EFFECT OF MAJOR NUTRIENTS ON THE YIELD AND QUALITY OF NUTS IN GRAFT - RAISED CASHEW

(*Anacardium occidentale* Linn.)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

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DECLARATION

I hereby declare that the thesis entitled "**Effect of major nutrients on the yield and quality of nuts in graft-raised cashew (*Anacardium occidentale* Linn.)** " is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Dedicated to my parents

And

To God

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Introduction

INTRODUCTION

Cashew (*Anacardium occidentale* Linn.) is one of the most important and highly profitable commercial crop in India, perhaps more profitable than plantation crops such as tea, coffee, rubber and cardamom. The uniqueness of this crop is that it needs minimum care, and can come up well under marginal and wastelands. The crop was introduced to the country in the sixteenth century by the Portuguese mainly for conserving soils. In India the crop covers an area of 7.32 lakh hectares with an annual production of around 4.31 lakh tonnes. The major cashew growing states in India are Kerala, Karnataka, Goa, Maharashtra, Andhra Pradesh and Tamil Nadu with 825 processing units with a capability to meet an annual demand of around 10-12 lakh tonnes. But due to low productivity even half of the production capacity cannot be met. However, it has emerged as one of the most important dollar-earning crop of the country. Currently India has the privilege of keeping itself first in the production of raw nuts and export of cashew kernels.

While reviewing the reasons for low productivity, it has been commonly noted that these plantations mainly grown on marginal lands hardly receive any fertilizer application. Majority of these cross-pollinated trees has been traditionally raised from seedlings where parental quality cannot be assured and often the productivity remains very low (Dixit, 1999). Efforts to replace these traditional cashew plants with high yielding graft-raised cashew have not gained momentum for various reasons. Therefore, it is imperative to improve considerably the production of cashew by adopting a comprehensive approach by increasing the area, adoption high yielding varieties through integrated management practices.

At present, there is ample inadequacy of information on the nutritional requirements of graft-raised cashew. Many of the earlier experiments conducted at various Cashew Research Centers across the country, which represented many agro climatic situations, viz; Vengurla (Maharashtra), Bapatla (Andhra Pradesh), applied NPK under different agro climatic situations, with fairly wide variations existing between different locations for the same set of treatments. This necessitated a detailed study on the response of a pre-determined set of treatments under different agro-climatic situations, necessarily keeping Cashew Research Station at Madakkathara as one of the important centers in Kerala. In order to generate sufficient information on the effects of different levels of fertilizers on various yield and quality aspects of cashew, the current study has been undertaken on uniformly grown graft raised cashew (BLA-39-4) through a well laid out experiment at CRS Madakkathara with the following objectives.

1. To study the effects of fertilizer nutrients on the growth, yield and nutrient off take of graft raised cashew

2. To assess the effects of nutrients on nut and apple quality

REVIEW OF LITERATURE

One of the main means by which we can improve the productivity of existing perennial crops is through nutrient management. Cashew trees are mainly planted on wastelands for soil conservation and as such very little nutrient management is practised on cashew plantations. The present information on nutrient management technology is arbitrary to a high degree. This highlights the need for a better nutrient management programme. Literature on the nutritional aspects of cashew trees relevant to the present study has been reviewed here.

2.1 Effect of NPK nutrition on growth

In Tanzania, Tsakaris (1967) measured the canopy development of young cashew trees growing on a loamy to sandy loam soil and found that under reasonably favourable conditions, young trees might have a growth rate of up to one meter per year. He also observed an increase in canopy diameter of young cashew trees by about 1.5 to 2.0 m per year on sand loam soil for the initial five to six years after which growth slows down.

Lefebvre (1973) found that mineral fertilization was important for cashew growth. He observed that application of nitrogen and phosphorus resulted in an increase in plant growth. However, potassium failed to record any increase in growth. Falade (1978) reported maximum growth at 1.2% leaf nitrogen content and an optimum growth at 0.113% leaf phosphorus content. Ohler (1979) pointed out that the growth of the tree depended on the soil physical conditions as well as on soil fertility status.

Significant increase in height and girth of trees by the application of 1000g N tree^{-1}year^{-1} over the lower dose of 250 or 500g N was reported from laterite soils of Madakkathara (KAU, 1980). Marked improvement in growth characters of cashew by increased levels of nutrients, especially nitrogen have been reported by several workers (Sawke, 1980; Reddy *et al.*, 1982; Gosh and Bose, 1986; Kumar *et al.*, 1997).

Nambiar (1983) reported that application of 1000g N to cashew trees grown on sandy soils of Bapatla resulted in significantly taller trees (4.73 m) as compared to 500g nitrogen application (4.33 m) and control (4.11 m). He also observed that application of phosphorus at the rate of 200 and 400g recorded a significant increase in plant height from 4.41 to 4.52 m respectively as compared to control plots (4.24 m). Potassium application did not show significant effect on tree growth.

Investigating the differential response of layers and seed progress at Cashew Seed Farm, Shantigodu, Kumar (1985) found that seed progeny and layers recorded maximum heights at 450 and 300g N tree^{-1} year^{-1}, respectively. He also observed increased height due to phosphorus and potassium applications. Sawke *et al.* (1986) observed that phosphorus application increased canopy volume as well as produced a significant increase in tree height.

Gosh (1990a) observed an increase in height, girth and canopy spread of trees with increasing levels of nitrogen in laterite soils of Jhagram (West Bengal). According to Latha (1992) increasing nitrogen from 500 to 1000g tree^{-1} significantly improved tree height in seed progeny of BLA-39-4 in the laterite soils of Madakkathara. Kumar *et al.* (1993) noticed that application of NPK at different levels gave an insignificant difference in height as compared to control plots. The height ranged from 3.58 m in control to 4.78 m in maximum dose of NPK. The spread of the plant was significantly superior in all the levels of nutrients over control.

Latha *et al.* (1996a) observed that nitrogen, phosphorus and potassium application produced significant influence on height of trees as compared to control. The levels of nitrogen and phosphorus showed variation whereas levels of potassium did not produce significant variation. All interaction effects were found to be significant and the maximum height was obtained at 1000g N tree^{-1} year^{-1} along with 500g of P_2O_5 tree^{-1} year^{-1} and 1000g K_2O tree^{-1} year^{-1}.

2.2 Effect of NPK on yield characters

During the flushing period each leader shoot gives rise to two to three lateral shoots, which bear panicles or may end as vegetative shoots. Studies revealed that the lateral shoot production in cashew trees increased with increasing levels of NPK applications (Kumar, 1985). He also reported an increase in the number of nuts with increasing levels of nitrogen and phosphorus applications as compared to potassium applications. Ghosh and Chatterjee (1987) evaluated the performance of 17 cashew types at Jhargram, W. Bengal and observed that the number of nuts per panicle varied from 1.6 to 4.7 between types.

Studies conducted on number of panicles produced per unit area indicated that there was significantly increased number of panicles per unit area in all the levels of fertilizers over control. The number of panicles per square meter varied from 4.49 (control) to 13.74 (higher dose of NPK i.e. 500:250:250) (Kumar *et al.*, 1993). An experiment conducted by KADP, College of Horticulture, Vellanikkara, Thrissur revealed that the number of flushes produced per square meter responded significantly to nitrogen and potassium applications. Phosphorus applications increased the number of flushes per m^2 although not to a significant level. (Latha *et al.*, 1996a).

It has been reported that increasing levels of N, P and K application has a significant positive effect on number of panicles per m^2 and net weight per 100g of nut. (Latha *et al.*, 1996c). Panda *et al.* (1996) observed that the number of laterals per shoot varied from 4.6 to 5.06 in stage I flush and from 1.98 to 12.14 in stage II flush. The number of leaves per lateral varied from 12.76 to 13.83 in stage I flush and from 1.61 to 6.77 in stage II flush.

2.3 Effect of mineral nutrition on soil nutrient status and nutrient off take

2.3.1 Soil Nutrient Status

In an experiment undertaken at Central Plantation Crops Research Institute, Regional Station, Vittal, Dakshina Kannada, Karnataka, Kumar (1982) reported that the soil nutrient status in cashew orchard as available nitrogen 0.02%, phosphorus 0.0033% and potassium 0.0108%.

On estimating the nutrient content of soils, Kumar (1985) found that nitrogen, phosphorus and potassium levels significantly increased the soil nitrogen content, while nitrogen application and Potassium application upto the intermediate level decreased soil available phosphorus content. Also intermediate level of nitrogen application and all levels of phosphorus and potassium application increased the soil, potassium content.

2.3.2 Nutrient off take

Beena *et al.* (1995) observed through a study on nutrient off take in cashew, that a five year old cashew tree yielding 4.08 kg nut and 4.15 kg apple on dry weight basis, removes 239g N, 7.51g P and 110g K.

2.4 Effect of NPK nutrition on leaf nutrient content

Leaves of healthy and unhealthy cashew trees grown under favourable physical condition of soil wetness contained 0.21 and 0.1% phosphorus respectively. Healthy trees contained 1.98% nitrogen and unhealthy trees contained 1.52% nitrogen. In case of potassium, healthy trees contained 1.69% K as compared to 0.97% K in leaves of unhealthy trees (Calton, 1961). Lefebvre (1973) observed a leaf phosphorus status of 0.08% and nitrogen was around 1.73% in leaves. Haag *et al.* (1975) recorded maximum growth at 2.4 to 2.8% and poor growth at 0.98 to 1.38% leaf nitrogen concentration. He also gave a range of 0.16 to 0.2% leaf phosphorus content as the adequate range for growth and 0.11 to 0.14% of leaf phosphorus as the deficient range of growth.

Kumar and Nagabhushanam (1981) observed higher concentration of nitrogen in leaf and shoot when higher levels of nitrogen were applied to cashew trees. Reddy *et al.* (1982) observed from studies carried out on cashew nutrition in a coastal sandy soil that application of fertilizer nitrogen up to 1000g and 500g each of P_2O_5 and K_2O per tree was found to increase the leaf nitrogen content. He also stated that nutrient content in leaves were variable as there were two peaks, a small one in September and the major peak in November and December for nitrogen and in November for phosphorus and potassium.

According to Kumar *et al.* (1982), flowering and fruiting had a depressive effect on the major nutrient composition of cashew leaves. Leaves at the top position did not vary in their NPK contents with that of lower portions. Freshly matured leaves emerging after fruiting showed higher content of NPK than matured leaves of the previous season. He reported a nitrogen content of 1.41% before fruiting and 1.48% after fruiting. Phosphorus content in the pre-fruiting stage was 0.09% and after fruiting it was 0.12%. Potassium content was 0.6% in pre-fruiting stage and 0.7% in post fruiting stage.

Kumar, (1982) reported that the percentage of nitrogen in vegetative shoots was 1.4 as compared to 2.16 in flowering shoots. Phosphorus content varied from 0.02% in vegetative shoots to 0.13% in flowering shoots. Potassium percentage was found to be 0.45 in vegetative shoots whereas it was around 1.13 in flowering shoots.

Kumar (1985) found an increase in leaf nitrogen from 2.04 to 2.53 per cent by application of 300g N $tree^{-1}$ $year^{-1}$ while leaf phosphorus decreased with increase in nitrogen application from 150 to 450g N $tree^{-1}$ $year^{-1}$ and leaf potassium showed a decline with increasing nitrogen levels. In case of leaf phosphorus, there was an increase in content with increasing levels of phosphorus application. Higher levels of potassium application increased the nitrogen and potassium content in leaves while leaf phosphorus content was found to decrease.

Kumar and Sreedharan (1986) reported that the critical concentration of nitrogen and phosphorus are 2.09 and 0.14 % respectively in cashew leaf with reference to yield. A study carried out in the laterite soil at Jharghan in West Bengal revealed that nutrient content in plant showed higher concentration of nitrogen in leaf and shoot when treated with increased nitrogen levels. The percentage of phosphorus and potassium in leaves in general showed a rise with increasing levels of nutrients irrespective of time of sampling (Ghosh and Bose, 1986).

Mathew (1990) reported that the extent of variation in leaf nitrogen with respect to the position of leaf and stage of sampling was from 1.24 to 2.76% while phosphorus content varied from 0.063 to 0.316%. The content of potassium was within a range of 0.54 to 2.74%. Sanyal and Mitra (1991) reported the nitrogen content of cashew leaves to be in the range of 2.11 to 2.86%, phosphorus content in the range of 0.88 to 0.135 % and potassium content in the range of 1.13 to 1.52%. Leaf nitrogen content was found to increase with increasing levels of nutrient (NPK) application over control. Between levels, no significant difference was observed (Latha *et al.*, 1994).

2.5 Effect of NPK on physio-chemical characteristics of cashew apple

It has been reported that cashew apple has a maximum juice percentage of 84.3, an average T.S.S. content of 12.4 Brix, an average Ascorbic acid content of 20.7mg $100gm^{-1}$ and an average nitrogen percentage of 0.05 (Natarajan, 1979). Nanundaswamy (1984) reported that cashew apple exhibits a juice percentage of 60 to 70, the T.S.S. of cashew apple ranges from 12 to 13% and the ascorbic acid content varies from 120 to 306 mg in different varieties.

Kumar (1985) related the apple characters such as fruit volume, fruit weight and total soluble solids (T.S.S.) of juice with mineral fertilization and found that those characters are differentially influenced by NPK fertilization. Increasing levels of nitrogen and phosphorus tended to decrease fruit volume and T.S.S while fruit weight showed insignificant decrease with increasing levels of these nutrients. Potassium application resulted in significant increase in fruit volume and weight, while in T.S.S. it showed marked variations. Nitrogen, phosphorus and potassium applications were found to increase the juice percentage in apples. He also found that increasing levels of nitrogen, phosphorus and potassium increased the ascorbic acid content in fruits.

Among 13 types evaluated by Aravindakshan *et al.* (1986) cashew apple weight was the highest (132.7g) in the hybrid H-3-13 and the lowest (31.3g) in the type K-28-2. Nalini and Sunithakumari (1991) reported from Anakkayam that the apple weight varied from 27 to 80g in various cashew types. Sapkal *et al.*

(1992) noticed that within nine varieties of cashew the weight of cashew apple varied from 19.32 to 26.82g. While the volume ranged from 22.46 to 43.73cc. The T.S.S. was within a range of 12.83 to 17.92%, while the ascorbic acid, content was found to be between 0.16 to 0.43%. Sena *et al.* (1995) observed that apple weight varied from a minimum of 18.14g to a maximum of 87.28g with an average range of 25.75 to 66.25g. The T.S.S. content of apple varied from a minimum of 10° brix to a maximum of 13° brix.

Application of different levels of nutrients did not have any significant positive influence on the weight of apple and the juice content. However, the total soluble solids of the apple and apple yield per tree increased significantly due to levels of nutrients (Kumar *et al.*, 1996).

Attri and Singh (1999) have observed from studies carried out in five different commercial cashew cultures that the cashew apple residue contained 0.44 to 1.23%, 0.072 to 0.180% and 7.04 to 7.12% of nitrogen, phosphorus and potassium respectively. The T.S.S was found to be in the range of 9.2° to 11.0° brix while ascorbic acid content was found to be between 183.00mg $100g^{-1}$ and 236.19mg $100g^{-1}$. Heloisa and Ricardo (2001) have reported a weight of 70 to 90g per apple. Juice percentage was found to be approximately around 80%, T.S.S. was within a range of 9.8 to 14° brix and vitamin C content was in the range of 139 to 387mg $100g^{-1}$. Augustine (2001) has recorded phosphorus content of 10mg $100g^{-1}$ in cashew apple.

2.6 Effect of NPK on Biochemical characteristics of cashew nuts

Ankaiah (1981) reported that soil application of nitrogen fertilizers resulted in an increase in crude protein content in Kernels (27.4%) over control plots (22.3%). Kumar (1985) reported an increasing content of kernel protein with every increment in the level of nitrogen, phosphorus and potassium. Nitrogen and potassium interactions were also found to be significant. Jisha *et al.* (1991) reported a content of 1570 mg g^{-1} of protein, 101mg g^{-1} of total carbohydrate and 46.4 g $100g^{-1}$ of lipid content in fresh kernel.

Latha *et al.* (1996b) studied the quality of nuts in terms of protein content of kernels as influenced by NPK fertilization and found that there was a significant increase in protein content of kernels upto 500g of N per tree per year. Although phosphorus and potassium applications showed considerable influence on the protein content, the variations were found to be insignificant. Suria (1998) estimated the protein content to be 21%, the fat content to be 47% and the carbohydrate content to be 22% in Cashew kernels. Studies have revealed that cashew nuts contain 20.5% protein, 50.9% fat and 18.8% carbohydrates (Suman, 2001).

2.7 Effect of NPK nutrition on physical characters of cashew nuts

It was observed that nitrogen and phosphorus applications brought down the weight of nuts with increasing levels, but potassium levels did not show any significant reduction. Shelling percentage was found to be positively significant with increasing levels of NPK. Among interactions, only P and K combinations gave significant difference. Weight of kernels was found to increase with nitrogen and potassium application (Kumar, 1985).

Kumar and Sreedharan (1986) found that nitrogen and phosphorus application reduced the nut weight and volume. Smallest nuts were observed at 450g $tree^{-1}$ $year^{-1}$ application of nitrogen with 150g $tree^{-1}$ $year^{-1}$ of phosphorus. Nut weight was found to reduce with every increment in the level of nitrogen and phosphorus application. Potassium application did not have any significant effect. He also reported that shelling percentage and Kernel protein content increased with increasing levels of nitrogen, phosphorus and potassium applications. He also found that the number of nuts per tree increased with nitrogen and phosphorus application as compared to potassium application.

Gosh (1987) reported that the shelling percentage of nuts increased with application of 500g of nitrogen and 200g each of phosphorus and potassium. Gosh (1990b) recorded significantly increased number of nuts and total weight of nut per plant with highest level of nitrogen application (600g $plant^{-1}$ $year^{-1}$). He also observed that the application of higher level of phosphorus improved nut yield in both number and weight of nuts, while in potassium lower levels of application were effective. He also recorded an increase in shelling percentage with higher levels of nitrogen only. Higher levels of potassium tended to decrease the shelling percentage.

Kumar *et al.* (1993) noted that nut weight was maximum (6.5g) with the treatment receiving 250:125:125 g NPK plant^{-1}. It was also observed that at higher levels of nutrients the nut weight was low. An experiment laid out at Agricultural Research Station, Ullal revealed that shelling percentage increased with higher levels of nutrient applications. A maximum shelling percentage of 33.07 was recorded at 500:250:250g NPK tree^{-1} (Kumar *et al.*, 1993).

Kumar *et al.* (1995) reported that application of different levels of nutrients significantly increased the shelling percentage as compared to control. Different levels of nutrients were found to have significant influence on the length as well as weight of nuts. The maximum length of nuts was recorded in plants with highest application of nitrogen, which was significantly different over control but was on par with intermediate levels of nitrogen. The weight of nuts was found to increase substantially as compared to control with increasing levels of nitrogen. Increasing levels of phosphorus and potassium did not produce significant results (Kumar *et al.*, 1995).

Mahanthesh and Melanta (1996) reported that the number of nuts and total nut weight per plant increased significantly with the application of 500g of N, 100g of P and 250g of K respectively. Salam *et al.* (1997) reported the highest shelling percentage in the variety BLA-139-1 (37 %) and lowest in H-1608 (29.8 %) based on the evaluation of the performance of 18 cashew varieties from various states.

Kumar and Hegde (1998) observed that application of different levels of NPK nutrients significantly increased the nut weight, length, breadth and thickness of nuts over control. In case of nut weight it was observed that a treatment application of 250:125:125g NPK plant^{-1} year^{-1} gave optimum results (nut weight of 6.83 g) while in the case of length, breadth and thickness, treatment with 500:125:125 and 500:250:250g NPK $plant^{-1}$ $year^{-1}$ gave optimum results (nut length of 3.24 to 3.26 cm).

Based on a study using 18 cashew varieties, Salam (1998) reported that nut weight ranged from 3.81 to 10g while the shelling percentage ranged from 28.1 to 37%. The nut yield ranged from 3.6 to 9.7 kg $tree^{-1}$ in different varieties.

2.8 Effect of NPK on yield

Lefebvre (1973) reported significant interaction of nitrogen and phosphorus in relation to yield in cashew. Application of potassium had significant effect in increasing the yield of cashew only in the presence of nitrogen. Pujari (1976) observed that deficiency of phosphorus and nitrogen hampered the reproductive phase by 25 to 30%, while deficiency of potassium has negligible effect.

Mishra *et al.* (1980) carried out an investigation for three years at the Cashew Research Station, Aiginia, Department of Horticulture, O.U.A.T, Bubaneshwar on old cashew plants and found that the plants responded only to nitrogen and not to phosphorus and potassium. In addition, it was cited that there was no response to potassium on yield of cashew in experiments conducted at Vrindhachalam under All India Co-ordinated Spices and Cashew Improvement Project.

Ankaiah (1981) conducted an observational trial at Cashew Research Station Bapatla, on sandy soils with treatments as full foliar application as well as full soil application fertilizers. He found that fertilization resulted in an increase in the yield of cashew crop. It was also observed that application of nitrogen to the soil as a whole gave higher yield of nuts. Similar results were also noted at CPCRI, Kasaragod. Reddy *et al.* (1982) recorded 42, 80 and 90 per cent increase in yield over control with nitrogen application at 500, 1000 and 1500g $tree^{-1}$ $year^{-1}$, respectively.

It has been observed that application of 1000g N sufficiently out yielded the treatments with 500g N and control, while phosphorus and potassium applications did not show any significant effect on cashew yield in the coastal sandy soils of Bapatla (Nambiar, 1983).

Rao *et al.* (1984) reported that nitrogen application alone had increased the tree yield significantly. He failed to observe an improvement in yield due to phosphorus and potassium applications in sandy loam soils.

Kumar (1985) observed a substantial yield increase from 2.92 to 4.27 kg when nitrogen application was increased from 150 to 300g N tree^{-1} year^{-1}, beyond which there was only marginal increase in yield, where as in case of phosphorus application, yield increased significantly from 50g P_2O_5 to 150g P_2O_5 tree^{-1} year^{-1}. In case of potassium, a linear response up to 150g K_2O tree^{-1} year^{-1} was observed. Veeraraghavan *et al.* (1985) observed from an NPK trial conducted at the Cashew Research Station, Madakkathara that application of nitrogen alone increased the yield per tree significantly over no nitrogen. Response in phosphorus and potash application was found to be insignificant. Also, there was no evidence of interaction effect.

Gosh and Bose (1986) reported that the nut yield plant^{-1} (weight) increased significantly with the application of higher levels of nitrogen. Increasing levels of phosphorus and potassium applications also increased the yield of nuts. Babrinath *et al.* (1987) observed an increase in yield from 5.34 kg tree^{-1} in control (N_{250} P_{250} K_{250}) to 6.96 kg tree^{-1} on application of a higher dose of NPK (500:250:375g NPK tree^{-1}).

An experiment carried out in the Regional Research Station at Jhargram with three different levels of nitrogen, phosphorus and potassium, revealed that the number of nuts and total weight of nuts per plant increased significantly with the application of 500g of nitrogen and 200g each of phosphorus and potassium (Gosh, 1987).

Mathew (1990) observed from an experiment carried out at Madakkathara that yield in cashew trees increased with increasing levels of nitrogen and

Materials and Methods

phosphorus in laterite soils. The increase in yield with potassium application was not as significant as that of nitrogen and phosphorus.

Higher yields were obtained in all the nutrient levels over control plots. The highest mean nut yield over control was recorded at treatment level of 500:250:250 g NPK plant^{-1} (7.84 kg tree^{-1}). Response to higher levels of nitrogen application was greater than response to phosphorus and potassium applications (Kumar *et al.*, 1993).

It has been reported that increasing the level of nitrogen up to 500g tree^{-1} year^{-1}, gave a significant increase in yield above which there was no difference. Increasing levels of phosphorus and potassium gave a significant difference over control but the increase in yield was seen to be insignificant between levels of phosphorus and potassium (Latha *et al.*, 1994).

Mahanthesh and Melanta (1994) recorded an increase in the weight of cashew apple with increased levels of application of nitrogen, phosphorus and potassium fertilizers. Highest yield of cashew apple was recorded from the plant treated with 500g of N, 100g of P and 250g of K. Application of different levels of nutrients was found to significantly increase the nut yield per tree as compared to control. Among the levels 500:250:250g NPK plant^{-1} year^{-1} gave maximum nut yield per tree, which was at par with the intermediate level of nutrient application (Kumar *et al.*, 1995).

Latha *et al.* (1996c) reported that increasing the nitrogen application rate from 250 to 500g tree^{-1} year^{-1} significantly increased the yield. Phosphorus and potassium application progressively increased the yield. Kumar *et al.* (1998) recorded a cashew yield of 3.72 kg per plant through split application of water-soluble fertilizers and a yield of 3.03 kg through normal fertilizer application.

MATERIALS AND METHODS

3.1 Materials

A well-laid out and ongoing experiment at Cashew Research Station Madakkathara was used to monitor the effect of major nutrients on the yield and quality of nuts in graft-raised cashew. BLA-39-4 (Madakkathara-1) variety cashew grafts planted in 1992 and nurtured on scientific lines till time has been used as the experimental material to meet the objectives of the study. The details of the experiment conducted are as follows.

3.1.1 Location

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

3.1.2 Soil

The soil of the experimental site is lateritic in nature and the textural class of the same is sandy clay loam .The average physicochemical properties of the soil at the experimental site is as shown in Table 1.

Table 1. Physicochemical properties of the soil at the experimental site

Soil properties	Values	Rating
PH	5.8	Acidic
Available nitrogen	282.20 kg ha^{-1}	Medium
Available phosphorus	2.16 kg ha^{-1}	Low
Available potassium	117.44 kg ha^{-1}	Low

3.1.3 Fertilizer sources

The major nutrients required for the experiment were supplied through three independent sources namely Urea (46% nitrogen), Rajphos (18% phosphorus) and Muriate of potash (60%potassium) respectively. These major nutrients were applied to the experimental plots at pre-calculated doses.

3.1.4 Leaf samples

For estimating the major nutrient status of the cashew trees, already standardized index leaves (Mathew, 1990) were collected from the experimental trees at two stages of the experiment. Pre-treatment leaf samples were collected in September while post harvest leaf samples were collected in March.

3.1.5 Soil samples

The soil samples were collected from independent plots during the month of September and used for estimating the major nutrient status of the soil in the tree basin.

3.1.6 Cashew apple samples

Cashew fruits and dried samples of cashew apple were used for TSS, vitamin C and major nutrient analysis respectively. Fresh samples of cashew apple collected during December and February were utilized for getting physical observations.

3.1.7 Nut samples

Nut samples collected from each tree during December and February were used for both biochemical analysis as well as physical observations.

3.2 Methods

3.2.1 Details of the field experiment

3.2.1.1 Treatments

The treatments consisted of N, P and K at three levels of each as is shown in Table 2.

Table 2. Levels of treatment application

Nutrients	Levels	Levels (g)
Levels of Nitrogen	3 (n0, n1, n2)	0, 500, 1000g plant^{-1}year^{-1}
Levels of phosphorus	3 (p0, p1, p2)	0, 125, 250g plant^{-1} year^{-1}
Levels of potassium	3 (k0, k1, k2)	0, 125, 250g plant^{-1} year^{-1}

3.2.1.2 Design and layout

The design and plan of the layout are shown in Table 3 and Fig. 1 respectively.

Table 3. Design of the field experiment

Design	3x3x3 factorial experiment (RBD)
Replication	2
Total number of treatment combinations	27
Total number of plots	54
Number of plants per plot	3
Spacing	8m x 8m
Variety	BLA-39-4

3.2.1.3 Imposition of Treatments

At the fag end of the southwest monsoons, fertilizers were incorporated in the basin in a single dose as per treatment. After removing the weeds, fertilizers were applied at a distance of 1.5m around the trunk. Addition of organic manure was avoided in all experimental plots to ward off the supplementary sources of major nutrients to the experimental trees. However, the standard cultural operations were carried out uniformly in all the experimental trees.

3.2.2 Collection, preparation and analysis of soil and plant samples

The soil and plant samples were collected separately from the plots and 162 plants (3 plants per plot from 27 treatments and 2 replications) and stored properly after preliminary processing.

3.2.2.1 Soil sample collection and analysis

Soil samples from a depth of 0 to 40 cm were collected from the basin of each tree within a radius of 1.5 m in four different directions (north, south, east, and west). Pre-treatment and post harvest soil samples were collected during September and March respectively. Soil samples from each experimental plot collected in the above fashion were pooled to get a representative sample of each treatment. Thus finally 54 composite samples were generated from all the experimental plots including replication, which were then dried, sieved and stored in labeled polythene covers for further analysis. Appropriate quantities of these samples were then used for the estimation of major nutrients such as N, P and K.

- The available nitrogen content was estimated by the alkaline permanganate method (Subbiah and Asija, 1956).
- The available phosphorous was determined by the Bray and Kurtz P1 method (Bray and Kurtz, 1945).
- The available potassium in the soil was extracted using I N neutral ammonium acetate and the K content in the extract was determined using a flame photometer (Jackson, 1958).

The contents of these elements in the soil were expressed as Kg ha^{-1}.

Fig. 1. Layout of the experimental plot

R1B1	N1P1K1 *1 2 3 **(1)	N2P2K2 4 5 6 (2)	N0P1K2 7 8 9 (3)	N0P2K1 10 11 12 (4)	N2P0K1 13 14 15 (5)	N1P2K0 16 17 18 (6)	27	N1P0K2 19 20 21 (7)	N0P0K0 22 23 24 (8)	N2P1K0 25 26 (9)	N1P2K1 55 56 57 (19)	N0P2K2 58 59 60 (20)	N0P1K0 61 62 63 (21)	N2P1K1 64 65 66 (22)	R1B3
R1B2	N0P1K1 28 29 30 (10)	N2P0K0 31 32 33 (11)	N1P1K0 34 35 36 (12)	N2P2K1 37 38 39 (13)	N0P2K0 40 41 42 (14)	N1P2K2 43 44 45 (15)	N0P0K2 46 47 48 (16)	N2P1K2 49 50 51 (17)			N1P0K1 52 53 54 (18)	N2P2K0 67 68 69 (23)	N1P1K2 70 71 72 (24)	N2P0K2 73 74 75 (25)	
R2B1	N2P1K2 82 83 84 (28)	N2P0K1 85 86 87 (29)	N1P0K0 88 89 90 (30)	N0P2K1 91 92 93 (31)	N2P2K0 94 95 96 (32)	N1P1K1 97 98 99 (33)	N1P2K2 100 101 102 (34)	N0P0K2 103 104 105 (35)			N0P1K0 106 107 108 (36)	N0P0K1 76 77 78 (26)	N1P0K0 79 80 81 (27)		
R2B2	N2P1K0 109 110 111 (37)	N2P2K2 112 113 114 (38)	N1P0K2 115 116 117 (39)	N2P0K0 118 119 120 (40)	N0P2K0 121 122 123 (41)	N0P0K1 124 125 126 (42)	N0P1K2 127 128 129 (43)	N1P2K1 130 131 132 (44)			N2P1K1 133 134 135 (45)				
R2B3	N2P1K0 136 137 138 (46)	N1P1K2 139 140 141 (47)	N0P1K1 142 143 144 (48)	N2P0K2 145 146 147 (49)	N0P0K0 148 149 150 (50)	N0P2K2 151 152 153 (51)	N2P2K1 154 155 156 (52)	N1P0K1 157 158 159 (53)			N1P2K0 160 161 162 (54)				

N
↑
W ← → E
↓
S

** Figure in brackets indicate plot number

* 1 to 162 indicates the tree numbers of the experiment (Three trees per plot)

3.2.2.2 Leaf sample collection and analysis

The fully matured leaf from the top (three to five) of the selected shoot at 50 percent flushing stage was collected from each tree in four directions (north, south, east, and west). In order to comply with the standard procedure of collection of sample as out lined by Mathew (1990), samples were collected from three fourth canopy height. Leaf samples from each experimental tree within a plot were collected and pooled to finally yield 54 independent composite leaf samples. These samples were initially air-dried and then dried in an oven at 60^0 C, later these samples were powdered, labeled and packed in polythene covers. Suitable quantities of these samples as mentioned in the standard procedures were then used for the estimation of the major nutrients in the leaf.

- The total nitrogen content of the leaf samples was determined by using the Kjeldahl digestion and distillation method (Tandon, 1993).
- The determination of the total phosphorous and potassium was done by digesting a known weight of the sample (as given in the procedure) in a di-acid mixture of nitric acid and perchloric acid (9:4). The total phosphorous content was then estimated colorimetrically by vanadomolybdophosphoric yellow colour method in nitric acid medium and potassium was determined using a flame photometer (Tandon, 1993).

The contents of these elements in the index leaf samples were expressed in percentage.

3.2.2.3 Cashew Apple samples

The appearance of the first ripened apple in a tree marked the stage of harvesting and it continued till the ripening of the last apple. In between these two stages ten uniformly matured cashew apples were identified and collected from each tree. Immediately after harvest the mean weight of the uniformly matured cashew apples of each tree in an experimental plot was recorded and expressed in grams. The volumes of these cashew apples were determined by water displacement method and expressed in millilitres. After these observations, the fruits were then sun dried and later oven dried at 60^0C till constant weight and the dry weight was recorded. The calculated loss in weight of apples was expressed as per cent juice content on fresh weight basis. The dried samples were then powdered, labeled and stored for further analysis.

- Known quantities of the dried apple samples were used for the estimation of major nutrients using standard procedures (Tandon, 1993).
- The ascorbic acid content in fresh apple was estimated by extracting the fruit pulp with 0.4% oxalic acid and titrating the same against 2,6-dichlorophenol indophenol dye by visual titration method (Roe, 1954), and the values were expressed as mg $100g^{-1}$ of fresh fruit.
- Ten randomly selected ripened fruits were macerated and the total soluble solids (T.S.S.) content were estimated from the fruit juice using a hand held refractometer and the result was expressed in percentage.

3.2.2.4 Nut samples

Matured nuts were either collected directly from the tree or from fallen fruits. The appearance of the first ripened apple in a tree marked the stage of harvesting and it continued till the ripening of the last apple. During this period, the nuts were collected and pooled for each treatment. The physical observations of 20 nuts collected at random from each tree were recorded for length and weight.

- A vernier calliper was used for gauging the accurate length and the measurement recorded in centimeters.
- The weight of nuts was recorded using a sensitive top loading balance and expressed in grams. The average weight was computed and these values were projected for 100 nuts to satisfy the requirement of the observations.
- In order to compute the shelling percentage, one kilogram of the raw nuts was dried properly and shelled using an improvised cutter to separate the shell, testa and kernel. The weight of both the shells and kernels were recorded using a sensitive balance.

- ❖ The shelling percent was then computed from the weight of raw nut and kernel weight of nuts and expressed in percentage.
- ❖ Known quantities (as given in the standard procedures) of the separated testa, shell and kernel were processed for specifically assessing the major nutrient off-take from cashew trees using standard procedures for nitrogen, phosphorus and potassium.
- ❖ Protein, fat, carbohydrate and sugar content of the kernel samples were analysed using standard procedures as outlined by Sadasivam and Manickam (1996).

The grading of kernels could not be done on account of the lack of sufficient quantity of kernels arising due to a considerable reduction in yield due to instances of heavy attack of tea mosquito in many experimental trees causing heavy damage to the already set fruits.

3.2.3 Methods of Biometric observations

3.2.3.1 Tree height

A pre-calibrated metal pole was introduced along the side of the main stem and the height of the tree was measured from the ground level to the upper tip of the foliage.

3.2.3.2 Tree girth

Tree girth was measured at one-meter height along the trunk from the soil surface with the help of a measuring tape and the value recorded in meters.

3.2.3.3 Tree spread

The spread of all experimental trees was measured separately using a standard measuring tape in two directions (North-south and East-west directions.), covering the fringes of the foliage and the average value expressed in meters.

3.2.3.4 Days to flushing

The date of flushing was recorded in September using a prefabricated 0.25 m^2 quadrant. The quadrant was placed along four direction (North, South, East and West) of the tree canopy. The total number of shoots falling within the quadrant were noted and the date at which approximately 50 per cent of the shoots observed were new shoots was recorded as the date of flushing. This was then expressed as days to flushing keeping 31st August 2001 as the reference date.

3.2.3.5 Number of flushes m^{-2}

A prefabricated 0.25-m^2 quadrant was used for observing the number of flushes appearing in four direction (North, South, East and West) of the tree canopy. The recorded observation was then extrapolated to one square meter area. The observations were recorded when 50 per cent of the flushes were in bloom during the month of October.

3.2.3.6 Number of leaves per flush

A representative flush in each of the four directions is identified and the number of leaves in the identified flush was observed. The average values were computed and the count recorded.

3.2.3.7 Days to flowering

The date of flowering was recorded in October using a prefabricated 0.25 m^2 quadrant. The quadrant was placed along four direction (North, South, East and West) of the tree canopy. The date at which approximately 50 per cent of the shoots observed within the quadrant flowered was recorded as the date of flowering. This was then expressed as days to flowering keeping 30th September 2001 as the reference date.

3.2.3.8 Number of panicles per meter square

A prefabricated 0.25-m^2 quadrant was placed randomly along the four directions (North, South, East, West) around the tree canopy. A physical count on the number of panicles appearing within the quadrant was made and the values projected to that for one square meter area. The average value of this was computed and noted as a count. This observation was recorded during the month of November 2001.

3.2.3.9 Number of nuts per panicle

The numbers of nuts set on the representative panicles along each of the four different direction around each tree canopy was physically counted, averaged and the value recorded as a count. This observation was recorded in December 2001.

3.2.4 Nutrient off-take

Nutrient off take was estimated as the amount of nutrients removed through shell, testa, kernel and apple per tree. It was estimated as a product of percentage nutrient of the component and D.M.O of each component (shell, testa, kernel and apple) and by adding all these together.

3.2.5 Yield

The appearance of the first ripened apple in a tree marked the stage of harvesting and it continued till the ripening of the last apple. The collections of matured nuts were made either directly from the tree or from the fallen fruits. The cashew nuts were harvested at regular intervals and the total weight of nuts collected per tree was recorded .At the end of the harvest season, the total yield per tree was computed.

Due to instances of heavy attack of tea mosquito in many experimental trees considerable damage was caused to the already set fruits resulting in a reduction in the yield of nuts from cashew trees. An attempt was made to estimate expected yield of nuts and apples based on the data collected for the study (average nut weight, average apple weight, number of nuts per square meter of the canopy and the spread of trees).

The canopy surface area was computed from the height and spread of trees using the following formula

Canopy Surface Area = π R L

Where,	R	=	radius of canopy	(Canopy spread x 0.5)
	L	=	Slant height	$= \sqrt{(R^2 + h^2)}$
	H	=	height of the tree	= 1.5x R

(Salam and Razak, 2002)

3.2.6 Statistical analysis

The data collected by the methods described above were then statistically analysed by using the analysis of variance method to find the individual as well as the interaction effects of major nutrients on the different parameters recorded.

Results

RESULTS

The results of the study on the effect of major nutrients on the yield and quality of nuts in graft-raised cashew (*Anacardium occidentale.* Linn) are presented here.

4.1 Pre-treatment analysis

4.1.1 Soil nutrient status

The nutrient status of the soil from various treatment plots before the application of fertilizers were studied and the analytical results are presented in Table 4. It was found that the available mineralisable nitrogen content of the soils on an average varied from 269.53 to 286.42 Kg ha^{-1}, indicating a medium fertility range for nitrogen. In case of available phosphorus, it was found to be in the range of 2.05 to 2.27 kg ha^{-1} indicating a low fertility range. Available potassium content was also found to be in the low fertility range with value varying from 111.50 to 123.95 kg ha^{-1}. From the analytical data, it was observed that there was no significant difference in the major nutrient status of the soil between the various experimental plots.

4.1.2 Leaf nutrient status

Index leaves of cashew were analysed before the application of fertilizers. The data on the pre-treatment major nutrient status of the index leaves are presented in Table 4. From the data it can be seen that leaf nitrogen content in the index leaves on an average varies from 1.63 to 2.22 per cent indicating that the nitrogen content was in the medium range. Phosphorus content indicated an adequate range with values ranging from 0.15 to 0.16 per cent. Potassium content was found to range between 0.90 to 0.93 per cent. Nitrogen percentage showed significant variation among the treatment plots. The average nitrogen content within plots with zero application of nitrogen showed a low content of 1.63 per cent, while the highest was 2.22 per cent in plots which received the highest level of nitrogen application (1000g).

Table 4. Pre-treatment soil and plant nutrient status

	Soil Nutrients			Plant Nutrients		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (%)	P (%)	K (%)
N						
n_0	269.53	2.19	117.72	1.63	0.15	0.88
n_1	281.16	2.43	119.61	1.88	0.15	0.97
n_2	286.42	1.85	114.99	2.22	0.16	0.92
SE	**12.60**	**0.50**	**6.88**	**0.03**	**0.01**	**0.04**
CD	**25.80**	**1.02**	**14.10**	**0.07**	**0.02**	**0.08**
	NS	**NS**	**NS**	**S**	**NS**	**NS**
P						
p_0	286.20	2.05	123.82	1.81	0.16	0.93
p_1	275.79	2.15	111.89	1.94	0.15	0.88
p_2	275.11	2.27	116.60	1.98	0.16	0.96
SE	**12.60**	**0.50**	**6.88**	**0.03**	**0.01**	**0.04**
CD	**25.80**	**1.02**	**14.10**	**0.07**	**0.02**	**0.08**
	NS	**NS**	**NS**	**S**	**NS**	**NS**
K						
k_0	284.99	2.48	111.50	1.89	0.15	0.90
k_1	276.79	1.75	116.87	1.92	0.15	0.93
k_2	275.32	2.24	123.95	1.92	0.16	0.93
SE	**12.60**	**0.50**	**6.88**	**0.03**	**0.01**	**0.04**
CD	**25.80**	**1.02**	**14.10**	**0.07**	**0.02**	**0.08**
	NS	**NS**	**NS**	**NS**	**NS**	**NS**
NP						
n_0p_0	264.68	2.05	117.97	1.56	0.15	0.88
nop_1	266.68	2.78	110.13	1.70	0.14	0.85
n_0p_2	277.23	1.75	125.07	1.61	0.16	0.90
n_1p_0	301.02	2.23	133.65	1.72	0.15	0.97
n_1p_1	272.18	2.08	116.90	1.93	0.15	0.92
n_1p_2	270.28	2.98	108.27	2.00	0.16	1.01
n_2p_0	292.90	1.86	119.84	2.15	0.17	0.93
n_2p_1	288.51	1.60	108.64	2.19	0.15	0.86
n_2p_2	277.83	2.08	116.48	2.33	0.15	0.97
SE	**21.82**	**0.86**	**11.92**	**0.06**	**0.01**	**0.06**
CD	**44.68**	**1.76**	**24.41**	**0.12**	**0.03**	**0.13**
	NS	**NS**	**NS**	**S**	**NS**	**NS**
NK						
n_0k_0	257.28	2.61	106.77	1.58	0.14	0.88
n_ok_1	262.80	1.64	117.97	1.62	0.14	0.80
n_0k_2	288.51	2.34	128.43	1.68	0.17	0.95
n_1k_0	297.26	2.90	116.48	1.89	0.15	0.93
n_1k_1	284.72	1.65	115.78	1.88	0.16	1.02
n_1k_2	261.50	2.75	126.56	1.87	0.15	0.95
n_2k_0	300.43	1.93	111.25	2.22	0.15	0.90
n_2k_1	265.92	1.34	110.18	1.77	0.16	0.97
n_2k_2	275.95	1.63	116.85	2.21	0.15	0.90
SE	**21.82**	**0.86**	**11.92**	**0.06**	**0.01**	**0.06**
CD	**44.68**	**1.76**	**24.41**	**0.12**	**0.03**	**0.13**
	NS	**NS**	**NS**	**NS**	**NS**	**NS**

Continuation of table 4

	Soil Nutrients			Plant Nutrients		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (%)	P (%)	K (%)
PK						
p_0k_0	309.20	1.57	117.60	1.82	0.14	0.90
p_0k_1	268.43	1.41	129.92	1.80	0.17	0.99
p_0k_2	280.97	3.16	123.95	1.81	0.16	0.89
p_1k_0	281.10	2.68	114.99	1.88	0.15	0.83
p_1k_1	282.86	2.12	103.09	1.94	0.15	0.88
p_1k_2	263.42	1.67	117.60	2.01	0.15	0.92
p_2k_0	264.68	3.20	101.92	1.98	0.16	0.97
p_2k_1	279.08	1.72	117.60	2.02	0.14	0.92
p_2k_2	281.58	1.89	130.29	1.94	0.17	0.99
SE	**21.82**	**0.86**	**11.92**	**0.06**	**0.01**	**0.06**
CD	**44.68**	**1.76**	**24.41**	**0.12**	**0.03**	**0.13**
	NS	**NS**	**NS**	**NS**	**NS**	**NS**
NPK						
$n_0p_0k_0$	250.24	2.93	106.40	1.58	0.13	0.88
$n_0p_0k_1$	261.54	1.34	137.76	1.51	0.15	0.76
$n_0p_0k_2$	282.25	1.90	109.76	1.61	0.17	1.00
$n_0p_1k_0$	269.45	3.12	92.96	1.58	0.14	0.83
$n_0p_1k_1$	276.60	2.23	117.60	1.65	0.13	0.82
$n_0p_1k_2$	254.00	3.00	119.84	1.89	0.16	0.90
$n_0p_2k_0$	252.15	1.79	120.96	1.58	0.14	0.92
$n_0p_2k_1$	250.25	1.34	98.56	1.72	0.15	0.83
$n_0p_2k_2$	329.29	2.12	155.68	1.54	0.18	0.96
$n_1p_0k_0$	317.95	0.67	132.16	1.75	0.14	0.89
$n_1p_0k_1$	287.85	0.67	134.40	1.68	0.18	1.16
$n_1p_0k_2$	297.25	5.36	134.40	1.72	0.14	0.86
$n_1p_1k_0$	302.90	2.68	128.80	1.93	0.15	0.85
$n_1p_1k_1$	259.65	2.01	97.58	1.93	0.15	0.92
$n_1p_1k_2$	254.00	1.56	124.32	1.93	0.16	1.00
$n_1p_2k_0$	270.93	5.36	88.48	2.00	0.17	1.05
$n_1p_2k_1$	306.65	2.26	115.36	2.03	0.15	0.97
$n_1p_2k_2$	233.25	1.34	120.96	1.96	0.16	1.00
$n_2p_0k_0$	359.40	1.12	114.24	2.14	0.16	0.94
$n_2p_0k_1$	255.90	2.23	117.60	2.21	0.18	1.04
$n_2p_0k_2$	263.40	2.23	127.68	2.10	0.16	0.82
$n_2p_1k_0$	270.95	2.23	123.20	2.14	0.15	0.82
$n_2p_1k_1$	312.34	2.12	94.08	2.24	0.17	0.89
$n_2p_1k_2$	282.25	0.45	108.64	2.21	0.13	0.86
$n_2p_2k_0$	270.95	2.46	96.32	2.38	0.15	0.95
$n_2p_2k_1$	280.35	1.56	138.88	2.31	0.13	0.96
$n_2p_2k_2$	282.20	2.23	114.24	2.31	0.17	1.01
SE	**37.79**	**1.49**	**20.65**	**0.10**	**0.02**	**0.11**
CD	**77.39**	**3.05**	**42.29**	**0.21**	**0.05**	**0.23**
	NS	**NS**	**NS**	**NS**	**NS**	**NS**

4.2 Growth characters

4.2.1 Height (m)

The data on plant height as influenced by the different levels of application of fertilizers in graft- raised cashew are presented in Table 5. It is seen from the table that the application of nitrogen was found to be significant in increasing the height of trees. Maximum height was recorded in trees receiving 1000g application of nitrogen. Although effects of N_1 and N_2 levels of nitrogen were significant between themselves, there was no significant difference between the effects of N_1 and N_0 application. However there was apparent significant difference in the height of plants that received the highest level of nitrogen application when compared with control. Application of different levels of phosphorus and potassium could not bring about any significant variation in tree height. None of the interaction effects was found to be significant with respect to height of trees.

4.2.2 Girth (cm)

The data on plant girth as influenced by the application of NPK at different levels in graft- raised cashew are given in Table 5. Application of major nutrients could bring only marginal differences in tree girth and these differences were not statistically significant. Among the different interactions studied, only the effect of various NK interactions appeared to be significant. Maximum girth (81.89 cm) was observed at N_2K_0 level of application.

4.2.3 Spread of canopy (m)

The data on the influence of NPK nutrition on spread of canopy is presented in Table 5. It is clearly seen that effect of nitrogen application alone resulted in a significant increase in the spread. A minimum spread of 6.62m was recorded at N_0 level and a maximum of 7.53m at N_2 level, necessarily making higher levels of nitrogen application significant especially when compared to N_0 level. Between the effect of N_1 and N_2 levels, there was significant difference in canopy spread. The canopy spreads achieved at N_0 and N_1 levels were on par.

Table 5. Effect of NPK on growth characters of cashew tree

	Height (m)	Girth (cm)	Spread (m)
N			
n_0	5.35	74.50	6.62
n_1	5.60	72.00	7.00
n_2	5.91	75.91	7.53
SE	**0.14**	**3.01**	**0.25**
CD	**0.29**	**6.16**	**0.51**
	S	**NS**	**S**
P			
p_0	5.64	76.96	7.15
p_1	5.66	73.24	6.88
p_2	5.57	72.20	7.13
SE	**0.14**	**3.01**	**0.25**
CD	**0.29**	**6.16**	**0.51**
	NS	**NS**	**NS**
K			
k_0	5.60	73.72	7.11
k_1	5.69	76.19	7.01
k_2	5.57	72.50	7.03
SE	**0.14**	**3.01**	**0.25**
CD	**0.29**	**6.16**	**0.51**
	NS	**NS**	**NS**
NP			
n_0p_0	5.06	77.22	6.56
nop_1	5.59	74.89	6.31
n_0p_2	5.41	71.39	6.98
n_1p_0	5.70	74.39	7.09
n_1p_1	5.64	70.44	6.88
n_1p_2	5.47	71.17	7.04
n_2p_0	6.16	79.28	7.80
n_2p_1	5.75	74.39	7.44
n_2p_2	5.82	74.06	7.35
SE	**0.25**	**5.21**	**0.43**
CD	**0.50**	**10.67**	**0.88**
	NS	**NS**	**NS**
NK			
n_0k_0	5.26	72.50	6.74
n_ok_1	5.71	80.50	6.88
n_0k_2	5.09	70.50	6.22
n_1k_0	5.58	66.78	6.84
n_1k_1	5.50	71.56	6.79
n_1k_2	5.73	77.67	7.38
n_2k_0	5.97	81.89	7.74
n_2k_1	5.63	70.61	6.78
n_2k_2	5.90	69.33	7.48
SE	**0.25**	**5.21**	**0.43**
CD	**0.50**	**10.67**	**0.88**
	NS	**S**	**NS**

Continuation of table 5

	Height (m)	Girth (cm)	Spread (m)
PK			
p_0k_0	5.67	78.00	7.33
p_0k_1	5.69	77.89	7.17
p_0k_2	5.55	75.00	6.95
p_1k_0	5.61	76.67	7.17
p_1k_1	5.64	73.83	6.51
p_1k_2	5.72	69.22	6.94
p_2k_0	5.53	66.50	6.83
p_2k_1	5.73	76.83	7.36
p_2k_2	5.45	73.28	7.18
SE	**0.25**	**5.21**	**0.43**
CD	**0.50**	**10.67**	**0.88**
	NS	**NS**	**NS**
NPK			
$n_0p_0k_0$	5.19	68.83	6.50
$n_0p_0k_1$	5.20	91.17	7.13
$n_0p_0k_2$	4.79	71.67	6.06
$n_0p_1k_0$	5.24	78.83	6.93
$n_0p_1k_1$	6.02	74.83	6.18
$n_0p_1k_2$	5.50	71.00	5.82
$n_0p_2k_0$	5.35	69.83	6.81
$n_0p_2k_1$	5.90	75.50	7.34
$n_0p_2k_2$	4.99	68.83	6.79
$n_1p_0k_0$	5.64	80.17	7.53
$n_1p_0k_1$	5.75	70.50	6.80
$n_1p_0k_2$	5.70	72.50	6.93
$n_1p_1k_0$	5.79	65.50	6.60
$n_1p_1k_1$	5.23	65.83	6.19
$n_1p_1k_2$	5.90	80.00	7.84
$n_1p_2k_0$	5.31	54.67	6.41
$n_1p_2k_1$	5.52	78.33	7.38
$n_1p_2k_2$	5.58	80.50	7.35
$n_2p_0k_0$	6.18	85.00	7.96
$n_2p_0k_1$	6.13	72.00	7.58
$n_2p_0k_2$	6.18	80.83	7.86
$n_2p_1k_0$	5.80	85.67	7.99
$n_2p_1k_1$	5.68	80.83	7.17
$n_2p_1k_2$	5.76	56.67	7.18
$n_2p_2k_0$	5.91	75.00	7.28
$n_2p_2k_1$	5.76	76.67	7.38
$n_2p_2k_2$	5.78	70.50	7.40
SE	**0.42**	**9.02**	**0.74**
CD	**0.87**	**18.48**	**1.52**
	NS	**NS**	**NS**

Applications of phosphorus and potassium could not bring in any significant difference in spread. Interaction effects were also found to be insignificant.

4.3 Yield characters

4.3.1 Days to flushing

The data collected on the influence of NPK nutrition on the days to flushing from 31st September has been depicted in Table 6. Main effects of N, P and K could not register any significant difference in the mean number of days to flushing. The interaction effects also could not influence any significant difference. However, it has been observed that with increasing levels of nitrogen a non-significant decrease in the average number of days to flushing was observed between the highest (N_2) and the lowest (N_0) level .The interaction effects of nitrogen, phosphorus and potassium could in no way affect the average number of days to flushing.

4.3.2 Number of flushes per square meter

The data on the number of flushes per square meter as influenced by the effect of NPK application has been indicated in Table 6. It is seen from the table that the main effect of nitrogen had significant effect in enhancing the mean number of flushes per square meter. Application of nitrogen at 500g tree^{-1} (N_1) did not give a significant increase in number of flushes when compared to control, while application at 1000g tree^{-1} (N_2) resulted in a significant increase in the number of flushes per square meter over control, but between both these treatments (N_1 and N_2) there was no statistically significant difference. Phosphorus with increasing levels of application had brought in non-significant increase in the number of flushes produced per square meter. However, the application of potassium at all levels had no significant effect in enhancing the production of flushes. Interaction effects of nutrients were found to have no effect in enhancing the number of flushes.

4.3.3 Number of leaves per flush

The data on the average number of leaves per flush as influenced by NPK application in different combination levels is given in Table 6. While comparing the effects of major nutrients on the mean number of leaves per flush, it is seen from the table that only the main effect of nitrogen had significant influence. Though there was marginal influence of N_1 and N_2 levels of nitrogen on the production of more number of leaves per flush, these differences were not statistically significant. However, when the effect of highest level of nitrogen application was compared with that of the control, there was a significant increase. Minimum numbers of eight leaves per flush were observed at N_0 level and maximum numbers of nine leaves per flush were observed at N_2 level. Effect of Phosphorus and potassium on the production of number of leaves per flushes had no significant effect.

Among the interaction effects, only NK interactions were found to be significant. The maximum of 10 numbers of leaves per flush were observed to be produced at N_2K_2 level and this figure was significantly greater than that produced at the N_0K_2 level (eight leaves).

4.3.4 Days to flowering

The data on effect of major nutrients at different levels on the average number of days to flowering from 30[th] September is given in Table 6. It can be seen from the table that neither the effect of nitrogen nor the effect of potassium remained significant in influencing the number of days to flowering. Application of phosphorus had a significant influence on the number of days to flowering. Application of the highest level of phosphorus (P_2) significantly reduced the number of days to flowering as compared to P_1 and P_0 levels. However, the effects of P_0 and P_1 levels were found to be statistically on par. The interaction effects could not make any impact in decreasing the number of days to flowering.

Table 6. Effect of NPK on yield characters

	Days to Flushing	No of flushes/m²	No of leaves /flush	Days to flowering	No of panicle /m²	No of nuts/panicle
N						
n0	9.85	29.33	7.74	17.13	18.33	2.93
n1	9.31	30.56	8.21	17.43	21.13	3.22
n2	8.61	32.19	8.66	17.48	23.50	3.49
SE	0.67	1.06	0.28	0.42	1.20	0.13
CD	1.38	2.18	0.57	0.86	2.47	0.26
	NS	S	S	NS	S	S
P						
p0	9.09	30.24	8.10	18.04	20.59	2.83
p1	9.20	30.46	8.18	17.44	21.04	3.20
p2	9.48	31.37	8.32	16.56	21.33	3.60
SE	0.67	1.06	0.28	0.42	1.20	0.13
CD	1.38	2.18	0.57	0.86	2.47	0.26
	NS	NS	NS	S	NS	S
K						
k0	8.93	31.56	8.19	17.54	20.59	3.20
k1	9.09	30.98	8.10	17.11	21.41	3.32
k2	9.76	29.54	8.31	17.39	20.96	3.12
SE	0.67	1.06	0.28	0.42	1.20	0.13
CD	1.38	2.18	0.57	0.86	2.47	0.26
	NS	NS	NS	NS	NS	NS
NP						
n0p0	10.17	28.39	7.82	17.56	17.44	2.46
nop1	10.06	29.06	7.90	16.94	17.22	3.11
n0p2	9.33	30.56	7.50	16.89	20.33	3.23
n1p0	8.89	32.11	7.72	18.67	22.11	3.06
n1p1	8.94	30.11	8.49	17.94	20.61	3.14
n1p2	10.11	29.44	8.41	15.67	20.67	3.46
n2p0	8.22	30.22	8.76	17.89	22.22	2.99
n2p1	8.61	32.22	8.15	17.44	25.28	3.37
n2p2	9.00	34.11	9.06	17.11	23.00	4.11
SE	1.17	1.84	0.48	0.73	2.09	0.22
CD	2.39	3.77	0.98	1.48	4.27	0.46
	NS	NS	NS	NS	NS	NS
NK						
n0k0	9.61	30.67	7.74	18.22	18.94	3.02
nok1	9.83	30.28	7.90	16.56	17.67	3.03
n0k2	10.11	27.06	7.58	16.61	18.39	2.75
n1k0	8.83	30.33	7.89	17.17	20.67	3.22
n1k1	8.72	31.33	8.89	17.44	20.72	3.23
n1k2	10.39	30.00	7.84	17.67	22.00	3.20
n2k0	8.33	33.67	8.95	17.22	22.17	3.35
n2k1	9.44	30.94	8.31	17.17	20.28	3.12
n2k2	8.78	31.56	9.51	17.89	22.50	3.41
SE	1.17	1.84	0.48	0.73	2.09	0.22
CD	2.39	3.77	0.98	1.48	4.27	0.46
	NS	NS	S	NS	NS	NS

Continuation of table 6

	Days to Flushing	No of flushes/m²	No of leaves /flush	Days to flowering	No of panicle /m²	No of nuts/panicle
PK						
p0k0	9.22	30.83	8.13	17.89	21.17	2.70
p0k1	8.11	30.39	8.20	18.22	19.39	2.96
p0k2	9.94	29.50	7.97	18.00	21.22	2.84
p1k0	9.00	31.67	8.37	17.50	21.00	3.21
p1k1	9.44	32.17	7.71	17.44	21.50	3.37
p1k2	9.17	27.56	8.45	17.39	20.61	3.04
p2k0	8.56	32.17	8.09	17.22	19.61	3.68
p2k1	9.72	30.39	8.38	15.67	23.33	3.65
p2k2	10.17	31.56	8.51	16.78	21.06	3.47
SE	1.17	1.84	0.48	0.73	2.09	0.22
CD	2.39	3.77	0.98	1.48	4.27	0.46
	NS	NS	NS	NS	NS	NS
NPK						
n0p0k0	12.00	27.00	7.04	18.67	18.67	2.51
n0p0k1	7.50	29.50	8.67	18.00	15.50	2.52
n0p0k2	11.00	28.67	7.75	16.00	18.17	2.35
n0p1k0	8.83	30.00	8.63	17.00	17.33	3.08
n0p1k1	11.00	32.00	7.15	17.17	16.17	3.53
n0p1k2	10.33	25.17	7.92	16.67	18.17	2.72
n0p2k0	8.00	35.00	7.56	19.00	20.83	3.47
n0p2k1	11.00	29.33	7.88	14.50	21.33	3.05
n0p2k2	9.00	27.33	7.06	17.17	18.83	3.18
n1p0k0	7.67	32.17	7.29	18.00	22.00	2.85
n1p0k1	8.67	30.67	8.25	18.83	20.67	3.32
n1p0k2	10.33	33.50	7.63	19.17	23.67	3.00
n1p1k0	9.67	30.33	8.35	18.00	21.83	3.28
n1p1k1	8.67	32.83	8.79	18.17	18.83	3.01
n1p1k2	8.50	27.17	8.31	17.67	21.17	3.12
n1p2k0	9.17	28.50	8.02	15.50	18.17	3.53
n1p2k1	8.83	30.50	9.63	15.33	22.67	3.37
n1p2k2	12.33	29.33	7.58	16.17	21.17	3.48
n2p0k0	8.00	33.33	10.04	17.00	22.83	2.75
n2p0k1	8.17	31.00	7.69	17.83	22.00	3.03
n2p0k2	8.50	26.33	8.54	18.83	21.83	3.18
n2p1k0	8.50	34.67	8.13	17.50	23.83	3.25
n2p1k1	8.67	31.67	7.19	17.00	29.50	3.57
n2p1k2	8.67	30.33	9.13	17.83	22.50	3.28
n2p2k0	8.50	33.00	8.69	17.17	19.83	4.05
n2p2k1	9.33	31.33	7.63	17.17	26.00	4.53
n2p2k2	9.17	38.00	10.88	17.00	23.17	3.75
SE	2.02	3.19	0.83	1.26	3.61	0.39
CD	4.14	6.53	1.70	2.57	7.40	0.79
	NS	NS	NS	NS	NS	NS

4.3.5 Number of panicles per square meter

The data on number of panicle production per square meter consequent to different levels of application of major nutrients is presented in Table 6. It is seen from the table that nitrogen applications had significant effect in enhancing the number of panicles per square meter. Enhancement in the levels of application of nitrogen especially N_1 and N_2 though had not brought significant difference between them in the production of number of panicles per square meter, they appeared to be significant over control. Phosphorus and potassium applications at different levels could not produce any significant difference in enhancing the number of panicles per square meter. However, a non-significant marginal increase in the production of number of panicles per square meter was observed at P_1 and K_1 levels respectively. Interaction effects of major nutrients could not influence the production of panicles per square meter.

4.3.6 Number of nuts per panicle

The data on the number of nuts per panicle as influenced by the different levels of application of NPK is depicted in Table 6. Both nitrogen and phosphorus application at all levels produced a significant increase in the number of nuts per panicle. Potassium application at all levels could not make any significant difference in the number of nuts per panicle. Interaction effects between nutrients could not make any significant difference in the production of number of nuts.

4.4 Physical analysis

4.4.1 Physical analysis of cashew apple

The weight, volume and juice percentage of apple as influenced by different treatment levels is given below.

4.4.1.1 Apple weight

The weight of cashew apple obtained from different treatments is given in Table 7. Application of nitrogen and phosphorus at all levels, though had brought marginal differences in apple weight, these differences remained statistically insignificant. On the contrary, the different levels of potassium application had significant effect in increasing the weight of cashew apple. However statistically the difference observed in the weight of apple from K_1 and K_2 levels were not significantly different. A significant difference of 3.1g has been observed as the average weight difference of apple from treatment receiving K_1 (150 g tree^{-1}) and K_0. Enhancement of potassium level from K_1 (150 g tree^{-1}) to K_2 (250 g tree^{-1}) could not produce any further significant increase in weight of apple. These levels on comparison with control remained significantly superior in enhancing the apple weight. Increasing levels of nitrogen and phosphorus applications could not impart any significant difference in apple weight. From the table it is seen that these nutrients instead of making a more positive effect with increasing levels on the apple weight, had made a more negative effect by decreasing the weight of apple (with maximum and minimum weight of 37.53g and 34.93g getting recorded at N_0 level and N_2 level respectively). A similar trend has been observed with phosphorus applications recording a maximum weight of 36.06g at P_0 level and a minimum weight of 35.54g at P_2 level. The interaction effects of NPK at different levels of application remained insignificant in altering the weight of cashew apple.

4.4.1.2 Apple volume

The data on apple volume as influenced by the NPK nutrition at different levels is given in Table 7. From the data, it can be seen that the effect of nitrogen and potassium remained significant with enhanced nitrogen application negatively influencing the volume of apple. However, in case of potassium a reverse trend was observed with $K_1$and K_2 levels of application significantly increasing the apple volume over control. The decrease in volume with increasing levels of nitrogen application was apparent only up to N_1 level and increase in nitrogen up to N_2 level could not produce any further significant reduction in apple volume. Phosphorus at all levels of applications could not influence any significant change in apple volume, although a marginal decrease in volume was observed at higher levels of application as is evident with a maximum volume of 38.51cc getting recorded at P_0 level and a minimum volume of 35.79cc getting recorded in treatments receiving 250 g P $tree^{-1}$ (P_2 level). Unlike in the case of nitrogen and phosphorus there was an increase in volume of cashew apple upto the first level of application and this increase remained statistically superior to control (K_0 level). The difference in the apple volume observed between K_1 and K_2 levels, though found marginally different from one another there was no statistical difference between them making their effects in influencing the changes on apple volume on par. Interaction effects of major nutrients could hardly produce any significant difference in either positively or negatively influencing the apple volume.

4.4.1.3 Juice content in cashew apple

Table 7 provides the data on juice percentage of apple obtained from different treatments, which received NPK at different levels of application. The juice percentage of apple was found to be positively influenced by nitrogen and potassium upto their first level of application and later higher levels of applications of both, though had brought marginal influence in the percentage of apple juice and these differences were not statistically significant. Phosphorus at all levels of application could not bring in any apparently significant change in juice percentage though marginal increase in juice percentage have been observed with higher levels of phosphorus application. These values even when compared against control could not make the levels of application of phosphorus significant in enhancing the juice percentage in cashew apple. Interaction effects of major nutrients remained ineffective in bringing changes in juice percentage of cashew apple.

Table 7. Effect of NPK on physical characters of cashew apple

	Apple weight (g)	Apple volume (ml)	Juice %
N			
n0	37.53	40.49	83.62
nl	35.54	36.61	85.99
n2	34.93	35.19	87.12
SE	**1.42**	**1.71**	**1.00**
CD	**2.91**	**3.49**	**2.05**
	NS	**S**	**S**
P			
p0	36.06	38.51	84.27
pl	36.40	38.00	85.96
p2	35.54	35.79	86.50
SE	**1.42**	**1.71**	**1.00**
CD	**2.91**	**3.49**	**2.05**
	NS	**NS**	**NS**
K			
k0	33.70	33.09	83.75
kl	36.80	37.92	86.17
k2	37.50	41.28	86.81
SE	**1.42**	**1.71**	**1.00**
CD	**2.91**	**3.49**	**2.05**
	S	**S**	**S**
NP			
n0p0	36.13	42.21	81.41
nopl	40.77	43.56	86.37
n0p2	35.67	35.71	83.07
nlp0	37.46	35.88	84.82
nlpl	33.29	35.52	84.69
nlp2	35.88	38.43	88.48
n2p0	34.58	37.44	86.59
n2pl	35.13	34.90	86.82
n2p2	35.07	33.23	87.95
SE	**2.46**	**2.95**	**1.73**
CD	**5.04**	**6.05**	**3.55**
	NS	**NS**	**NS**
NK			
n0k0	36.37	38.71	83.57
nokl	36.78	38.17	84.38
n0k2	39.43	44.61	82.89
nlk0	32.33	29.31	82.63
nlkl	37.32	40.47	86.64
nlk2	36.98	40.04	88.71
n2k0	32.40	31.25	85.03
n2kl	38.29	37.08	85.27
n2k2	36.08	39.20	88.84
SE	**2.46**	**2.95**	**1.73**
CD	**5.04**	**6.05**	**3.55**
	NS	**NS**	**NS**

Continuation of table 7

	Apple weight (g)	Apple volume (ml)	Juice %
PK			
p0k0	33.72	32.55	81.80
p0k1	35.09	39.33	84.44
p0k2	39.37	43.64	86.58
p1k0	34.84	34.77	82.97
p1k1	38.78	38.16	86.37
p1k2	35.57	41.05	88.53
p2k0	32.54	31.95	86.47
p2k1	36.53	36.26	87.70
p2k2	37.56	39.16	85.33
SE	**2.46**	**2.95**	**1.73**
CD	**5.04**	**6.05**	**3.55**
	NS	**NS**	**NS**
NPK			
n0p0k0	35.37	36.83	76.53
n0p0k1	30.55	39.17	82.88
n0p0k2	42.49	50.63	84.82
n0p1k0	37.69	41.33	88.25
n0p1k1	43.02	42.33	83.04
n0p1k2	41.61	47.03	87.81
n0p2k0	36.06	37.96	85.95
n0p2k1	36.76	33.00	87.22
n0p2k2	34.20	36.17	76.04
n1p0k0	32.87	32.25	83.57
n1p0k1	41.43	41.50	82.91
n1p0k2	38.07	33.88	87.98
n1p1k0	31.56	27.82	78.13
n1p1k1	36.69	36.74	85.68
n1p1k2	31.62	42.00	90.24
n1p2k0	32.55	27.88	86.20
n1p2k1	33.83	43.17	91.34
n1p2k2	41.26	44.25	87.90
n2p0k0	32.92	28.56	85.31
n2p0k1	33.28	37.33	87.53
n2p0k2	37.56	46.42	86.93
n2p1k0	35.28	35.17	82.53
n2p1k1	36.62	35.42	90.38
n2p1k2	33.47	34.13	87.54
n2p2k0	29.00	30.02	87.26
n2p2k1	39.00	32.61	84.55
n2p2k2	37.22	37.06	92.04
SE	**4.27**	**5.12**	**3.00**
CD	**8.74**	**10.48**	**6.15**
	NS	**NS**	**NS**

4.4.2 Physical analysis of nuts

4.4.2.1 Nut length

The length of nuts as observed from different treatments is being presented in Table 8. Application of nitrogen and phosphorus at all levels of application could not impart significant variations in nut length though marginal increase in nut length has been observed with increase in levels of application. Application of potassium had significant and positive influence in controlling the nut length. Upto K_1 level it was observed that the application of potassium had significantly influenced the nut length and further increase in levels of addition of potassium had no significant effect. Effects of K_1 and K_2 were significant over control. Nitrogen and phosphorus applications could not produce any statistically significant difference in length but it was seen that increasing levels of nitrogen and phosphorus resulted in a marginal increase in nut length. A maximum nut length of 2.88 cm was recorded at 1000g application of nitrogen and at 250 g application of potassium and a minimum nut length of 2.83 cm at N_0 and 2.84 cm at P_0 level. The interaction effect of phosphorus and potassium was found to have a significant in influence on the nut length.

4.4.2.2 Nut weight

The data on nut weight as obtained from different treatments is given in Table 8. On comparison with control, application of nitrogen and potassium had significantly contradicting effect in influencing the nut weight. Application of nitrogen up to N_1 level had significantly reduced the nut weight, further increase in the level of application (N_2) could not bring any further significant reduction in the weight of nuts. In case of potassium, only the application of the highest level (K_2) of the nutrient significantly increased the nut weight. The treatments K_1 and K_2 were found to be at par with each other. Phosphorus application at all levels could hardly influence any significant increase or decrease in nut weight. The interaction effects of major nutrients in cashew significantly failed to influence the nut weight either positively or negatively.

4.4.2.3 Shelling percentage

Data on shelling percentage of nuts obtained from different treatments is presented in Table 8. Shelling percentage in cashew was found to be positively and significantly influenced by nitrogen and potassium application. On comparison with the control both N_1 and N_2 levels of application remained significantly superior in influencing the shelling percentage while the specific effect of N_1 and N_2 in enhancing the shelling percentage was not prominent and they remained statistically on par with each other. The average shelling percentage recorded from N_0, N_1 and N_2 levels of application were 24.9, 26.9 and 27.6 per cent respectively. An identical trend in influencing the shelling percentage has been observed for potassium application where 25.5, 26.9 and 27.0 per cent have been recorded from K_0, K_1 and K_2 levels respectively. Phosphorus applications had no influence in making a significant increase or decrease in the shelling percentage in cashew. Interaction effects of major nutrients were not seen to significantly influence the shelling percentage in cashew.

4.4.2.4 Kernel weight

The data on the processed kernel weight obtained from different treatments is provided in Table 8. Among the major nutrients only potassium had positive influence in enhancing the kernel weight in cashew, where as nitrogen and phosphorus could not bring in any significant variations. In the case of potassium, increasing levels of application had positive and significant influence in enhancing the weight of kernels. Compared to control increasing levels of application of potassium had significant and positive influence only upto the K_1 and further increase in the level of application up to K_2 did not bring any further significant increase in the weight of kernels. Interaction effects of major nutrients were also found to be insignificant in influencing the kernel weight.

Table 8. Effect of NPK on physical characters of nuts

	Nut length (cm)	Nut weight (g)	Shelling %	Kernel weight (g)
N				
n0	2.83	5.96	24.85	1.39
n1	2.87	5.70	26.91	1.45
n2	2.88	5.54	27.55	1.45
SE	0.03	0.08	0.58	0.04
CD	0.07	0.16	1.18	0.07
	NS	S	S	NS
P				
p0	2.84	5.77	26.40	1.43
p1	2.87	5.68	26.42	1.42
p2	2.88	5.75	26.49	1.44
SE	0.03	0.08	0.58	0.04
CD	0.07	0.16	1.18	0.07
	NS	NS	NS	NS
K				
k0	2.81	5.66	25.45	1.35
k1	2.88	5.67	26.86	1.44
k2	2.89	5.87	27.00	1.50
SE	0.03	0.08	0.58	0.04
CD	0.07	0.16	1.18	0.07
	S	S	S	S
NP				
n0p0	2.81	6.02	24.46	1.38
nop1	2.90	5.92	25.17	1.42
n0p2	2.78	5.94	24.92	1.39
n1p0	2.86	5.66	26.84	1.43
n1p1	2.86	5.62	27.09	1.45
n1p2	2.89	5.81	26.80	1.46
n2p0	2.83	5.63	27.89	1.49
n2p1	2.85	5.51	27.01	1.39
n2p2	2.97	5.50	27.74	1.46
SE	0.06	0.13	1.00	0.06
CD	0.11	0.27	2.04	0.13
	NS	NS	NS	NS
NK				
n0k0	2.75	5.80	24.25	1.30
nok1	2.88	5.87	26.25	1.46
n0k2	2.86	6.20	24.06	1.42
n1k0	2.87	5.64	26.12	1.40
n1k1	2.87	5.64	26.89	1.43
n1k2	2.87	5.81	27.72	1.51
n2k0	2.81	5.53	25.98	1.35
n2k1	2.86	5.64	26.82	1.42
n2k2	2.94	5.60	29.21	1.57
SE	0.06	0.13	1.00	0.06
CD	0.11	0.27	2.04	0.13
	NS	NS	NS	NS

Continuation of table 8

	Nut length (cm)	Nut weight (g)	Shelling %	Kernel weight (g)
PK				
p0k0	2.81	5.73	26.23	1.42
p0k1	2.81	5.53	26.43	1.38
p0k2	2.89	6.05	26.54	1.50
p1k0	2.88	5.57	25.31	1.31
p1k1	2.86	5.76	26.94	1.46
p1k2	2.87	5.72	27.02	1.48
p2k0	2.73	5.67	24.82	1.32
p2k1	2.98	5.72	27.21	1.47
p2k2	2.92	5.85	27.43	1.52
SE	**0.06**	**0.13**	**1.00**	**0.06**
CD	**0.11**	**0.27**	**2.04**	**0.13**
	S	**NS**	**NS**	**NS**
NPK				
n0p0k0	2.71	5.70	23.92	1.27
n0p0k1	2.82	5.85	24.94	1.38
n0p0k2	2.90	6.52	24.53	1.48
n0p1k0	2.92	5.85	25.00	1.34
n0p1k1	2.90	5.97	27.27	1.57
n0p1k2	2.86	5.93	23.24	1.34
n0p2k0	2.61	5.86	23.82	1.29
n0p2k1	2.91	5.80	26.53	1.43
n0p2k2	2.81	6.15	24.40	1.45
n1p0k0	2.91	5.77	26.62	1.47
n1p0k1	2.83	5.41	26.51	1.34
n1p0k2	2.85	5.81	27.40	1.47
n1p1k0	2.84	5.39	26.12	1.32
n1p1k1	2.85	5.71	27.43	1.48
n1p1k2	2.89	5.76	27.73	1.55
n1p2k0	2.85	5.76	25.63	1.40
n1p2k1	2.92	5.80	26.73	1.45
n1p2k2	2.88	5.86	28.04	1.52
n2p0k0	2.82	5.73	28.13	1.52
n2p0k1	2.78	5.34	27.85	1.40
n2p0k2	2.90	5.81	27.69	1.55
n2p1k0	2.88	5.46	24.80	1.26
n2p1k1	2.82	5.61	26.12	1.34
n2p1k2	2.85	5.47	30.10	1.57
n2p2k0	2.73	5.39	25.01	1.27
n2p2k1	3.11	5.57	28.36	1.52
n2p2k2	3.05	5.53	29.84	1.58
SE	**0.10**	**0.23**	**1.73**	**0.11**
CD	**0.20**	**0.47**	**3.54**	**0.22**
	NS	**NS**	**NS**	**NS**

4.5 Chemical analysis

4.5.1 Apple analysis

The NPK content, total soluble solids and ascorbic acid content of cashew apples collected from different experiments and as influenced by various levels of nutrient applications is provided under different heads.

4.5.1.1 NPK content in cashew apples

Data on the nitrogen, phosphorus and potassium content in apples is given in Table 9. Application of nitrogen, phosphorus and potassium at different levels hardly made any significant impact in varying the NPK contents of cashew apple obtained from different treatments as these contents remained more or less same in all the samples analysed. For the different treatments the range of NPK percentage in the apple varied on an average from 0.96 to 1.05 per cent for nitrogen, 0.20 to 0.22 per cent for phosphorus and 0.72 to 0.76 per cent respectively. The interaction effects between major nutrients were also found to be insignificant in modifying the nutrient content in apple. A direct but non-significant influence of the levels of nitrogen, phosphorus and potassium application on the apple nitrogen content was evident. Similar effect was absent in the case of apple phosphorus and potassium content.

4.5.1.2 Total soluble solids

The data on total soluble solids seen in apples as influenced by the different levels of NPK application is presented in Table 9. Among the major nutrients, which have been added at different levels, only nitrogen was found to influence the T.S.S. of apples significantly. The T.S.S. content of apples was found to increase significantly upto N_1 level and thereafter additional enhancement of nitrogen to N_2 level of application could not register any significant increase, when compared with N_1 level of application. All the same, the effects of $N_1$and N_2 remained significantly higher when compared against control. The percentage of T.S.S observed at N_0, N_1 and N_2 levels of application were 11.1, 12.6 and 13.1 per cent respectively. Phosphorus and potassium

Table 9. Effect of NPK on the chemical characters of cashew apple

	Apple N (%)	Apple P (%)	Apple K (%)	T.S.S (%)	Ascorbic acid (mg/100g)
N					
n0	0.96	0.21	0.76	11.10	226.68
n1	0.98	0.22	0.70	12.57	261.15
n2	1.05	0.19	0.77	13.14	265.29
SE	**0.06**	**0.02**	**0.11**	**0.38**	**12.77**
CD	**0.13**	**0.04**	**0.23**	**0.77**	**26.16**
	NS	**NS**	**NS**	**S**	**S**
P					
p0	0.95	0.20	0.74	12.33	232.94
p1	0.98	0.20	0.69	12.28	251.80
p2	1.06	0.22	0.80	12.21	268.38
SE	**0.06**	**0.02**	**0.11**	**0.38**	**12.77**
CD	**0.13**	**0.04**	**0.23**	**0.77**	**26.16**
	NS	**NS**	**NS**	**NS**	**S**
K					
k0	0.97	0.20	0.72	12.34	223.33
k1	1.00	0.20	0.75	12.12	255.77
k2	1.02	0.22	0.76	12.35	274.02
SE	**0.06**	**0.02**	**0.11**	**0.38**	**12.77**
CD	**0.13**	**0.04**	**0.23**	**0.77**	**26.16**
	NS	**NS**	**NS**	**NS**	**S**
NP					
n0p0	0.90	0.21	0.87	11.04	207.10
nop1	0.92	0.21	0.78	10.82	231.97
n0p2	1.05	0.21	0.62	11.44	240.96
n1p0	0.89	0.18	0.65	12.21	234.35
n1p1	0.99	0.23	0.66	12.89	275.87
n1p2	1.07	0.24	0.78	12.61	273.23
n2p0	1.06	0.21	0.69	13.73	257.36
n2p1	1.03	0.17	0.63	13.13	247.57
n2p2	1.07	0.21	1.00	12.57	290.95
SE	**0.11**	**0.04**	**0.19**	**0.65**	**22.12**
CD	**0.22**	**0.08**	**0.40**	**1.33**	**45.30**
	NS	**NS**	**NS**	**NS**	**NS**
NK					
n0k0	0.84	0.21	0.83	11.14	193.09
nok1	0.95	0.23	0.81	10.61	232.76
n0k2	1.07	0.20	0.62	11.55	254.19
n1k0	1.00	0.22	0.70	12.63	241.75
n1k1	1.05	0.17	0.69	12.87	262.91
n1k2	0.91	0.26	0.71	12.21	278.78
n2k0	1.08	0.18	0.62	13.26	235.14
n2k1	0.96	0.18	0.61	12.23	242.02
n2k2	1.07	0.22	0.94	13.29	289.10
SE	**0.11**	**0.04**	**0.19**	**0.65**	**22.12**
CD	**0.22**	**0.08**	**0.40**	**1.33**	**45.30**
	NS	**NS**	**NS**	**NS**	**NS**

Continuation of table 9

	Apple N (%)	Apple P (%)	Apple K (%)	T.S.S (%)	Ascorbic acid (mg/100g)
PK					
p0k0	1.01	0.18	0.72	12.03	233.03
p0k1	0.92	0.22	0.79	12.57	219.01
p0k2	0.91	0.20	0.70	12.38	246.78
p1k0	0.94	0.21	0.74	12.58	208.69
p1k1	1.00	0.18	0.75	12.00	261.33
p1k2	1.00	0.21	0.58	12.27	285.40
p2k0	0.97	0.21	0.69	12.42	228.26
p2k1	1.08	0.19	0.73	11.81	286.98
p2k2	1.14	0.26	0.99	12.39	289.89
SE	**0.11**	**0.04**	**0.19**	**0.65**	**22.12**
CD	**0.22**	**0.08**	**0.40**	**1.33**	**45.30**
	NS	**NS**	**NS**	**NS**	**NS**
NPK					
n0p0k0	0.78	0.15	0.84	10.60	179.33
n0p0k1	0.90	0.28	1.09	10.67	188.06
n0p0k2	1.01	0.21	0.69	11.85	253.92
n0p1k0	0.81	0.26	0.95	11.57	183.30
n0p1k1	0.98	0.21	0.80	10.33	261.86
n0p1k2	0.98	0.18	0.59	10.57	250.75
n0p2k0	0.92	0.20	0.71	11.27	216.63
n0p2k1	0.98	0.21	0.55	10.83	248.37
n0p2k2	1.23	0.21	0.59	12.23	257.89
n1p0k0	0.95	0.20	0.73	12.43	283.28
n1p0k1	0.98	0.17	0.60	12.63	191.23
n1p0k2	0.73	0.16	0.64	11.57	228.53
n1p1k0	1.09	0.24	0.66	12.07	239.64
n1p1k1	0.92	0.15	0.68	13.23	286.45
n1p1k2	0.95	0.30	0.65	13.37	301.53
n1p2k0	0.95	0.22	0.71	13.40	202.34
n1p2k1	1.23	0.20	0.79	12.75	311.05
n1p2k2	1.04	0.31	0.85	11.68	306.29
n2p0k0	1.29	0.19	0.60	13.07	236.46
n2p0k1	0.90	0.21	0.69	14.40	277.73
n2p0k2	1.01	0.23	0.79	13.73	257.89
n2p1k0	0.92	0.14	0.61	14.10	203.14
n2p1k1	1.09	0.19	0.76	12.43	235.67
n2p1k2	1.06	0.17	0.50	12.87	303.91
n2p2k0	1.04	0.19	0.64	12.60	265.82
n2p2k1	1.04	0.16	0.84	11.83	301.53
n2p2k2	1.15	0.26	1.54	13.27	305.50
SE	**0.18**	**0.07**	**0.34**	**1.13**	**38.32**
CD	**0.38**	**0.13**	**0.69**	**2.30**	**78.47**
	NS	**NS**	**NS**	**NS**	**NS**

applications at all levels of application failed to register any significant variation in T.S.S. content of a cashew apple The interaction effects of major nutrient were found to be insignificant in inducing any significant variation in total soluble solids.

4.5.1.3 Ascorbic acid content of cashew apples

The ascorbic acid content in apples as observed from different treatments receiving NPK at various levels have been presented in Table 9. It has been observed that all the major nutrients had positive and significant effect in enhancing the ascorbic acid content of cashew apples. At lower levels of application, only nitrogen and potassium had shown significant increase in the ascorbic acid content of apples. In the case of phosphorus, lower levels of application could not induce any significant variation in ascorbic acid content, especially when compared with control. Higher levels of nitrogen, phosphorus and potassium application brought in significant variations in ascorbic acid content of cashew apple, especially when compared with control. None of the interaction effects of major nutrients was effective in ordering a change in the ascorbic acid content of cashew apple.

4.5.2 Nut analysis

The effect of different levels of application of NPK on the protein, fat, carbohydrate and sugar content of the cashew kernels have been presented below under different sub heads.

4.5.2.1 Kernel protein content

Table 10 depicts the protein content of kernels as influenced by the different levels of NPK application in cashew. Among the effects of major nutrients in influencing the protein content of kernels, only nitrogen was found to have significant effect. Effects of phosphorus and potassium were found to have practically no effect in altering the protein content of cashew kernels. In the case of nitrogen, significant enhancement of proteins in kernels was observed at all levels of nutrient application. The percentage protein content, registered at N_0, N_1 and N_2 levels was 18.9, 23.2 and 25.9 per cent respectively.

Among the major nutrient interaction effects, only NP interactions remained significant in enhancing the protein content of kernels. N_2P_1 level of application recorded the highest (27.09 %) level of protein content, while N_0P_1 recorded the lowest (17.42 %) protein content.

4.5.2.2 Kernel carbohydrate content

The data on carbohydrate content of kernels is presented in Table 10. Enhancement of carbohydrate content was influenced more by nitrogen application than phosphorus and potassium. In the case of nitrogen, all levels of application remained significant in enhancing the carbohydrate content with maximum carbohydrate content being recorded at N_2 level of application (16.25 mg $100mg^{-1}$). Effects of phosphorus and potassium applications at all levels were found to have no significant effect in enhancing the carbohydrate content. Among the interaction effects of major nutrients, only NP interaction was found to be significant in elevating the carbohydrate content. N_2P_2 level of application, recorded a maximum carbohydrate content of 17.04 (mg $100mg^{-1}$) in kernels.

4.5.2.3 Fat content in kernels

The data on fat percentage in kernel is given in Table 10. From the table values, it is seen that neither the main effects nor the interaction effects of major nutrients remained significant in altering the fat percentage in kernels.

4.5.2.4 Sugar content in kernel

(i) Reducing sugars in kernel (mg $100mg^{-1}$)

Data on the percentage of reducing sugars in kernel is given in Table 10. From the table it is seen that the application of only nitrogen helped to increase the content of reducing sugars in kernel. All levels of nitrogen application resulted in significant enhancement of the content of reducing sugars. The level of reducing sugars in kernels had increased from 3.82 to 5.23 mg $100mg^{-1}$ in N_0

Table 10. Effect of NPK on the chemical characters of cashew kernel

	Protein (%)	Carbohydrate (mg/100mg)	Fat (%)	Reducing sugar (mg/100mg)	Non reducing sugars (mg/100mg)
N					
n0	18.90	10.75	44.67	3.82	6.93
n1	23.21	12.74	43.66	4.53	8.21
n2	25.86	16.25	44.01	5.23	11.03
SE	**0.79**	**0.61**	**1.30**	**0.20**	**0.59**
CD	**1.62**	**1.24**	**2.66**	**0.41**	**1.21**
	S	**S**	**NS**	**S**	**S**
P					
p0	22.62	13.33	43.71	4.39	8.94
p1	22.80	13.20	44.35	4.52	8.68
p2	22.54	13.21	44.28	4.67	8.55
SE	**0.79**	**0.61**	**1.30**	**0.20**	**0.59**
CD	**1.62**	**1.24**	**2.66**	**0.41**	**1.21**
	NS	**NS**	**NS**	**NS**	**NS**
K					
k0	22.30	13.49	44.03	4.51	8.98
k1	22.94	13.04	44.26	4.53	8.51
k2	22.73	13.21	44.05	4.53	8.68
SE	**0.79**	**0.61**	**1.30**	**0.20**	**0.59**
CD	**1.62**	**1.24**	**2.66**	**0.41**	**1.21**
	NS	**NS**	**NS**	**NS**	**NS**
NP					
n0p0	20.48	12.10	43.81	3.99	8.11
nop1	17.42	10.02	46.16	3.67	6.35
n0p2	18.79	10.12	44.03	3.80	6.33
n1p0	23.74	11.74	44.81	4.53	7.20
n1p1	23.90	14.00	44.16	4.50	9.50
n1p2	21.99	12.47	42.01	4.55	7.93
n2p0	23.63	16.14	42.49	4.64	11.50
n2p1	27.09	15.58	42.74	5.39	10.20
n2p2	26.85	17.04	46.81	5.65	11.39
SE	**1.37**	**1.05**	**2.25**	**0.35**	**1.03**
CD	**2.80**	**2.16**	**4.61**	**0.71**	**2.10**
	S	**S**	**NS**	**NS**	**NS**
NK					
n0k0	18.38	10.89	44.90	3.71	7.18
nok1	19.92	10.69	45.09	3.90	6.78
n0k2	18.39	10.67	44.01	3.84	6.83
n1k0	23.61	12.89	44.36	4.41	8.48
n1k1	22.14	12.92	42.18	4.46	8.45
n1k2	23.88	12.41	44.43	4.71	7.70
n2k0	24.90	16.71	42.82	5.41	11.29
n2k1	22.63	12.02	43.05	4.11	7.90
n2k2	25.92	16.55	43.71	5.04	11.51
SE	**1.37**	**1.05**	**2.25**	**0.35**	**1.03**
CD	**2.80**	**2.16**	**4.61**	**0.71**	**2.10**
	NS	**NS**	**NS**	**NS**	**NS**

Continuation of table 10

	Protein (%)	Carbohydrate (mg/100mg)	Fat (%)	Reducing sugar (mg/100mg)	Non reducing sugars (mg/100mg)
PK					
p0k0	22.42	13.47	43.64	4.18	9.28
p0k1	22.31	14.00	42.69	4.41	9.58
p0k2	23.13	12.52	44.78	4.57	7.95
p1k0	21.09	13.12	42.34	4.71	8.41
p1k1	23.61	12.39	45.77	4.49	7.90
p1k2	23.70	14.09	44.94	4.35	9.74
p2k0	23.38	13.89	46.10	4.63	9.26
p2k1	22.89	12.73	44.33	4.69	8.04
p2k2	21.35	13.01	42.42	4.67	8.34
SE	1.37	1.05	2.25	0.35	1.03
CD	2.80	2.16	4.61	0.71	2.10
	NS	NS	NS	NS	NS
NPK					
n0p0k0	21.39	12.60	44.36	3.58	9.02
n0p0k1	19.42	14.30	44.01	4.37	9.94
n0p0k2	20.64	9.41	43.08	4.02	5.39
n0p1k0	13.97	9.51	44.77	3.76	5.76
n0p1k1	19.30	8.64	47.67	3.70	4.94
n0p1k2	18.99	11.90	46.04	3.54	8.36
n0p2k0	19.80	10.55	45.58	3.78	6.77
n0p2k1	21.02	9.12	43.60	3.64	5.48
n0p2k2	15.54	10.70	42.90	3.97	6.72
n1p0k0	23.63	12.22	47.02	4.24	7.98
n1p0k1	23.50	11.90	38.86	4.03	7.88
n1p0k2	24.10	11.09	48.54	5.34	5.75
n1p1k0	23.70	13.07	39.78	4.29	8.78
n1p1k1	23.35	15.02	46.67	4.67	10.35
n1p1k2	24.64	13.91	46.01	4.54	9.37
n1p2k0	23.50	13.36	46.27	4.69	8.68
n1p2k1	19.57	11.83	41.01	4.69	7.14
n1p2k2	22.89	12.23	38.75	4.26	7.97
n2p0k0	22.25	15.58	39.54	4.73	10.85
n2p0k1	24.01	15.78	45.20	4.85	10.93
n2p0k2	24.64	17.05	42.73	4.34	12.71
n2p1k0	25.62	16.78	42.47	6.09	10.69
n2p1k1	28.18	13.50	42.98	5.09	8.42
n2p1k2	27.47	16.46	42.78	4.98	11.48
n2p2k0	26.84	17.77	46.44	5.43	12.34
n2p2k1	28.06	17.24	48.37	5.74	11.49
n2p2k2	25.63	16.12	45.61	5.79	10.33
SE	2.37	1.82	3.90	0.60	1.78
CD	4.86	3.73	7.98	1.23	3.64
	NS	NS	NS	NS	NS

and N_2 level of applications respectively. Phosphorus and potassium could hardly initiate any significant difference in the content of reducing sugars. The interaction effects of major nutrients were also not seen to be effective in making significant changes in the content of reducing sugars.

(ii) Non-reducing sugars in kernel (mg $100mg^{-1}$)

Data on the percentage of non-reducing sugars as influenced by different levels of NPK is presented in Table 10. Among the effect of major nutrients, only nitrogen application was significant in enhancing the content of non-reducing sugars in kernel. It is seen that at all increasing levels of nitrogen there had been a corresponding significant influence in the percentage of non-reducing sugars in kernel. The effect of phosphorus and potassium applications could not initiate changes in the non-reducing sugar content in kernel. Among the major nutrient interactions, none were found to influence any significant differences in the content of non-reducing sugars.

4.6 Post harvest analysis

4.6.1 Major nutrient status of the soils.

The available nutrient status in soil as influenced by the different levels of application of NPK fertilisers after the harvest of the crop is provided under different sub-heads.

4.6.1.1 Available nitrogen

The data on the analysis for available nitrogen from soils, which received NPK at different levels, is provided in Table 11. It is seen that increasing levels of nitrogen application significantly increased the available nitrogen content of soil. There was not much of significant difference in the available nitrogen content recorded at N_1 and N_2 levels of applications though these levels remained significantly superior when compared against control. The applications of phosphorus, potassium and the interaction effects of major nutrients were not significant in modifying the nitrogen content of soils.

4.6.1.2 Available phosphorus

The data on the available phosphorus content of soils is given in Table 11. From the analytical values, it is seen that application of phosphorus alone was capable of enhancing the available phosphorus content of soils. It was seen that the significant enhancement of available phosphorus in soil was possible only at P_2 level. Application of phosphorus at P_1 level was not significant in enhancing the available phosphorus status in soils. On comparison with P_0 level of application, there was no significant difference. A maximum content of 3.44 Kg ha^{-1} available phosphorus was recorded from soils receiving P_2 level of application. Nitrogen and potassium applications did not have any significant influence in altering the available phosphorus content of soils. None of the interaction effects major nutrients was found to be effective significantly in modifying the available nitrogen content.

4.6.1.3 Available potassium

The data on the available potassium content of soils after the harvest of the crop has been presented in Table 11. Among the major nutrients applied only potassium fertiliser application were capable of enhancing the available potassium status of soils to a significant extent. The highest content of available potassium (628.01 kg ha^{-1}) was recorded at K_1 level of application, which on comparison with control showed significant variation. K_2 level of application had remained statistically on par with K_1 with marginal differences existing between them. Applications of nitrogen and phosphorus were not able to influence the level of available potassium status in cashew soils. The interaction effects of major nutrients were also ineffective in imparting changes in the available potassium status of soils.

4.6.2 Cashew leaf nutrient status

4.6.2.1 Leaf nitrogen content

Table 11 provides the nitrogen content of the leaf in the post harvest stage. Nitrogen and phosphorus application had showed profound and significant differences in maintaining variations in nitrogen content of leaves at all levels of application. The highest content of nitrogen (1.16 %) in leaf was recorded at N_2 level. Application of potassium had not brought any significant influence in altering the percentage of nitrogen content in the cashew leaves. The content of leaf nitrogen analysed at P_1 and P_2 levels were not much different and their effects were statistically on par. Among the interaction effects of major nutrients in enhancing the leaf nitrogen content, only NP interactions were found to be significant with a high content of 1.24 per cent being recorded at $N_2 P_2$ level. The leaf nitrogen content recorded at $N_0 P_2$ level (0.69 %) was significantly inferior to that recorded at $N_2 P_2$ level (1.24 %).

4.6.2.2 Leaf phosphorus content

The data on the content of phosphorus in leaf as influenced by different levels of NPK is provided in Table 11. It is seen that the influence of nitrogen and potassium were not effective in modifying the phosphorus content in cashew leaf. The variations in phosphorus content observed in the index leaves as influenced by the different levels of phosphorus though different from one another, significant difference existed mainly between P_2 (0.21 %) and control (0.17 %). In this case, not much of significant difference existed between the effect of P_1 (0.18 %) and control (0.17 %). Interaction effects of NPK remained insignificant in modifying the content of phosphorus in cashew leaf.

4.6.2.3 Leaf potassium content

The data on the post harvest leaf sample (index leaves) analysis on potassium content is provided in Table 11. Main effect of potassium was significantly influential in enhancing the potassium content of index leaves in cashew at all levels of application and even when compared with control. The content of potassium analysed in cashew leaf at K_0, K_1 and K_2 were 1.01, 1.26 and 1.39 per cent respectively. Phosphorus and nitrogen at all levels of application failed to make any significant changes in the leaf potassium percentage. None of the major interaction effects was significant in modifying the potassium content in cashew leaf.

Table 11. Effect of NPK on the nutrient status of post harvest soil and leaf samples

	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Leaf N (%)	Leaf P (%)	Leaf K (%)
N						
n0	296.94	2.15	463.87	0.72	0.18	1.26
n1	606.49	2.60	422.80	0.88	0.18	1.17
n2	612.92	2.99	459.95	1.16	0.20	1.23
SE	123.84	0.41	115.68	0.03	0.01	0.06
CD	253.62	0.84	236.91	0.07	0.02	0.12
	S	NS	NS	S	NS	NS
P						
p0	538.65	1.98	473.14	0.86	0.17	1.16
p1	490.12	2.31	360.14	0.93	0.18	1.27
p2	487.59	3.44	513.33	0.97	0.21	1.23
SE	123.84	0.41	115.68	0.03	0.01	0.06
CD	253.62	0.84	236.91	0.07	0.02	0.12
	NS	S	NS	S	S	NS
K						
k0	667.65	2.43	133.53	0.93	0.19	1.01
k1	413.93	2.50	628.01	0.91	0.19	1.26
k2	434.78	2.80	585.08	0.93	0.18	1.39
SE	123.84	0.41	115.68	0.03	0.01	0.06
CD	253.62	0.84	236.91	0.07	0.02	0.12
	NS	NS	S	NS	NS	S
NP						
n0p0	315.81	1.33	609.47	0.71	0.16	1.16
nop1	272.28	1.96	334.51	0.76	0.19	1.30
n0p2	302.75	3.15	447.63	0.69	0.20	1.32
n1p0	593.15	1.96	367.73	0.77	0.18	1.13
n1p1	645.98	2.72	380.80	0.89	0.18	1.23
n1p2	580.34	3.12	519.87	0.98	0.19	1.16
n2p0	706.99	2.66	442.21	1.10	0.18	1.20
n2p1	552.10	2.26	365.12	1.13	0.18	1.29
n2p2	579.68	4.05	572.51	1.24	0.22	1.21
SE	214.49	0.71	200.36	0.06	0.02	0.10
CD	439.28	1.46	410.34	0.11	0.03	0.21
	NS	NS	NS	S	NS	NS
NK						
n0k0	327.36	1.96	145.79	0.72	0.18	1.12
nok1	222.08	2.12	660.61	0.70	0.19	1.28
n0k2	341.39	2.36	585.20	0.74	0.18	1.38
n1k0	801.26	2.22	122.27	0.90	0.18	0.95
n1k1	688.97	2.95	706.72	0.85	0.20	1.15
n1k2	329.25	2.62	439.41	0.89	0.18	1.42
n2k0	874.33	3.12	132.53	1.15	0.20	0.95
n2k1	460.27	3.09	780.27	0.77	0.19	1.22
n2k2	633.71	3.42	730.61	1.14	0.19	1.38
SE	214.49	0.71	200.36	0.06	0.02	0.10
CD	439.28	1.46	410.34	0.11	0.03	0.21
	NS	NS	NS	NS	NS	NS

Continuation of table 11

	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Leaf N (%)	Leaf P (%)	Leaf K (%)
PK						
p0k0	827.75	1.63	134.03	0.90	0.17	0.96
p0k1	496.89	1.96	789.04	0.83	0.18	1.20
p0k2	291.32	2.36	496.35	0.84	0.16	1.33
p1k0	700.97	2.06	140.37	0.90	0.19	1.11
p1k1	352.37	2.79	453.04	0.90	0.19	1.31
p1k2	417.02	2.09	487.01	0.99	0.18	1.39
p2k0	474.24	3.62	126.19	0.98	0.20	0.95
p2k1	392.52	2.76	641.95	1.00	0.21	1.27
p2k2	596.00	3.95	771.87	0.94	0.21	1.46
SE	**214.49**	**0.71**	**200.36**	**0.06**	**0.02**	**0.10**
CD	**439.28**	**1.46**	**410.34**	**0.11**	**0.03**	**0.21**
	NS	**NS**	**NS**	**NS**	**NS**	**NS**
NPK						
n0p0k0	414.02	1.39	152.32	0.82	0.16	0.95
n0p0k1	207.92	1.20	766.08	0.61	0.15	1.09
n0p0k2	325.50	1.39	910.00	0.69	0.16	1.43
n0p1k0	332.41	1.79	149.52	0.67	0.18	1.21
n0p1k1	281.22	2.29	420.00	0.72	0.20	1.40
n0p1k2	203.20	1.79	434.00	0.90	0.19	1.28
n0p2k0	235.67	2.69	135.52	0.67	0.20	1.19
n0p2k1	177.10	2.89	795.76	0.77	0.21	1.34
n0p2k2	495.47	3.88	411.60	0.64	0.21	1.43
n1p0k0	1049.88	1.79	120.96	0.80	0.16	0.88
n1p0k1	567.77	2.69	747.04	0.74	0.20	1.12
n1p0k2	161.81	1.39	235.20	0.77	0.18	1.40
n1p1k0	997.20	1.99	129.36	0.93	0.20	1.08
n1p1k1	635.95	3.69	798.00	0.81	0.17	1.20
n1p1k2	304.80	2.49	215.04	0.93	0.19	1.41
n1p2k0	356.71	2.89	116.48	0.98	0.17	0.90
n1p2k1	863.18	2.49	575.12	1.01	0.22	1.12
n1p2k2	521.12	3.98	868.00	0.96	0.18	1.45
n2p0k0	1019.34	1.69	128.80	1.09	0.20	1.04
n2p0k1	714.97	1.99	854.00	1.14	0.19	1.40
n2p0k2	386.66	4.28	343.84	1.06	0.16	1.15
n2p1k0	773.30	2.39	142.24	1.09	0.18	1.05
n2p1k1	139.94	2.39	141.12	1.17	0.20	1.34
n2p1k2	743.05	1.99	812.00	1.14	0.17	1.49
n2p2k0	830.33	5.28	126.56	1.28	0.23	0.76
n2p2k1	137.28	2.89	554.96	1.22	0.21	1.35
n2p2k2	771.42	3.98	1036.00	1.22	0.23	1.51
SE	**371.51**	**1.23**	**347.04**	**0.10**	**0.03**	**0.17**
CD	**760.85**	**2.52**	**710.73**	**0.20**	**0.06**	**0.36**
	NS	**NS**	**NS**	**NS**	**NS**	**NS**

4.7 Nutrient off-take per tree through cashew nuts and apples

The extent of nitrogen, phosphorus and potassium removed from the plants by way of both apple and nut have been computed and presented in Table 12. The average nitrogen off take per tree through testa, shell, kernel and apples was found to be significantly increased with highest level of nitrogen application. Lowest nitrogen off take of 217.64g was seen at N_1 level and a highest of 365.34g was seen at N_2 level of application. Phosphorus and potassium applications did not affect the nitrogen off take per tree. Interaction effect NPK significantly increased the nitrogen off take per tree with a lowest off take of 145.29g seen at $N_0P_0K_0$ level and a highest off take of 451.85g seen at $N_2P_0K_0$ level of application. In case of phosphorus off take, only the main effect of potassium at K_2 level of application increased the off take of the nutrient significantly. Nitrogen, phosphorus and the interaction effects of the nutrients did not affect the phosphorus off take per tree. Application of nitrogen at N_2 level significantly increased the off take of potassium over control as well as N_1 level of application with a lowest of 155.41g being recorded at N_0 level and a highest of 231.57g being recorded at N_2 level of application. Phosphorus, potassium as well as the interaction effects of the major nutrients could not affect the potassium off take per tree. In general, the average nitrogen, phosphorus and potassium off take per tree through nuts and apples were found to be 279.42, 41.58 and 186.40 g $tree^{-1}$ respectively.

4.8 Yield of cashew nuts and apples

The estimated yield of cashew nuts and apples from different treatments receiving different levels of NPK is depicted in Table 13. Though the application of phosphorus and potassium at different levels showed a marginal increase in yield of nuts in cashew the increase was not statistically significant. A statistically significant increase in yield of cashew nuts was observed only in the case of nitrogen application. The increase in yield of nuts at N_2 level of application was significantly higher than that at N_1 and N_0 levels. Average yields of 2.44, 2.73 and 3.51 kg of nuts were recovered from treatments receiving

Table 12. Nutrient Off take per tree through nuts and apples

Nutrient off take through nuts and apples (g)			
	N off take	P off take	K off take
n0	217.64	36.15	155.41
n1	246.58	40.90	165.34
n2	365.34	46.90	231.57
SE	**25.92**	**5.91**	**23.16**
CD	**53.09**	**12.10**	**47.43**
	S	**NS**	**S**
p0	262.01	39.78	179.88
p1	273.22	39.59	174.29
p2	294.33	44.58	198.14
SE	**25.92**	**5.91**	**23.16**
CD	**53.09**	**12.10**	**47.43**
	NS	**NS**	**NS**
k_0	253.80	35.31	161.86
k_1	265.92	38.02	181.53
k_2	309.84	50.61	208.93
SE	**25.92**	**5.91**	**23.16**
CD	**53.09**	**12.10**	**47.43**
	NS	**S**	**NS**
n_0p_0	172.43	31.34	152.57
nop_1	224.93	39.30	171.76
n_0p_2	255.57	37.81	141.89
n_1p_0	230.95	32.46	152.32
n_1p_1	243.29	41.74	157.14
n_1p_2	265.50	48.49	186.57
n_2p_0	382.65	55.54	234.76
n_2p_1	351.43	37.73	193.98
n_2p_2	361.93	47.42	265.98
SE	**44.90**	**10.24**	**40.11**
CD	**91.96**	**20.96**	**82.15**
	NS	**NS**	**NS**
n_0k_0	167.67	30.68	150.91
n_ok_1	231.24	41.16	169.77
n_0k_2	254.02	36.61	145.55
n_1k_0	216.87	33.58	135.94
n_1k_1	227.50	29.85	152.61
n_1k_2	295.36	59.27	207.48
n_2k_0	376.86	41.69	198.73
n_2k_1	234.77	31.82	141.87
n_2k_2	380.14	55.96	273.78
SE	**44.90**	**10.24**	**40.11**
CD	**91.96**	**20.96**	**82.15**
	NS	**NS**	**NS**

Continuation of table 12

Nutrient off take through nuts and apples (g)			
	N off take	P off take	K off take
p_0k_0	281.67	36.39	175.08
p_0k_1	229.16	37.94	168.45
p_0k_2	275.19	45.01	196.12
p_1k_0	253.66	38.58	172.73
p_1k_1	269.00	35.10	178.89
p_1k_2	296.99	45.09	171.26
p_2k_0	226.07	30.97	137.75
p_2k_1	299.58	41.02	197.26
p_2k_2	357.35	61.73	259.41
SE	44.90	10.24	40.11
CD	91.96	20.96	82.15
	NS	NS	NS
$n_0p_0k_0$	145.29	22.04	148.16
$n_0p_0k_1$	145.66	32.56	150.69
$n_0p_0k_2$	226.35	39.41	158.86
$n_0p_1k_0$	172.55	38.83	164.24
$n_0p_1k_1$	276.76	47.58	215.00
$n_0p_1k_2$	225.49	31.48	136.04
$n_0p_2k_0$	185.16	31.17	140.31
$n_0p_2k_1$	271.31	43.34	143.60
$n_0p_2k_2$	310.23	38.93	141.75
$n_1p_0k_0$	247.87	35.38	153.77
$n_1p_0k_1$	246.02	30.97	150.48
$n_1p_0k_2$	198.95	31.03	152.71
$n_1p_1k_0$	224.26	38.35	135.99
$n_1p_1k_1$	186.97	21.16	131.52
$n_1p_1k_2$	318.64	65.72	203.91
$n_1p_2k_0$	178.49	26.99	118.05
$n_1p_2k_1$	249.50	37.42	175.84
$n_1p_2k_2$	368.51	81.06	265.81
$n_2p_0k_0$	451.85	51.74	223.31
$n_2p_0k_1$	295.81	50.29	204.17
$n_2p_0k_2$	400.28	64.60	276.80
$n_2p_1k_0$	364.16	38.57	217.96
$n_2p_1k_1$	343.28	36.56	190.13
$n_2p_1k_2$	346.84	38.06	173.84
$n_2p_2k_0$	314.56	34.75	154.90
$n_2p_2k_1$	377.94	42.31	272.34
$n_2p_2k_2$	393.30	65.20	370.69
SE	77.77	17.73	69.47
CD	159.28	36.31	142.28
	S	NS	NS

Table 13. Effect of NPK on the yield of cashew nuts and apples

	Nut yield (kg)	Apple yield (kg)
n_0	2.44	15.60
n_1	2.73	16.80
n_2	3.51	22.20
SE	**0.20**	**1.38**
CD	**0.40**	**2.82**
	S	**S**
p_0	2.77	17.62
p_1	2.88	18.23
p_2	3.02	18.75
SE	**0.20**	**1.38**
CD	**0.40**	**2.82**
	NS	**NS**
k_0	2.71	16.10
k_1	2.79	18.24
k_2	3.17	20.27
SE	**0.20**	**1.38**
CD	**0.40**	**2.82**
	NS	**S**
n_0p_0	2.07	13.01
nop_1	2.51	17.31
n_0p_2	2.72	16.48
n_1p_0	2.53	16.66
n_1p_1	2.69	15.58
n_1p_2	2.96	18.16
n_2p_0	3.71	23.20
n_2p_1	3.43	21.81
n_2p_2	3.39	21.60
SE	**0.34**	**2.38**
CD	**0.70**	**4.88**
	NS	**NS**
n_0k_0	2.03	13.13
n_ok_1	2.65	16.73
n_0k_2	2.63	16.94
n_1k_0	2.40	13.63
n_1k_1	2.51	16.29
n_1k_2	3.26	20.49
n_2k_0	3.70	21.54
n_2k_1	2.41	16.19
n_2k_2	3.61	23.37
SE	**0.34**	**2.38**
CD	**0.70**	**4.88**
	NS	**NS**

Continuation of table 13

	Nut yield (kg)	Apple yield (kg)
p_0k_0	2.88	17.05
p_0k_1	2.49	16.11
p_0k_2	2.94	19.71
p_1k_0	2.75	17.11
p_1k_1	2.71	18.37
p_1k_2	3.17	19.22
p_2k_0	2.50	14.14
p_2k_1	3.18	20.25
p_2k_2	3.39	21.87
SE	**0.34**	**2.38**
CD	**0.70**	**4.88**
	NS	**NS**
$n_0p_0k_0$	1.82	11.87
$n_0p_0k_1$	2.04	10.79
$n_0p_0k_2$	2.36	16.37
$n_0p_1k_0$	2.14	13.98
$n_0p_1k_1$	3.01	21.23
$n_0p_1k_2$	2.39	16.72
$n_0p_2k_0$	2.14	13.53
$n_0p_2k_1$	2.89	18.18
$n_0p_2k_2$	3.14	17.74
$n_1p_0k_0$	2.85	16.18
$n_1p_0k_1$	2.27	17.25
$n_1p_0k_2$	2.48	16.56
$n_1p_1k_0$	2.25	13.25
$n_1p_1k_1$	2.06	13.15
$n_1p_1k_2$	3.75	20.34
$n_1p_2k_0$	2.12	11.46
$n_1p_2k_1$	3.21	18.47
$n_1p_2k_2$	3.55	24.57
$n_2p_0k_0$	3.98	23.12
$n_2p_0k_1$	3.16	20.27
$n_2p_0k_2$	3.98	26.20
$n_2p_1k_0$	3.87	24.10
$n_2p_1k_1$	3.06	20.72
$n_2p_1k_2$	3.37	20.60
$n_2p_2k_0$	3.26	17.41
$n_2p_2k_1$	3.43	24.10
$n_2p_2k_2$	3.49	23.29
SE	**0.59**	**4.13**
CD	**1.21**	**8.46**
	NS	**NS**

nitrogen at N_0, N_1 and N_2 respectively. The interaction effects of NPK at different levels had no influence on the nut yield.

In case of apple yield, the application of nitrogen and potassium at the highest level (N_2 and K_2, respectively) significantly increased the yield of cashew apple over control and $N_1$and K_1 respectively. A highest yield of 22.20 and 20.27 kg was recorded at N_2 and K_2 respectively, while a lowest yield of 15.60 and 16.10 kg was recorded at N_1 and K_1 respectively. Phosphorus applications as well as the interactions effects could not influence the yield of apples in cashew.

Discussion

DISCUSSION

5.1 Pretreatment analysis

5.1.1 Soil nutrient status

Nitrogen content in the soil samples analysed before the application of treatments was found to be in the medium fertility range, while phosphorus and potassium content was found to be in the low fertility range as classified by Biswas and Mukerjee (1977). In spite of the heavy addition of nitrogen, the maintenance of medium nitrogen content in soil coul'd be due to the utilization of nitrogen for growth and development. Further, the nutrient off take through nuts and apples might have contributed to the removal of nutrients. High fixation of phosphorus in soils could have been a major reason to keep the available phosphorus in the low range. High utilization of potassium by the plant and high mobility of the element in the soil might have contributed to the low content of potassium in the soil.

5.1.2 Leaf nutrient status

Analysis of index leaf samples prior to application of fertilizers in cashew trees showed significant variations in the nitrogen content in different experimental plots. Lowest content was recorded in those plots, which received practically no application of nitrogen, while those plots which received the highest level of application of nitrogen during the previous year recorded the maximum content, indicating that there was positive and significant response to all levels of application in enhancing the nitrogen content of the index leaf. The residual effects of nitrogen arising from the previous year's application might have been responsible for maintenance of variation in fertility levels between the treatment plots. The range observed for nitrogen and phosphorus is in conformity with that defined by Haag *et al.* (1975).

5.2 Growth characters

5.2.1 Height

The application of nitrogen at the rate of 1000g tree $^{-1}$ in the form of urea significantly increased the height of trees over a similar source applied at half the dose (as is seen in Fig. 2). This increase in height observed at higher level of application could have been due to the direct effect of nitrogen sources employed in the experiment. KAU (1980) reported a similar finding in cashew. Reports of Nambiar (1983) and Kumar (1985) endorse the same observations. The role played by nitrogen in the synthesis and translocation of phytohormones especially auxins might have played a major role in the elongation of tissues, necessarily enhancing the height of trees. The general low availability of phosphorus and potassium in the experimental area on account of either fixation or leaching losses might have relegated these elements from significantly influencing the height. The short time gap between treatment application and the current observation on tree height must be another reason for the failure of these nutrients in influencing the height of plants.

5.2.2 Girth

Since the only effect, which remained significant in increasing the girth of cashew trees, was NK interaction, especially at N_2K_0 level the specific and positive role played by nitrogen application, more so at higher levels has been proved very clearly. Nitrogen is necessary for chlorophyll synthesis and as a part of the chlorophyll molecule, is involved in photosynthesis. Green pigments in chlorophyll absorbs light energy needed to initiate photosynthesis, chlorophyll helps to convert carbon, hydrogen and oxygen to simple sugars. These sugars and their conversion products are then used for growth and development. This might be the reason for the positive effect of nitrogen on growth characters in cashew trees (Pandey and Sinha, 1972). A similar view has been endorsed by (Childers, 1966).

5.2.3 Spread

Application of nitrogen at the highest level of 1000g tree $^{-1}$ was prominent in indicating positive significant effect in enhancing the spread of cashew trees (as is clearly shown in Fig. 3). Latha (1992) and Gosh (1990a) had also observed a similar trend conforming the effect of higher doses on the spread. Nitrogen is an integral part of the chlorophyll molecule and as such plays a role in photosynthesis, which might have helped in the growth and development of cashew trees.

5.3 Yield characters

5.3.1 Days to flushing

Nitrogen, phosphorus and potassium applications as well as the interaction effects did not have any significant influence in altering the number of days to flushing, although a non significant decrease in the number of days was observed with increased levels of nitrogen application which in all probability may be due to the well known effect of nitrogen in inducing vegetative growth.

5.3.2 Number of flushes per square meter

A significantly higher number of flushes per square meter produced in trees receiving the highest levels of nitrogen application (1000g tree^{-1}), which is clearly shown in Fig. 4, might have been due to the direct effect of nitrogen in enhancing the vegetative growth. In the absence of any nitrogen application in control plots, the effect when compared with higher levels naturally remained significant in maintaining more number of flushes per meter square. This was in conformity with the results observed by Latha *et al.* (1996a). All levels of application of nitrogen helped to maintain proportionately higher levels of nitrogen in soil available for absorption by plants necessarily keeping higher content of the same in leaf tissues. This is clearly evident from the data provided in Table 11, which provides details on the effect of NPK addition on the content of major nutrients in plants. The observed effect of nitrogen might have increased the total chlorophyll and subsequent enhancement of photosynthesis, might have favored production of more number of flushes per meter square. Failure of either Phosphorus or potassium or the interaction effects of major nutrients could be due to the low availability of the respective nutrients due to various extraneous reasons operating between the soil, plant continuum.

5.3.3 Number of leaves per flush

Application of nitrogen at 1000g $tree^{-1}$ significantly increased the number of leaves per flush over control (Fig. 5). This could be due to the beneficial role of nitrogen in inducing vegetative growth, which has been well documented by many workers.

N_2K_2 level of application produced the maximum number of leaves making the NK interactions significant. This must have been possible only with the help of higher levels of potassium, which initiates better partitioning of photosynthates to the flushes making these areas stronger towards the reproductive phase. The independent effects of either phosphorus or potassium were not remarkable in enhancing the number of leaves per flush.

5.3.4 Days to flowering

Higher level of phosphorus application especially at 250g $tree^{-1}$ significantly decreased the number of days to flowering from 30^{th} September by one day when compared with control (Fig. 6). This must have been possible either on account of the direct effect in initiating the growth of reproductive primordia or due to the functional role-played by phosphorus in the development of structure and alterations in metabolic activity. Nitrogen, potassium and interaction effects were insignificant

5.3.5 Number of panicles per square meter

As is clearly seen in Fig. 7, the number of panicles per square meter in trees receiving nitrogen application at 500g $tree^{-1}$ and 1000g $tree^{-1}$ were significantly superior over control possibly on account of the direct effect of nitrogen in initiating the growth of reproductive primordia. The effect of nitrogen in increasing the number of flushes per square meter is already established. Flushes are the real progenitor of panicles and naturally the production of greater number of flushes resulted in higher panicle numbers. Though phosphorus plays an important role in the plant system related to structure, metabolism and reproduction, the reason for all levels of phosphorus application giving non-significant increase in the number of panicles over control might be the failure to get proper response of the added phosphorus at the critical periods of growth on account of many extraneous factors operating in soil. However, in the case of potassium, its direct influence in promoting the translocation and metabolic activities also might have provided conducive situations in marginally increasing the number of panicles. This overall trend observed in this experiment with respect to panicle production is very much similar to that observed by Latha *et al.* (1996c).

5.3.6 Number of nuts per panicle

All the levels of nitrogen and phosphorus application especially the higher levels were able to impart significant increase in the number of nuts per panicle (as is seen in Fig. 8 and Fig. 9 respectively) for reasons, which have been explained in the earlier section. Potassium application and interaction effects were insignificant in enhancing the number of nuts per panicle. Kumar (1985) also obtained a similar trend.

A high internal concentration of nitrogen in the plant system as has been noted in pretreatment and post harvest index leaves (from Table 4 and Table 11 respectively), which might have led to the simulation of development of new meristems at the panicle initiation stage, resulting in an increase in the number of nuts per panicle.

The increase in the number of nuts due to the application of phosphorus could either be through the indirect effect of the element in energy transfer or through the direct role in regulating the primordial for reproduction.

Fig. 2. Effect of nitrogen on height of cashew trees (m)

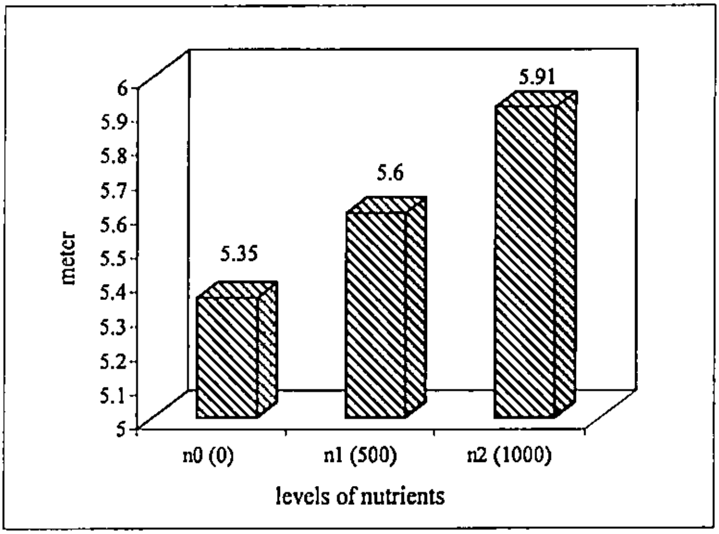


Fig. 3. Effect of nitrogen on spread of canopy (m)

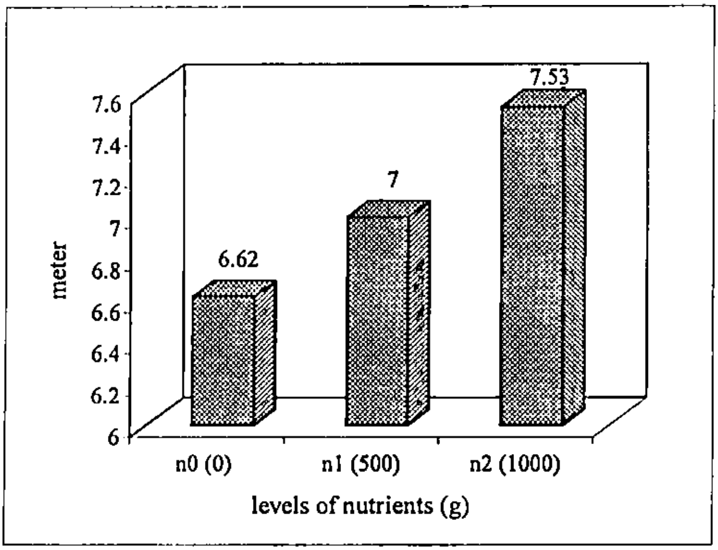


Fig. 4. Effect of nitrogen on number of flushes per square meter

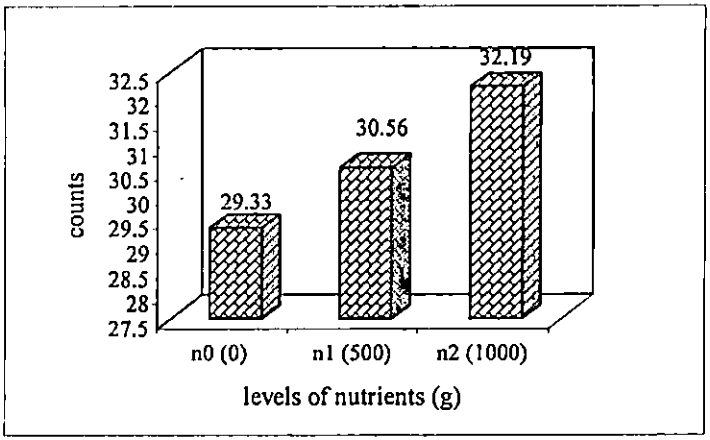


Fig. 5. Effect of nitrogen on number of leaves per flush

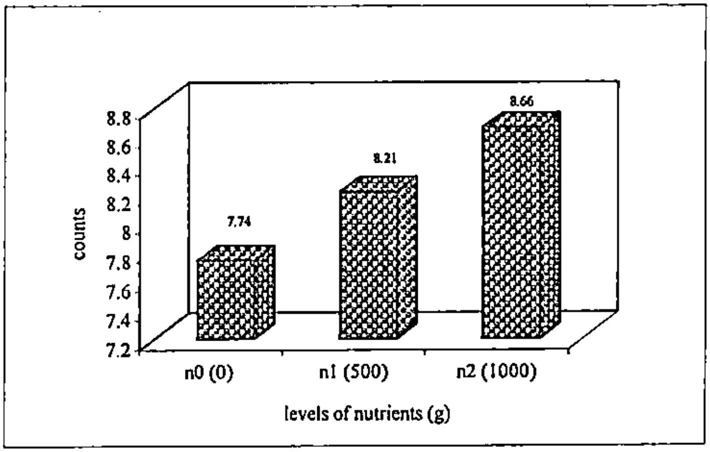


Fig. 6. Effect of phosphorus on days to flowering (October)

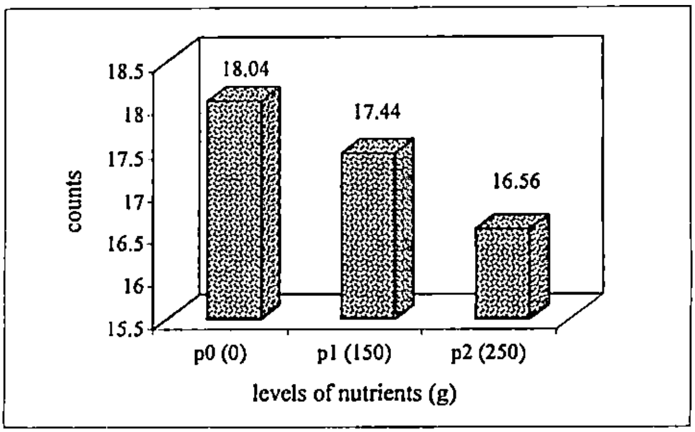


Fig. 7. Effect of nitrogen on number of panicles per square meter

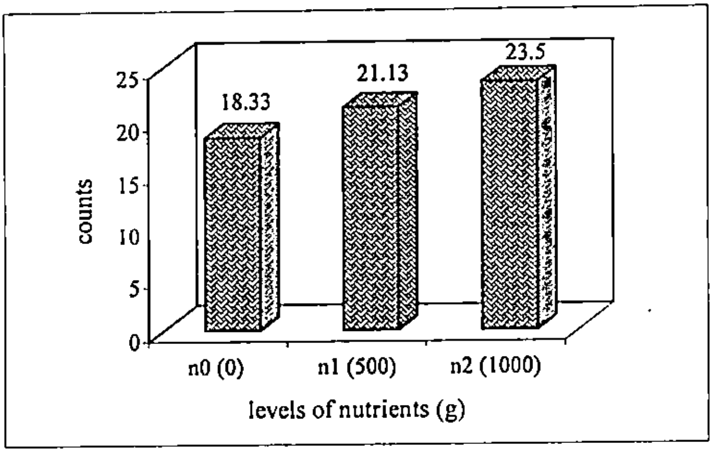


Fig. 8. Effect of nitrogen on number of nuts per panicle

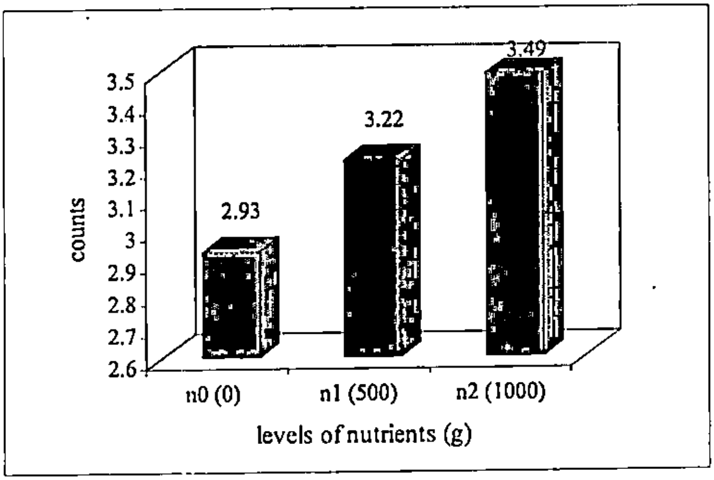
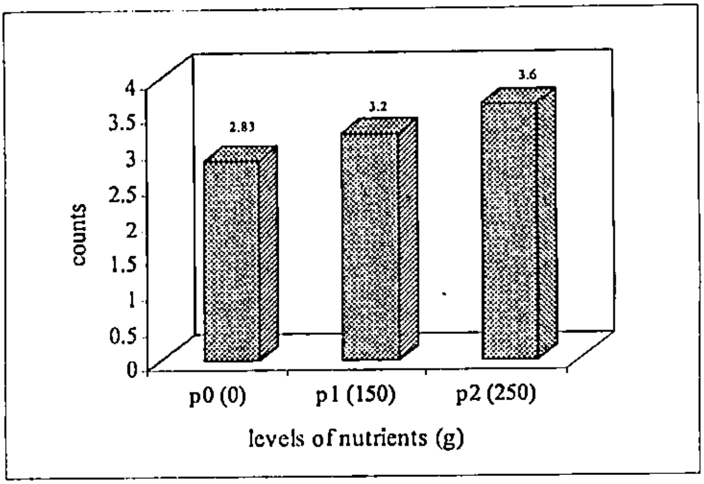


Fig. 9. Effect of phosphorus on number of nuts per panicle



5.4 Physical analysis

5.4.1 Cashew apple

5.4.1.1. Apple weight

Application of potassium up to 150 g tree^{-1} significantly increased the apple weight as compared to control. Further application up to 250 g tree^{-1}, although significant over control was at par with 150 g tree^{-1} application. This is clearly seen in Fig. 10. The role of potassium in translocating sugars into the developing fruit might have helped in increasing the apple weight (Kiely *et al.*, 1972). Application of nitrogen and phosphorus at increasing levels gave an insignificant marginal reduction in apple weight. It is assumed that the photosynthetic activity before flower formation decides on the sink strength after which under high levels of nutrition greater sink strength is formed. From Table 6 it is clearly visible that the number of panicles increased with nitrogen and phosphorus application. Due to increased sink strength, the photosynthates are evenly distributed among the developing sinks. The increase in sink strength is presumed to be higher than the source strength, there by the photosynthates available per sink are reduced causing a reduction in weight. Interaction effects of major nutrients failed to register significant difference in the apple weight. A similar trend in apple weight was observed by Kumar (1985) due to the application of increasing levels of NPK.

5.4.1.2 Apple volume

Application of nitrogen at 1000 and 500 g tree^{-1} significantly reduced the apple volume over control although they were at par with each other (Fig. 11). In the case of phosphorus, also increasing levels of application had showed a decrease in fruit volume although this decrease was insignificant. The increase in sink strength might have led to the partitioning of photosynthates resulting in a decrease in the apple volume. Potassium applications at increasing levels

Fig. 10. Effect of potassium on apple weight (g)

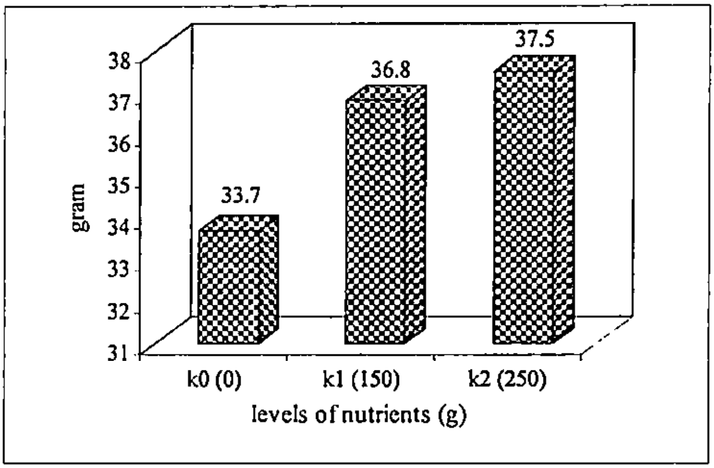


Fig. 11. Effect of nitrogen on apple volume (ml)

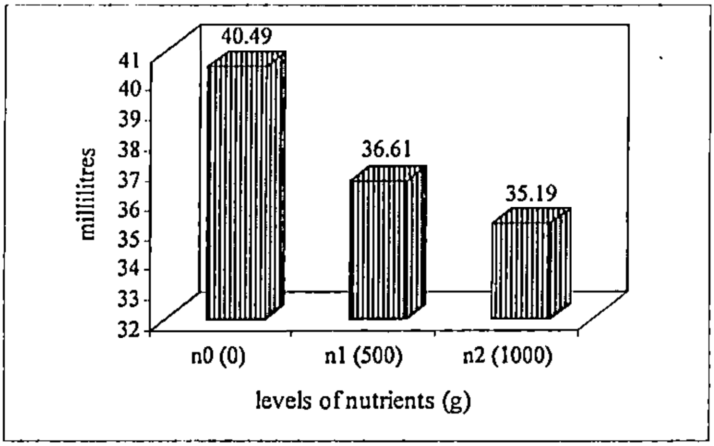
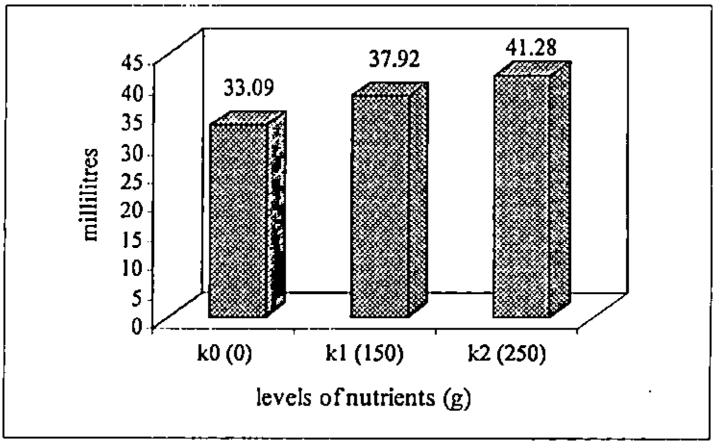


Fig. 12. Effect of potassium on apple volume



significantly increased the volume of apple over control although the increase in volume between higher levels was at par. The beneficial role of potassium in translocation of sugars to the developing fruit might have led to the increase in the apple volume. A similar trend in fruit volume was also observed by Kumar (1985) due to increasing levels of major nutrients. (Fig. 12)

5.4.1.3. Juice content in cashew apples

Application of nitrogen and potassium at 500g $tree^{-1}$ and 150g $tree^{-1}$ significantly increased the juice percentage of apples over control (Fig.13 and Fig.14 respectively). Further increase in the levels of nitrogen and potassium application had brought only a non-significant marginal increase in the juice percentage as compared to the first levels of application of both the nutrients. This must be due to the formation of higher number of nuts at higher levels of application of nitrogen necessarily compromising on the quality parameters mostly juice percentage. Direct effect of phosphorus applications as well as interaction effects of major nutrients failed to register a significant increase in juice percentage.

Kumar (1985) obtained similar results. Lower level of potassium application helped in increasing both weight and volume of cashew apples, which must have led to an enhancement in the uptake of water from the soils certainly increasing the juice percentage of apples. Further, nitrogen applications must have initiated the protein synthesis, which ultimately resulted in enhancement of plant growth. This enhancement might have necessitated the uptake of water by the plant directly manifesting in an increase in the juice percentage.

5.4.2 Physical analysis of nuts

5.4.2.1 Nut length

Nitrogen and phosphorus at all levels of application could not bring about any significant variation in increasing the length of nuts in cashew. This might possibly be due to the diversion of photosynthates (consequent to higher doses of nitrogen application) to more number of developing nuts. However, potassium

Fig. 13. Effect of nitrogen on juice percentage

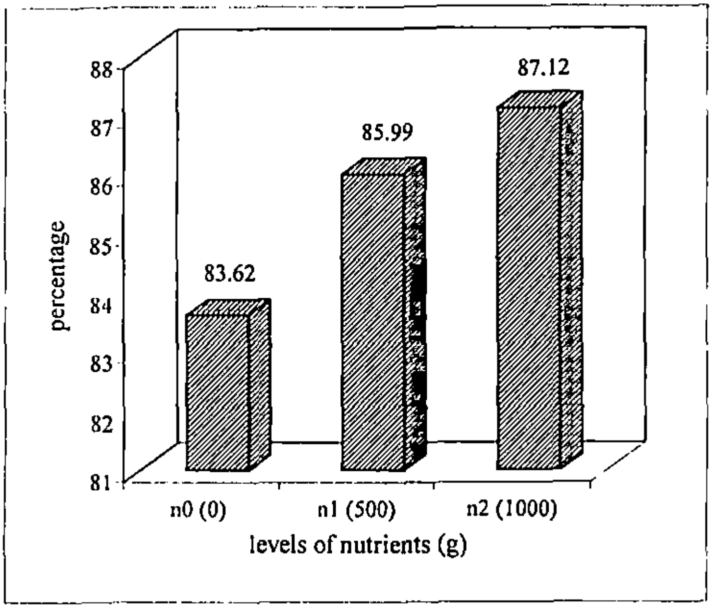


Fig.14. Effect of potassium on juice percentage

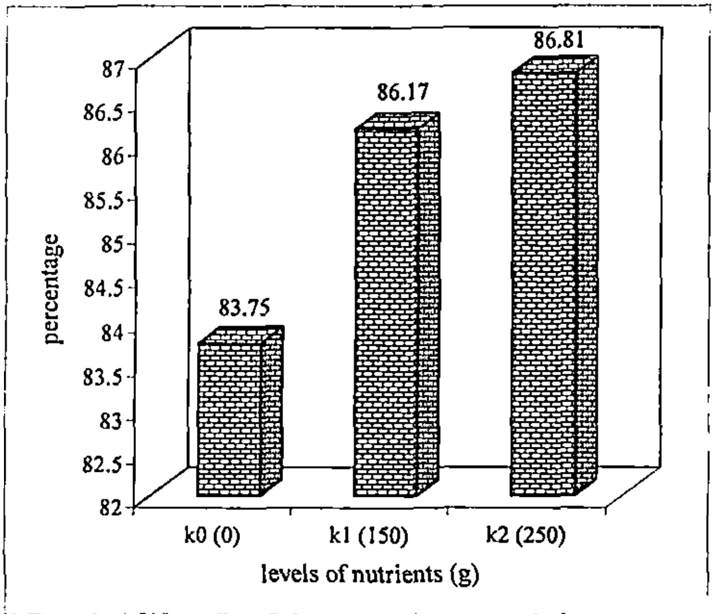


Fig. 15. Effect of potassium on nut length (cm)

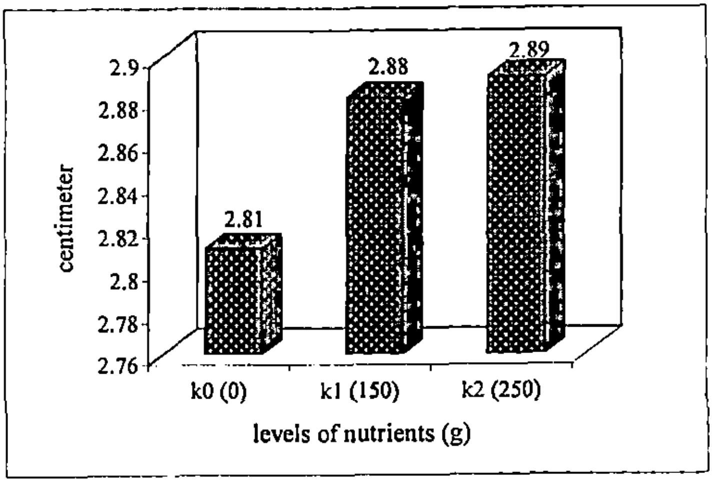


Fig. 16. Effect of nitrogen on nut weight

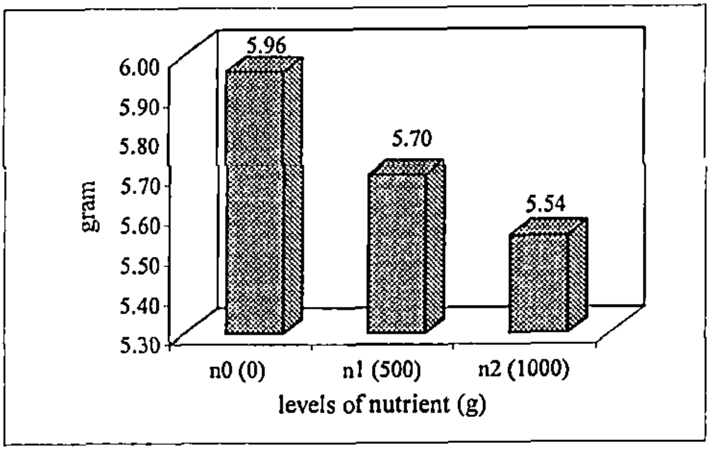
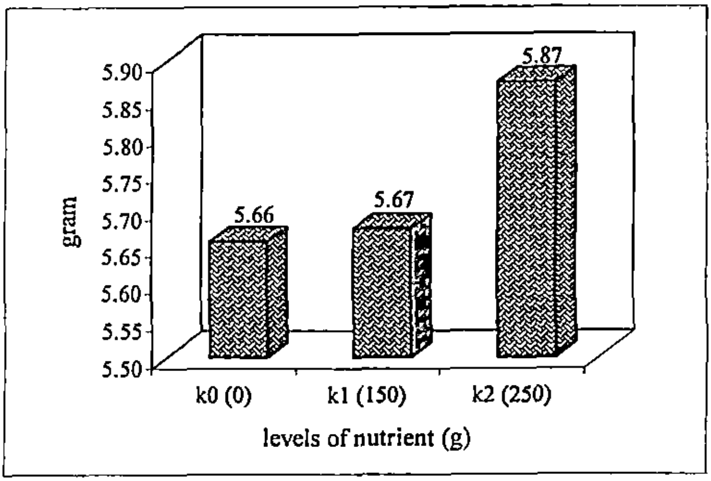


Fig. 17. Effect of potassium on nut weight



application at 150g $tree^{-1}$ and 250g $tree^{-1}$ significantly increased the length of nuts over control although they were statistically at par with each other (Fig. 15), which again must be due to formation of new tissues consequent to translocation of elements, necessarily enhancing the nut dimensions, particularly the length of nuts. Interaction effect of PK was found to be significant in increasing the length of nuts.

5.4.2.2 Nut weight

Nitrogen and potassium applications had contradicting effects in influencing the nut weight of cashew, which is clearly shown in Fig. 16 and Fig. 17 respectively. Application of nitrogen up to the first level (500g N $tree^{-1}$) significantly reduced the weight of nuts over control. Due to higher nut set in plants with increasing levels of nitrogen application and in the event of photosynthates getting distributed between the nuts, there was a reduction in the average weight of nuts. While in case of potassium, significant increase in nut weight has been observed only at highest level of application. The increase in nut weight observed at highest level of potassium application might be due to role of potassium in the translocation of photosynthates to the developing nuts, enhancing metabolic activities and development of new tissues. Role of Phosphorus in altering the weight of nuts was not apparently visible in the study as it effect must have been more associated to the energy transfer in the metabolic activities. The individual effect of Phosphorus and the interaction effects of major nutrients were found to have no influence in altering the weight of nuts in cashew.

Kumar and Sreedharan (1986) has also reported higher nut weight due to increased levels of potassium application and a reduction in the nut weight with increasing levels of nitrogen application.

5.4.2.3 Shelling percentage

Application of higher levels of nitrogen and potassium were found to positively influence the shelling percentage (Fig. 18 and Fig. 19 respectively). In case of both nitrogen and potassium the significant increase in the shelling percentage was found to be only up to the first level of application (500 g N tree^{-1} and 150 g K tree^{-1}, respectively). Gosh (1987), Kumar and Sreedharan (1986b) and Kumar *et al.* (1993) also recorded similar trend in shelling percentage due to the application of higher levels of nitrogen and potassium.

As seen earlier, application of increasing levels of nitrogen was found to reduce the weight of nuts, this must have led to the increase in shelling percentage. Potassium application was found to increase the nut weight as well as the kernel weight as is seen in Table 8. The effect of potassium in increasing the kernel weight might have been due to its direct effect in enhancing the translocation of photosynthates especially to the sink, which automatically gets reflected through an increase in the weight of nuts as well as kernels. The increase in the weight of kernels might have been greater than the increase in the nut weight, which might have influenced an increase in the shelling percentage. Phosphorus applications and interaction effects of the major nutrients were found to be insignificant in influencing the shelling percentage in cashew nuts.

5.4.2.4 Kernel weight

As is clearly seen in Fig. 20, application of potassium at the lower level (150 g tree^{-1}) was found to influence the kernel weight significantly when compared with control. The possible reason for this might be due to the fact that potassium is essential for photosynthesis, protein synthesis, starch formation and for the translocation of sugars. Further, its extremely mobile nature within plants (Brady, 1996) must have led to an increase in the kernel weight. The maintenance of a non significant increase in kernel weight between the lower level and higher level of application of potassium (250g K tree^{-1}), might have been in all probability due to the higher nut set in panicles and in the event of photosynthates getting distributed between the nuts. Individual effects of nitrogen and phosphorus as well as the interaction effects of the major nutrients failed to register any significant difference in the kernel weight.

A similar increase in the kernel weight due to the application of higher levels of potassium was observed by Gosh (1990a).

Fig. 18. Effect of nitrogen on shelling percentage

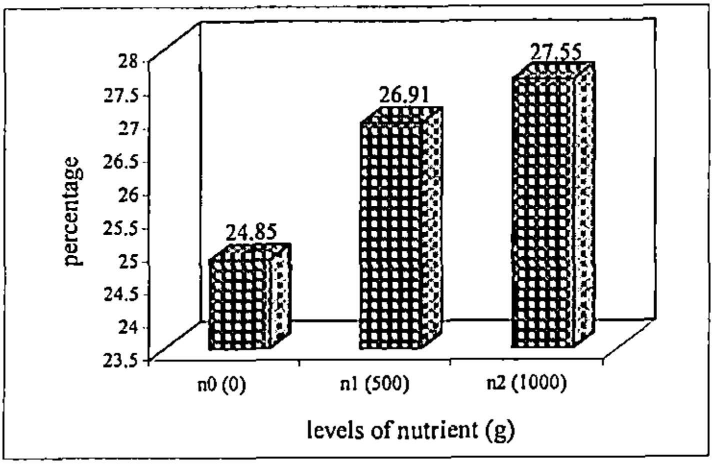


Fig. 19. Effect of potassium on shelling percentage

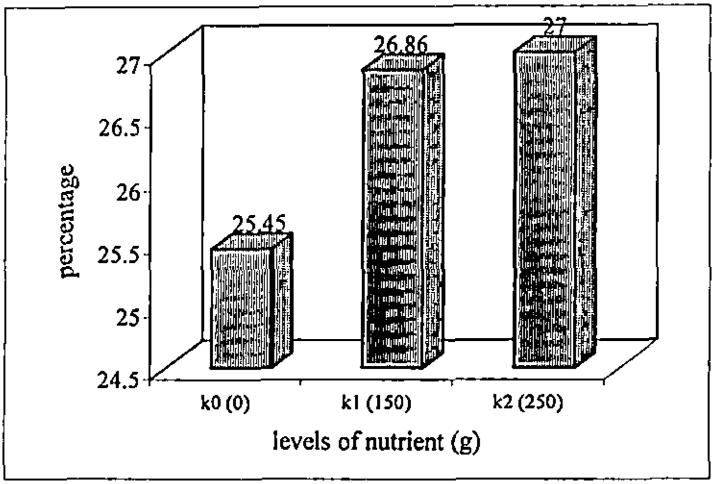
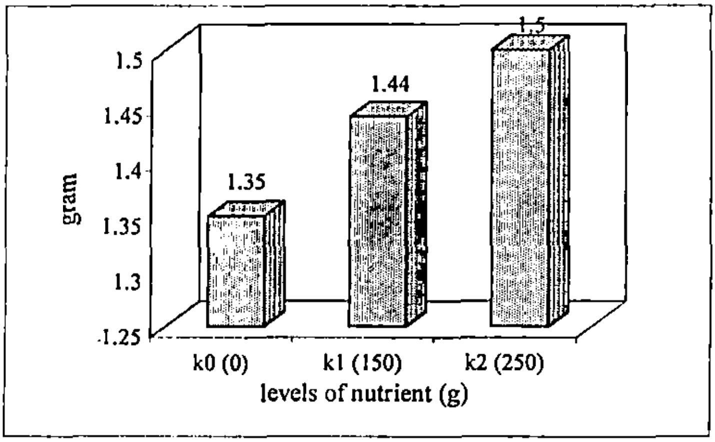


Fig. 20. Effect of potassium on kernel weight (g)



5.5 Chemical analysis

5.5.1 Apple analysis

5.5.1.1 NPK content in cashew apple

Individual effects of NPK as well as the interaction effects of major nutrients were found to have no significant influence, in modifying the major nutrient content of cashew apples. This might be due to an increased fruit set per panicle due to applications of NPK at different levels resulting in an even distribution of translocated elements between the fruits

5.5.1.2 Total soluble solids (T.S.S.)

Application of higher levels of nitrogen increased the total soluble solid (T.S.S.) content in apples. This is clearly seen in Fig. 21. The statistically significant influence in increasing the T.S.S. up to the first level of application (500g N tree^{-1}) as compared to control might have been due to the translocation of photosynthates and its subsequent conversion to sugars. This combined with the fact that nitrogen reduced the volume of apple (as is seen in Table 7) might have increased the T.S.S. content in apples due to concentration effect.

However, the failure to observe such a significant variation between the first and second level of application (1000g N tree^{-1}) could only be due to apparently higher number of fruits set and an apparent reduction in the average weight of apples at higher levels of application of nitrogen, as is seen in Table 7. Application of potassium, phosphorus and the interaction effects of the major nutrients failed to register any influence either positive or negative on the T.S.S. content of apples. Kumar *et al.* (1996) also observed an identical trend in T.S.S due to nitrogen application similar results.

Fig. 21. Effect of nitrogen on T.S.S (%)

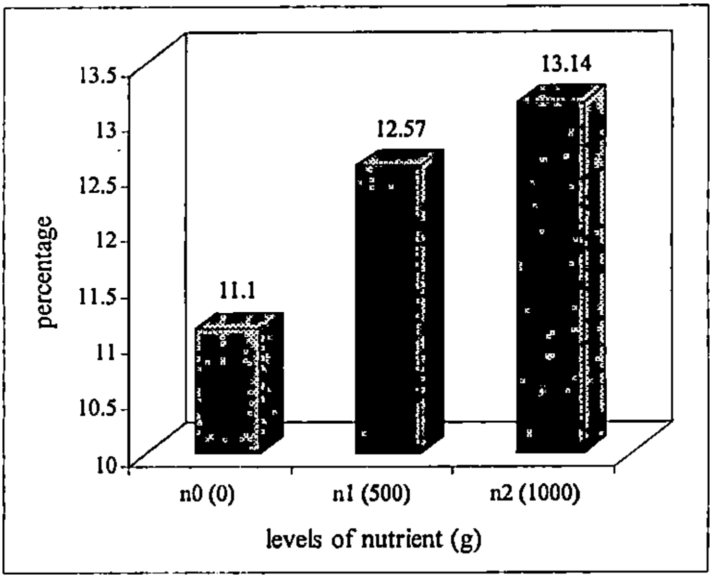


Fig. 22. Effect of nitrogen on ascorbic acid content (mg/100g)

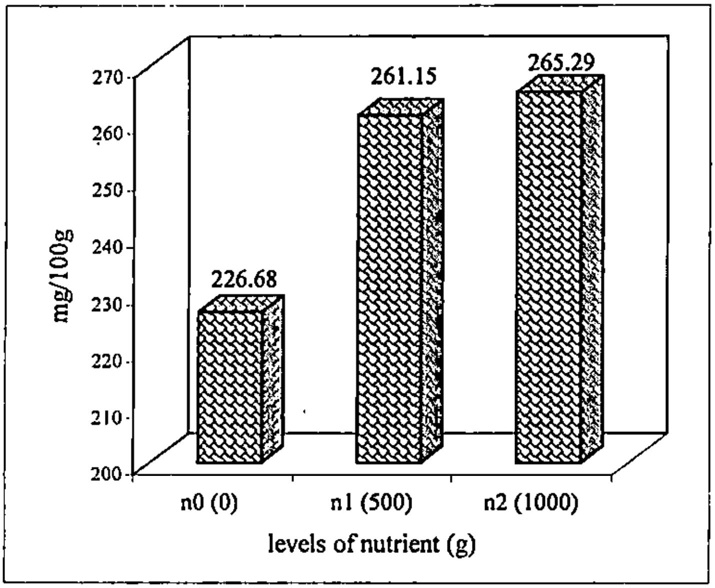


Fig. 23. Effect of phosphorus on ascorbic acid (mg/100g)

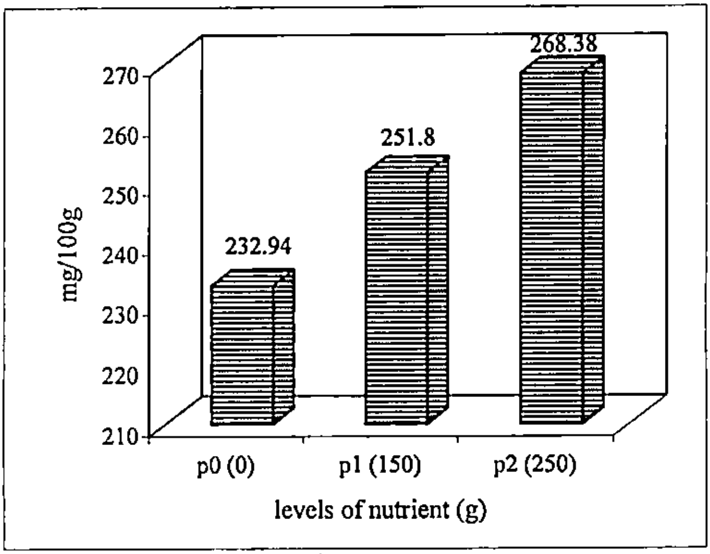
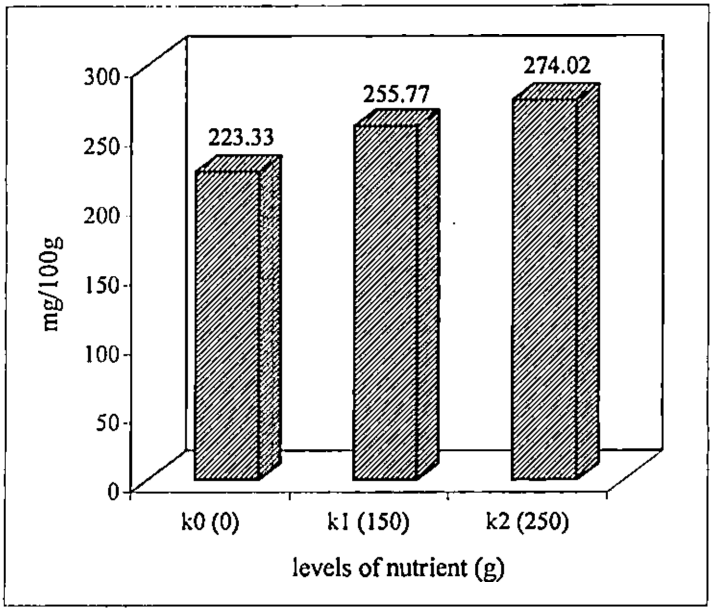


Fig. 24. Effect of potassium on ascorbic acid content (mg/100g)



5.5.1.3 Ascorbic acid content of apples

Application of major nutrients had significant influence in the enhancement of the ascorbic acid content of apples (Fig. 22, Fig.23 and Fig.24) Though nitrogen and potassium applications seemed to have significantly increased the ascorbic acid content at all levels of application, the effect could have been apparently more due to the application of nitrogen. Nitrogen, phosphorus and potassium applications must have enhanced activation of enzymes necessary for the synthesis of Ascorbic acid, necessarily keeping the high content of Ascorbic acid in apples.

Interaction effects were found to be insignificant in influencing the ascorbic acid content of cashew apples. Kumar (1985) also observed that increasing levels of NPK increased the ascorbic acid content in apples.

5.5.2 Nut analysis

5.5.2.1 Kernels protein content

Application of nitrogen at all levels significantly increased the protein content in kernels compared to control. This is clearly seen in Fig. 25. This implies that part of the nitrogen applied through soil has been used for the synthesis of amino acids, which effectively might have been translocated into the kernel, there by enhancing its protein content. Failure of both phosphorus and potassium application at all levels to register any significant difference in the protein content might have been mainly due to the absence of any direct role. A similar trend in protein content due to nitrogen application was also obtained by Latha *et al.* (1996b), Kumar (1985) and Ankaiah (1981).

NP interaction was found to increase protein content. Phosphorus applications helped in an increased uptake of nitrogen in the plant as is evident from Table 11 therefore indirectly bringing an increase in the protein content of kernels.

5.5.2.2 Kernel carbohydrate content

Application of nitrogen at all levels significantly enhanced the carbohydrate content in kernels over control. This is clearly visible in Fig.26. Different levels of application of phosphorus and potassium did not have any significant influence on the carbohydrate content. Among the interaction effect of major nutrients, only NP interaction was found to significantly influence the carbohydrate content.

Nitrogen plays an important role in photosynthesis and thereby indirectly influences the production of carbohydrates. This might probably be the reason for an increase in carbohydrate content where higher levels of nitrogen application had been adopted. Since phosphorus application was found to favour the uptake of nitrogen in cashew (Table 11), it might have indirectly influenced the synthesis of carbohydrate thus increasing the carbohydrate content with increasing levels of application.

5.5.2.3 Fat percentage in kernels

Neither the main effects nor the interaction effects of major nutrient application influenced the fat content of kernels.

5.5.2.4 Sugar content in Kernel

(i) Reducing sugars in kernel

Application of nitrogen at all levels (0, 500 and 1000g N tree^{-1}) significantly enhanced the content of reducing sugars in kernel over control (Fig. 27). The application of phosphorus, potassium and the interaction effects of major nutrients did not have any influence on the content of reducing sugars in kernel.

(ii) Non-reducing sugars in kernel

Here also the application of nitrogen at all levels gave a significant increase in the content of non-reducing sugars in kernels (Fig. 27). The

Fig. 25. Effect of nitrogen on protein content of kernel (%)

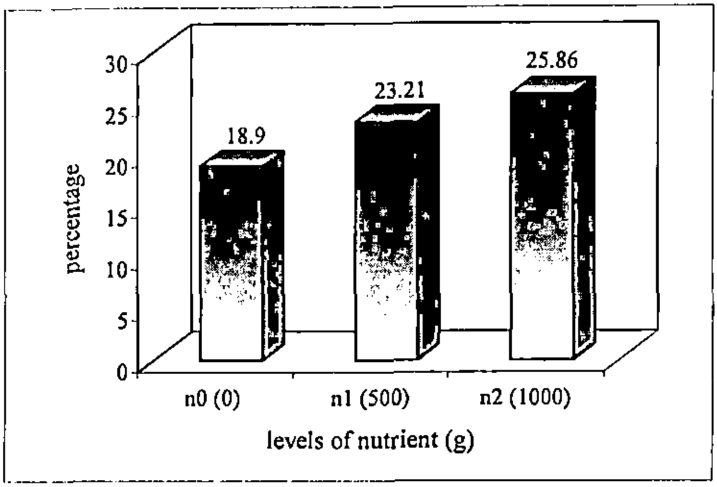


Fig. 26. Effect of nitrogen on carbohydrate content of kernel (mg/100mg)

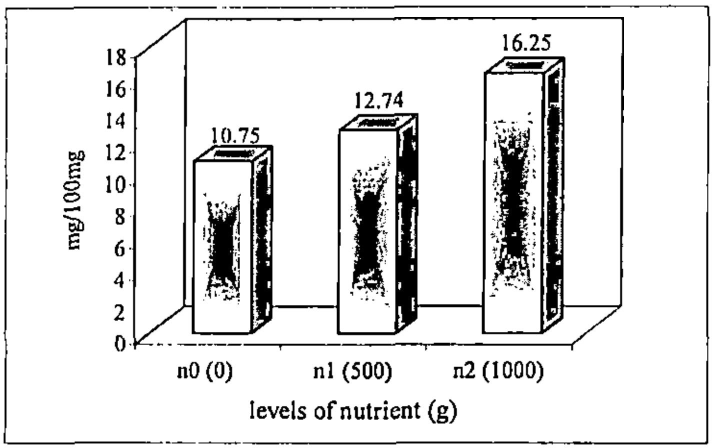
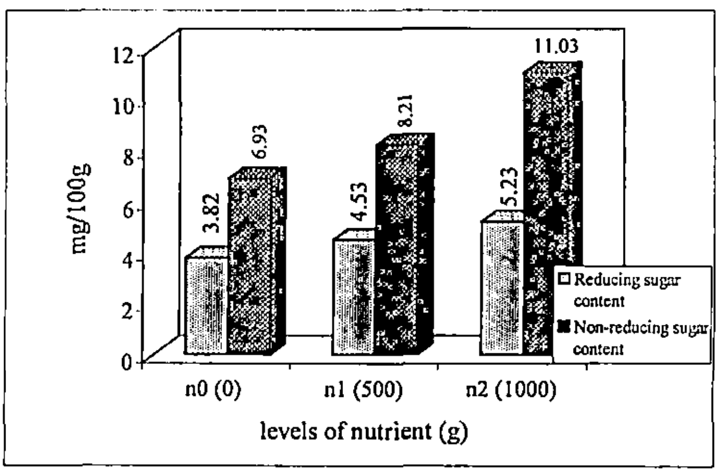


Fig. 27. Effect of nitrogen on reducing and non reducing sugars content of kernel



application of phosphorus and potassium as well as the interaction effects of major nutrients failed to register any significant increase or decrease in the non-reducing sugar content of kernels.

Reducing and non-reducing sugars totally make up the carbohydrate content. As has been explained previously nitrogen forms an integral component of chlorophyll, thereby playing an indirect role in photosynthesis. Increase in the application of nitrogen might have increased the chlorophyll content indirectly increasing photosynthesis leading to an increase in the content of reducing sugars. Application of nitrogen also has increased the growth. Since non-reducing sugars contain the structural carbohydrates, the increase in growth might have led to an increase in the content of non-reducing sugars in kernels.

5.6 Post harvest analysis

5.6.1 Major nutrient status of the soil

5.6.1.1 Available nitrogen

Application of nitrogen at all higher levels was found to be significant in increasing the content of available nitrogen in soils over control. This must have been due to either the residual effect of application of nitrogen fertilizers or must have been due to the recycling of organic matter (through fallen leaves). The reason for maintaining the available nitrogen content on par in soil between N_1 and N_2 in all probability might have been due to a proportionately higher utilization of nitrogen from N_2 levels. Neither the independent effects of application of phosphorus, potassium nor the interaction effects of major nutrients had any significant influence on the available nitrogen content of the soil for the fact that these nutrients might have been locked up in chemical combination or might have been fixed.

The application of higher levels of nitrogen had left comparatively more available nitrogen in soil possibly as residual nitrogen after meeting the normal demands for growth and development.

5.6.1.2 Available phosphorus

Only at the highest level of application of phosphorus (250g tree^{-1}) there was statistically significant difference in the available phosphorus content especially over control. This observed increase in available phosphorus might have been due to enhanced mineralization from reaction products of phosphorus in soil.

5.6.1.3 Available potassium

In case of available potassium content of the soil, the applications up to a level of 250g tree^{-1}was found to significantly enhance the content of available potassium in soil over control. This observed increase in available content of the soil might have been due to it's residual effect. Reason for maintaining the available potassium content on par between K_1 and K_2 levels might have been due to a higher utilization of potassium from higher doses of application or might be due to the possible losses (mainly leaching losses) from the relatively higher levels of application.

5.6.2 Major nutrient status in cashew leaf

5.6.2.1 Leaf nitrogen content

Application of nitrogen, phosphorus and their major interaction effects were found to enhance the nitrogen content in the index leaf samples. This might have been due to enhanced absorption of this element, which in all probability might have been promoted by a balanced application of nitrogen and phosphorus, which is essentially required in the metabolic process operating in the plant. Application of nitrogen at all levels significantly increased the leaf nitrogen content clearly indicating the response to nitrogen applications. Though the maintenance of nitrogen content in the leaves were observed to be on par with P_1 and P_2 levels of application, considerable and significant variation observed over control is a clear indication of the need for phosphorus application in maintaining the nitrogen content in plant especially in cashew. Similar results have been observed by Gosh and Bose (1986), Kumar (1985), Reddy *et al.* (1982) and Kumar and Nagabhushanam (1981)..

5.6.2.2 Leaf phosphorus content

The observed significant increase of phosphorus content in the index leaf due to application of phosphorus at the highest level (250g tree^{-1}) especially over control could be due to the relatively higher absorption of this element by the plant as a part of it's requirement in metabolic activities. The maintenance of leaf phosphorus content on par between control and application at 150g P tree^{-1} might have been possibly due to the unavailability of this element from the reaction products of phosphorus in soil. Kumar (1985) and Gosh and Bose (1986) also recorded similar observations:

5.6.2.3 Leaf potassium content

Significant increase in the leaf potassium content in cashew at all levels of application of potassium more so when compared with control could be due to a proportionately higher up-take initiated by a higher concentration of the element in the soil solution. Similar results were also observed by Kumar (1985) and Gosh and Bose (1986).

5.7 Nutrient off take

Application of nitrogen at highest level of 1000g tree^{-1} increased the nitrogen as well as the potassium off take by the tree. Since nitrogen plays a role in photosynthesis increase in levels of application of nitrogen might have increased photosynthesis thereby resulting in increased utilization of sunlight energy causing an increase in the nutrient uptake by the plant. The average nutrient off take per tree through nuts was found to be 93.56, 2.89 and 48.85g of nitrogen, phosphorus and potassium respectively from an expected average yield of 2.89 kg tree^{-1}. While in case of apples the average off take was found to be 185.87, 38.69 and 137.54g of nitrogen, phosphorus and potassium respectively from an estimated average yield of 18.20 kg tree^{-1}. These computed values highlight the removal of nutrients, which in no way is likely to be recycled. The response of nutrients at higher levels of application and the reason for poor response at lower levels of application might have been partly due to offsetting such losses from the added source. This further emphasizes the need for balanced application of nutrients along with integration of organic matter at the recommended levels to sustain a reasonable productivity in cashew.

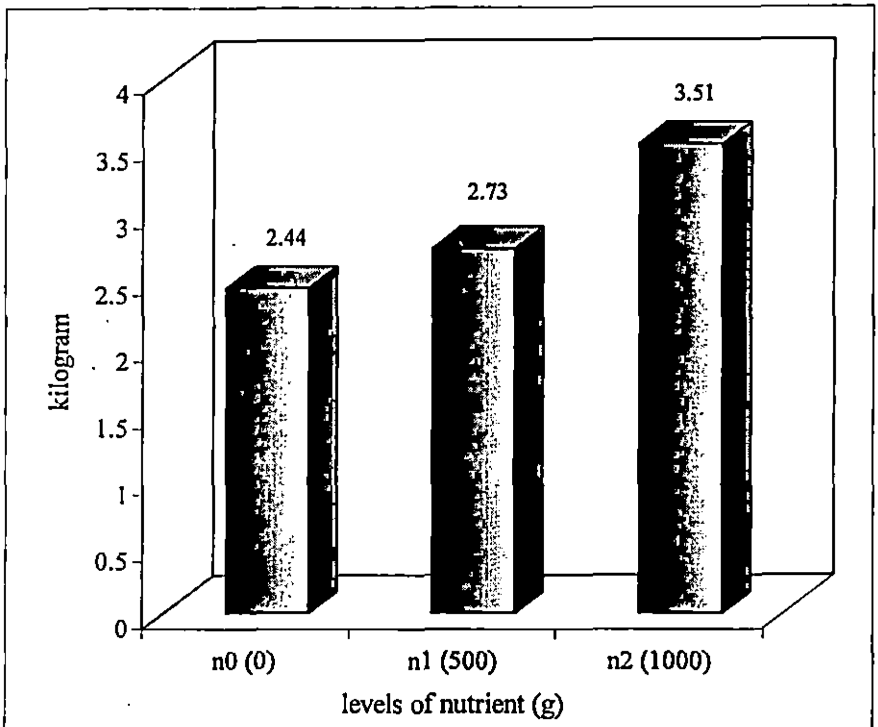
5.8 Yield of cashew nuts and apples

It has been estimated that nitrogen and potassium applications at the highest level (1000g tree^{-1} and 250g tree^{-1} respectively) gave a significant increase in the yield of apples over the other levels as well as control. Application of increasing levels of nitrogen produced more number of nuts (as is seen from Table 6), which must have led to more number of apples getting developed resulting in an increased yield of apples. From Table 7 it is clearly seen that application increasing levels of potassium resulted in an increase in the weight of apples consequently this must have led to an increase in the yield of apples with increased level of potassium application.

The application of nitrogen at the highest level resulted in a significant increase in the yield of nuts from cashew trees (as seen in Fig. 28) for these higher levels have been sufficient to counter the off take and offset the possible losses from soil to produce a positive response. Further in this study it has been observed that many yield parameters like number of flushes, number of panicles per square meter, number of nuts formed per panicle, nut weight, nut volume are being influenced by higher levels of nitrogen application. Although increasing levels of nitrogen was found to reduce the individual nut weight on account of formation of higher nuts per panicle (Table 8 and Table 6), the decrease in nut weight might have been overly compensated by an increase in the number of nuts. A similar observation has been recorded by Mishra *et al.* (1980).

The application of phosphorus and potassium at all levels could not influence any significant difference in the yield of cashew nuts possibly on account of various extraneous factors operating in the soil consequent to application of these nutrients. A similar observation where no response to

Fig. 28. Effect of nitrogen on nut yield of cashew (kg/tree)



phosphorus and potassium application in cashew nut yields has been reported by Mishra *et al.* (1980). However, in case of phosphorus all levels of application have been observed to influence the number of nuts per panicle resulting in lower weight per nut possibly due to the dilution effect (Table 6 and Table 8, respectively) resulting in a marginal but insignificant increase in the nut yield. Although higher levels of potassium applications increased the nut weight, an apparent increase in yield of nuts could not be observed due to absence of higher number of nuts per panicle (as is seen in Table 8 and Table 6, respectively).

The general trend observed in this experiment with the application of nutrients and yield of nuts is in conformity with that of Nambiar (1983), Rao *et al.* (1984) and Veeraraghavan *et al.* (1985).

Summary

SUMMARY

A comprehensive study was conducted at Cashew Research Station, Madakkathara to assess the effect of major nutrients on yield and quality of nuts in graft raised cashew during 2000-01 and 2001-02. For this purpose an existing NPK experiment with eight-year-old trees receiving three major nutrients at three levels had been selected with two replications to make a total of 54 treatments. To accomplish the objectives of the study, various observations were recorded in the field by employing standardized methods. To ensure the validity of many observations, both plant and soil samples were collected at the appropriate time and analyzed using standard procedures all through the experimental period. The findings of the investigation are summarized as follows.

Before the imposition of treatments, the soil showed a medium fertility range for available nitrogen and a low fertility range available phosphorus and potassium. The range of values for nitrogen, phosphorus and potassium were 269.53 to 286.42, 2.05 to 2.27 and 111.5 to 123.9 kg ha^{-1} respectively.

Analysis of pre-treatment index leaf samples from plots receiving nitrogen and phosphorus applications during yester years showed significant variations in their nitrogen content. However the average nutrient content of these leaf samples were found to be medium for nitrogen (1.63 to 2.22%) and adequate for phosphorus (0.15 to 0.16 %). Potassium showed a range of (0.88 to 0.97 %).

Among the major nutrients, nitrogen application significantly increased the tree height and the tallest trees were those, which received the highest dose of nitrogen (1000g $tree^{-1}$).

With regard to the influence of major nutrients in maintaining the tree girth, only NK interactions were found to have major role in imparting the significant variations in tree girth. Maximum tree girth was recorded at N_2K_0 level of application.

Spread of trees was significantly increased by the application of nitrogen with maximum spread being recorded at the highest level of nitrogen application (1000g $tree^{-1}$).

Nitrogen applications significantly increased the number of flushes per meter square with highest number of flushes per meter square being observed in trees that received 1000g N $tree^{-1}$ application.

Application of nitrogen significantly increased the number of leaves per flush. Highest number of leaves per flush was recorded in trees that received 1000g N $tree^{-1}$ application.

The number of days to flowering was significantly reduced in cashew trees, which received 250g P $tree^{-1}$ application of phosphorus.

The number of panicles per square meter was found to be significantly enhanced by the application of nitrogen with highest number of panicles per square meter being observed in those trees which received 1000g N $tree^{-1}$ application.

Number of nuts per panicle a major yield attributing parameter was significantly increased by the application of nitrogen and phosphorus. Highest numbers of nuts per panicle were observed in trees that received 1000g $tree^{-1}$ nitrogen application and 250g $tree^{-1}$ phosphorus application.

Weight of Apple was found to be significantly enhanced by the application of potassium with a highest weight being recorded in those trees that received 250g $tree^{-1}$ potassium application.

Application of nitrogen and potassium had significant but contradictory influence as volume of apples significantly decreased with increasing levels of nitrogen application up to 500 g $tree^{-1}$ after which there was no further significant decrease, while there was a significant increase in the volume of cashew apples up to 150 g $tree^{-1}$ potassium application. Further increase in the level of application did not produce any further significant increase.

Apple juice percentage was significantly enhanced by the application of nitrogen and potassium with highest juice percentage being recorded at the highest level of application (1000 and 250 g $tree^{-1}$ respectively) of both the nutrients.

Application of potassium significantly influenced the nut length and weight with maximum length and weight being recorded at 250g K $tree^{-1}$ level of application. Nut weight recorded significant lower values with increase in the levels of nitrogen application and lowest weight was recorded at 1000g N $tree^{-1}$ level of application. Shelling percentage was significantly increased by the application of nitrogen and potassium, with highest shelling percentage being recorded in those trees that received 1000g N $tree^{-1}$ level of application and 250g K $tree^{-1}$ level of application respectively.

Potassium application significantly increased the kernel weight and the highest weight of 1.5g $kernel^{-1}$ was recorded in those trees that received the highest level of potassium (250g K $tree^{-1}$) was applied.

Total soluble solids (T.S.S.) content of apples was found to be significantly influenced by nitrogen applications with 500 and 1000g $tree^{-1}$ level of application giving significant increase over control and maximum T.S.S. values were recorded at the highest level of nitrogen application.

All levels of nitrogen and potassium significantly increased the Ascorbic acid content of apples. Phosphorus at the highest level of application recorded a significant increase in the ascorbic acid content. Highest ascorbic acid contents were recorded at the highest level of each nutrient.

Protein content of kernels was significantly enhanced by nitrogen at all levels of applications. However it's interaction with phosphorus has also brought significant increase in protein content. The maximum protein content of 27.09% was analysed in trees, which received 1000g N $tree^{-1}$ in combination with 150g P $tree^{-1}$ level of application.

Nitrogen applications at all levels significantly increased the quality of cashew kernels, which include carbohydrate, reducing sugar and non-reducing sugar. Interaction effect of nitrogen and phosphorus was also found to significantly influence the carbohydrate content with a maximum value of 17.04 mg $100mg^{-1}$ registering against trees, which received 1000g N $tree^{-1}$ in combination with 250g P $tree^{-1}$ applications.

References

Application of nitrogen, phosphorus and potassium at all levels significantly increased their respective available nutrient status in soils over control.

Nitrogen and phosphorus application significantly increased the nitrogen content of leaves at all levels of application. A highest content of 1.24 % nitrogen in leaf was recorded at 1000g N tree^{-1} in combination with 250 g tree^{-1} level of application. Phosphorus at the highest level and potassium at all levels of application were found to significantly enhance their respective nutrient content in leaves.

The average nutrient off take per tree through nuts and apples in cashew was 279.43, 41.58 and 186.40g of nitrogen, phosphorus and potassium respectively. It was also observed that the increasing levels of nitrogen significantly increased the off take of nitrogen and potassium by the tree with highest off take of each being recorded at 1000 g N tree^{-1} level of application

Nitrogen application at the highest level was found to significantly enhance the yield of nuts as well as apples in cashew recording a maximum yield of 3.51 kg of nuts per tree and 22.20 kg of apples per tree at 1000g tree^{-1} level of application. Potassium at the highest level of 250g tree^{-1} application was found to significantly increase the apple yield over all other levels recording a highest yield of 20.27 kg.

In general among the major nutrients which have been applied at different levels nitrogen especially at the highest level of it's application had shown exceedingly high effects in sustaining higher growth characters, yield parameters and quality parameters in cashew.

REFERENCES

Anakaiah, S. 1981. Effect of foliar fertilization of nitrogen on cashew. *Indian Cashew J.* **13** (2): 15-17

Aravindakshan, K., Celine, V.A., Balakrishnan, S. and Veeraraghavan, P.G. 1986. Studies on certain physico-chemical attributes of apple and nuts of selected cashew types. *Cashew causerie* **8** (4): 5-7

Attri, B.L. and Singh, D.B. 1999. Compositional and storage study of cashew (*Anacardium occidentale* L.) apple. *Cashew* **13** (2): 23-30

Augustin, A. 2001. Utilisation of cashew apple. *Proceedings of World Cashew Congress 2001, India.* The Cashew export promotion council of India, pp. 57-66

Badrinath, Krishnappa, A.M., Khan, M.M. and Rao, K.B. 1987. Effect of lime and nutrients on the yield of cashew. *Cashew* **1** (4): 14-15

Beena, B., Salam, M.A. and Wahid, P.A. 1995. Nutrient off take in cashew (*Anacardium occidentale* L.). *Cashew* **9** (3): 9-15

Biswas, T.K. and Mukherjee, S.K. 1997. *Text Book of Soil Science*. Second edition. Tata McGraw Hill publishing company Ltd., New Delhi, p.433

Brady N.C. 1996. *The Nature and Properties of Soils*. Tenth edition. Prentice-Hall of India Pvt. ltd. New Delhi, p.621

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* **59**: 39-45

Calton, W.E. 1961. Leaf composition of some tropical crops. *E. Afr. Agric. For. J.* **27**: 13-19

Childers, N.F. 1966. *Fruit Nutrition*. Horticultural publications, Rutgers State University, New Jersey, U.S.A., p. 585

Dixit, S. 1999. Role of field demonstrations in promoting cashew production technology. *Cashew* 13 (12): 11

Falade, J.A. 1978. Effect of macronutrient on growth and dry matter accumulation of cashew. *Turrialba* **28** (2): 123-127

Gosh, S.N. 1987. Effect of Nitrogen, Phosphorus and Potassium on flowering duration, yield and shelling percentage of cashew (*Anacardium occidentale* L.). *Indian Cashew J.* **19** (1): 19-23

Gosh, S.N. 1990a. Effect of different levels of Nitrogen on growth and yield of cashew in old plantations. *Cashew* **4** (1): 15-16

Gosh, S.N. 1990b. Studies on the NPK requirement of cashew in laterite tract of West Bengal. *Cashew* **4** (2): 6-8

Gosh, S.N. and Bose, T.K. 1986. Effect of Nutrition on NPK content in leaf and shoot of cashew. *Cashew causerie* **8** (2): 9-13

Gosh, S.N. and Chatterjee, M.L. 1987. Study on performance of some cashew types and their susceptibility levels against tee mosquito at cashew research station, Jhargram, West Bengal. *Cashew* **1** (1): 21-23

Haag, H.P., Sarruge, T.R., Oliveira, D.G. and Dechen, A.R. 1978. Nutricao mineral do cajueiro. *Anais. da. Escota-Superior du Agricultura, Leriz de queiroz.* **32**: 185-204

Heloisa, A.C.F. and Ricardo, E.A. 2001. Cashew apple for fresh consumption in Brasil. *Proceedings of World Cashew Congress 2001, India*. The Cashew Export Promotion Council of India, pp. 53-55

Jackson, M.L. 1958. *Soil Chemical Analysis*. First edition. Prentice-hall of India, Pvt. Ltd., New Delhi, p. 498

Jisha, K.G., Rekha Ravindran and Padma Nambisan. 1991. Changes in protein, carbohydrate and lipid content of cashew kernels during storage under two humidity conditions. *Indian Cashew J.* **23** (4): 11-13

KAU, 1980. Nutritional studies in cashew (KADP). Research Report; 1981-82. Kerala Agricultural University, Vellanikkara, p.250

Kiely, T.B., Cox, J.E., Cradock, F.W. and Barkers, B. 1972. Nutrition studies on Valencia oranges. *Agric. Gaz. N.S.W.*, **83**: 20-22

Kumar, D.P. and Hegde, M. 1998. Influence of NPK and growth substances on nut size in cashew (*Anacardium occidentale* L.). *Cashew Bull.* **35** (8): 3-7

Kumar, D.P., Hegde, M. and Guruprasad, T.R. 1998. Fertigation for higher nut production in cashew. *Cashew Bull.* **35** (4): 2-4

Kumar, D.P., Hegde, M. and Khan, M.M. 1993. Effect of Nitrogen, Phosphorus and Potassium on growth and yield of cashew in the coastal soils of Karnataka. *Cashew Bull.* **30** (12): 9-12

Kumar, D.P., Joshi, S., Prasad, T.G. and Herle, P.S. 1995. Influence of levels of Nutrients (NPK) on fruit set, fruit drop, fruit retention, nut characters, yield and quality of cashew. *Cashew Bull.* **32** (7): 3-11

Kumar, D.P., Khan, M.M. and Herle, P.S. 1997. Effect of NPK nutrient on vegetative growth and floral characteristics of cashew (*Anacardium occidentale* L.). *Cashew* **11** (2): 17-24

Kumar, D.P., Khan, M.M. and Melanta, K.R. 1996. Effect of nutrition and growth regulators on apple characters and yield in cashew. *Cashew* **10** (2): 17-19

Kumar, H.P. 1982. Nutrient distribution in cashew. *Indian Cashew J.* **14** (3): 13-17

Kumar, H.P. 1985. Effect of NPK on seed progenies and air layers in cashew. Ph.D. thesis, Kerala Agricultural University; Vellanikkara, p.230

Kumar, H.P. and Nagabhushanam, S. 1981. Leaf nutrient content of cashew as influenced by different methods of fertilizer application. *Indian Cashew J.* **13** (3): 9-11

Kumar, H.P. and Sreedharan, C. 1986 a. Nut characters as influenced by different levels of NPK in cashew. *Indian Cashew J.* **18** (2): 15-17

Kumar, H.P. and Sreedharan, R. 1986 b. Determination of critical concentrations of N and P in cashew leaf. *Indian Cashew J.* **18** (3): 22-23

Kumar, H.P., Nair, B.P., Rakhiappan, P., Nagabhushanam, S. and Mohan, E. 1982. Variation in mineral composition of leaves of cashew (*Aanacardium occidentale* L.) as affected by season position and age. *Indian Cashew J.* **14** (1): 7-10

Latha, A. 1992. Growth and yield of cashew in relation to soil and foliar nutrient levels. MSc. thesis, Kerala Agricultural University, Vellanikkara, p.196

Latha, A., John P.S. and Mercy, G. 1996a. Effect of NPK fertilization on the growth of Cashew. *Cashew* **10** (3): 8-10

Latha, A., John, P. S., Mercy, G. and Krishnan, S. 1994. Productivity of cashew as influenced by chlorophyll and leaf nitrogen content. *J. trop. Agric.* **32** (1): 86-88

Latha, A., John, P.S. and Mercy, G. 1996b. Effect of fertilizer management on the quality of nuts in cashew. *Cashew* **10** (4): 26-28

Latha, A., John, P.S. and Mercy, G. 1996c. Response of cashew to nutrient application in laterite soil. *J. trop. Agric.* **34** (1): 41-43

Lefebvre, A. 1973. Mineral fertilization of cashew tree. *Fruits* **28**: 691-697

Mahanthesh, B. and Melanta, K.R. 1994. Effect of Nitrogen, Phosphorus and Potassium on the yield of cashew apple. *Cashew* **8** (4): 14-18

Mahanthesh, B. and Melanta, K.R. 1996. Effect of Nitrogen, Phosphorus and Potassium on the yield of cashew nut (*Anacardium occidentale* L.). *Cashew Bull.* **33** (2): 5-9

Mathew, R. 1990. Yield prediction in cashew used on foliar nutrient levels. M.Sc. thesis, Kerala Agricultural University, Vellanikkara, p.210

Mishra, S.N., Sahu, P.K. and Das, R.C. 1980. Studies on fertilizer application in old cashew plantation. *Cashew causerie* **2** (3): 13-14

Nalini, P.V. and Santhakumari, S. 1991. Study on performance of selected types of cashew at Cashew Research Station, Anakkayam, Kerala. *Cashew* **3** (1): 3-6

Nambiar, M.C. 1983. Annual Reports 1982-83. All India Co-ordinated Spices and Cashew nut Improvement Project. CPCRI, Kasaragod, Kerala, p. 253

Nanjundaswamy, A.M. 1984. Economic utilisation of cashew apple. *Cashew causerie.* **6** (2): 2-6

Natarajan, C.P. 1979. Cashew apple - A by-product of cashew industry and its utilization. *Cashew causerie* 1 (1): 16-17

Ohler, J.G. 1979. "Cashew" Communication No: 71. Royal Tropical Institute, Amsterdam, p.543

Panda, J.M., Sahu, A. and Nath, P.K. 1996. Studies on vegetative growth in relation to flowering in cashew. *Cashew Bull.* **33** (12): 3-4

Pandey, S.N. and Sinha, B.K. 1972. *Plant Physiology.* Vikas Publishing House Pvt. Ltd., Delhi, p. 300

Pujari, K.L. 1976. Hungry cashew retards yield. *Cashew Bull* 13 (12): 5-6

Rao, M.R., Reddy, S.K. and Rao, R.R. 1984. Effect of NPK on nut yield of cashew. *Cashew causerie* **6** (1): 3

Reddy, A.V., Rao, P.V.N., Ankaiah, S. and Rao, I.V.S. 1982. Cashew NPK nutrition in relation to growth under graded doses of nitrogen fertilization. *Indian Cashew J.* **14** (4): 15-19

Roe, J.H. 1954. Chemical determination of ascorbic, dehydroascorbic and diketogluconic acids. *Methods of biochemical analysis.* **1**: 115-139

Sadasivam, S. and Manickam, A. 1996. *Biochemical Methods*. Second edition. New Age International publishers. New Delhi. p. 256

Salam, M.A. 1998. Processing characteristics and Production potential of cashew (*Anacardium occdentale* L.) varieties. *Cashew* **12** (1): 27-37

Salam, M.A. and Razak, A.M.P. 2002. Regression model for tree height in cashew. *J. plantation Crops* **30** (1): 12-16

Salam, M.A., Pushpalatha, P.B., Usha, K.E., Suma, A. and Kumar, T.N.J. 1997. Comparative performance of 18 cashew (*Anacardium occidentale* L.) varieties in the oxisols of Kerala. *Cashew Bull.* **34** (9): 11-16

Sanyal, D. and Mitra, S.K. 1991. Standardization of leaf sampling technique for mineral composition of cashew. C.V. Red Hazari. *Cashew* **5** (2): 9-11

Sapkal, B.B., Hulamani, N.C. and Nalwadi, U.G. 1992. Studies on some qualitative aspects of cashew apple (*Anacardium occidentale* L.). *Cashew* **6** (2): 8-10

Sawke, D.P. 1980. Cashew nut Research Station. Vengurla. *Cashew causerie* **2** (2): 15-16

Sawke, D.P. Deshpande, S.B. and Gunjate, R.T. 1986. Nutrient management in Cashew. *J. Plantation Crops* **24** (2): 3-9

Sena, D.K., Lenka, P.C., Maharana, T. and Behura, S. 1995. Physico-chemical properties of cashew apples of some promising clones. *Cashew* **9** (1): 14-16

Subbaiah, B.V. and Asija, C.L. 1956. A rapid procedure for estimation of available

Suman, C.R. 2001. Cashew nut as a constituent of healthy diet. *Proceedings of World. Cashew congress 2001, India*. The cashew export promotion council of India, pp. 67-71

Suria, P.N. 1998. Cashew. The wonder nut-Elixir of life. *Cashew Bull.* **35** (7): 3-7

Tandon, H.L.S. 1993. *Methods of Analysis of Soils, Plants, Waters and Fertilizers*. Fertilizers Development and Consultation Organisation, New Delhi, India, p.144

Tsakaris, A. 1967. Cashew nut Production in the Southern Region of Tanzania. II. An economic study of cashew nut production by present farmers at lulindra. *E. Afr. Agric. For. J.* **32**: 445-449

Veeraraghavan, P.G., Celine, V.A. and Balakrishnan, S. 1985. Study on the fertilizer requirement of cashew. *Cashew causerie* 7 (2): 6-7

EFFECT OF MAJOR NUTRIENTS ON THE YIELD AND QUALITY OF NUTS IN GRAFT - RAISED CASHEW
(*Anacardium occidentale* Linn.)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

An experiment was conducted to study the "Effect of major nutrients on the yield and quality of nuts in graft raised cashew" at Cashew Research Station Madakkathara Kerala. The treatments consisted of three levels each of N, P and K on eight year old cashew trees. The salient findings are abstracted below.

The study revealed that increasing levels of nitrogen significantly increased the height and spread of cashew trees, while the girth was significantly increased by the interaction effects of nitrogen and potassium.

The yield parameters such as number of flushes, number of leaves per flush, number of panicles and the number of nuts per panicle were significantly enhanced by the application of nitrogen at increasing levels, while the application of phosphorus at increasing levels also significantly increased the number of nuts per panicle.

The yield of cashew nuts and apples were significantly increased due to the highest level of nitrogen applications. Application of potassium at the highest level also significantly increased the apple yield per tree.

Weight and volume of cashew apples was significantly increased by the application of increasing levels of potassium but nitrogen application was found to significantly decrease the weight of fruits. The juice percentage was positively and significantly influenced by the application of nitrogen and potassium.

Potassium applications were found to significantly increase the nut length and weight while nitrogen applications were found to reduce the nut weight. Shelling percentage of cashew nuts was enhanced by the application of nitrogen and potassium at increasing levels. The kernel weight was increased due to the application of potassium.

Ascorbic acid content of cashew apples was positively influenced due to the application of increasing levels of NPK. The Total Soluble Solids of the apple was significantly enhanced by the application of nitrogen.

Applications of nitrogen alone and in combination with phosphorus were found to increase the protein content of kernels. The carbohydrate, Non-reducing sugars and reducing sugars content of kernels were significantly enhanced by the application of different levels of nitrogen.

Increase in the soil major nutrient content due to the individual effects of nitrogen, phosphorus and potassium applications were also observed. The leaf phosphorus and potassium content was enhanced specifically due to the application of increasing levels of phosphorus and potassium respectively, while the nitrogen content of leaves was positively influenced by the application of nitrogen and phosphorus.

The average nutrient off-take through nuts and apples was computed to be 279.43, 41.58 and 186.40g of nitrogen, phosphorus and potassium respectively. The average nutrient off take per tree through nuts from an average yield of 2.89 kg $tree^{-1}$ was found to be 93.56, 2.89 and 48.85g of nitrogen, phosphorus and potassium respectively and through apples was found to be 185.87, 38.69 and 137.54g of nitrogen, phosphorus and potassium respectively from an average yield of 18.20 kg $tree^{-1}$.

In general, among the major nutrients applied at different levels only nitrogen had shown exceedingly high effects in sustaining the growth, yield and quality parameters. The yield and quality parameters were also seen to be affected to a certain extent by potassium applications but the response of the crop to phosphorus was seen to be exceedingly limited.