application was increased to its highest level the response was modified and the maximum height was observed at N_3 P_2 K_3 combination.

Table 3. Interactions of nutrients on height of the tree

N x P	N_1	N_2	N_3	Total
P_1	6.38	5.03	6.35	5.92
P_2	5.88	5.71	6.73	6.11
P_3	5.85	5.55	6.43	5.94
Total	6.03	5.43	6.5	

N x K	N_1	N_2	N_3	Total
K_1	6.25	5 13	6.3	5.89
K_2	6.01	5 81	6.4	6.07
K_3	5.85	5.35	6.82	6.01

P x K	P_1	P_2	P_3
K_1	5.98	5 88	5.81
K_2	6.05	6 13	6.05
K_3	5.73	6.31	5 96

N x P x K

	N_1			N_2			N_3		
	P_1	P_2	P_3	P_1	P_2	P_3	P_1	P_2	P_3
K_1	6.75	6.4	5 6	5.05	4.7	5.65	6.15	6 55	6.2
K_2	6.35	5.4	6.3	5.6	6.35	5.5	6.2	6.65	6.35
K_3	6.05	5.85	6 65	4.45	6.1	5.5	6.7	7.0	6.75

4 1 2. Number of flushes per m^2

Effect of N

It can be seen from the Table 4a that the effect of nitrogen in number of flushes produced was significant in both the years. The increase in flushes was 117 and 67 per cent during 1990-91 and 1991-92, respectively, over control. Further analysis (Appendix 1) showed that the significant difference with control was observed from N_2 level in 1990-91, however the difference was significant even with the lowest level in 1991-92.

Significant increase in the number of flushes was observed when the level of nitrogen was increased from 250 to 500 g per plant (Table 4b) and the mean increase worked out to 31.5 per cent. Further increase in the level of nitrogen did not have any significant effect on flushes.

Effect of P

The data on the effect of phosphorus application on production of flushes (Table 4a) showed that mean effect for two years accounted for an increase in 88 per cent of flushes over control. In 1990-91 the significant difference with control was developed from P_2 level (Appendix 1), however, the effect observed in 1991-92 was not significant.

Table 4 Effect of fertilizer management on number of flushes/m^2

	1990-91	1991-92	Mean
a <u>Control vs treatment</u>			
Control	6.0	6.0	6.0
Effect due to nitrogen	13.0**	10.0**	11.5
Effect due to phosphorus	12.8**	9 9	11.3
Effect due to potassium	8.8	8.7**	8.8
b <u>N levels</u>			
N_1	12.1	10.1	11.1
N_2	15.6	13.6	14.6
N_3	16.3	12.8	14.5
CD (0.05)	1.40	1.33	
c <u>P levels</u>			
P_1	13.1	11.3	12.2
P_2	14.9	12.4	13.6
P_3	16.3	12.8	14.5
CD (0.05)	1.40	NS	
d. <u>K levels</u>			
K_1	14.1	11.4	12.8
K_2	14.8	12 1	13.5
K_3	15.1	13.0	14.1
CD (0 05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Observations on the effect of graded levels of P on flushes (Table 4c) showed that the crop registered a linear increase with increasing levels in both the years. The significant increases when the level was raised from P_1 to P_2 and P_2 to P_3 were worked out to be 14 and 9 per cent, respectively during 1990-91 The result was not significant in 1991-92.

Effect of K

Potassium application increased the flushes in both the years The increase was significant only during 1991-92 with an increase of 2.8 flushes/m^2 over control (Table 4a) and this response was significant even with the lowest level of potash application (Appendix I).

No significant difference was observed with increasing levels of K (Table 4d), however the response was increasing linearly

Relationship between leaf and soil nutrients and number of flushes

Correlation studies revealed that the relationship between leaf N content (x) and number of flushes (y) was significant ($R^2 = 0.579$), the regression equation being $y = 1.78 + 0.022x^*$. While leaf P and K content at all the three stages and leaf N at flowering and fruiting were related nonsignificantly with number of flushes (Appendix 14). However, a positive relationship observed between leaf P at fruiting (x) and number of flushes (y) during 1990-91 was significant, the regression equation $y = 0.11 + 0\ 0003x^*$ ($R^2 = 0.568$)

A positive nonsignificant relationship was observed between soil nutrients and number of flushes in general But in cases of soil N, soil P and number of flushes in 1991-92, a negative correlation was observed (Appendix 15)

4.2. Effect on leaf nutrient composition

4 2 1 Leaf nutrient composition at flushing

4.2.1 1 Leaf N content at flushing

N, P or K application had significant effect on leaf N content at flushing over control. However, leaf N content was increased by treatments. The levels of N, P or K also did not bring about any significant response on leaf N content at flushing (Table 5)

4.2.1.2 Leaf P content at flushing

Effect of N

The phosphorus content of leaf at flushing was significantly influenced by nitrogen application and the increase was about 13 per cent over control (Table 6a). The significant difference was manifested even with the application of lowest level (Appendix 2)

Different levels of N also affected the leaf P content at flushing The P content of 0 079 per cent at 250 g N/tree/year application reached a significantly higher value of 0 087 per cent when N level was increased to 500 g of N/tree/year However,

Table 5. Effect of fertilizer management on leaf N content (%) at flushing

a. Control vs treatment	1991-92
Control	1.89
Effect due to nitrogen	2.04**
Effect due to phosphorus	1.99**
Effect due to potassium	1.93**
b. N levels	
N_1	2.01
N_2	2.13
N_3	2.14
CD (0.05)	NS
c P levels	
P_1	2.06
P_2	2.09
P_3	2.13
CD (0.05)	NS
d. K levels	
K_1	2.06
K_2	2.11
K_3	2.12
CD (0.05)	NS

** Denotes significant difference with control at 1 per cent level

Table 6. Effect of fertilizer management on leaf P content (%) at flushing

a. Control vs treatment	1991-92
Control	0.070
Effect due to nitrogen	0.079**
Effect due to phosphorus	0.076**
Effect due to potassium	0.072**
b. N levels	
N_1	0.079
N_2	0.087
N_3	0.089
CD (0.05)	0.0045
c. P levels	
P_1	0.079
P_2	0.087
P_3	0.089
CD (0.05)	0.0045
d. K levels	
K_1	0.083
K_2	0.086
K_3	0.086
CD (0.05)	NS

** Denotes significant difference with control at 1 per cent level

further increase to 1000 g N/tree/year did not bring about a significant difference (Table 6b).

Effect of P

P application also significantly increased the leaf P content at flushing by about 8 5 per cent (Table 6a) and even with the lowest level was sufficient to cause significant increase (Appendix 2).

The comparison of different P application rates showed that application of 250 g of P_2O_5/tree/year effected an increase of leaf P content by 10 per cent over 125 of P_2O_5/tree/year. However, further increase did not cause much variation (Table 6c).

Effect of K

K application significantly improved the P status of leaf at flushing (Table 6a). Effect due to all the levels was at par (Table 6d).

4.2.1.3. Leaf K content at flushing

Effect of N

N application caused an increase of 16 per cent over control (Table 7a).

Significant difference between levels of N was observed when the nitrogen level was increased from 500 g N/tree/year to the highest level of 1000 g N/tree/year (Table 7b).

Table 7. Effect of fertilizer management on leaf K content (%) at flushing

	1991-92
a **Control vs treatment**	
Control	0.51
Effect due to nitrogen	0.59**
Effect due to phosphorus	0.52**
Effect due to potassium	0.57**
b. **N levels**	
N_1	0.62
N_2	0.62
N_3	0.73
CD (0.05)	0.069
c. **P levels**	
P_1	0.65
P_2	0.63
P_3	0.69
CD (0.05)	NS
d. **K levels**	
K_1	0.58
K_2	0.65
K_3	0.74
CD (0.05)	0.069

** Denotes significant difference with control 1 per cent level

Effect of P

P application caused an increase of 2 per cent in leaf K content at flushing which was found to be significant (Table 7a). But the levels of P produced no significant variation on leaf K content at flushing (Table 7c).

Effect of K

The significant increase by 12 per cent was observed due to K application (Table 7a).

The levels of K caused a significant variation. The leaf K content increased with every increment of K application upto the highest level of 1000 g K_2O/tree/year (Table 7d).

Relationship between leaf and soil nutrients at flushing

A positive nonsignificant relationship was seen between leaf N, P and K content at flushing and soil nutrients, N, P and K (Appendix 14).

4.2.1 4. Chlorophyll 'a' of leaves

Effect of N, P and K

Application of nitrogen or phosphorus or potassium did not bring about any significant effect on chlorophyll 'a' of leaves over control. Hence the levels of N, P and K also did not differ significantly (Table 8).

Table 8. Effect of fertilizer management on the content of chlorophyll 'a' (mg/g tissue) of leaves

	1991-92
a <u>Control vs treatment</u>	
Control	0.39
Effect due to nitrogen	0.56
Effect due to phosphorus	0.50
Effect due to potassium	0.48
b <u>N levels</u>	
N_1	0.56
N_2	0 65
N_3	0.68
CD (0.05)	NS
c. <u>P levels</u>	
P_1	0.56
P_2	0.65
P_3	0.68
CD (0.05)	NS
d. <u>K levels</u>	
K_1	0.61
K_2	0.66
K_3	0.63
CD (0.05)	NS

4.2.1.5. Chlorophyll 'b' of leaves

Effect of N

Table 9a showed that there was significant increase of 60 per cent in chlorophyll 'b' of leaves over control which was observed from application of 500 g N/tree/year (Appendix 4).

Comparison of levels of N revealed that there was significant increase in chlorophyll 'b' of leaves when the N level was increased from 250 g to 500 g N/tree/year. But further increase in rate failed to produce a significant increase (Table 9b).

Effect of P

Phosphorus application resulted in a similar increase to that of N (Table 9a). But this significant effect was noticed only at the highest level of P application (Appendix 4).

Comparison of different levels of P did not bring about any significant difference in chlorophyll 'b' of leaves (Table 9c).

Effect of K

The mean increase in chlorophyll 'b' due to K application was 0.11 mg/g tissue of leaves over control (Table 9a). Varying levels of K showed similar responses in causing variation in chlorophyll 'b' of leaves as that of P (Table 9d).

Table 9. Effect of fertilizer management on the content of chlorophyll 'b' (mg/g tissue) of leaves

a. Control vs treatment	1991-92
Control	0.48
Effect due to nitrogen	0.77**
Effect due to phosphorus	0.77*
Effect due to potassium	0.59*
b. N levels	
N_1	0.74
N_2	0.87
N_3	0.96
CD (0.05)	0.115
c. P levels	
P_1	0.81
P_2	0.85
P_3	0.91
CD (0.05)	NS
d. K levels	
K_1	0.83
K_2	0.84
K_3	0.89
CD (0.05)	NS

** Denotes significant difference with control at 1 per cent level

4.2.1.6. Total chlorophyll of leaves

Effect of N

It was evident from Table 10a that there was significant increase of 0.68 mg/g tissue in total chlorophyll over control due to N application. This effect was exercised from the application of 250 g N/tree /year (Appendix 4).

Among the levels of N, no significant difference was noticed when the N level was increased from 250 g to 500 g N/tree/year, but further increase to 1000 g N/tree/year produced significant effect (Table 10b).

Effect of P

Significant increase in total chlorophyll was 70 per cent over control due to P application (Table 10a) and it was observed from the lowest level of 125 g P_2O_5/tree/year (Appendix 4). Varying levels of P did not produce any significant effect on total chlorophyll of leaves (Table 10c).

Effect of K

Similar to N and P, K application also produced significant increase over control (Table 10a) which was effected from the lowest level (Appendix 4). There was no significant difference between levels of K (Table 10d).

Table 10. Effect of fertilizer management on the content total chlorophyll (mg/g tissue) of leaves

		1991-92
a	Control vs treatment	
	Control	0.76
	Effect due to nitrogen	1.44**
	Effect due to phosphorus	1.29*
	Effect due to potassium	1.14*
b	N levels	
	N_1	1.28
	N_2	1.40
	N_3	1.67
	CD (0.05)	0.226
c.	P levels	
	P_1	1.38
	P_2	1.44
	P_3	1.52
	CD (0.05)	NS
d.	K levels	
	K_1	1.47
	K_2	1.37
	K_3	1.5
	CD (0.05)	NS

** Denotes significant difference with control at 1 per cent level

Relationship between leaf and soil nutrient contents and chlorophyll

Eventhough, there was positive correlation between leaf N, P and K at flushing, flowering and fruiting, and total chlorophyll and its constituent components, it was not significant (Appendix 14). But leaf P at fruiting (x) with chlorophyll 'a'(y) was found to be significant (R^2 = 0.5) in 1991-92, the regression equation being $y = 0.11 + 0.057x^*$.

The relationship between soil nutrients and total chlorophyll and its components was positive, though, not significant, except available K content of soil and chlorophyll 'a' where a negative relationship was observed (Appendix 15).

4.2.2. Leaf nutrient composition at flowering

4 2.2 1. Leaf nitrogen content at flowering

Effect of N

The data presented in Table 11a showed that there was no significant effect due to N application on leaf N content at flowering in 1990-91. But in 1991-92 there was significant increase by 18 per cent over control. The application of 250 g N/tree/year was effective in producing significant increase in 1991-92 (Appendix 5).

Among the different levels of N, increasing the N application from 250 g to 500 g N/tree/year produced a significant increase

Table 11. Effect of fertilizer management on leaf nitrogen content (%) at flowering

a. Control vs treatment	1990-91	1991-92	Mean
Control	2.2	2.2	2.2
Effect due to nitrogen	2.4	2.6**	2.5
Effect due to phosphorus	2 3	2.4**	2.4
Effect due to potassium	2.4	2.4**	2.4
b. N levels			
N_1	2.34	2.46	2.4
N_2	2.62	2.84	2.7
N_3	2.55	3.02	2.8
CD (0.05)	0.172	NS	
c. P levels			
P_1	2.40	2.67	2.5
P_2	2.56	2.81	2.7
P_3	2.55	2.85	2.7
CD (0.05)	NS	NS	
d. K levels			
K_1	2.38	2.72	2.6
K_2	2.59	2.81	2.7
K_3	2.54	2.81	2.7
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

by 13 per cent and further increase in N application to 1000 g N/tree/year failed to register any increase in leaf N content at flowering in 1990-91 (Table 11b), while in 1991-92 there was no significant influence on the leaf N content by the graded doses of fertilizers. However, there was a linear increase from 2.46 per cent to 3 02 per cent, respectively from N_1 to N_3 level.

Effect of P

Similar to nitrogen, phosphorus application was also effective in producing significant effect on leaf N content at flowering in 1991-92. The leaf N content increased by 9 per cent (Table 11a) in 1991-92 over control and even the lowest level of 125 g P_2O_5/tree/year produced the significant effect (Appendix 5).

Comparison of levels of P showed that eventhough there was linear increase in leaf N content due to P application, it was not significant (Table 11c).

Effect of K

There was significant increase in leaf N content at flowering due to K application in 1991-92 (Table 11a). The leaf N content increased from 2.2 per cent at no K application to 2.4 per cent with K application. Application of 250 g K_2O/tree/year (K_1) produced this significant effect (Appendix 5).

There was no significant effect between levels of K applied on N content of leaf at flowering (Table 11d). The leaf N was maximum at flowering in both the years (Fig. 3).

4.2.2.2. Leaf P content at flowering

Effect of N

There was significant effect on leaf P content due to N application at flowering in both the years (Table 12a). The mean P content was increased by 88 per cent by N application. The significant effect over control was observed even from the lowest level of N application in both the years (Appendix 5).

The different levels showed significant difference in leaf P content at flowering (Table 12b). The mean increase for two years was 6 per cent and 18 per cent with 500 g and 1000 g N/tree/year, respectively over the lowest rate.

Effect of P

The data in Table 12a clearly showed the significant effect of P application on leaf P content at flowering in both the years. The mean increase for two years was about 8 per cent over no P application. In both the years the significant effect was noticed from the lowest level of 125 g P_2O_5/tree/year (Appendix 5).

Comparing the levels of P, the significant effect was noticed only In 1990-91 (Table 12c) and there was increase in leaf P

FIG 3 RELATIONSHIP BETWEEN LEAF N CONTENT AND STAGES OF GROWTH

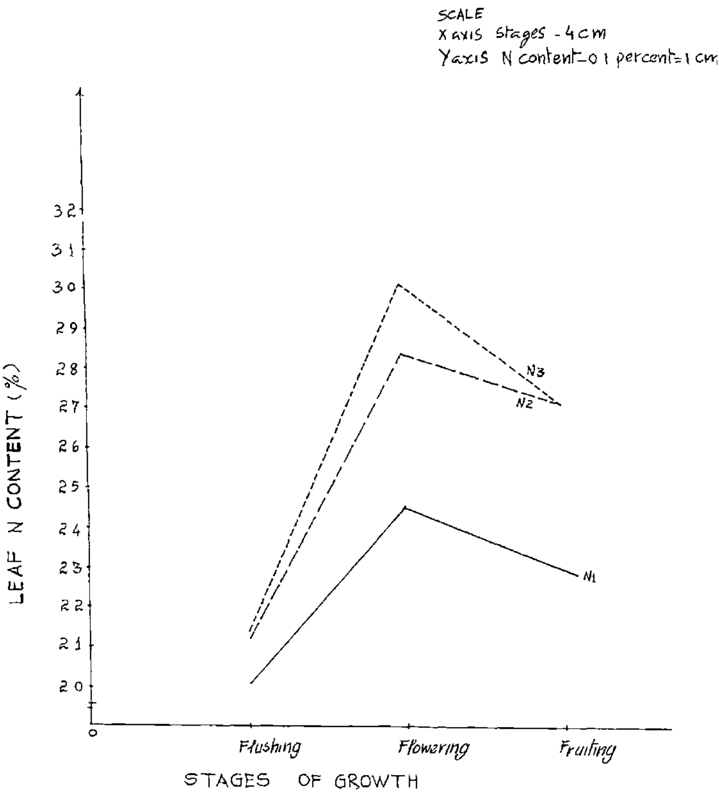
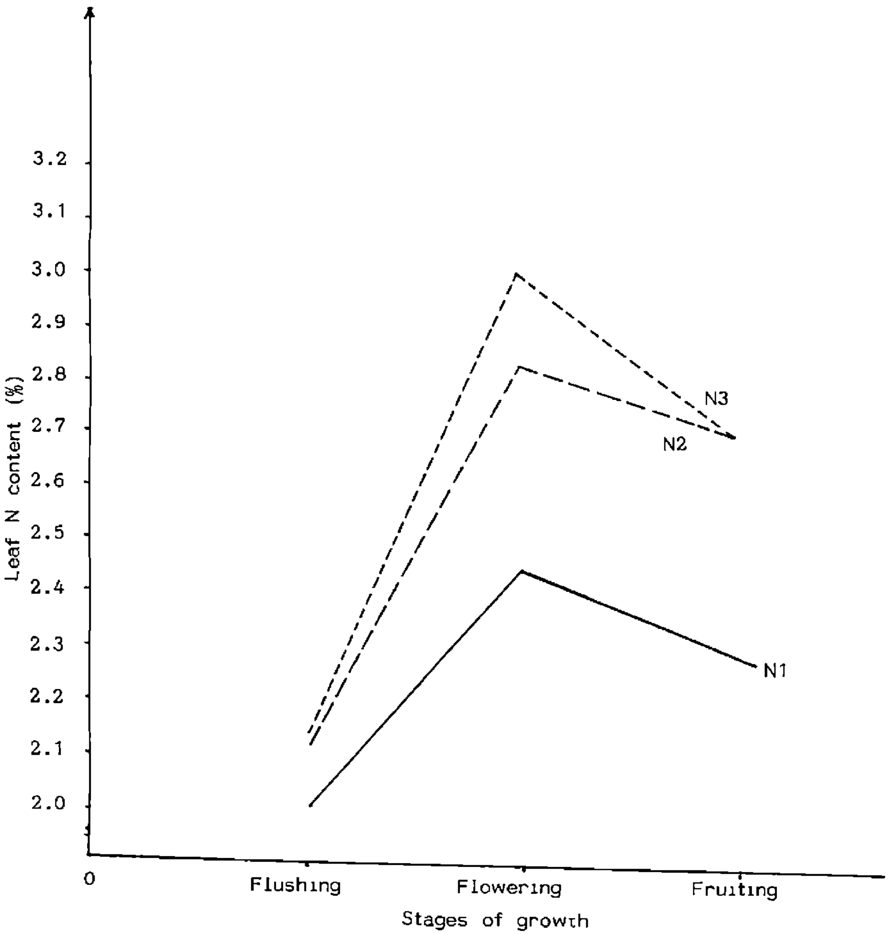


Fig. 3. Relationship between leaf N content and stages of growth

Scale
X axis · Stages - 4 cm
Y axis : N content - 0 1 per cent = 1 cm



content of 8 per cent with increasing level from 125 g to 250 g P_2O_5/tree/year. The leaf P content at P_2 was on par with P_3 In 1991-92, eventhough there was no significant effect, a linear progressive increase was noticed with increasing levels of P

Effect of K

No response was obtained with the application of K in both the years (Table 12a). Consequently the levels of K did not influence the leaf P content at flowering in both the years (Table 12d).

4 2 2.3. Leaf K content at flowering

Effect of N

Application of N together with varying levels of N resulted in significant increase of leaf K content at flowering stage (Table 13a) The K content increased from 0.9 per cent in control to 1.23 per cent in 1990-91 and from 0.5 per cent to 1.06 per cent in 1991-92, respectively due to N application. The response was brought about by the lowest dose in 1990-91 but with N_2 level in 1991-92 (Appendix 6).

Eventhough there was a linear increase in leaf K content at flowering due to graded levels of N, there was no significant effect in 1990-91. But in 1991-92 there was significant increase due to application of levels of N. The increase in leaf K content

Table 13. Effect of fertilizer management on leaf K content (%) at flowering

	1990-91	1991-92	Mean
a <u>Control vs treatment</u>			
Control	0.9	0.5	0.7
Effect due to nitrogen	1.23**	1.01**	1.12
Effect due to phosphorus	1.20**	0.98**	1.09
Effect due to potassium	1.26**	1.06**	1.16
b <u>N levels</u>			
N_1	1 25	1.19	1.22
N_2	1.33	1.29	1.31
N_3	1.34	1.48	1.41
CD (0.05)	NS	0.127	
c <u>P levels</u>			
P_1	1.27	1.25	1.26
P_2	1.32	1.34	1.33
P_3	1.32	1.37	1.35
CD (0.05)	NS	NS	
d. <u>K levels</u>			
K_1	1.27	1.26	1.25
K_2	1.27	1.27	1.27
K_3	1.38	1.43	1.41
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

was more pronounced at 1000 g N/tree/year compared to 500 g N/tree/year. There was an increase of 15 per cent due to increasing the level of N from 500 g to 1000 g N/tree/year (Table 13b).

Effect of P

It can be observed from Table 13a that P application increased the leaf K content at flowering by 33 per cent and 96 per cent in 1990-91 and 1991-92, respectively over control. Eventhough this significant effect can be noticed from 125 g P_2O_5 per tree per year in 1990-91, application of 250 g P_2O_5 per tree per year was significant in increasing leaf K content at flowering in 1991-92 (Appendix 6).

The increasing levels of P did not bring about a significant difference on leaf K content at flowering in both the years (Table 13c).

Effect of K

Significant positive response was observed due to application of potassium over no application of K in increasing the leaf K content at flowering. The increase was accounted to be 40 per cent and 112 per cent in 1990-91 and 1991-92, respectively (Table 13a). In 1990-91 the response was observed even with the lowest level, while in 1991-92 500 g K_2O per tree per year was required to produce the same effect (Appendix 6).

The level of K failed to record any significant difference (Table 13d). An increase of leaf K content was noticed only from K_2 level onwards in 1990-91, while there was 13 per cent increase in leaf K content with increased level of K from 250 g to 1000 g K_2O per tree per year in 1991-92. Leaf K was recorded a maximum value at flowering (Fig. 5) in both the years.

The relationship between leaf nutrients at flowering and soil nutrients

The correlation studies between leaf nutrient at flowering and soil nutrients revealed positive, though, not significant relation in general (Appendix 14). However, negative correlation was observed in case of leaf P and K and soil N content in 1990-'91 and K content in soil and leaf K in 1991-'92.

4 2.3. Leaf nutrient composition at fruiting

4.2.3.1 Leaf N content at fruiting

Effect of N

It can be seen from Table 14a that N application had significant effect on leaf N content at fruiting in 1991-92. The increase in leaf N content due to N application was 24 per cent in 1991-92. Further analysis showed that the response to N was obtained only with 500 g N/tree/year (Appendix 6).

The data on the effect of N levels on nitrogen content of leaf (Table 14b) showed that there was significant increase in

Table 14. Effect of fertilizer management on leaf N content (%) at fruiting

a. <u>Control vs treatment</u>	1990-91	1991-92	Mean
Control	2.08	2.06	2.07
Effect due to nitrogen	2.20	2.56**	2.38
Effect due to phosphorus	2.20	2.27*	2.24
Effect due to potassium	2.15	2.24*	2.19
b. <u>N l vels</u>			
N_1	2.22	2.31	2.26
N_2	2.39	2 71	2.55
N_3	2.49	2.71	2.6
CD (0.05)	0.133	NS	
c. <u>P levels</u>			
P_1	2.24	2.54	2.39
P_2	2.42	2.54	2.48
P_3	2.44	2.64	2.54
CD (0.05)	NS	NS	
d. <u>K levels</u>			
K_1	2.32	2.58	2.45
K_2	2.41	2 56	2.48
K_3	2.37	2.59	2.48
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

leaf N content with every increment in N levels from 250 g to 1000 g N/tree/year in 1990-91 The nitrogen content at the highest level of N application was 2.49 per cent. The leaf N content at this level was about 20 per cert more than that at control. While in 1991-92 the levels of N did not bring about significant increase in leaf N content at fruiting. However, there was increase of about 17 per cent with increasing N level from 250 g to 500 g N/tree/year and found to be at par with the highest level.

Effect of P

Table 14a showed that P application significantly influenced the leaf N content at fruiting in 1991-92. The leaf N content was increased by about 10 per cent The significant increase was noticed only with the higher levels of 500 g and 1000 g P_2O_5/tree/year (Appendix 6).

It is clear from Table 14c that there was no significant increase in leaf N content at fruiting due to increased levels of P. However, there was a linear increase with every increment of P application in both the years.

Effect of K

The data presented in Table 14a showed that there was a significant increase of 9 per cent in leaf N content at fruiting due to K application in 1991-92

No significant response to varying levels of K application was observed in leaf N content in both the years (Table 14d).

4 2 3.2. Leaf P content at fruiting

Effect of N

The significant influence of N application on leaf P content at fruiting was observed only in 1990-91 with increase of 22 per cent over control (Table 15a). The significant effect was exercised from the lowest level itself (Appendix 7).

In both the years, varying levels of N caused significant difference (Table 15b). In 1990-91 there was a steady significant increase of 7 per cent with every increment of nitrogen level. While, in 1991-92 the increase was more when the nitrogen level was increased from 250 g to 500 g N/tree/year.

Effect of P

P application improved significantly the leaf P content at fruiting in 1990-91 (Table 15a). However the increase in leaf P content was low due to P application compared to N application.

The levels of P had no response in 1990-91 while in 1991-92 a significant increase upto 250 g P_2O_5/tree/year was observed (Table 15c).

Table 15. Effect of fertilizer management on leaf P content (%) at fruiting

a. Control vs treatment	1990-91	1991-92	Mean
Control	0.110	0.120	0.115
Effect due to nitrogen	0.136**	0.132	0.134
Effect due to phosphorus	0.130**	0.123	0.127
Effect due to potassium	0.123**	0.126	0.125
b N levels			
N_1	0.140	0.130	0.135
N_2	0.150	0 147	0.148
N_3	0.160	0 158	0 159
CD (0.05)	0.0082	0.0073	
c P levels			
P_1	0.140	0.133	0.136
P_2	0.150	0.149	0.149
P_3	0.150	0 152	0.151
CD (0.05)	NS	0.0073	
d K levels			
K_1	0.140	0.141	0.140
K_2	0.150	0.145	0.147
K_3	0.150	0.149	0.149
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Effect of K

Table 15a clearly showed that there was significant effect of K application on leaf P content at fruiting in 1990-91 which was effected from the lowest level itself (Appendix 7).

The levels of K failed to produce any significant effect in both the years (Table 15d). However, maximum leaf P content was recorded at fruiting (Fig. 4).

4.2 3 3. Leaf K content at fruiting

Effect of N

Significant response for N application on enhancing the K content of leaves at fruiting stage of cashew can be seen in Table 16a. In 1991-92 leaf K content was increased by 40 per cent. This significant increase was noticed even with lowest level of N application (Appendix 7).

Compairing of levels of N, in 1990-91, levels did not bring about any significant difference. However, there was a progressive increase from 1.2 per cent to 1.28 per cent due to higher levels of N But in 1991-92 there was significant increase with every increment of N levels, the per cent increase being 15 per cent and 10 per cent, respectively (Table 16b).

Fig. 4. Relationship between leaf P content and stages of growth

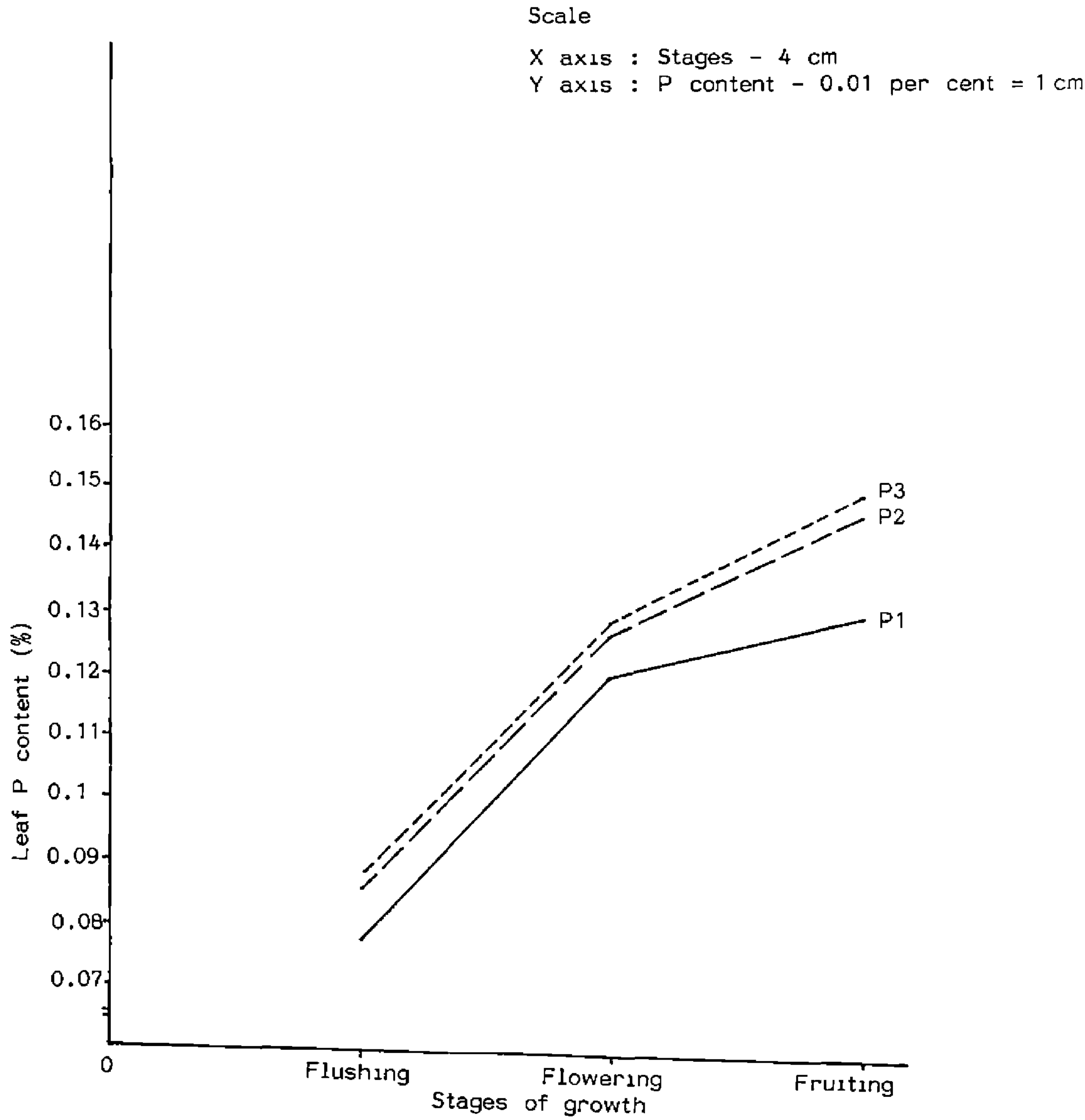
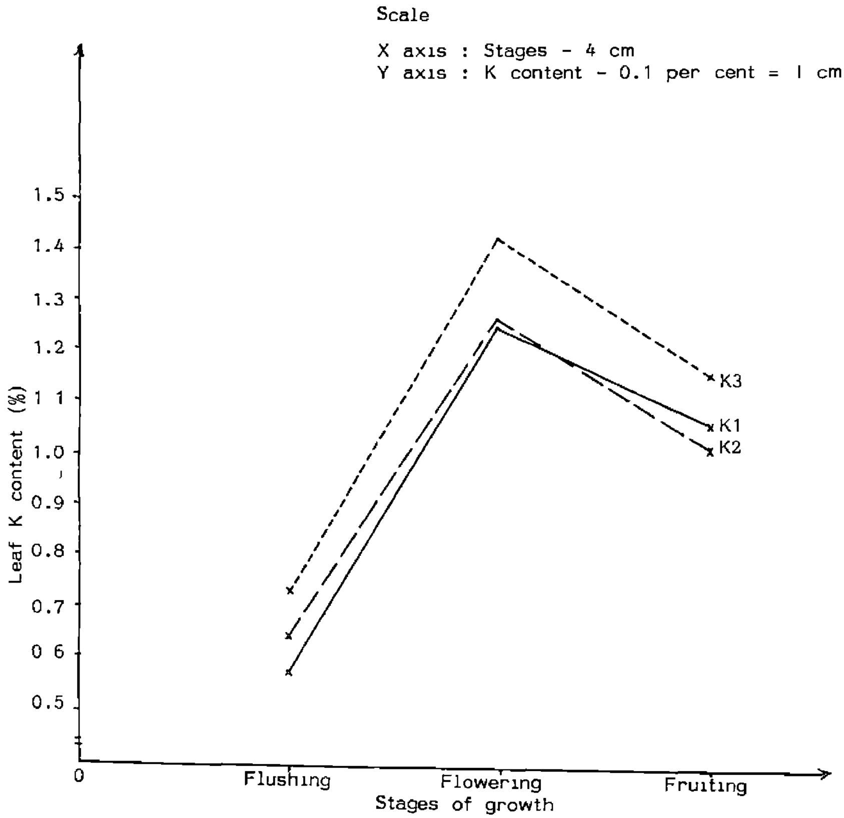


Table 16. Effect of fertilizer management of leaf K content (%) at fruiting

a Control vs treatment	1990-91	1991-92	Mean
Control	0.84	0.84	0 84
Effect due to nitrogen	1 10**	1.18**	1.14
Effect due to phosphorus	1.15**	0.92**	1.03
Effect due to potassium	1.21**	0.97**	1.09
b. N levels			
N_1	1.19	0.96	1.07
N_2	1.24	1.10	1 17
N_3	1.28	1 21	1.25
CD (0.05)	NS	0 097	
c. P levels			
P_1	1.20	1.10	1.15
P_2	1.35	1.06	1.16
P_3	1.25	1.12	1.18
CD (0.05)	NS	NS	
d K levels			
K_1	1.21	1.08	1.14
K_2	1.20	1.03	1.12
K_3	1.30	1.17	1.23
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Fig. 5. Relationship between leaf K content and stages of growth



Effect P

Similar to N, significant increase in leaf P content was noticed due to application of phosphorus at fruiting over control (Table 16a). This increase was realised from the application of 125 g P_2O_5 per tree per year (Appendix 7). Varying levels of P applied did not influence the leaf K content at fruiting (Table 16c).

Effect of K

The data on the effect of K on leaf K content showed that there was significant increase by 44 per cent and 15 per cent in leaf K content due to K application over control (Table 16a). Further analysis showed that the increase was realised at the lowest level itself in both the years (Appendix 7).

The varying levels of K from 250 g K_2O per tree per year to 1000 g K_2O per tree per year failed to produce significant difference between levels of K, but a linear increase was noticed in both the years (Table 16d).

Relationship between leaf nutrients at fruiting and soil nutrients

As in the case of flushing and flowering a positive non-significant relationship was observed between leaf nutrients at fruiting and soil nutrients in both the years in general (Appendix 14). In case of leaf K content and soil N in 1990-91, and soil K content and leaf P and K content in 1991-92, a negative relationship was seen.

4.3. Effect on available nutrient content of soil

4.3.1 N content of soil

Effect of N

The data presented in Table 17a showed a significant increase in soil N content in both the years. N application increased the N content by 10 per cent and 19 per cent, respectively in 1990-91 and 1991-92. This increase was observed even from the lowest level of 250 g N per tree per year (Appendix 8).

Comparison of N content as influenced by different levels of N application did not show significant variation in 1991-92. However, in 1990-91 significant increase was observed with increasing level from 250 g to 500 g N per tree per year (Table 17b).

Effect of P

P application produced a significant increase of 7 per cent and 14 per cent in N content of soil in 1990-91 and 1991-92, respectively (Table 17a). As in the case of N, lowest level of P was sufficient in registering the significant effect in N content of soil in both the years (Appendix 8).

There was significant difference between levels of P in 1990-91 (Table 17c). The N content of soil was decreased by

Table 17 Effect of fertilizer management on N content (%) of soil

a. Control vs treatment	1990-91	1991-92	Mean
Control	0.156	0.159	0 157
Effect due to nitrogen	0.171**	0.190**	0.181
Effect due to phosphorus	0.167**	0.181**	0.174
Effect due to potassium	0.182**	0.181**	0.182
b. N levels			
N_1	0.177	0.184	0.180
N_2	0.184	0.187	0.180
N_3	0.172	0.188	0.180
CD (0.05)	0.0067	NS	
c. P levels			
P_1	0.183	0.190	0.186
P_2	0 175	0.182	0.178
P_3	0.175	0.187	0.181
CD (0.05)	0.0067	NS	
d. K levels			
K_1	0.169	0.185	0.177
K_2	0.185	0.185	0.185
K_3	0.179	0.190	0.184
CD (0.05)	0.0067	NS	

** Denotes significant difference with control at 1 per cent level

5 per cent with increase in P application from 125 g to 250 g P_2O_5 per tree per year But further increase in P application did not bring about any increase in N content of soil and stabilized at 0.18 per cent. But in 1991-92 no significant difference was noticed between levels of P. However, a decreasing trend was noticed (Table 17c).

Effect of K

As in the case of N and P, K application also brought about significant effect on N content of soil in both the years over control (Table 17a). The lowest level of 250 g K_2O per tree per year was sufficient to produce significant increase of 17 per cent and 14 per cent in 1990-91 and 1991-92, respectively (Appendix 8).

Comparing the levels of K, there was an increase of 0.016 per cent in N content of soil due to 500 g K_2O per tree per year over the lowest level. But a further increase in K application to 1000 g K_2O per tree per year decreased N content of soil in 1990-91 while in 1991-92 an increasing trend was noticed with increasing level of K. However, the variation was not significant (Table 17d).

4.3.2. Available P content of soil

Effect of N

N application did not produce any significant effect on the available P content of soil (Table 18a). A comparison between P content of soil in presence of different levels of N showed a significant difference between the highest and lower levels. The available P content increased from 31.5 ppm to 42.8 ppm due to increased application of N from 500 g to 1000 g N per tree per year (Table 18b).

Effect of P

It is evident from Table 18a that P application had produced significant increase of 28 per cent in available P content of soil in 1991-92 over control. But it failed to produce significant increase, eventhough there was increase by 10.1 ppm due to P application over control in 1990-91. In 1991-92 the application of 250 g P_2O_5 per tree per year produced significant effect on available P content (Appendix 8).

In both the years, the different levels of P effected significantly on available P content of soil. In 1990-91 a significant increase of 14 ppm in available P content was noticed with increased level of P from 250 g to 500 g P_2O_5 per tree per year But in 1991-92 significant difference was noticed with every increment in P application. The available P content increased from 25 4 ppm to 45.7 ppm due to higher levels of P (Table 18c).

Table 18. Effect of fertilizer management on available P content (ppm) of soil

	1990-91	1991-92	Mean
a Control vs treatment			
Control	10.0	13.4	11.7
Effect due to nitrogen	14.7	18.9	16.8
Effect due to phosphorus	20.1	41.4**	30.8
Effect due to potassium	12.3	26.8*	19.5
b. N levels			
N_1	19.2	35.9	27.5
N_2	24.2	31.5	27 9
N_3	20.5	42.8	31.6
CD (0 05)	NS	6.35	
c P levels			
P_1	13.2	25.4	19.3
P_2	18.3	39.1	28.7
P_3	32.3	45.7	39.0
CD (0.05)	5 42	6.35	
d. K levels			
K_1	21.3	38.1	30.0
K_2	19.1	33.3	26.2
K_3	23.5	38.9	31.2
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Effect of K

Table 18a showed that there was significant effect of K application on available P content of soil only in 1991-92. In both the years there was no significant difference between levels of K (Table 18d).

4 3.3. Available K content of soil

Effect of N

N application did not produce significant effect on available K content of soil in both the years (Table 19a) over no nitrogen application. However, the available K content of soil increased by 12 per cent due to N application in 1991-92. Among the levels of N, there was no significant difference between levels of N in both the years (Table 19b). In 1990-91 an increasing trend was noticed with every increment in N application, on contrast, in 1991-92 a decreasing trend was noticed.

Effect of P

From Table 19a, it is evident that P application did not influence the available K content of soil significantly and no significant difference was noticed between levels of P in both the years (Table 19c).

Effect of K

There was increase in available K content of soil to 315 ppm

Table 19. Effect of fertilizer management on available K content (ppm) of soil

a Control vs treatment	1990-91	1991-92	Mean
Control	175.0	191.5	183.2
Effect due to nitrogen	249.2	193.8	221.5
Effect due to phosphorus	202.5	212.1	207.3
Effect due to potassium	315.0	242.1	278.6
b N levels			
N_1	316.8	244.4	280.6
N_2	309.0	237.3	273.2
N_3	343.3	218.5	280.9
CD (0.05)	NS	NS	
c. P levels			
P_1	319.0	230.6	274.8
P_2	353.9	215.8	284.9
P_3	296.3	253.9	275.1
CD (0.05)	NS	NS	
d. K levels			
K_1	236.7	197.4	217.0
K_2	329.7	220.3	275.0
K_3	402.8	282.6	342.7
CD (0.05)	61.82	31.15	

** Denotes significant difference with control at 1 per cent level

and 242 ppm over 175 ppm and 192 ppm at control, respectively in 1990-91 and 1991-92 but not significant in both the years (Table 19a).

Comparison of levels of K revealed that there was significant difference with every increment in K application on available K content of soil in 1990-91 and the available K content increased by 166 ppm with increase in K level from 250 g to 1000 g K_2O per tree per year. While in 1991-92 significant difference was observed between K_2 and K_3 and there was 28 per cent increase in available K content at the highest level of 1000 g K_2O per tree per year (Table 19d).

4.4. Effect on yield attributes and yield

4.4.1. Yield attributes

4 4.1.1. Number of panicles/m^2

Effect of N

The data on the effect of nitrogen on number of panicles/m^2 (Table 20a) showed that N application significantly increased the number of panicles/m^2 from 2.2 in the control to 7.7 in the treatment in both the years. The lowest level of 250 g N per tree per year was not sufficient to cause any change, but the significant increase started with only N_2 level of 500 g N per tree per year (Appendix 9).

Table 20. Effect of fertilizer management on number of panicles/m^2

a. Control vs treatment	1990-91	1991-92	Mean
Control	2 2	2.3	2.2
Effect due to nitrogen	7.7**	7.7**	7.7
Effect due to phosphorus	6.3**	6 5**	6.4
Effect due to potassium	6.1**	6.1**	6.1
b. N levels			
N_1	6.5	7.1	6.8
N_2	8.5	10.1	9.3
N_3	10.6	9.9	10.2
CD (0.05)	0.87	1.16	
c P levels			
P_1	7.7	8.2	8.0
P_2	9.0	9.3	9.1
P_3	8.9	9.6	9.2
CD (0.05)	NS	NS	
d. K levels			
K_1	8.6	8.1	8.3
K_2	8.6	9.0	8.8
K_3	8.4	9.8	9.1
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Comparison of levels of N application (Table 20b) showed significant linear increase in the number of panicles with every increment of nitrogen from 250 g to 1000 g N per tree per year in 1990-91. But in 1991-92 the significant response was only upto 500 g N per tree per year and when 1000 g N per tree per year was applied there was a marginal decrease in the number of panicles by 2 per cent.

Effect of P

P application significantly increased the number of panicles/m^2 in both the years and mean increase was worked out to be 184 per cent over no phosphorus application (Table 20a). The contrasts worked out between control and levels of P (Appendix 9) showed that application of 125 g P_2O_5 per tree per year exercised its effect in 1990-91. However, in 1991-92 the highest level of 500 g P_2O_5 per tree per year only produced significanceover control on production of panicles.

Comparison of different levels of P showed no significant difference in the production of panicles in both the years. However in 1991-92, there was a progressive linear increase in the number of panicles due to increased levels of P application. The increase from P_1 to P_2 levels were worked out to be 16.5 and 13.5, respectively for 1990-91 and 1991-92 (Table 20c).

Effect of K

The data in Table 20a showed that there was significant response to K application by cashew for its panicle production. The mean increase in the number of panicles per m^2 for 1990-91 and 1991-92 was estimated to be 197 per cent and when the N effect was splitted and compared with control (Appendix 9) it was observed that the significant response was not shown by the lowest level of 250 g K_2O per tree per year but only with its higher levels of 500 g and 1000 g of K_2O per tree per year.

The comparison of the effect between different applied K levels showed no significant difference (Table 20d). However, the mean production of panicles in 1990-91 and 1991-92 increased in linear order from 8.3 to 9.1 from the lowest to highest levels of K

Relationship between leaf and soil nutrients and number of panicles per m^2

The correlation between leaf N at flushing, flowering and fruiting and number of panicles had shown that only in 1991-92 a significant positive relationship (R^2 = 0.571) between leaf N at flowering (x) and number of panicles (y) was observed, the regression equation being $y = 2.12 + 0.072x^*$

At flushing, leaf P content was related significantly (R^2= 0 54) with number of panicles, while at flowering a positive non-significant relationship was observed between them (Appendix 14) In both the years at fruiting significant positive relationship was seen with R^2 = 0.58 and 0 535 in 1990-91 and 1991-92, respectively, the regression equations being $y = 0.11 + 0.004x^*$ and $y = 0.12 + 0\ 003x^*$ in 1990-91 and 1991-92, respectively where y - number of panicles and x - leaf P content.

The relationship between leaf K content at flushing and flowering in both the years and number of panicles was positive nonsignificant (Appendix 14) while a positive significant (R^2 = 0.567) relationship was obtained with leaf K content at fruiting in 1991-92.

Correlation between soil nutrients and number of panicles was nonsignificant, eventhough positive, in both the years (Appendix 15).

4 4.1.2. Test weight of nuts

Effect of N

It can be seen from Table 21a that N application significantly increased the test weight of nuts by 23 per cent and 25 per cent in 1990-91 and 1991-92, respectively over control. This significant effect was noticed even from the lowest level of N in both the years (Appendix 10).

Table 21. Effect of fertilizer management on test weight (g/nut) of nuts

a. Control vs treatment	1990-91	1991-92	Mean
Control	407.5	387.5	397.5
Effect due to nitrogen	500.3**	485.8**	493.1
Effect due to phosphorus	502.3**	521.7**	512.0
Effect due to potassium	482.3**	510.8**	496.6
b. N levels			
N_1	535.6	547.5	541.5
N_2	560.7	564.2	562.4
N_3	597.7	619.2	608.2
CD (0.05)	29.69	33 83	
c. P levels			
P_1	539.1	547.5	543.3
P_2	568.6	599.4	584.0
P_3	585.8	598.9	592.4
CD (0.05)	NS	33.83	
d. K levels			
K_1	524.7	532.8	528.7
K_2	557.5	600.0	583.8
K_3	611.3	613.1	612.2
CD (0.05)	29.69	33.83	

** Denotes significant difference with control at 1 per cent level

Comparing the levels of N, it was seen that the significant increase in test weight of nuts was noticed when the N level was increased from 500 to 1000 g N per tree per year in 1990-'91 and 1991-'92, respectively (Table 21b). The per cent increase was worked out to be 11 and 13 per cent, respectively in 1990-91 and 1991-92 when the N level was increased from 250 g to 1000 g N per tree per year.

Effect of P

P application had also produced significant increase in test weight of nuts in both the years (Table 21a). The test weight of nuts increased by 94.8 g and 134.2 g, respectively in 1990-91 and 1991-92 due to P application. Even the lowest level of 125 g P_2O_5 per tree per year produced the significant increase (Appendix 10).

Significant difference between levels of P was observed in 1991-92 only. The significant difference was noticed between P_1 and P_2. The test weight of nuts increased by 51.9 g when the P application was increased from 125 g to 250 g P_2O_5 per tree per year (Table 21c).

Effect of K

It can be observed from Table 21a that K application also significantly increased the test weight of nuts in both the years by 18 per cent and 31.8 per cent respectively and the effect was evident with the lowest level of K (Appendix 10).

The levels of K also showed significant difference with test weight of nuts in both the years (Table 21d). The significant increase of 33 g and 54 g in test weight of nuts was seen with every increment in K application from 250 g to 1000 g K_2O per tree per year in 1990-91. While in 1991-92 significant increase was observed when the K application was increased from 250 g to 500 g K_2O per tree per year. Further increase in K had no significant effect on test weight of nuts.

4.4.2. Yield and related characters

4 4.2.1. Yield of plants

Effect of N

N application produced significant effect on yield of plants in both the years over control (Table 22a). The yield of plant increased by 4.3 kg and 4.4 kg over no nitrogen in 1990-91 and 1991-92, respectively (Fig. 6). However, the response was noticed from 500 g N per tree per year in 1991-92 (Appendix 10).

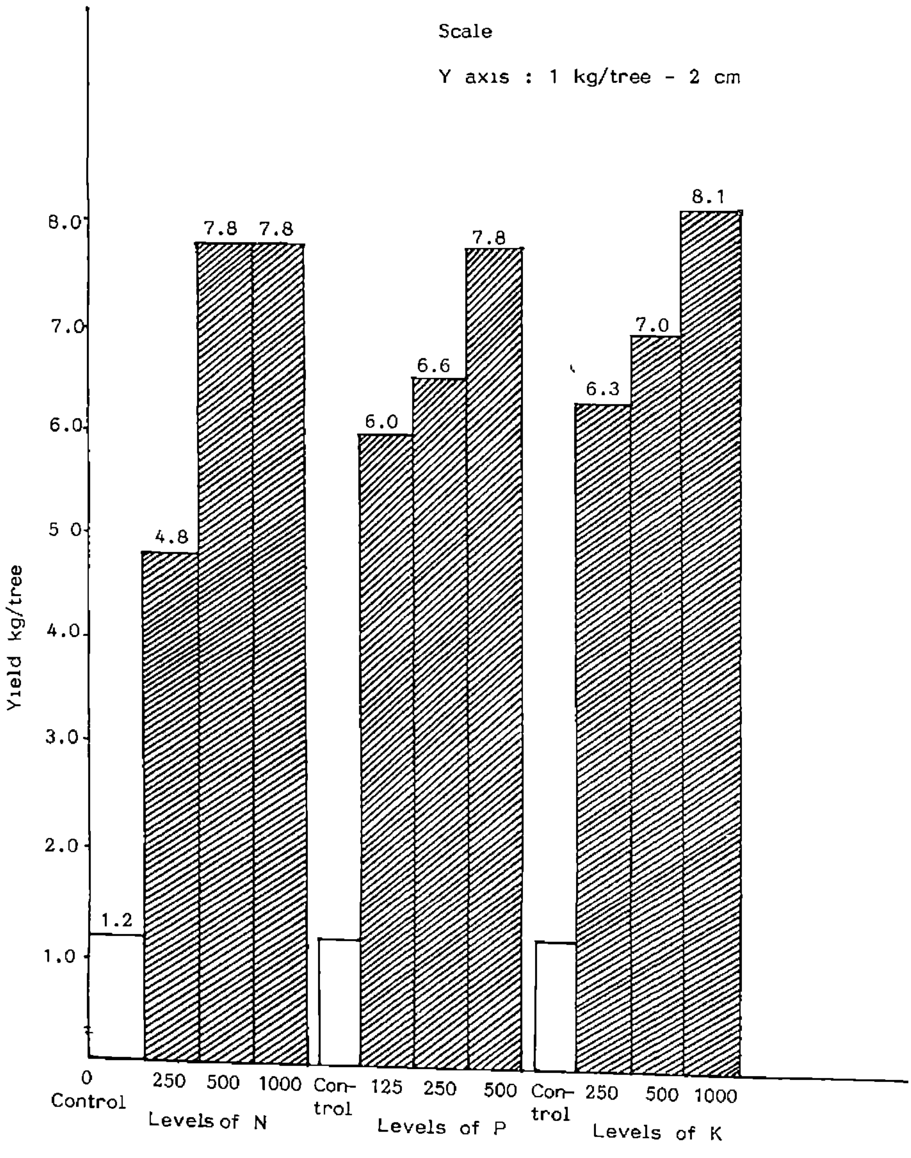
Significant increase between levels of N was noticed in both the years. There was significant increase of 93 per cent due to increased level of N from 250 g to 500 g N per tree per year in 1990-91. Further increase in nitrogen did not contribute to higher yield. In 1991-92 significant increase of 36 per cent

Table 22. Effect of fertilizer management on yield (kg/tree) of plants

a. Control vs treatment	1990-91	1991-92	Mean
Control	1.1	1.3	1.2
Effect due to nitrogen	5.4*	5.7**	5.6
Effect due to phosphorus	4.0	4.9*	4.5
Effect due to potassium	4.6*	4.1	4.4
b. N levels			
N_1	4.3	5.3	4.8
N_2	8.3	7.2	7.8
N_3	8.2	7.4	7.8
CD (0.05)	1.22	1.06	
c. P levels			
P_1	6.2	5.7	6.0
P_2	6.6	6.5	6.6
P_3	8.0	7.6	7.8
CD (0.05)	NS	NS	
d. K levels			
K_1	6.4	6.1	6.3
K_2	7.1	6.8	7.0
K_3	7.3	8.9	8.1
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Fig. 6. Relationship between levels of N, P and K and yield



was noticed for the increase of N to 500 g N per tree per year from lowest level (Table 22b).

Effect of P

The Table 22a showed that significant response to applied P was only during 1991-92 and this increase was observed at the highest level of 500 g P_2O_5 per tree per year (Appendix 10).

No significant difference was noticed between levels of P in both the years (Table 22c). However, an increasing trend was noticed with increasing levels of P in both the years (Fig. 6).

Effect of K

K application had significant effect on yield of plants only in 1990-91 and the increase was worked out to be 319 per cent (Table 22a).

The levels of K did not show significant difference between them in both the years. However, similar to P an increasing trend was observed (Table 22d).

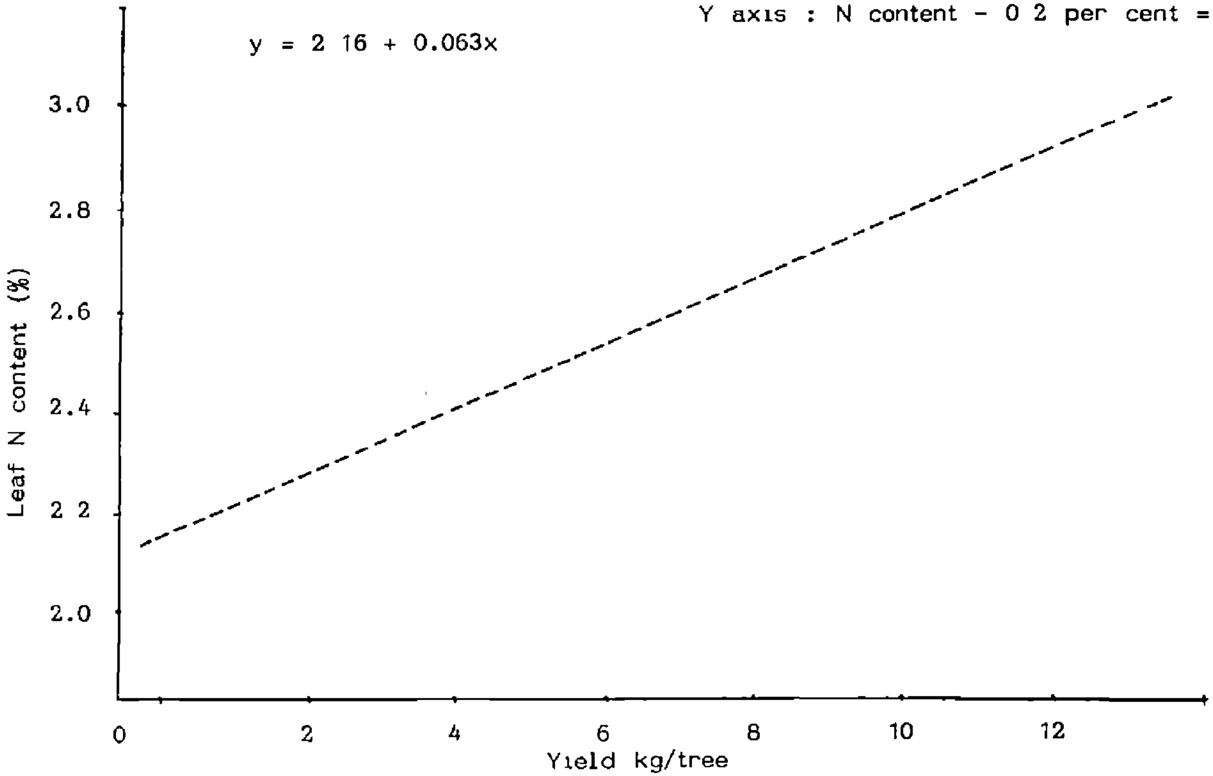
Relationship between leaf and soil nutrients and yield

Significant positive relationships were observed between leaf N (R^2 = 0.516) and P (R^2 = 0.555) at flowering and yield in 1991-92 and leaf N (R^2 = 0.548) at fruiting during 1990-91

Fig. 7. Relationship between leaf N content at fruiting and yield

Scale

X axis : 2 kg/tree - 1 cm
Y axis : N content - 0 2 per cent = 1.5 cm



(Fig. 7) and leaf P (R^2 = 0.554) at fruiting in 1991-92 (Fig.8) and yield, in a study of correlation between leaf nutrients at flushing, flowering and fruiting and yield In all the other cases a positive nonsignificant relationship was observed (Appendix 14). Leaf K also developed a positive nonsignificant relationship at all stages with yield (Fig. 9).

A positive nonsignificant relationship was observed between soil nutrients and yield in both the years, in general (Appendix 15). But soil N content showed a negative relationship with yield in 1990-91.

4.4.2.2. Nut volume

Effect of N

The Table 23a showed significant increase of 22 per cent and 28 per cent in nut volume over control due to N application in 1990-91 and 1991-92, respectively. The significant increase was noticed from the lowest level in both the years (Appendix 11).

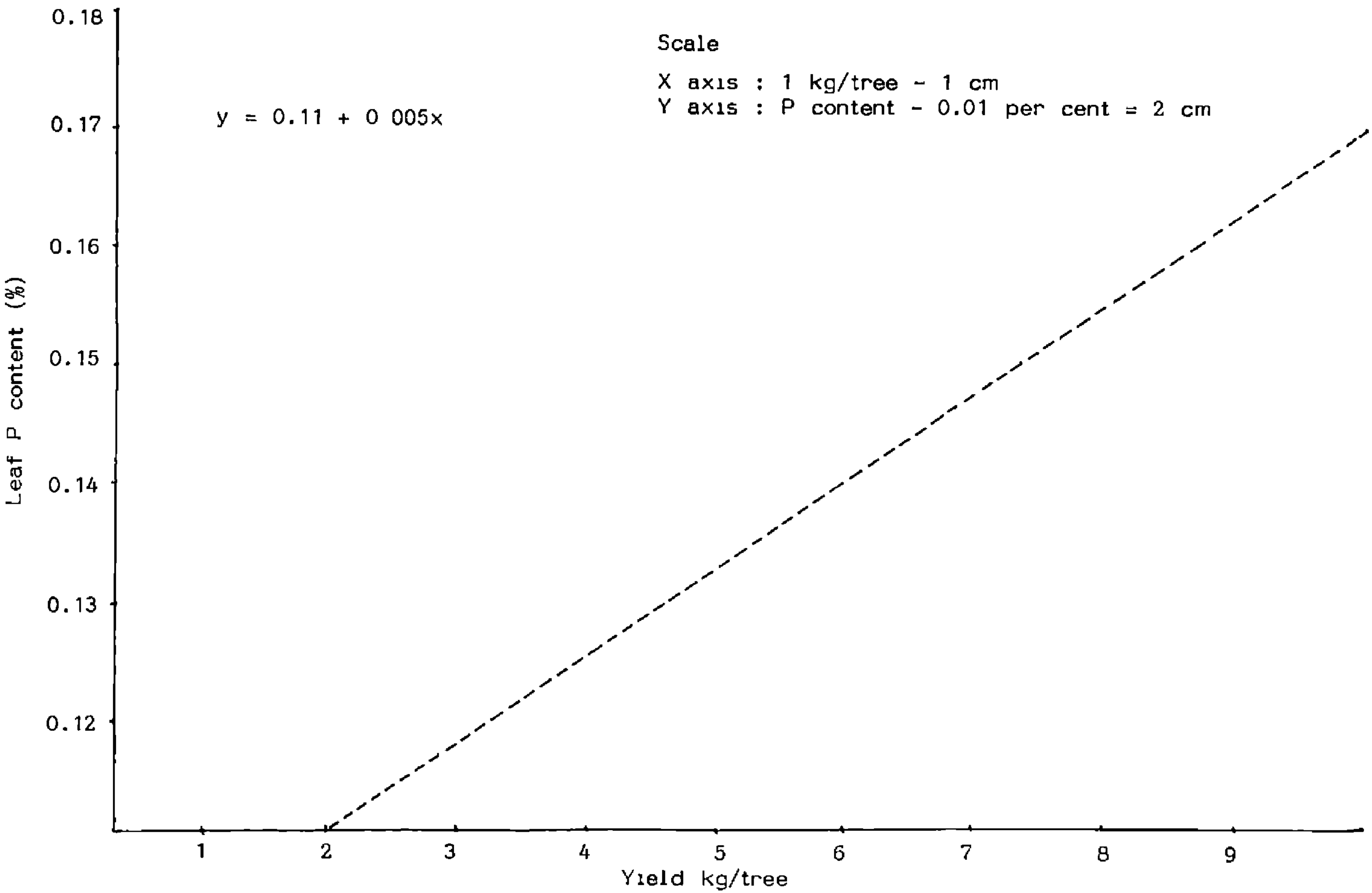
Comparing levels of N, it was seen that the significant steady increase of 0.4 cc/nut was observed with every increment of nitrogen application in 1990-91. But in 1991-92 the significant difference was seen with increasing N level from 500 g to 1000 g N per tree per year. The nut volume at N_1 was on par with N_2 (Table 23b).

Table 23. Effect of fertilizer management on nut volume (cc/nut)

a. Control vs treatment	1990-91	1991-92	Mean
Control	4.2	4 0	4.1
Effect due to nitrogen	5.1**	5.1**	5.1
Effect due to phosphorus	5.1**	5.4**	5.3
Effect due to potassium	4.9**	5.3**	5.1
b. N levels			
N_1	5.4	5.8	5.6
N_2	5.8	5.8	5.8
N_3	6.2	6.4	6.3
CD (0.05)	0.25	0.31	
c. P levels			
P_1	5.5	5.7	5.6
P_2	5.8	6.1	6.0
P_3	6.1	6.1	6.1
CD (0.05)	0.25	NS	
d. K levels			
K_1	5.4	5.5	5.4
K_2	5.7	6.1	5.9
K_3	6.2	6.3	6.3
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

Fig. 8. Relationship between leaf P content at fruiting and yield



Effect of P

The significant increase of 0.9 cc and 1.4 cc in nut volume was produced due to P application, in 1990-91 and 1991-92 respectively. This corresponded to 22 per cent and 35 per cent increase in nut volume due to P application (Table 23a). The significant effect was seen from the lowest level itself (Appendix 11)

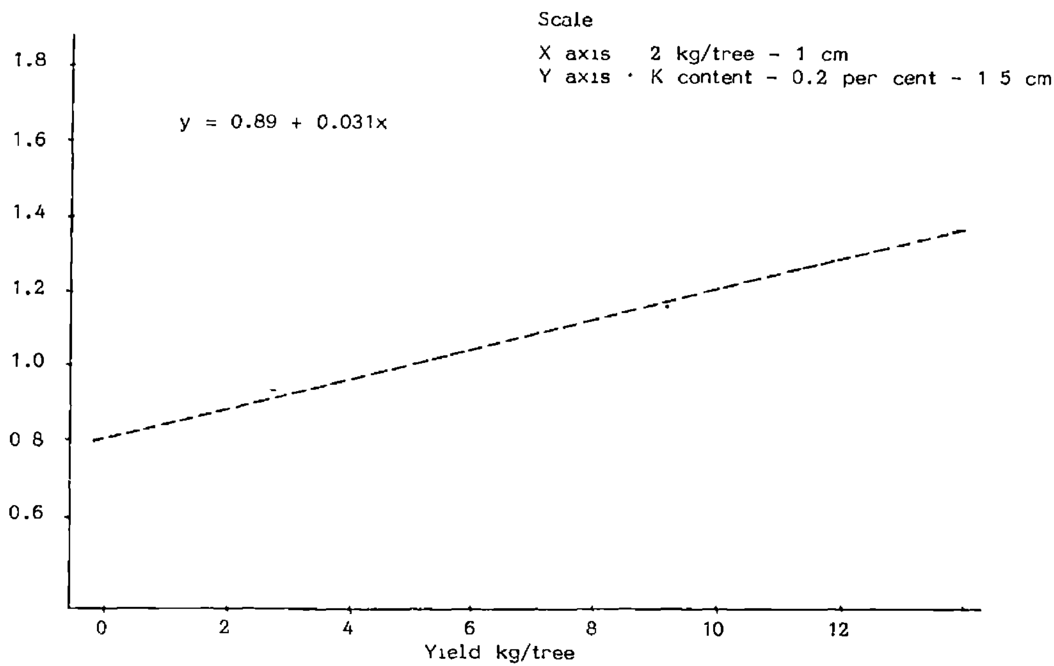
In 1990-91 the significant difference was noticed between levels of P There was significant increase with every increment of P applied. Eventhough nut volume of 6.1 cc was produced at the highest level of P in both the years, the levels of P failed to register significant difference in 1991-92 (Table 23c).

Effect of K

K application also produced significant increase of 17 per cent and 33 per cent in nut volume in 1990-91 and 1991-92, respectively over control (Table 23a). Similar to N and P, lowest level of K was sufficient to produce significant increase (Appendix 11)

The levels of K did not produce any significant difference in nut volume in both the years. However an increasing trend was noticed with increasing levels of K (Table 23d).

Fig. 9. Relationship between leaf K content at fruiting and yield



4.4.2.3 Protein content of kernel

Effect of N

N application influenced the protein content of kernels in both the years over control (Table 24a) N application accounted for an increase of 31 per cent and 26 per cent over no nitrogen application This increase was noticed even from the lowest level of N (Appendix 11).

From Table 24b it is clear that there was significant difference between levels of N in both the years. In 1990-91 the increase in N level from N_1 to N_2 alone produced significant difference but at N_3 no difference was observed. In 1991-92 significant increase in protein content was noticed when the N level was increased from 250 g to 500 g N per tree per year The protein content at 500 g N per tree per year was on par with 1000 g N per tree per year.

Effect of P

The Table 24a showed the significant increase of about 25 per cent in protein content of kernels in both the years due to P application over control. This significant difference was noticed even from the lowest level of 125 g P_2O_5 per tree per year (Appendix 11)

The levels of P failed to record any significant difference in both the years However protein content increased by 1.2 per

Table 24. Effect of fertilizer management on protein content (%) of kernels

a. Control vs treatment	1990-91	1991-92	Mean
Control	18.9	18.4	18.6
Effect due to nitrogen	24.7**	23.2**	24.0
Effect due to phosphorus	23.6**	23.0**	23.3
Effect due to potassium	23.4**	22.0**	22.7
b. N levels			
N_1	23.3	22.8	23.1
N_2	25.3	25.6	25.5
N_3	25.9	25.6	25.8
CD (0.05)	0.98	1.02	
c. P levels			
P_1	24.7	23.6	24.2
P_2	24.7	24.6	24.7
P_3	25.0	25.7	25.4
CD (0.05)	NS	NS	
d. K levels			
K_1	24.9	24.8	24.9
K_2	24.5	24.8	24.7
K_3	25.1	24.3	24.7
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

cent and 4.6 per cent respectively in 1990-91 and 1991-92 (Table 24c).

Effect of K

It is clear from Table 24a that there was significant increase due to K application over control in both the years. The protein content was increased to 23 per cent and 22 per cent compared to 19 per cent and 18 per cent at control in 1990-91 and 1991-'92, respectively. The lowest level itself showed the significant effect (Appendix 11).

Table 24d revealed no significant difference between levels of K. An increasing trend was observed in both the years with increase in K application.

4.4.2.4. Fruit weight

Effect of N

It can be seen from Table 25a that the mean increase in fruit weight due to N application were 35.7 per cent and 36.9 per cent in 1990-91 and 1991-92, respectively. The significant difference with control was developed from N_1 level itself in both the years (Appendix 12).

Comparing the levels of N, the significant increase was obtained with every increment in nitrogen level in 1990-91.

Table 25. Effect of fertilizer management on fruit weight (g/fruit)

a. Control vs treatment	1990-91	1991-92	Mean
Control	40.0	36.5	38.3
Effect due to nitrogen	54.3**	50.0**	52.2
Effect due to phosphorus	47.7**	54.3**	51.0
Effect due to potassium	48.2**	49.3**	48.8
b. N levels			
N_1	52.1	57.7	54.9
N_2	60.1	57.6	58.8
N_3	63.6	58.9	61.2
CD (0.05)	3.06	~~4.0~~ NS	
c. P levels			
P_1	54.8	51.8	53.3
P_2	61.4	60.0	60.7
P_3	59.6	62.5	61.0
CD (0.05)	3.06	NS	
d. K levels			
K_1	58.4	56.2	57.3
K_2	58.1	58.4	58.2
K_3	59.2	59.7	59.4
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

In 1991-92 there was increase in fruit weight from 57.7 g to 58.9 g with increase in level of N from 250 g to 1000 g N per tree per year (Table 25b).

Effect of P

The mean increase of fruit weight of 7.7 g and 17.8 g was found to be significant (Table 25a) due to P application over control in 1990-91 and 1991-92, respectively. The lowest level of 125 g P_2O_5 per tree per year was found to record the significant effect (Appendix 12).

The significant difference between levels of N was observed in 1990-91 only. There was significant increase in fruit weight by 6.6 g with increase in level of P from P_1 to P_2. With further increase to P_3 caused a decrease by 2.8 g in 1990-91. But in 1991-92 eventhough there was no significant difference between levels of P the fruit weight increased from 51.8 g to 62.5 g with increased levels of P (Table 25c).

Effect of K

K application brought about a significant increase of 20.5 per cent and 35 per cent over no K application (Table 25a) in 1990-91 and 1991-92, respectively. 250 g K_2O per tree per year produced this significant effect in both the years (Appendix 12).

Comparison of levels of K revealed that there was no significant difference between levels of K. However, fruit weight increased with increasing levels of K (Table 25d).

4.4.2.5. Fruit volume

Effect of N

Table 26a showed the significant influence of N on fruit volume in both the years. The percent increase worked out to be 20.9 per cent and 30 per cent in 1990-91 and 1991-92, respectively over control. Application of 250 g N per tree per year was enough to produce significant increase in fruit volume in both the years (Appendix 12).

Comparison of levels of N revealed significant difference between levels in 1990-91 only. When the N level was increased from 250 g to 500 g N per tree per year the fruit volume increased significantly from 55.4 cc to 64.0 cc This corresponded to 8 per cent increase in fruit volume. But further increase was not significant. Eventhough there was no significant difference between levels, an increasing trend was observed in 1991-92 (Table 26b).

Effect of P

The mean increase of 17.4 per cent and 35.38 per cent in fruit volume was observed due to P application over control

Table 26. Effect of fertilizer management on fruit volume (cc/fruit)

a. Control vs treatment	1990-91	1991-92	Mean
Control	43.0	39.0	41.0
Effect due to nitrogen	54.0**	53.8**	53.9
Effect due to phosphorus	50.5**	52.8**	51.7
Effect due to potassium	51.0**	50.7**	50.9
b. N levels			
N_1	55.4	58.2	56.8
N_2	64.0	60.4	62.2
N_3	66.4	57.8	62.1
CD (0.05)	2.93	NS	
c P levels			
P_1	58.0	55.7	56.9
P_2	63.8	59.9	61.9
P_3	63.1	60.8	61.9
CD (0.05)	2.93	NS	
d. K levels			
K_1	58.7	54.7	56.7
K_2	61.7	59.8	60.8
K_3	65.4	61.9	63.6
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per cent level

in 1990-91 and 1991-92, respectively (Table 26a) and this significant increase was evident from 125 g P_2O_5 per tree per year (Appendix 12).

In 1990-91 a significant difference was observed between P_1 and P_2 and the increase due to 500 g P_2O_5 per tree per year was not significant. The levels of P did not bring about a significant difference in 1991-92 eventhough fruit volume increased from 55.7 cc to 60.8 cc with higher levels of P (Table 26c).

Effect of K

Table 26a showed that there was significant increase of 8.0 cc and 11.7 cc in fruit volume due to K application in 1990-91 and 1991-92, respectively and lowest level of K showed this significant effect in both the years (Appendix 12).

The levels of K failed to record any significant increase in fruit volume in both the years. However an increase of 6.7 cc and 7.2 cc was observed in 1990-91 and 1991-92, respectively due to increased levels of K (Table 26d).

4.4.2.6. Total soluble solids of apple

Effect of N

From Table 27a it is evident that N application recorded a significant increase of 10.75 per cent and 36.3 per cent in 1990-91 and 1992-92, respectively over control. This significant effect

Table 27. Effect of fertilizer management on TSS (%) of apple

a. Control vs treatment	1990-91	1991-92	Mean
Control	9.3	8.8	9.0
Effect due to nitrogen	10.3**	12.0**	11.2
Effect due to phosphorus	10.1**	12.5**	11.3
Effect due to potassium	9.3**	11.3**	10.3
b. N levels			
N_1	10.9	11.7	11.3
N_2	12.0	12.0	12.0
N_3	12.8	12.2	12.5
CD (0.05)	0.77	0.24	
c. P levels			
P_1	11.3	11.7	11.5
P_2	12.7	12.3	12.5
P_3	11.7	11.8	11.8
CD (0.05)	0.77	0 24	
d. K levels			
K_1	11.3	11.8	11.6
K_2	12.1	11.8	12.0
K_3	12.2	12.1	12.2
CD (0.05)	NS	NS	

** Denotes significant difference with control at 1 per-cent level was observed from N_2 level in 1990-91 while lowest level itself produced the same effect in 1991-92 (Appendix 13).

The levels of N showed significant difference in both the years. The significant increase of 9.1 per cent was observed when the N level was increased from N_1 to N_2. But further increase to N_3 did not produce significant increase on TSS of apple (Table 27b).

Effect of P

The P application produced a significant increase to 10.1 per cent and 12.5 per cent over 9.3 per cent and 8.8 per cent at control in 1990-91 and 1991-92, respectively (Table 27a). The significant effect was noticed from P_2 level in 1990-91 while it was observed at 125 g P_2O_5 per tree per year in 1991-92 (Appendix 13).

There was significant difference between levels of P in both the years. The trend of variation of increase upto P_2 level and further decrease at P_3 level was also found to be similar in both the years (Table 27c).

Effect of K

K application significantly increased the TSS of apple to 9.3 per cent and 11.3 per cent compared to 9.2 per cent and 8.8 per cent at control in 1990-91 and 1991-92, respectively

(Table 27a). This increase was evident from K_2 level in 1990-91 while from K_1 level in 1991-92 (Appendix 13).

The levels of K failed to record any significant increase in TSS of apple in both the years (Table 27d).

Interaction of nutrients

The significant interactions between N and P; and N and K were noticed in relation to TSS of apple in 1991-92. In presence of 250 g P_2O_5 per tree per year maximum TSS of 13 per cent was recorded at the highest level of N and in presence of K_2 level also (500 g K_2O/tree/year) TSS was maximum at N_3 level. The maximum value of 13 per cent TSS was observed at the nighest level of N in combination with second level of P. The similar interaction was recorded for N and K too

4.5. Critical level of nutrients

Critical levels of nutrients were calculated from second order regression equation ($y = a + bx + cx^2$) at three different stages of growth (Table 29). The slope of the equation indicated the critical level. All the regression equations resulted in significant R^2 value of more than 0.9. The highest value of critical concentrations computed for N, P and K were observed at flowering. Critical level was calculated from a range of 1.93 to 3 02 per cent for leaf N, 0.072 to 0 159 per cent for leaf P and 0.52 to 1.48 per cent for leaf K.

Table 28. Interactions of nutrients on T.S.S. of apple

	N x P					N x K			
	N_1	N_2	N_3	Total		N_1	N_2	N_2	Total
P_1	11.33	11.93	11.93	11.73	K_1	12.50	11.28	11.76	11.85
P_2	11.73	12.31	12.88	12.31	K_2	10.93	12.45	12.10	11.82
P_3	11.93	11.65	11.70	11.76	K_3	11.56	12.16	12.65	12.12
Total	11.66	11.96	12.17						

4.6. Yield prediction based on foliar nutrient levels

Yield prediction equation developed by Mathew (1990) when fitted to the data on leaf nutrient contents and its ratio observed in this study yielded a very low R^2 showing a poor fit. Hence a new prediction equation was arrived at by a stepwise selection of explanatory variables and analysis of their contribution at every stage.

In this stepwise regression procedure, eighteen explanatory variables were selected initially The output of the explanatory variables were

$$Y = -65.62 + 0\ 051x_2 - 1.216x_2 - 1\ 498x_3 + 0.962x_4 + 0.962x_5 - 0.167x_6 + 0.209x_7 - 0\ 689x_8 + 0.321x_9 + 0.814x_{10} + 2.348x_{11} + 0.476x_{12} + 0.122x_{13} + 0.112x_{14} + 0.154x_{15} + 0.142x_{16} + 1.394x_{17} + 1.24x_{18}$$

where, Y - yield

x_1 - N content of leaf at flushing

x_2 - P content of leaf at flushing

x_3 - K content of leaf at flushing

x_4 - N/P ratio of leaf at flushing

x_5 - N/K ratio of leaf at flushing

x_6 - K/P ratio of leaf at flushing

x_7 - N content of leaf at flowering

x_8 - P content of leaf at flowering

x_9 - K content of leaf at flowering

x_{10} - N/P ratio of leaf at flowering

x_{11} - N/K ratio of leaf at flowering

x_{12} - K/P ratio of leaf at flowering

x_{13} - N content of leaf at fruiting

x_{14} - P content of leaf at fruiting

x_{15} - K content of leaf at fruiting

x_{16} - N/P ratio of leaf at fruiting

x_{17} - N/K ratio of leaf at fruiting

x_{18} - K/P ratio of leaf at fruiting

Subsequently, eliminating the characters which are less important in relation to yield at each step, the final regression equation arrived at was

$$Y = 5.33 + 0.364x_1 + 0.746x_2 + 0.211x_3 + 0\ 378x_4$$

$$R^2 = 0.552^* \ (P = 0.01)$$

where

Y - Yield of the plant

x_1 - N content of leaf at flushing

x_2 - N content of leaf at flowering

x_3 - N content of leaf at fruiting

x_4 - N/P ratio at flushing

4.7. Economic optimum doses

The economic optimum doses are given in Table 30. These were computed from a range of 250 to 1000 g for N and K, and 125 to 500 g for P (Table 30).

4.8. Economic analysis

Accounting the cost of inputs and outputs, the net return was calculated to be Rs.55/- per tree when the lowest levels of 250:125:250 g N, P_2O_5 and K_2O per tree per year was applied. It increased to Rs 130/tree for medium levels of 500:250:500 g N, P_2O_5 and K_2O per tree per year with 13.6 per cent increase over the lowest level. But further increase of fertilizers to the highest level of 1000 g : 500 g : 1000 g N, P_2O_5 and K_2O per tree per year gave only Rs.140 per tree with 7.6 per cent increase over the medium level (Table 31)

Table 29 Critical levels of nutrients (%) at different stages

Nutrients	Flushing	Flowering		Fruiting	
		1990-91	1991-92	1990-91	1991-92
Leaf N	1.89	2.14	2.18	2.07	2.03
Leaf P	0.069	0.113	0.124	0.111	0.119
Leaf K	0.50	0 91	0 89	0.87	0 83

Table 30. Economic optimum doses (g/tree/year) of fertilizers

Nutrients	Economic optimum dose (g/tree/year)
Nitrogen	748 g N
Phosphorus	329 g P_2O_5
Potassium	765 g K_2O

Table 31. Economic analysis at different levels of fertilizer application

	Per tree per year (Rs.)	Per ha per year (Rs.)
Net return at lowest level (N_1 P_1 K_1)	55/-	8,580/-
Net return at medium level (N_2 P_2 K_2)	130/-	20,280/-
Net return at higher level (N_3 P_3 K_3)	140/-	21,840/-

Discussion

5. DISCUSSION

Results generated from the studies conducted to examine the effect of foliar and soil nutrient levels of cashew on growth and yield are discussed in this chapter.

5.1. Growth attributes

Significant positive effects of N and its levels on the cumulative height as well as seasonal flushes have been observed in the present study. Beneficial influence on vegetative characters of cashew has been reported by Nambiar (1983) and Kumar (1985) N application has increased the nitrogen available for absorption as well as its content in tissue which increased the total chlorophyll and its 'b' component (section 5 2.4), perhaps enhancing the rate of photosynthesis which has been reflected in the cumulative height and the seasonal flushes. A greater response to the applied nitrogen towards growth was observed, since the stored nitrogen in the plant might have been used for regular growth of the plant leaving little behind for putting forth new flushes The finding of Ankaiah (1980) is in agreement with this.

It has been reported (Zelitch, 1973) that photosynthesis will increase only upto 6 mg N/dm^2 of leaf area. Probably that level has been reached with 500 g N per tree per year and further increase there by not resulted in any increase in flushes

Chlorophyll 'b' is the main acceptor of radiant energy which is funneled to P_{700} of chlorophyll 'a'. The increase in the chlorophyll 'b' indicated more efficient photosynthetic assimilation which has reflected in the increased flushes. Increase in flushes due to N application through increased chlorophyll content will further confirm the role of applied N in enhancing vegetative growth.

The interrelation between N levels and leaf N content, and leaf N and chlorophyll further suggest the pathway of nitrogen in the production of flushes.

The effect of P significantly increasing the height and flushes can be attributed to its functional roles in structure, metabolism and reproduction. Similar, positive response to applied P in enhancing vegetative growth in cashew has been reported by Nambiar (1983). The response upto the highest level of P used in their trial may be suggestive of the low capacity factor of P in this soil in the experimental area as the thin layer of surface soil is underlaiden with hard laterite. The steady linear response among levels as well as between control further points to the low capacity factor of the soil. The dissimilar results obtained in the present study compared to those reported by Mishra et al. (1980) may be because of variation in capacity, intensity and rate of release characteristics of the soil.

The role of K in plants is attributed to the improvement of internal nutritional environment and does not have any direct effect on growth and development. Significant response to K application between control and among levels in enhancing height and production of flushes observed in this study may be attributed to this indirect role of K in influencing translocation of other nutrients Amir and Reinhold (1971) have demonstrated clear depression of translocation of nutrients under conditions of even mild potassium deficiency. While the work of Kumar (1985) agrees with the present finding, Lefebvre (1973) did not observe any effect of K on growth of cashew.

The role of P and K discussed above is reiterated by the significant interations shown in the effectiveness of these nutrients towards the height of tree. For the effective utilization of higher levels of N demanded a corresponding increases in the levels of other nutrients too, to the highest level of K but to a moderately higher level of P.

5.2. Leaf elemental composition at flushing

5.2.1. Leaf nitrogen

The application of N, P or K independently enhanced the leaf nitrogen content at flushing over control. Since the control plots were not given any fertilizer application since planting, this results underscore the need for application of these nutrients even at a minimum scale. Flushing is the initial expression of yearly growth of cashew. As discussed earlier, the limited supply of N restricted the number of flushes and tends the plant to distribute the available N in each flush.

Eventhough different levels of N applied caused a linear increase in N content of leaf, the change was not significant. This suggests that if the N supply is more the plant utilizes it for production of more number of flushes and not for increasing the nitrogen content of leaves. It is also to be mentioned that the leaf N content was the lowest at flushing compared to other growth stages of cashew (Fig. 3).

The different levels of P and K applied also behaved similarly to N with regard to N content of leaf at flushing.

Considering the time of application of fertilizers, it seems that flushing is too early for absorption of nitrogen from the soil in greater quantity by plant and hence did not reflect in nitrogen content of newly formed flushes. A recent report by Mathew (1990) state that leaf N content of cashew increase with the advancement of growth stage from flushing and is in agreement with this result.

5.2.2. Leaf phosphorus

The P content in leaf at flushing was enhanced to a greater extent by N application than P application itself as seen in Table 6 and this indicates the importance of N nutrition in cashew. Further, among levels of applied N and P, similar responses are seen in enhancing the leaf P content. Since flushing is too early for the reflection of fertilizer elements in leaf as mentioned earlier, the enhanced mineralisation of N and availability of residual P in continuously N and P applied plots also might have a reason for the response with different levels.

Eventhough K didn't cause any significant variation in leaf P due to its different levels of application, it produced significant response over control plots. This signifies the necessity of yearly application of K even at a minimal level.

5.2.3. Leaf potassium

Application of N, P or K independently enhanced the leaf K content at flushing. Although the different levels of N and K resulted in significant linear increase in the concentration of K in leaf, the effect of P levels was not pronounced. Similar observations are reported by Ghosh and Bose (1986). Increase in K content is probably due to direct absorption of K. The favourable effect of N on higher productivity in terms of yield and yield attributing characters (section 5.6) exerted more demand for K. The rate of release of K^+ ions is more compared to phosphate ions and hence K fixation is less in presence of P and the availability and uptake of K was more (Tisdale and Nelson, 1975).

5.2.4. Chlorophyll content of leaves

N application had no significant improvement in chlorophyll 'a' content of leaves. However, chlorophyll 'b' synthesis and thereby total chlorophyll content were increased by N application.

The significant increase in chlorophyll 'b' as against a mean static level of chlorophyll 'a' with increasing N application is indicative of the increase in the relative proportion of chlorophyll 'a' to chlorophyll 'b'. This would mean that at lower levels of N, chlorophyll 'a' alone will develop and chlorophyll 'b' which is believed to be derived from chlorophyll 'a' fails to develop probably because of an inhibition in the concerned reactions (Bridgit and Potty, 1992) This incidently will explain the reasons for low productivity under low nitrogen situations as chlorophyll 'b' known to be the acceptor of radiant energy which is subsequently funneled to the real sites of synthesis. Mayers and French (1960) reported that photosynthetic efficiency will be maximum only in the two pigment system process. A deficiency in one will bring about more than proportionate reduction in assimilation rate.

Positive and profound increase of chlorophyll 'b' as enhanced level of P in leaf suggest that chlorophyll 'b' formation is inhibited probably, through failure in energy transfer reactions. The formation of chlorophyll 'a' has not proceeded inspite of comparatively higher content of chlorophyll 'a' in relation to chlorophyll 'b' because of inhibitions in the metabolic level. This is to be expected as the feeding zone of the crop has been limited due to the underlaiden hard laterite. Thus it appears that the role of P in enhancement of chlorophyll 'b' is through its role in energy transfer.

The significant response in increasing the chlorophyll 'b' and thereby the total chlorophyll due to K application in all probabilities is due to the enhanced P uptake as shown by higher P content in presence of K, as well as the improvement in internal nutritional environment as has been reported by Marykutty et al. (1992).

5.3. Leaf elemental composition at flowering

5.3.1. Leaf nitrogen

Eventhough there was yearly seasonal variation, a linear increase of N content in leaves at flowering was observed in both the years due to N application. In 1991-92 the significant increase was by about 18 per cent over control. It is to be mentioned that there was a high rainfall following the fertilizer application and part of the nutrients applied might have been lost in 1990-91 and hence the low response. The significant increase in the N content noticed upto N_2 level of 500 g N/tree/year and a decrease at the highest dose of 1000 g N/tree/year also points out to the probable loss of applied N due to rain in 1990-91. In 1991-92 a linear increase of N content from 2.46 to 3.02 per cent was observed with increasing rate of application. This was found to be in conformity with the observations of Kumar and Nagabhushanam (1981) and Ghosh and Bose (1986). The mean N content in nitrogen applied trees improved from 2.04 per cent at flushing to 2.5 per cent at flowering. At fruiting still a lower concentration was observed. Mathew (1990) also reported a maximum value of leaf N content at flowering stage.

P and K application increased the leaf N content at flowering over control, possibly due to the favourable effects created in the rhizosphere due to balanced fertilizer and consequent uptake of nitrogen. The effect was significant only in 1991-92 due to probable reason mentioned above. The effect of different levels of P, eventhough resulted in linear increase in N content in both the years, was not significant. The favourable effect of P in enhancing root length density and root spread in continuously P applied plots resulted in consequent higher uptake of N. Similarly, application of increasing levels of K also resulted in greater nitrogen content in leaves possibly due to its role in translocation of nitrogen uptake. Works of Ghosh and Bose (1986) also showed the increasing N content in leaves due to high rates of P and K in cashew.

5 3.2. Leaf phosphorus

Significant increase in leaf P content was observed due to N application probablv due to the reasons already discussed The different N levels also resulted in significant linear increase in both years. Nitrogen being the most important inorganic component of chlorophyll, and with a high chlorophyll 'a', 'b' and total chlorophyll obtained with the increasing N application rates (section 5 2 4) put the plant in more demand for phosphorus in its system. However, Kumar (1985) observed decreasing leaf P content with increasing N application and suggested the reason of establishment of poor relation of leaf nitrogen with leaf phosphorus.

P application improved the leaf P content in both years. The linear progress with increasing levels observed in this study was in conformity with the results of Ghosh and Bose (1986) and Kumar (1985). As stated earlier, direct absorption of the plants may result in high concentration of P in leaf at higher application rates.

Application of K did not influence the leaf P status at flowering. However, in the plots which received continuous K application in every year increasing levels of K increased the leaf P content. The role of K in the translocation of relatively immobile phosphate in the plant system is well documented

5.3.3. Leaf potassium

N application increased the leaf potassium content at flushing to a great extent, possibly due to the high demand by the greater production of yield attributing characters as discussed earlier. However, the comparison among different levels of N showed significant effect only in 1991-92, the increasing trend was similar in both the years.

Similar responses were obtained with P and K application and its different levels of application.

The maximum leaf K content was observed at flowering stage and the mean value varied from 0.7 to 1.41 per cent. Mathew (1990) also observed highest K content in leaf at flowering stage, the range being 0.62 to 1.48 per cent due to NPK fertilization.

5.4. Leaf nutrient composition at fruiting

5 4.1. Leaf nitrogen

Similar to leaf N at flushing the significant response of N application on leaf N content at fruiting was seen only in 1991-92, probably due to the reason already discussed in the case of N content at flowering However, during this year, there was increase in leaf N with every increment of N, possibly due to greater direct absorption at higher doses. Greater demand for N during fruiting stage is expected since mobilization of N from the leaf to fruits is taking place. Also at fruiting all the newly formed leaves will be reaching its maximum photosynthetic efficiency. Increase in chlorophyll 'b' and total chlorophyll due to N application is already discussed. Kumar and Nagabhushanam (1981) and Kumar (1985) had reported increase in leaf N at fruiting with increasing rate of N application in cashew. N content at fruiting was less than at flowering probably due to the mobilization and utilization of N towards the development of panicles.

Similar to N, P and K application also resulted significant increase in leaf N only in 1991-92 Increasing levels of P effected a linear increase in N content. Eventhough P application enhanced N uptake and utilization, the leaf N may be drawn to developing nuts thereby the levels failed to produce significant increase.

5.4.2. Leaf phosphorus

The leaf P content at fruiting was enhanced by N application. It is already reported in this study that nitrogen application increased the vegetative characters as well as chlorophyll content of the crop. Consequently for higher growth there was high demand for P and a higher level of P was manifested in the leaf. However, the report of Kumar (1985) is in disagreement with this. He observed a decreasing P content in leaf at fruiting with increasing N application.

P application had no marked effect on leaf P at fruiting over plants in the control plots. Increase in leaf P content due to P application was less than that due to N application. However, the increasing levels of P increased leaf P content. P with its role in energy transfer in internal plant system is demanded in greater quantity at fruiting, since the development of fat and oil rich fruit requires more energy. This resulted in more P uptake by direct absorption and maintained a higher concentration of leaf P at fruiting.

Among different stages maximum P content of 0.16 per cent was observed at fruiting (Fig. 4). However, Mathew (1990) observed the maximum leaf P content at flowering stage. The improvement of leaf P at the cost of K application was not pronounced at fruiting.

5.4.3. Leaf potassium

The application of N, P and K independently enhanced the K content of leaf at fruiting, the reason was reported elsewhere in this chapter. Leaf K content was lower at fruiting than at flowering where it registered the higher value (Fig. 5). The lower content at fruiting may be due to greater movement of K from the leaves to the development of cashew apple and nut. The pattern of distribution of K in leaf at various stages is in agreement with the finding of Mathew (1990).

5.5. Available nutrient content of soil

5.5.1. Soil nitrogen

Application of nitrogen increased the soil N content in both the years, irrespective of continuous uptake and utilization by the plant. There is evidence of residual effects of higher rates of nitrogen application. Although N may move down through the profile and enter the ground water, some will move down but perhaps not out of the root zone of the deeper rooted crops (Tisdale et al., 1990) The underlaiden hard laterite in the experimental area might not have allowed the leaching of N out of the root zone resulting in higher N content in soil. In similar works in cashew, but at different soil, Kumar (1985) observed soil N content increasing from 0.125 per cent with higher rate of N application.

Eventhough application of varying levels of P had no effect on the N content of soil, in general it increased in response to applied P. The applied P might have enhanced the mineralisation process since the nitrifying bacteria gave an adequate supply of P (Tisdale et al , 1990). Also in an inherently P deficient soil P-application might have enhanced the bacterial population with an average N P ratio of 4 : 1 and later release of N into the soil through a immobilisation-mineralisation process might have resulted in increased N content of soil

Potash application also brought about a similar increase in N content of soil over the plots with no potash application. A proper balance of elements present in the soil can enhance the bacterial population and enhance the N content as discussed above

5.5.2. Available phosphorus content of soil

The increasing N rates resulted in higher available P content of soil. There are reports that the N:P ratio of soil is closely related with mineralisation and immobilisation of phosphorus and suggested that the decreased supply of one resulted in the increased mineralisation of other. Thus, if N was limiting inorganic phosphate might accumulate in the soil and the formation of soil organic matter would be initiated. The additions of fertilizer N under such condition could result in the immobilisation not only of some of the inorganic phosphates but also some of the added fertilizer N (Tisdale and Nelson, 1975) This immobilised P could have resulted in the high P content observed six months after application in 1990-91.

P application and levels of P possibly influenced soil P content due to its direct effect. The increase in P content with K application, but not with its varying levels, may be due to the creation of favourable rhizosphere environment balanced with application of K.

5.5.3. Available K content of soil

Application of either N or P in its varying levels did not bring about any significant change in the available K status of soil. This can be expected in soil where K fixation is not to greater extend and no relation between N and K content is established.

However, K application as well as levels of K increased the available K content possibly due to the direct effect of enhancing its content in soil due to external application.

5.6. Yield attributing characters

5.6.1 Number of panicles/m^2

N application significantly increased the panicle production While production of new flushes are the expression of yearly growth, panicle production is the expression of productivity. Flushes are the real progenitor of panicles. Hence greater production of flushes observed with N application is the primary cause for higher number of panicles observed in this study. While the N application reulted in an enhancement of flushes by about 90 per cent, the panicle production was increased by 250 per cent. Milthorpe and Moorby (1979) reported stimulation of the development of new meristems and hence an increase in demand for more mineral ions due to a high internal concentration of minerals, especially nitrogen, in the plant system. It is already reported a concomittant increase in total chlorophyll and its constituent components in flushes due to N application, which perhaps enhanced the photosynthesis and ultimately increased the panicle production.

P application also significantly influenced the panicle production This is expected since the major role of P in the plant system is related with structure, metabolism and reproduction which enhanced the panicle production.

Greater response to K application observed in the panicle production may be related to its role in the translocation of elements on metabolic activities in plant system. K is identified to play an important role in the production of cofactors and enzymes As a result higher metabolic activities and hence higher panicle production was observed. K is reported to promote the growth of the meristematic tissue (Tisdale and Nelson, 1975).

5.7. Yield and related characters

5 7.1. Yield

Significantly higher yield was observed with N application and response was seen upto 500 g N/tree/year Yield is the ultimate expression of source-sink relationship. The positive effect of nitrogen in the development of some characters towards the enrichment of sink was discussed earlier. Hence a higher yield due to the favourable effect of N in the production of flushes, maintenance of high leaf N, chlorophyll content, greater number of panicle production and high test weight of nuts is expected. Several workers have reported significant yield increase due to high levels of N application (Pujari, 1979, Reddy et al., 1982, Kumar, 1985 and Mathew, 1990) even upto 1500 g N/tree/year depending upon soil type and age of the tree.

P application increased the yield significantly only in 1991-92 and the linear increase was observed with increasing P application. A good supply of phosphorus has been associated with increased root growth (Tisdale and Nelson, 1975), and helped in higher uptake of nutrients. The increase in vegetative and yield characters due to P application probably through indirect effect of energy transfer or through the direct role in laying down the primordia for its reproduction is already discussed. The yield increase observed may be due to the reasons already mentioned.

Almost similar results to yield was brought about by K application. The yield increase due to the improvement of growth and yield characters resulted by K application. Similar yield increase was reported by Ghosh (1990), Kumar (1985) and Mathew (1990).

The highest yield of 8.7 kg/tree obtained in this study correspond with the yearly application of 1000 g N, 250 g P_2O_5 and 500 g K_2O. This is seven fold higher than the yield in absolute control plots where no fertilizer application was done since planting and sixteen times higher than the average national productivity reported. This result emphasizes the importance of supplimenting nitrogen with phosphorus and potassium for higher productivity in any system where specific nutritional environment in soil is generated through continuous application of fertilizers. This implies that formulation of objective oriented management system of cashew and its judicious application in field will enable us not only to meet the entire requirements of cashew at present, but also boost the cashew industry to further heights.

5.7.2. Nut characters

N application as well as levels of N significantly influenced the test weight of nuts in both the years. The increase in test weight may be attributed to the greater sink strength due to N application. Higher contents of leaf N and chlorophyll observed with higher N application increased photosynthesis and hence more sink strength and test weight. Nut volume was also improved significantly by N application. However, Kumar (1985) observed a decrease in nut weight and volume due to N application. Probably due to increase in the number of panicles as observed by him.

P application as well as levels had similar effect as that of N on test weight of nuts, while P application alone effected the nut volume. Since N and P are required for the metabolism of plants, P application increased the uptake of P. This was also well evidenced by the increase in leaf P due to P applied. Increased uptake increase metabolism and sink strength.

K application also gave the similar results as that of N and P in the case of nut weight and volume. The influence of K in the translocation of photosynthates to the nut, is probably the reason for it, as potassium influences the translocation of sugars (Jones, 1979).

5 7.3. Protein content of kernels

Both N application as well as its levels influenced the protein content of kernels Similar results were obtained by Kumar (1985) and Ankaiah (1980). N is the important constituent of amino acids which are the building blocks of protein. So naturally increase in N application increase the amino acid content and hence the protein by the direct absorption of N.

P and K application were significantly responded to protein. But levels did not produce significant variation. Similar observations were made by Kumar (1985) in the case of P. But according to him, protein content was unaffected by K application. The increase in protein content due to K application may be partly due to its role in N metabolism and protein synthesis Tisdale and Nelson (1975) identified physiological function of K in N metabolism and synthesis of protein apart from catalytic action.

5.7.4. Characters of fruit

Eventhough N application influenced significantly the fruit volume and weight in both the years, the levels differed significantly in 1990-91 only. However, an increase was noticed in 1991-92 also. On contrast to it, Kumar (1985) found a decreasing effect on fruit volume and weight by N and P fertilization. N is important in carbohydrate formation as it is a component of respiration-energy carrier, ATP (Black, 1968).

N application along with its levels brought about significant effect on total soluble solids (TSS) of apple. An increasing trend due to N application was also noticed by Kumar (1985). The importance of N in photosynthetic process is discussed earlier. Hence high photosynthesis increased the convertion of more carbohydrates to sugar and hence increased the TSS of apple.

P and K application influenced fruit volume, weight and TSS of apple significantly. Increase of weight and volume due to K application probably may be due to the translocation of sugars to the developing fruit by potassium. Increase in TSS of apple due to P application was not pronounced as that due to N application, though levels of P also influenced it significantly. It may be due to indirect effect of P on photosynthesis through N. The significant interaction involving N with P and K well established the dependence of N for photosynthesis.

5.8. Critical level of nutrients

Critical level is the concentration of nutrient in the leaf below which a yield reduction occurs. The critical levels were computed separately for flushing, flowering and fruiting stages. Similar to the distribution of N and K in leaf, the highest critical values for N, P and K were obtained at flowering. The lowest values were worked out at flushing. Flushing is the initial stage and so absorbed nutrients are utilized for the formation of source alone. As the growing stage is advanced the absorbed nutrients are utilized for the development of source as well as for the formation of sink, hence a higher value is needed at flowering. As the fruiting stage is reached, the development of source is completed and the nutrients are used only for the sink development and relatively lower concentrations are sufficient.

Kumar and Sreedharan (1986) worked out the critical values of 2.09 and 0.14 per cent for leaf N and P, respectively and they couldn't work out that for K. The critical leaf contents reported by Kumar (1985) and the one obtained at fruiting in this study was found to be similar. Mathew (1990) also worked out the critical levels for leaf N and K as 2.00 and 1.03 per cent respectively. He could not calculate that for P because the yield of cashew was not significantly and positively correlated with leaf P. But in this study a significant positive correlation was obtained between leaf P at fruiting and yield.

5.9. Yield production based on foliar nutrient levels

The prediction equation developed by Mathew (1990) to predict cashew yield in relation to leaf nutrient content was found to restrict its general adaptability. A low R^2 value was observed when the required explanatory variables observed in this study was fitted in the said equation.

The stepwise regression procedure adopted in this study in order to obtain a better yield prediction equation revealed N content of leaf at flushing, flowering and fruiting and N/P ratio at flushing are the important dependent variables affecting the yield The yield of cashew could be predicted with a precision of 55 per cent using the present equation developed.

Mathew (1990) utilised the method of least squares and selected variables as explanatory variables based on the simple correlation observed between parameters and the contribution of each variable has not been examined. This may be the reason for low R^2 (0.362) when the equation was fitted to the data observed in this study. The stepwise regression procedure adopted in this study analysed the contribution of each variable in explaining the variability of dependent variable and hence a better prediction of yield was observed. The maximum contribution to yield was by N content of leaf at flowering followed by that of flushing. N at fruiting has least contribution Hence maintenance of leaf N content not less than the critical level at flushing and flowering is important with respect to productivity of cashew.

5.10. Economic optimum doses of fertilizer

Economic optimum doses of 748 g N, 329 g P_2O_5 and 765 g K_2O/tree/year were worked out. However, a low economic optimum doses of 430 g N and 130 g P_2O_5/tree/year were estimated by Kumar (1985). He could not work out that for K due to linear response to K application However, Kumar had made use of plants of 3 years old and yield stabilization was not reached while in this study 11 years old cashew trees were used where yield stabilization was achieved.

5.11. Economic analysis

Accounting the cost of inputs and cultural operations (Appendix-16) and sale price of cashew (Rs.21/kg) the net return worked out to be Rs.55/tree at N_1 P_1 K_1, while the value is almost three fold at N_2 P_2 K_2 (Rs.130/tree). But, with further increase to the highest level (N_3 P_3 K_3) the net return was only Rs.140/tree. This is the diminishing rate of increase in response of cashew to the highest doses of fertilizers. The net return of Rs.7.40/tree/year was only reported from an experimental condition for 6 years with the application of optimum doses of 666 g N, 266 g P_2O_5 and 533 g K_2O/tree/year (Anon., 1976). The high net return in this study may be due to high price of cashew compared to the price existed twelve years before.

Summary

SUMMARY

Studies on the growth and yield of cashew in relation to foliar and soil nutrient levels was carried out during 1990-92 by making use of seedling progenies of BLA-39-4 planted in 1979 under KADP (College of Horticulture) at Madakkathara. The experiment was laid out in 3^3+1 factorial RBD consisting of 3 levels each of N (250, 500 and 1000 g/tree/year), P (125, 250 and 500 g P_2O_5/tree/year) and K (250, 500, 1000 g K_2O/tree/year) and one absolute control (without NPK application).

Observations on growth and yield characters, leaf nutrient content at flushing, flowering and fruiting stages and available nutrient contents in soil were made in both the years. Computation of critical levels of nutrients in leaf, economic optimum doses of fertilizers, prediction of yield based on N, P and K content of leaves at various stages were done.

Application of N, P or K significantly increased the growth characters such as height and production of new flushes. The increasing levels of N upto 500 g/tree and P upto 250 g/tree resulted in significant increase, but no significant response was observed for increased K levels. Significant positive relationship was obtained between number of flushes and leaf N content.

Leaf N, P and K content at flushing and fruiting was significantly enhanced by application of the three nutrients. At flowering significant increase in leaf N and K content was observed with application of each nutrient. K application failed to produce significant effect on leaf P content. Significant response to increasing levels of nutrients was only seen in case of N at flushing and flowering.

N, P or K application produced significant increase in total chlorophyll content and chlorophyll 'b'. However, significant positive correlation was obtained between leaf P content and chlorophyll 'a'.

Leaf analysis at different stages revealed that leaf N varied from 1.93 to 3.02 per cent, leaf P between 0.072 to 0.16 per cent and leaf K between 0.57 to 1.48 per cent. Distribution of N and K showed a regular pattern with the highest concentration at flowering while highest leaf P content was recorded at fruiting stage. However, these three nutrients showed the lowest concentration in leaf at flushing stage.

Soil N content was significantly increased by N, P or K application. Increasing levels of the nutrients upto the second level of application increased the N content of soil. N application did not influence the P content of soil. However, P and K application significantly increased it. However, P and K application significantly increased the P content of soil. Available K content of soil was not effected by application of any of the nutrients. But increasing levels of K increased the K content of soil A negative, but nonsignificant relationship was obtained with soil and leaf nutrient contents.

N, P and K application significantly increased yield attributing characters such as number of panicles/m^2 and test weight of nuts. The test weight was significantly increased with increasing levels of all the nutrients mainly upto the second level, but panicle number was influenced only by the levels of N.

Cashew yield was significantly increased with N, P and K application. However, significant response with increasing levels was obtained only with N. Existence of significant correlation was obtained between leaf N and P contents at flowering and fruiting stages and yield. Between soil nutrient content and yield, a negative, though nonsignificant relationship was observed.

The highest yield of 8.7 kg in this study correspond with the yearly application of 1000 g N, 250 g P_2O_5 and 500 g K_2O/tre This is seven fold higher than the yield in absolute control plots where no fertilizer application was done since planting and sixteen times higher than the average national productivity reported.

N, P and K application brought about a progressive increase in nut volume, protein content of kernels, fruit weight, fruit volume and total soluble solids (TSS) of apple Protein content of kernels was significantly improved by N levels, but other characters were positively influenced by the levels of both N and P. Significant interaction of N with varying levels of P and K was found in the case of TSS of apple.

Critical levels of N, P and K were worked out at various stages and found maximum values of N, P and K at flowering. The critical values were 1.89, 0.069 and 0.51 per cent at flushing for N, P and K respectively. The values at flowering were 2 16, 0.118 and 0.90 per cent and at fruiting were 2 05, 0.115 and 0.85 per cent for N, P and K, respectively.

The yield prediction equation developed by Mathew (1990) was tested with the data in this study and found to be a poor fit. A modified equation was developed through stepwise regression procedure as follows.

$$y = 5.33 + 0\ 364x_1 + 0.746x_2 + 0.211x_3 + 0.378x_4$$

where,

y - yield of plant

x_1 - leaf N content at flushing

x_2 - leaf N content at flowering

x_3 - leaf N content at fruiting

x_4 - N/P ratio at flushing

The equation was found to be better fit with R^2 = 0.552 for yield prediction in relation to foliar nutrient levels.

Economic optimum doses were worked out to be 748 g N, 329 g P_2O_5 and 765 g K_2O/tree/year for cashew.

Economic analysis at different levels of fertilizer applied showed maximum net returns of Rs.21840/ha at highest levels of 1000 g N,, 500 g P_2O_5 and 1000 g K_2O/tree/vear. While net returns of Rs.8580/- and Rs.20280/- were obtained at lowest and medium levels of N, P and K.

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Appendices

Appendix 1. Abstract of ANOVA of the effect of fertilizer management on height of the tree and number of flushes/m^2

Source	df	Mean square		
		Height of the tree	Number of flushes/m^2	
		1991-92	1990-91	1991-92
Replication	1	0.9	46.4	10.7
Treatment	27	0 9	20.76	14.6
N	2	5.2**	89.3**	60 5**
P	2	0 2*	40 1*	11 1
NP	4	0.7**	12.4	34
K	2	0.2*	4 4	121
NK	4	0.6**	6 9	6.9
PK	4	0.2*	9 4	9.4
NPK	8	0.5**	3.9	3.9
Control vs treatments	1	2.8*	145 4**	113.7**
Error	27	0.06	8.4	7.45
Control vs base levels of NPK ($N_1P_1K_1$)	1	18 5**	5.1	45.4**
Control vs N	1	29.7**	73.5**	45.4**
Control vs N_2	1	6.8**	72.3**	76 6
Control vs N_3	1	13.7**	105.1**	64.0
Control vs P	1	33.3**	68.5	26.1
Control vs P_2	1	15.6**	72 3**	-
Control vs P_3	1	9.9**	156 3**	-
Control vs K	1	35 3**	12.0	44.0**
Control vs K_2	1	15 2**	-	52 6
Control vs K_3	1	13.0**	-	85 6

Appendix 2. Abstract of ANOVA of the effect of fertilizer management on leaf N content and leaf P content at flushing

Source	df	Mean square	
		Leaf N content	Leaf P conten
		1991-92	1991-92
Replication	1	0.01	0 000001
Treatment	27	0 02	0.0000001
N	2	0.08	0.001**
P	2	0.02	0.001**
NP	4	0.01	0 00001
K	2	0.02	0 000011
NK	4	0.01	0.00001
PK	4	0.01	0.000001
NPK	8	0.007	0.000001
Control vs treatment	1	0.09	0.001**
Error	27	0.02	0.00007
Control vs base levels of NPK ($N_1P_2K_1$)	1	2.1**	0.002**
Control vs N	1	2.9**	0 005**
Control vs N_2	1	1.4**	0 002**
Control vs N_3	1	1.5**	0.003**
Control vs P	1	2 8**	0 004**
Control vs P_2	1	1.2**	0 002**
Control vs P_3	1	1 1**	0.002**
Control vs K	1	2 6**	0 004*
Control vs K_2	1	1 0**	0.001**
Control vs K_3	1	1 0**	0.001**

Appendix 3. Abstract of ANOVA of the effect of fertilizer management on leaf K content at flushing and chlorophyll 'a' of leaves

Source	df	Mean square	
		Leaf K content at flushing	Chlorophyll 'a' of leaves
		1991-92	1991-92
Replication	1	0 6	0.001
Treatment	27	0 8	0 04
N	2	0.1^{*}	0.07
P	2	0.02	0.07
NP	4	0 07	0.03
K	2	0.2^{*}	0.01
NK	4	0 02	0.02
PK	4	0 07	0.01
NPK	8	0 2	0 05
Control vs treatment	1	0.04^{**}	0.2
Error	27	0.6	0 03
Control vs base levels of NPK ($N_1P_1K_1$)	1	0 3	-
Control vs N	1	0.5^{**}	0.28
Control vs N_2	1	0 3^{**}	-
Control vs N_3	1	0 3^{**}	-
Control vs P	1	0 09^{**}	0 53
Control vs P_2	1	0.05	-
Control vs P_3	1	0 05	-
Control vs K	1	0.08^{**}	0 19
Control vs K_2	1	0 04	-
Control vs K_3	1	0 04	-

Appendix 4 Abstract of ANOVA of the effect of fertilizer management on chlorophyll 'b' and total chlorophyll of leaves

Source	df	Mean square	
		Chlorophyll 'b' of leaves	Total chlorophyll
		1991-92	1991-92
Replication	1	0.06	0.2
Treatment	27	0.08	0.3
N	2	0.2*	0.7*
P	2	0 05	0.08
NP	4	0 04	0 2
K	2	0.02	0.09
NK	4	0.09	0.2
PK	4	0 03	0.01
NPK	8	0 08	0.4
Control vs treatment	1	0.3*	0.9*
Error	27	0 06	0.2
Control vs base levels of NPK ($N_1P_2K_1$)	1	0.1	1 2*
Control vs N	1	0 66**	2.1**
Control vs N_2	1	0 3**	0 8*
Control vs N_3	1	0.5**	1.4*
Control vs P	1	0 4*	1.4*
Control vs P_2	1	0.1	0.8*
Control vs P_3	1	0.3*	0.5*
Control vs K	1	0.3*	1.2*
Control vs K_2	1	0.1	0.1*
Control vs K_3	0 2	0.6*	

Appendix 5 Abstract of ANOVA of the effect of fertilizer management on leaf N and leaf P content at flowering

Source	df	Mean square			
		Leaf N content		Leaf P content	
		1990-91	1991-92	1990-91	1991-92
Replication	1	0.1	0.1	0.00001	0.000001
Treatment	27	0.1	0.2	0.0002	0.000001
N	2	0.4*	1.5	0.002**	0 001*
P	2	0.2	0.2	0.001**	0 000001
NP	4	0.1	0.2	0.000001	0 000001
K	2	0.2	0.04	0.000001	0 0000001
NK	4	0.1	0 02	0 000001	0.000001
PK	4	0.1	0.1	0.000001	0 000001
NPK	8	0.1	0.03	0 000001	0 000001
Control vs treament	1	0.3	0.6*	0.002**	0.001*
Error	27	0.1	0.1	0.0002	0.0002
Control vs base level of NPK ($N_1P_1K_1$)	1	1.2**	1.3**	0 003**	0.002**
Control vs N	1	4 1	5 0**	0 01**	0 01
Control vs N_2	1	2.2**	1.5**	0.003**	0.003**
Control vs N_3	1	1.9**	4 0**	0.007**	0.006**
Control vs P	1	3.8**	4.1**	0 01**	0.008**
Control vs P_2	1	1.3**	1 7**	0.004**	0 003**
Control vs P_3	1	2 2**	2 0**	0.005**	0 004**
Control vs K	1	3.3*	3 9**	0 01*	0 006*
Control vs K_2	1	1.4**	1 6**	0 004**	0.001**
Control vs K_3	1	1.3**	1.8**	0 004**	0 002**

Appendix 6. Abstract of ANOVA of the effect of fertilizer management on leaf K content at flowering and leaf N content at fruiting

Source	df	Mean square			
		Leaf K at flowering		Leaf N at fruiting	
		1990-91	1991-92	1990-91	1991-92
Replication	1	0.009	0.07	0.04	0.00001
Treatment	27	0.04	0.1	0.1	0.1
N	2	0.04	0.4**	0.3	0.9
P	2	0.01	0.07	0.2	0.1
NP	4	0 02	0.02	0 01	0.1
K	2	0.08	0.2	0.03	0.004
NK	4	0.01	0.1	0.03	0.02
PK	4	0.001	0.1	0.02	0.01
NPK	8	0.03	0 03	0.2	0.03
Control vs treatment	1	0.04**	1.2**	0 2	0 5**
Error	27	0.03	0.07	0.1	0.05
Control vs base level of NPK ($N_1P_1K_1$)	1	0.5**	0.06	1.2**	1.4
Control vs N	1	1.6**	1.1**	3.3*	5.3**
Control vs N_2	1	1.0**	0.9**	1.1**	3.0*
Control vs N_3	1	0.9**	1.1**	1.7**	2.9*
Control vs P	1	1.2**	1.0**	3.3*	3.8*
Control vs P_2	1	0.5**	1.0**	1.1**	1.4**
Control vs P_3	1	0.7**	0.8**	1.5**	1.8*
Control vs K	1	1.4**	1.2**	3.2*	3.7*
Control vs K_2	1	0.9**	1.1**	1.3**	1.4
Control vs K_3	1	0.6**	1.2**	1.3**	1.7

Appendix 7 Abstract of ANOVA of the effect of fertilizer management on leaf P and leaf K content at fruiting

Source	df	Mean square			
		Leaf P content		Leaf K content	
		1990-91	1991-92	1990-91	1991-92
Replication	1	0.00001	0.000001	0.04	0.00001
Treatment	27	0.000001	0.001	0 1	0.1
N	2	0.002**	0.003**	0.3	0.9**
P	2	0.0005	0.002**	0.2	0.1
NP	4	0.000001	0.0002	0.01	0.1
K	2	0.0005	0.005	0.03	0.004
NK	4	0.000001	0 000001	0.03	0.02
PK	4	0.0002	0.000001	0.02	0.01
NPK	8	0.00001	0.000001	0.2	0.03
Control vs treatment	1	0.002**	0.001	0.2**	0.5**
Error	27	0.0002	0.0002	0.1	0.05
Control vs base levels of NPK ($N_1P_1K_1$)	1	0 004**	0.004**	1.2**	1.4**
Control vs N	1	0.01**	0.01*	3.3**	5.3**
Control vs N_2	1	0.007**	0.005**	1.1**	3.0*
Control vs N_3	1	0.008**	0.006**	1.7**	2.9*
Control vs P	1	0.01**	0.01*	3.3**	3 8*
Control vs P_2	1	0.006**	0.003**	1.1**	1.4
Control vs P_3	1	0.007**	0.004**	1.5**	1.8
Control vs K	1	0.01**	0.01*	3.2**	3.7*
Control vs K_2	1	0.005**	0.004**	1.3**	1.4
Control vs K_3	1	0.004**	0.005**	1.3**	1.7

Appendix 8. Abstract of ANOVA of the effect of fertilizer management on N and available P content of soil

Source	df	Mean square			
		N content of soil		Available P content of soil	
		1990-91	1991-92	1990-91	1991-92
Replication	1	0.00001	0.001	0.002	0.06
Treatment	27	0.0003	0.000001	223.3	535.9
N	2	0.001*	0.000001	122.5	5821*
P	2	0.001*	0.0005	1762.0**	1918.6**
NP	4	0.0002	0.0002	176 0	278.3
K	2	0.001*	0.000001	87.4	164.6
NK	4	0.0002	0.000001	23 9	1044.0
PK	4	0.0002	0.0002	164.8	300.9
NPK	8	0.00001	0.00001	47.8	198.9
Control vs treatment	1	0.001*	0.002**	245.2	1054.4**
Error	27	0.002	0.0002	121 19	167.9
Control vs base levels of NPK ($N_1P_1K_1$)	1	0.007**	0.01**	-	-
Control vs N	1	0.08**	0.03**	-	320.8
Control vs N_2	1	0.01**	0.01**	-	-
Control vs N_3	1	0.007**	0.01**	-	-
Control vs P	1	0.02**	0.02**	-	2048.7**
Control vs P_2	1	0.007**	0.01**	-	1947.4**
Control vs P_3	1	0.008**	0.008**	-	2208.5**
Control vs K	1	0.03**	0.02**	-	746.3*
Control vs K_2	1	0.02**	0.01**	-	-
Control vs K_3	1	0.01**	0.01**	-	-

Appendix 9. Abstract of ANOVA of the effect of fertilizer management on available K content of soil and number of panicles/m^2

Source	df	Mean square			
		Available K content of soil		Number of panicles/m^2	
		1990-91	1991-92	1990-91	1991-92
Replication	1	3361.2	264.7	18.0	34.5
Treatment	27	17249.2	8288.7	10.0	13.7
N	2	5823.3	3242 6	76.0**	51.7**
P	2	15169.1	6618.0	9.0	8.8
NP	4	7069.9	5660 3	4.0	10.9
K	2	124768.1**	35065.7**	0.1	13.4
NK	4	12651.2	3330.9	11 9	8.2
PK	4	4979.3	6484.8	0.2	5.5
NPK	8	4141.2	8831.2	0.5	4.5
Control vs treatment	1	42275.2	3388.5	72.4**	88.1**
Error	27	15734.1	4003.8	3.1	5.7
Control vs base levels of NPK ($N_1P_1K_1$)	1	-	-	2.9**	2.9
Control vs N	1	54626.0	25317.5	22.05**	12.6**
Control vs N_2	1	-	-	19.4**	11.6**
Control vs N_3	1	-	-	20.7**	9.6**
Control vs P	1	31176.0	28669.5	13.7**	8.2**
Control vs P_2	1	-	-	10.7**	2.6
Control vs P_3	1	-	-	11.6**	10.3**
Control vs K	1	14106.6	47659.5	18.9**	7.5**
Control vs K_2	1	-	-	7.3**	5.08*
Control vs K_3	1	-	-	4 6**	5.08*

Appendix 10 Abstract of ANOVA of the effect of fertilizer management on test weight of nuts and yield of plants

Source	df	Mean square			
		Test weight of nut		Yield of plants	
		1990-91	1991-92	1990-91	1991-92
Replication	1	52951.5	944.6	0.6	0.7
Treatment	27	7907.2	9730.6	12.0	6.0
N	2	17305.2*	18716.7*	93.1**	24.3*
P	2	10074.9	16018.1*	15.8	17.1
NP	4	5033.6	3903.5	4.3	1.8
K	2	34374 9*	33401 4**	4.1	3.9
NK	4	2577.4	788.9	1.1	0.4
PK	4	264.6	3459.0	0.7	1.1
NPK	8	1367 9	2616.3	1.0	0.6
Control vs treatment	1	47537.4**	72916.7**	66 4**	54.4**
Error	27	3773.7	4734.5	6.2	4.7
Control vs base levels of NPK ($N_1P_1K_1$)	1	59414.1**	54639.1**	17.7	9.0
Control vs N	1	190816.7**	199837.5**	37.9*	41.3**
Control vs N_2	1	90751.5**	132314.1**	21.5	40.0**
Control vs N_3	1	109726.6**	201666.7**	2.9	33 1*
Control vs P	1	231084.4**	132314.1**	20.4	30.3*
Control vs P_2	1	135976.5**	84826.6**	-	19.8
Control vs P_3	1	73756.6**	137826.6**	-	40.0**
Control vs K	1	218504.2**	180266.7**	27.4*	19.6
Control vs K_2	1	101601.5**	68251.6**	14.2	-
Control vs K_3	1	151126.5**	116451.6**	18 7	-

Appendix 11. Abstract of ANOVA of the effect of fertilizer management on nut volume and protein content of kernels

Source	df	Mean square			
		Nut volume		Protein content of kernel	
		1990-91	1991-92	1990-91	1991-92
Replication	1	3.6	0.07	0.05	0.001
Treatment	27	0.9	1.0	5.9	8.9
N	2	3.3**	2.0*	33.2**	46.3**
P	2	1.7**	1.1	0.5	19.0
NP	4	0.3	0.6	1.5	0.6
K	2	3.1	3.4	1.4	1.3
NK	4	0.2	0.2	1.2	0.8
PK	4	0.1	0.2	0.5	1.6
NPK	8	0.1	0.3	1.0	2.6
Control vs treatment	1	5.1**	7.6**	67.7**	76.2**
Error	27	0.2	0.4	4.1	3.4
Control vs base levels of NPK ($N_1P_1K_1$)	1	4.8**	6.8**	204.5**	177.2**
Control vs N	1	8.6**	21.3**	508.9**	439.8**
Control vs N_2	1	9.9**	10.2**	250.4**	203.8**
Control vs N_3	1	12.6**	12.3**	245.9**	203.8**
Control vs P	1	20.5**	24.8**	446.6**	429.0**
Control vs P_2	1	9.0**	14.4**	180.9**	162.8**
Control vs P_3	1	14.4**	14.4**	215.1**	229.5**
Control vs K	1	17.7**	23.4**	439.8**	375.0**
Control vs K_2	1	7.0**	10.6**	203.1**	179.5**
Control vs K_3	1	3.2**	16.0**	233.3**	125.7**

Appendix 12. Abstract of ANOVA of the effect of fertilizer management on fruit weight and fruit volume

Source	df	Mean square			
		Fruit weight		Fruit volume	
		1990-91	1991-92	1990-91	1991-92
Replication	1	11.2	1003.0	0.018	617.7
Treatment	27	147 4	152 8	118.3	151.3
N	2	619.0**	10.4**	607.1**	34.1
P	2	209.7**	564.6	124.2*	137.4
NP	4	129.2	73.3	37.8	115.8
K	2	6.4	56.5	200.7	245.1
NK	4	44.2	171.0	38.6	157.4
PK	4	44.2	82.2	46 0	116.3
NPK	8	53.2	82.3	18.8	117.2
Control vs treatment	1	662.4**	897 7**	692.2**	757.9*
Frror	27	39.1	82.4	35.6	77.5
Control vs base levels of NPK ($N_1P_1K_1$)	1	400.0**	600.3**	552.3**	784.0**
Control vs N	1	2340.3**	2053.5**	2360.1**	4293.3**
Control vs N_2	1	784.0**	870.3**	1024.0**	1225.0**
Control vs N_3	1	1332.3**	1406.3**	1764.0**	1980.0**
Control vs P	1	1768.2**	2562.7**	1962.0**	2380.1**
Control vs P_2	1	784.3**	1190.3**	1225.0**	1122.3**
Control vs P_3	1	1332.3**	2070.3**	812.3**	1849.0**
Control vs K	1	18200.0**	1980.2**	2016.6**	2128.2**
Control vs K_2	1	784.0**	650.3**	784.0**	729.0**
Control vs K_3	1	1332.0**	1560.3**	1369.0**	1849.0**

Appendix 13. Abstract of ANOVA of the effect of fertilizer management on TSS of apple

Source	df	Mean square TSS of apple 1990-91	1991-92
Replication	1	3.6	0.2
Treatment	27	4.8	1.9
N	2	15 2**	1.2**
P	2	8.4*	1.9**
NP	4	4.5	0 8
K	2	4.7	0.5
NK	4	0.6	3.3
PK	4	1.0	0.6
NPK	8	3 8	1.5
Control vs treatment	1	19 0**	13.0**
Error	27	2.5	0.3
Control vs base levels of NPK ($N_1P_1K_1$)	1	8.6	60.0**
Control vs N	1	9.8**	120 2**
Control vs N_2	1	76 1**	55 9**
Control vs N_3	1	85.1**	48.7**
Control vs P	1	92.4**	133.0**
Control vs P_2	1	81.4**	60.5**
Control vs P_3	1	67.6**	65.2**
Control vs K	1	78.8**	102.0**
Control vs K_2	1	49.3**	26.7**
Control vs K_3	1	59.6**	51.5**

Appendix 14 Relationship between leaf N, P and K at different stages and other parameters

Parameters	Leaf N					Leaf phosphorus					Leaf potassium				
	Flushing	Flowering		Fruiting		Flushing	Flowering		Fruiting		Flushing	Flowering		Fruiting	
	91-92	90-91	91-92	90-91	91-92	91-92	90-91	91-92	90-91	91-92	91-92	90-91	91-92	90-91	91-92
Number of flushes/m^2	0.579*	0.407	0.395	0.457	0.437	0.397	0.474	0.406	0.568*	0.374	0.012	0.35	0.417	0.45	0.356
Chlorophyll 'a'	0.193	-	0.233	-	0.366	0 366	-	0.176	-	0.5*	0.199	-	0.43	-	0.224
Chlorophyll 'b'	0.108	-	0.325	-	0.375	0.409	-	0.422	-	0.45	0 465	-	0.336	-	0.368
Total chlorophyll	0.024	-	0.151	-	0.217	0.398	-	0.397	-	0.40	0.369	-	0.303	-	0.299
Number of panicles/m^2	0.268	0.255	0.571*	0.27	0.401	0.54*	0 468	0.46	0.58*	0.535*	0.337	0 197	0.414	0.309	0.567*
Yield	0.382	0.424	0.516*	0.548*	0.48	0.308	0.336	0.555*	0.386	0.554*	0 384	0.239	0.26	0.252	0.301
Soil nitrogen	0.224	0.204	0.210	0.267	0.166	0.154	-0.19	0.237	0.192	0.062	0.264	-0.061	0.187	-0.005	0.199
Available P of soil	0.065	0.346	0.195	0.117	0.298	0.170	-0.066	0.174	0.271	0.231	0.221	0.143	0.319	0.222	0.176
Available K of soil	0.229	0.18	0.195	0.113	0.122	0 148	0.158	0.182	0.288	-0.02	0.119	0.18	0.037	0.178	-0.103

* denotes significance at 1 per cent level
Total number of observations = 56

Appendix 15. Relationship between available nutrients of soil and other parameters

Parameters	Soil N		Available P of soil		Available K of soil	
	1990-91	1991-92	1990-91	19991-92	1990-91	1991-92
Yield	-0.078	0.171	0.197	0.318	0 217	0.017
Number of flushes/m^2	-0.099	-0.044	0.112	-0.024	0.299	0.224
Number of panicles/m^2	0.056	0.228	0.13	0.224	0.222	0.152
Chlorophyll 'a'		0.031		0.146		-0.127
Chlorophyl 'b'		0.214		0.109		0.083
Total chlorophyll		0.169		0.221		0.026

Appendix-16. Cost of inputs and outputs

Urea	- Rs.3/kg
Superphosphate	- Rs 1.35/kg
Murate of potash	- Rs.1.75/kg
Ring weeding (3 times)	- Rs 9.90
Trenching and fertilizer application	- Rs.3 30
Labour for spraying	- Rs 6 60
Endosulfan	- Rs 2.70
Nut collection charges	- Rs 8.00
Sale price of cashew/kg	- Rs.21 00

GROWTH AND YIELD OF CASHEW IN RELATION TO FOLIAR AND SOIL NUTRIENT LEVELS

By

LATHA. A.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
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Vellanikkara, Thrissur

1992

ABSTRACT

An experiment on the growth and yield of cashew in relation to foliar and soil nutrient levels was conducted during 1990-'92 by making use of seedling progenies of BLA-39-4 with three levels each of N (250, 500 and 1000 g/tree/year), P (125, 250 and 500 g P_2O_5/tree/year) and K (250, 500 and 1000 g K_2O/tree/year) and one absolute control (without NPK application).

Significant response in increasing height and number of flushes was observed only for N (500 g/tree/year) and P (250 g P_2O_5/tree/year). Leaf N and K content at flushing, flowering and fruiting were enhanced by application of all the three nutrients with maximum values at flowering. Leaf P content was enhanced by N, P and K application only at flushing and fruiting. N, P and K application also increased the chlorophyll 'b' and total chlorophyll.

There was increase in N and P content of soil by N, P and K application, while K content of soil was increased only with higher levels of K.

The number of panicles/m^2 and test weight of nuts and yield were increased by the application of N, P and K. A positive significant relationship was obtained between leaf N and P contents at flowering and fruiting stages and yield.

There was progressive increase in nut volume, protein content of kernels and fruit characters such as fruit weight, fruit volume and TSS of apple by N, P and K application.

Critical levels were worked out for N, P and K in leaves at different growth stages The values were 1.89, 0 069 and 0.51 per cent at flushing, for N, P and K, respectively. The values at flowering were 2.16, 0.118 and 0.90 and at fruiting were 2.05, 0 115 and 0 85 per cent for N, P and K, respectively.

The available prediction equation (Mathew, 1990) when fitted to the data in this study showed a poor fit and hence a new prediction equation was arrived at through a stepwise regression procedure establishing the relationship between leaf N content at flushing, flowering and fruiting stages and N/P ratio at flushing, and yield.

The economic optimum doses for yield were worked out to be 748 g N, 329 g P_2O_5 and 765 g K_2O/tree/year. But the maximum net return of Rs 21840/ha was obtained at 1000 g N, 500 g P_2O_5 and 1000 g K_2O/tree.