NUTRITIONAL CHARACTERISTICS IN RELATION TO GROWTH AND PRODUCTIVITY OF CASHEW (*Anacardium occidentale* L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Nutritional characteristics in relation to growth and productivity of cashew (*Anacardium occidentale* L)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other University or Society.

Place : *Vellanikkara*
Date : *27-10-2000*

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Certified that this thesis entitled **"Nutritional characteristics in relation to growth and productivity of cashew (*Anacardium occidentale* L)"** is a record of research work done independently by **Sri. T.N. JAGADEESH KUMAR** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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T.N. Jagadeesh Kumar

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INTRODUCTION

1. INTRODUCTION

Cashew (*Anacardium occidentale L.*) is one of the most important commercial crops in India. The crop was introduced to the country in the 16^{th} century mainly as a bio-agent for conserving soil. However it has over grown in its status and has emerged as one of the most important dollar-earning crops of the country. India ranks first in the production of raw nuts and export of cashew kernels. Our export earnings from cashew during 1998-99 was equivalent to Rs. 1609 crores (Directorate of Cashew Nut Development, 1999).

In India cashew is grown in an area of 7.32 lakh ha with a production of 4.31 lakh tonnes. There are 825 processing industries, which demands 10-12 lakh tonnes of raw nuts annually. It can thus be seen that the present production is hardly 50 per cent of the demand. The average growth rate in the requirement of kernels for export and internal consumption comes to around 1.3 per cent per annum. At this rate the demand of the industry by 2005 AD will be 2.5 times that of the present production (Balasubramanian, 1998).

It becomes imperative that concerted attempts are to be made to augment the internal production of raw nuts to around 25 lakh tonnes per annum. Increase in production is attainable by increasing area and productivity through high yielding varieties, better management and control of pests and diseases. Attempts are already afoot to increase the area under cashew. Most of the new area is being planted with high yielding varieties. The average productivity of cashew at present is only 835 kg ha^{-1} while the grafts of the improved varieties have a potential of giving upto 2 t ha^{-1} (Salam, 1999).

In cross pollinated crops like cashew, the seedling progeny do not result in true to type plants. Clonal plants are the only possibility for the availability of quality planting materials. It has already been confirmed that soft wood grafts of high yielding varieties are the best planting materials in cashew (Dixit, 1999). Production of successful grafts mainly depends on the health, vigour and uniformity of root stocks, besides good scion material and optimum growth conditions. Use of quality root stock enhances the success percentage in grafting and reduces the cost of cultivation (Ramesh *et al.*, 1998). This also necessitates to evolve appropriate nutritional strategies for the seedlings for root stocks.

Evaluation of the performance of high yielding varieties under different nutritional and moisture regimes has showed wide variation in yield of cashew under Kerala conditions (Latha, 1992). Higher productivity in cashew can be retained for a longer period if adequate nutrient status in the soil and leaf tissues is maintained. By correlating the quantity of fertilizer applied, tissue nutrient status and yield we can develop a nutrient management strategy for realizing potential yield.

At present there is inadequacy of information on the nutritional requirements of graft raised cashew. Being a perennial crop, it may be very difficult to standardize its nutritional requirement by repeated field experiments under each agro climatic condition. Therefore, it will be useful if a prediction model capable of providing information regarding the nutritional requirement could be developed. No much concerted attempts have been made in this direction so far.

The majority of the cashew growing tracts in Kerala are typically lateritic which is acidic and also deficient in bases such as Ca and Mg. Hence, the application of these elements is likely to have a bearing on the productivity of cashew. The addition of soil amendments such as lime and magnesium sulfate provides not only the secondary nutrients but also play a role in correcting the pH of the soil.

Under the above circumstances the present study was initiated with the following objectives.

1. To develop a nutritional strategy in cashew nursery for the production of vigorous root stocks for producing healthy grafts.
2. To study the response of graft raised cashew to varying nutrient regimes and to investigate the effect of nutrient regimes on leaf nutrient status; to quantify the nutrient removal of adult graft raised cashew and to develop yield prediction models based on tissue nutrient status.
3. To assess the effect of lime and magnesium sulphate on growth and productivity of cashew in the laterite soils.
4. To study the varietal variation in tissue nutrient status of promising cashew varieties and its relation to yield.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In perennial plantation crops with large canopy and high value produce the cultural practices starting from nursery preparation requires more attention. Suitable potting media and nutrient supplements for production of healthy root stocks for grafting is more important than raising seedlings for direct planting. Even though experiments have been conducted to study the effect of soil nutrient regimes on yield of cashew, its influence on leaf nutrient status and the extent of varietal variation in relation to nutrient composition of leaves and its role in yield has not been much explored. The effect of soil amendments like lime and magnesium sulphate on growth and productivity of graft raised cashew have to be investigated especially in the latertic soils of Kerala. The available literature regarding these aspects is reviewed in this chapter.

2.1 Nursery management

2.1.1 Effect of potting media on growth of seedlings

Potting media with soil, sand and FYM in 1:1:1 proportion has been found to be ideal for raising seedlings of most crops, but information pertaining to cashew is lacking. Hence available literature on the effect of potting media and nutrient supplements on seedlings of similar tree crops are also reviewed here.

The seedlings of *Erythrina falcata* grown in FYM mixed potting mixture recorded maximum dry weight and total N content on 45^{th}, 75^{th} and 150^{th} day compared to those grown without FYM (Freitas *et al.*, 1980). Singh and Sharma (1983) reported that addition of humus (25, 50, 75 and 100 per cent) to nursery soil improved the growth of spruce and silver fir.

Study conducted by Rimando (1981) indicated that medium containing humus and sand in 2:1 ratio was ideal for the growth of *Casuarina equisetifolia* seedlings and medium containing humus and decomposed coir dust in 1:2 ratio was found best for *Pithocellobium dulce* and *Gliricidia sepium* seedlings. Seeds of pedunculate oak (*Quercers robus*) gave larger and healthier seedlings when sown in beds of mixed peat, soil and fertilizer (Buresti, 1986).

According to Bharadwaj *et al.* (1986) an equal mixture of soil, sand and farmyard manure (FYM) was found to be ideal for *Pinus roxburghii* seedlings. Results of experiment conducted by Bahuguna *et al.* (1987) established that FYM is essential for better growth of seedling after completion of germination. Studying the effect of different media on germination and growth of *Acacia nilotica* seedlings, Maithani *et al.* (1988) observed better growth in 1:1:1, 1:2:1 and 1:3:1 mixtures of sand, soil and FYM than that in forest soil alone.

A study was made to find out the suitability of three rooting media (forest soil/sand 5:1, forest soil/cattle manure 1:1, and sand/cattle manure 1:1) for raising seedlings of *Eucalyptus camaldulensis*, *Eucalyptus tereticornis* and *Leucaena leucocephala* in the nursery. The media containing cattle manure was found better for all the species than the one without it (Anon, 1989).

Beniwal and Dhawan (1991) observed minimum germination of seeds of *Anthocephalus chinensis* when sown in pure soil medium and better germination and growth in the medium containing FYM. Kumar *et al.* (1992) found that a combination of soil, sand and FYM in 1:1:1 proportion increased seedling height and dry matter production of *Swietenia macrophylla* and *Dalbergia latifolia* seedlings.

Dhar *et al.* (1992) in their studies on the influence of rooting media on growth and dry matter accumulation of *Leucaena leucocephala* observed that FYM was the best medium for raising healthy and vigorous seedlings.

Misra and Jaiswal (1993) studied the effect of potting mixtures with different proportions of loam soil, sand and FYM on growth and survival of one month old seedlings of *Grevilia robusta*. Survival was the best in 1:1:1 mixture of soil, sand and FYM and best the growth was observed in a media containing 2:1:1 mixture of soil, sand and FYM.

Studying the effect of eight different rooting media on growth of seven tree crop seedlings, Sudheesan (1996) observed the largest increase in shoot length and collar diameter of *Ailanthus triphysa*, *Casuarina equisetifolia*, *Swietenea macrophylla* and *Tectona grandis* at 90 DAS in the medium containing soil and FYM in 2:1 proportion. The highest shoot length and collar diameter was noticed in the species *Albizia lebeck* and *Gmelina alborea* when grown in medium containing 1:1:1 soil, sand and FYM. Shoot dry matter production in *Casuarina*, *Tectona* and *Vateria* was the highest in 2:1 soil:FYM mixture, while in the species *Albizia, Gmelina* and *Swietenia* it was the highest in 1:1:1 soil sand FYM mixture. Significant improvement in all the biometric characters and dry matter accumulation in shoot as well as in roots in all the species was observed when FYM was included in the rooting media.

1.2 Effect of mineral supplements on growth of seedlings

Investigating the nutritional requirement of forest trees, Hassan and Dey (1979) applied all combinations of N, P and K at 0, 250 and 500 mg plant^{-1} monthly to six week old seedlings grown in sand culture. The best growth and the highest concentration of nutrients were observed in plants when N, P and K were applied at 250 mg plant^{-1} at monthly interval. Application of 1:2:1 NPK fertilizer mixture at the rate of 3 g seedling^{-1} increased shoot weight and collar diameter of *Didymopanax morototoni* seedlings (Marques and Yared, 1984).

Donald and Viser (1989) studied the effect of different rooting media and inorganic fertilizers on seedling growth of *Acacia mearnsii*, *Eucalyptus grandis* and *Pinus patula* and observed that all the three species responded to the addition of inorganic fertilizers irrespective of the potting media used.

Investigating the effect of mineral nutrient supplements on seedlings of teak and casuarina in soil sand mix in polybags, Rangaswamy *et al.* (1990) observed increased growth and nutrient content in teak and casuarina when supplemented with two doses of NPK fertilizers.

In a nursery experiment conducted at the Central Arid Zone Research Institute, Jodhpur, three species (*Dalbergia sisoo, Prosopis cineraria* and *Albizia lebeck*) were grown in media containing different proportions of sand, tank silt and FYM with supplementary N (0, 10, 20, 40 ppm as urea) and P (0, 15, 30 ppm P). All the species responded to tank silt and FYM in the growing media, but only *A. lebeck* responded to N and none of the species responded to P (Gupta, 1992).

Mohan *et al.* (1990) studied the response of selected social forestry species to mineral nutrients under varying soil texture and reported that *Albzia lebeck, Peltophorum pterocarpum* and *Eucalyptus terreticornis* were highly responsive to mineral nutrient application.

The use of mono ammonium phosphate (0, 5, 10, 15, 20 kg m^{-3} soil) or organic matter produced better seedlings of passion fruit with more root development, higher dry weight of aerial parts and roots and larger stem diameter (Peixoto *et al.*, 1999).

2.1.3 Effect of liming on growth of seedling

Two weeks old seedlings of *Pinus pinastro* were grown in nutrient solutions with four different pH values ranging from 3.5 to 6.5. After four weeks it was found that the root length was the lowest in seedlings grown under pH 3.5. Higher concentration of P, Fe and Al and lower concentration of K, Ca and Mg were observed in seedlings grown in nutrient solution with lower pH (Arduini *et al.*, 1998).

The effect of liming on the growth of seedlings of 15 woody species belonging to three ecological groups (Pioneer, Secondary and Climax) from the Brazilian savannah were evaluated in a green house with natural light by Furtini *et al.* (1999). Lime ($CaCO_3$ and $MgCO_3$) was added at 3.6 t ha^{-1} to raise the soil pH from 4.5 to 6.0. Plant height, stem diameter, dry weight of shoot, roots, whole plants and nutrient contents were determined after 150 days. In general, the pioneer and secondary species had higher total dry matter production (TDMP) in limed soil, but TDMP of climax species was unaffected.

A green house experiment was conducted to study the nutritional requirement of tropical tree *Peltophorum dubium*, in an oxisol substrate with low nutrient availability. Ten treatments, the first involving all the eight nutrients (N, P, K, Ca, Mg, S, B and Zn) and eight treatments each lacking one of these elements were given to 100 day old seedlings. The results indicated that *Peltophorum dubium* seedlings were affected by the omission of individual mineral nutrients in the following order: P>N>S>Ca>Mg>K>B. The omission of K, Ca and Mg affected absorption of S by plants (Venturin *et al.*, 1999).

2.2 Effect of nutrients on growth and yield of cashew

2.2.1 Nitrogen

a) Growth and physiological characters

Nitrogen plays a dominant role in the growth of cashew and the response to applied N depends on the soil type, climatic factors, age of the tree, genotype etc.

Marked improvement in growth characters of cashew by increased levels of nutrients, especially N have been reported by several workers (Sawke, 1980; Reddy *et al.*, 1982; Ghosh and Bose, 1986; Kumar *et al.*, 1997).

Significant increase in height and girth of trees by the application of 1000 g N $tree^{-1}$ $year^{-1}$ over the lower dose of 250 g or 500 g N was reported from the laterite soils of Madakkathara (KAU, 1980). Nambiar (1983) observed that in the sandy loam soils of Bapatala, application of 1000 g N tree^{-1} year^{-1} resulted in considerably higher number of leader shoots produced in a tree. He also observed linear increase in height of the trees with 500 and 1000 g N tree^{-1} over control. However, in the laterite soils of West Bengal, higher growth was obtained with the application of 400 g N tree^{-1} (Nambiar, 1983).

In a study to compare the response of layers and seed progeny of cashew to mineral nutrition at Shantigodu Seed Farm, Kumar (1985) noticed maximum height in seed progeny at 450 g N tree^{-1} and layers at 300 g N tree^{-1} year^{-1}.

In laterite soils of Jhargram (West Bengal) height, girth and canopy spread of trees increased with increasing levels of N (Ghosh, 1990). Maximum improvement in growth characters was observed through out the period of the four year study in plants receiving the highest dose of N at 600 g plant^{-1}. Increasing N from 500 g to 1000 g tree^{-1} *significantly improved tree height in seed progeny of* BLA-39/4 *in the* laterite soils of Madakkathara (Latha, 1992).

Kumar *et al.* (1993) did not get any significant increase in the height of trees by the application of N at 250 or 500 g tree^{-1} in combination with P and K at 125 or 250 g each, compared to the trees that received no fertilizer. But canopy spread was significantly higher in trees that received N and P at the higher dose of 500 g and 250 g tree^{-1} respectively, over control.

Plant height, stem girth and canopy spread were maximum in plants applied with the highest dose of N (500 g tree^{-1}), whereas unfertilized trees (control) recorded the lowest values (Kumar *et al.*, 1997).

Studying the effect of different levels of N, P and K on seed progeny of cashew, Ghosh (1988) observed considerably longer flowering periods at higher doses of N application. Prolonged flowering periods in air layers of cashew due to the application of N at a high dose of 500 g tree^{-1} has been reported from Agricultural Research Station, Ullal (Kumar *et al.*, 1993). The number of panicles per unit area increased significantly by the application of N at 250 or 500 g tree^{-1} in combination with 125 or 250 g each of P and K. In another study, Kumar *et al.* (1997) observed significant increase in the duration of flowering in a panicle as well as the duration of mixed phase by application of 250 or 500 g N tree^{-1} over control. Application of N also increased the percentage of bisexual flowers considerably.

Nitrogen is an integral constituent of chlorophyll. High level of chlorophyll in plant system is reported to be associated with high productivity. In a comparative study of the chlorophyll and other pigments in relation to yield in cashew, Ankiah and Rao (1983 a) observed significant positive correlation with leaf chlorophyll content and nut yield in five high yielders and five poor yielders of selected cashew types at Bapatla.

Increasing the dose of N from 150 g to 450 g $tree^{-1}$ significantly increased the chlorophyll *a* and chlorophyll *b* content of cashew leaves. Chlorophyll *a* and *b* increased by 14 per cent at 300 g N and by 26 per cent at 450 g N over the application of 150 g N $tree^{-1}$ $year^{-1}$ (Kumar, 1985). Application of N at the higher rate of 500 g $tree^{-1}$ significantly increased the chlorophyll content of leaves at flushing, flowering and fruiting stages (Latha *et al.*, 1994).

b) Effect of N on leaf nutrient content

In perennial tree crops like cashew, leaf nutrient content depends on the genotype, age of the tree, soil type, management practices and the physiological stage of the crop.

On comparing the leaf nutrient status of healthy and poorly growing cashew trees, Calton (1961) found that healthy trees contained 1.98 per cent N in leaves whereas unhealthy trees contained only 1.52 per cent. Marchal and Prevel (1971) analyzed the foliar N content of healthy cashew trees and those affected by 'little leaf' disease in Madagascar. The leaves of healthy trees contained 1.93 per cent N, whereas normal leaves of affected trees contained 2.01 per cent N and little leaves (diseased) contained 1.88 per cent N. Lefebvre (1973) reported an average content of 1.73 per cent leaf N in cashew in Madagascar.

In cashew seedlings grown in nutrient solution, 2.40 to 2.58 per cent leaf N was found to be in the sufficient range and 0.98 to 1.38 per cent in the deficient range (Haag *et al.*, 1975). From the results of a sand culture experiment, Falade (1978) concluded that leaf N content of 1.24 per cent was essential for maximum growth in cashew.

Foliar application of urea up to four per cent concentration significantly increased the leaf N content of cashew, beyond which there was nominal increase only. The maximum leaf N concentration of four per cent was recorded at three weeks after spraying four per cent urea (Ankiah and Rao, 1983b).

Leaf N concentration was the lowest (1.0 per cent) at the end of the fruiting season (April to July) and gradually attained the peak of 1.6 per cent in December. After flowering, in January the leaf N content gradually declined and touched the lowest mark in April (Kumar *et al.,* 1982).

Increasing the rate of N application from 0 to 1500 g plant^{-1} raised the leaf N concentration from 1.02 to 1.15 per cent during August and 1.84 to 2.30 per cent during December (Reddy *et al.,* 1982). Simultaneously the leaf P decreased from 0.149 to 0.124 per cent during August and 0.181 to 0.171 per cent during December. Increase in foliar N concentration as a result of N application has also been reported by Kumar and Nagabhushanam (1981), Kumar (1985) and Ghosh and Bose (1986).

Leaf N content rose from 2.04 to 2.53 per cent by the application of 300 g N tree^{-1} year^{-1}. Leaf P decreased with enhancement in N from 150 to 300 g tree^{-1}. Leaf K content declined from 0.99 to 0.90 per cent when N application was increased from 150 to 300 g tree^{-1} year^{-1} (Kumar, 1985).

Application of N at higher levels of 500 g or 1000 g N tree^{-1} did not significantly increase the leaf N content of cashew at flushing stage over the lower level of 250 g N tree^{-1} (Latha, 1992). Increasing N from 250 g to 500 g resulted in a significant increase of 13 per cent in leaf N at flowering stage. The highest dose of 1000 g tree^{-1} failed to register any subsequent increase in leaf N content at flowering.

c) Effect of nitrogen on yield attributes and nut yield

A fertilizer trial at Kasaragod (Nambiar, 974) revealed the inadequacy of very low levels of N to give higher yields, but resulted in significant increase in yield by the application of 300 g and 500 g N over 100 g N tree^{-1} year^{-1}.

Lefebvre (1973) reported that response to applied N in cashew was enhanced in the presence of P. Response to N was limited to 75 kg ha^{-1} in the absence of P and K, but it was observed upto 125 kg N ha^{-1} when P and K were applied.

Reddy *et al.* (1982) recorded 42, 80 and 90 per cent yield increase over control with N application at 500, 1000 and 1500 g tree^{-1} year^{-1}, respectively. Application of 1000 g N tree^{-1} out yielded (6.83 kg nuts tree^{-1}) the treatments with

500 g N (5.03 kg $tree^{-1}$) and control (3.83 kg^{-1}) in coastal sandy soils of Bapatla (Nambiar, 1983).

Kumar (1985) noticed substantial increase in yield from 2.92 kg to 4.27 kg $tree^{-1}$ when N application was increased from 150 to 300 g N $tree^{-1}$ $year^{-1}$, but the yield increase was marginal beyond 300 g N.Increasing the level of N from 200 to 500 g $plant^{-1}$ increased nut yield by 128.7 and 83.2 per cent in the successive years of a two-year study conducted in the red lateritic soils of Jhargram, West Bengal (Ghosh, 1988).

From the results of a long term fertilizer experiment on seed progeny of cashew receiving constant levels of NPK for a period of 10 years, Mathew (1990) reported a nut yield of 8.34 kg $tree^{-1}$ at 1000 g N $tree^{-1}$ against 6.91 kg $tree^{-1}$ at 250 g N.

Studying the response of cashew to nutrient application in laterite soils of Madakkathara, Latha (1992) observed that increasing N application rate from 250 to 1000 g $tree^{-1}$ $year^{-1}$ significantly improved the yield contributing factors such as panicle number and nut weight. However, response in yield was positively maintained only upto the medium level of N at 500 g N $tree^{-1}$ $year^{-1}$.

In the red sandy loam soils of Bangalore where the available N content of the soil was low (65 kg ha^{-1}), Mahanthesh and Melanta (1996) recorded higher number of nuts $plant^{-1}$ (1386.5) at the highest level of N (500 g $tree^{-1}$). They also reported significant linear increase in nut yield by the application of N at 250 and 500 g plant-1 over control.

Very low to marginal response to the application of N to cashew has been reported by various workers. Nair *et al.* (1972) did not observe any significant increase in nut yield by the application of 220 g N $tree^{-1}$. According to them, the response is governed by the level of application and concluded that no additional advantage will be obtained if the level of N was limited to 220 g $plant^{-1}$ or below. A fertilizer trial at Kasaragod (Nambiar, 1974) also revealed that very low N application was not sufficient for high yield. Based on experiments in Tanzania, Ohler (1979) suggested that response to mineral fertilizers is governed by soil fertility and may be expected only in poor soils. Adi and Kurnea (1983) observed that young cashew trees responded quickly to mineral fertilizers than older ones.

Soil or foliar application of N upto 220 g $tree^{-1}$ did not bring about any significant increase over control in the content of N, P or K of cashew apple and nuts (Nair *et al.*, 1972).

Progressive improvement in shelling percentage was observed with incremental doses of N and the highest level of 500 g N $plant^{-1}$ gave the maximum recovery of kernel (Ghosh, 1988, 1990). Veeraraghavan (1990) reported significant increase in shelling percentage of cashew from 29.6 per cent (control) to 35.6 per cent by the application of N at the highest level of 500 g $tree^{-1}$ $year^{-1}$. Kumar *et al.* (1993) recorded higher shelling percentage at all levels of nutrients over unfertilized control. The highest kernel recovery (33.07 per cent) was obtained at the highest level of nutrients (500 g N, 250 g P and 250 g K $tree^{-1}$ $year^{-1}$).

Studying the effect of NPK and growth regulators on quality characters of cashew, Kumar *et al.* (1995) observed significant increase in shelling percentage and kernel weight with increasing levels of NPK. Application of the highest levels of NPK along with growth regulators considerably increased the percentage of export grade kernels (W 210 and W 240) in Ullal-1 variety of cashew.

Investigating on the NPK requirement of cashew in the lateritic tract of West Bengal, Ghosh (1990) concluded that N application improved the yield through increase in the number of nuts per plant as well as the individual nut weight. According to Kumar (1983) the effect of N in enhancing the productivity especially at higher level is through producing more nuts per panicle.

Progressive increase in N levels did not affect the weight of cashew apple but increased the volume. Increasing N application from 150 to 450 g $tree^{-1}$ increased the fruit volume by 24 per cent and decreased the total soluble solid (TSS) content of juice by 10 per cent (Kumar, 1985). Increase in cashew apple yield and TSS content by the application of NPK fertilizers was reported by Kumar *et. al.* (1996).Kumar (1985) found about 8 percent increase in protein content of cashew kernels by the application of 450 g N $tree^{-1}$ $year^{-1}$.

2.2.2 Effect of phosphorus

a) Growth and physiological characters

Phosphorus plays a significant role in early vegetative growth and development of cashew. The colour of leaves of P deficient seedlings changed very slowly from normal green to dark green during the first three months and gradually to a bronze green to yellowish shade during the next two months (Ohler and Coaster, 1979).

In sandy loam soils of Bapatla, application of P at different doses from 200 g to 400 g $tree^{-1}$ resulted in linear increase in plant height. The number of leader shoots produced per plant also increased by higher levels of P (Nambiar, 1983). Plant height increased by about 12 per cent when P application was increased from 50 to 150 g $tree^{-1}$ (Kumar, 1985).

Phosphorus application increased the canopy volume (Sawke *et al.*, 1986). Application of P at 125 g $tree^{-1}$ increased the height of tree by 31 per cent over control. Phosphorus at 250 g $tree^{-1}$ recorded significant increase in height of plant over the lower level, but the highest level of 500 g $plant^{-1}$ failed to produce any response (Latha, 1992). Kumar *et al.* (1993) could not observe any significant increase in height of plants by the levels of phosphorus over control. But the canopy spread of the plant was significantly superior at all the levels of P compared to control.

Application of P increased the chlorophyll *a*, chlorophyll *b* and the total chlorophyll content in cashew leaves. When P application was increased from 50 to 150 g $tree^{-1}$, chlorophyll *a* increased by 23 per cent and chlorophyll *b* by 20 per cent (Kumar, 1985).

Phosphorus at higher levels considerably decreased the flowering duration in cashew. The number of nuts per plant increased significantly at higher levels of phosphorus (Ghosh, 1988).

b) Effect of P on leaf nutrient content

Leaves of healthy and unhealthy cashew trees grown under unfavourable physical condition of soil wetness contained 0.21 per cent and 0.10 per cent P, respectively (Calton, 1961).

Investigating the nutrient deficiency symptoms of cashew in Madagascar, Lefebvre (1973) observed 0.08 per cent P in leaves. The adequate range of leaf P was reported to be 0.16 to 0.20 per cent and the deficient range from 0.11 to 0.14 per cent (Haag *et al.* 1975). Maximum growth in cashew seedlings was observed when leaf P concentration was 0.12 per cent (Falade, 1978).

Increasing P application from 50 to 150 g tree^{-1} increased the leaf P content from 0.11 to 0.16 per cent (Kumar, 1985). Cashew seedlings grown in Hoagland's solution containing P recorded 0.34 per cent P in leaves, whereas the seedlings grown in nutrient solution completely devoid of P contained 0.11 per cent P only (Gopikumar and Aravindakshan, 1989).

Application of phosphorus at 125, 250 or 500 g plant^{-1} resulted in significant increase in P content of cashew leaves at flushing, flowering and fruiting stages over control. The highest leaf P concentration was noticed at all the stages when P was applied at the rate of 250 g tree^{-1} (Latha, 1992).

c) Effect of P on yield attributes and nut yield

Response of cashew to application of P was very poor in sandy loam soils of Kasaragod (Nambiar, 1974), in sandy loam of Bapatla (Rao *et al.*, 1984) and in laterite soils of Madakkathara (Veeraraghavan *et al.*, 1985).

Vidyachandra and Hanamshetti (1984) observed considerable response to the application of P compared to N and K. Nut yield increased from 1.55 kg in control to 3.25 kg by the application of 181 g P tree^{-1}. Sawke *et al.* (1986a) noticed that the effect of P by itself in increasing the yield was limited upto 25 kg ha^{-1}, but when supplemented with N the influence of P on yield was noticed upto 75 kg ha^{-1}.

Nut yield in seed progenies of cashew increased from 1.49 kg at 50 g P to 2.0 kg at 150 g P tree^{-1} year^{-1}. In the case of air layers, application of 100 g P gave an yield of 4.97 kg in comparison to 3.25 kg at 50 g P tree^{-1} (Kumar, 1985).

In the laterite soils of Jhargram, yield increase was noticed upto the highest level of P application at 300 g tree^{-1} (Ghosh and Bose, 1986). Ghosh (1988) observed 22.7 per cent increase in yield by application of P at 200 g plant^{-1} over the lower dose of 100 g plant^{-1}. Further increase in P to 300 g plant^{-1} failed to give any response in yield.

In the laterite soils of Madakkathara, yield increase of 73 per cent was obtained when P application was raised from 125 g to 500 g tree^{-1} (Mathew, 1990). Phosphorus, when applied at 100 g tree^{-1} was effective in increasing the nut yield over control. The highest dose of 200 g P plant^{-1} could not register any increase in nut production over the lower dose (Mahanthesh and Melanta, 1996).

2.2.3 Effect of potassium

a) Growth and physiological characters

Lefebvre (1973) did not observe any effect on growth of cashew by the application of potassium. The response of young cashew to K is limited and need not be applied during early stages (CPCRI, 1979).

Kumar (1985) observed significant increase in height of cashew by K application. Cashew seedlings grown in Hoagland's nutrient solution completely devoid of K were shorter by 7.03 cm compared to seedlings grown in nutrient solution containing K. The number of leaves per plant also decreased by 25 per cent in the absence of K in the nutrient solution (Gopikumar and Aravindakshan, 1989). An increase in plant height by application of K upto 1000 g tree^{-1} year^{-1} was observed by Latha (1992) in seed progeny of cashew.

Application of K at 150 g tree^{-1} increased the chlorophyll *a*, chlorophyll *b* and total chlorophyll content of cashew by 18, 15 and 30 per cent over 50 g K tree^{-1} (Kumar, 1985).

b) Effect of K on leaf nutrient content

Healthy cashew trees contained 1.69 per cent leaf K whereas unhealthy trees contained only 0.97 per cent K in the leaves (Calton, 1961). In cashew seedlings grown in nutrient solution, the leaf K content from 1.11 to 1.29 per cent was considered to be in the sufficient range and 0.20 to 0.26 per cent in the deficient range (Haag *et al.*, 1975). Falade (1978) observed maximum growth in cashew when the leaf K concentration was 0.34 per cent. Cashew seedlings grown in Hoagland's nutrient solution completely devoid of K contained 1.06 per cent K whereas it was 3.17 per cent in seedlings grown in nutrient solution containing K (Gopikumar and Aravindakshan, 1989).

Increase in K application from 50 to 150 g tree^{-1} increased the leaf K content from 0.85 to 0.98 per cent (Kumar, 1985). Higher level of K application increased the leaf K content irrespective of the rate of other nutrients applied (Ghosh and Bose, 1986). Enhancing the K application from 0 to 1000 g tree^{-1} raised the leaf K concentration from 1.14 to 1.23 per cent (Latha, 1992). Leaf K content of six month old cashew seedlings increased from 1.70 per cent in control to 3.10 per cent when K was applied at the rate of 200 kg ha^{-1} (Latha, 1998).

c) Yield attributes and nut yield

Application of K alone to cashew gave 44 per cent increase in yield over control, whereas in combination with N, the yield increase was 95 per cent (Lefebvre, 1973).

Linear response in nut yield to the application of K upto the highest level of 150 g $tree^{-1}$ was observed in the lateritic clay loam soils of Shantigodu, Karnataka, where the available K content of soil was 130 kg ha^{-1} (Kumar, 1985). Potassium application increased the yield upto 200 g $plant^{-1}$, beyond which there was little response (Ghosh, 1988).

Response in yield to higher doses of K was not as marked as that of N and P. The yield increased from 5.44 to 7.23 kg $tree^{-1}$ when K application was increased from 250 g to 1000 g $tree^{-1}$ (Mathew, 1990). Latha (1992) observed significant linear increase in yield with application of 125, 250 or 500 g K $tree^{-1}$ over control, but the levels of K did not differ significantly with regard to nut yield. Linear increase in nut yield of cashew with increasing level of K has been reported (Mahanthesh and Melanta, 1996). Plants receiving K at 250 g and 125 g $tree^{-1}$ recorded higher yields of 9.8 kg and 8.3 kg $tree^{-1}$ respectively, where as the lowest yield of 7.4 kg was recorded in trees given no potassium.

But reports of limited response to no response to application of K in cashew are also available (Venkataraman, 1979; Rao *et al.*, 1984; Veeraraghavan *et al.*, 1985). Nambiar (1983) reported that K application did not show any significant effect on cashew yield in sandy loam soils of Bapatla or the laterite soils of Vengurla while in the lateritic tract of Jhargram in West Bengal there was considerable response to K fertilizers.

Application of K increased the fruit weight and decreased the fruit volume. The protein content of kernel and the TSS content of cashew apple juice was unaffected by levels of K (Kumar, 1985).

2.2.4 Nutrient interaction

Significant interaction between N, P and K leading to differential response in growth, physiological characters, yield and leaf nutrient status in cashew have been reported by many researchers (Lefebvre, 1973; Ghosh, 1988; Mathew, 1990).

Lefebvre (1973) reported significant interaction of N and P in relation to yield in cashew. Application of K had significant effect in increasing the yield of cashew only in the presence of N. Similarly linear increase in yield with N application was observed at higher levels of K only.

Investigating the nutrient deficiency symptoms of cashew in Madagascar, Prevel *et al.* (1974) found that the combined effect of N and P on growth and flowering was much greater than the sum of responses due to the two nutrients applied separately. Consequent to N application leaf N content in cashew increased, but P content decreased. Application of P increased leaf P content, while it decreased leaf N and K content.

Significant effect on yield of cashew due to the interaction of N, P and K was observed in a fertilizer trial at Vengurla (AICS & CIP, 1981). Response to N was obtained only upto 75 kg ha^{-1} in the absence of applied P and K. There was response to P application without K at all levels of N. Eventhough, there was no response due to application of K alone, at higher levels of N considerable response to K was observed.

Sawke *et al.* (1986) noticed differential response to N with varying levels of P and K. At 50 kg P and 100 kg K ha^{-1}, response was obtained upto 125 kg N ha^{-1}. But in the absence of P and K, response to N was limited to 75 kg ha^{-1}. Response to P was restricted to 25 kg ha^{-1} at low levels of N, while higher levels of N in combination with high levels of P gave significantly higher yields.

Increasing the level of N significantly increased the duration of flowering in cashew, while higher rates of P and K reduced it. The duration of flowering was considerably longer due to treatment with 500 g N and 100 g P, whereas shortest flowering period was observed in plants treated with N and P at 200 g each (Ghosh, 1988).

Ghosh (1990) recorded the highest nut yield consecutively for two years in cashew with the treatment combination of 600 g N and 300 g K $plant^{-1}$. Among the levels of nutrients tried by Mahantesh and Melanta (1996) in red sandy loam soils of Bangalore the highest dose of N and K in combination with medium dose of P (500 g N: 100 g P: 250 g K) gave the highest nut yield

Investigating the effect of levels of N, P and K on growth of cashew, Kumar *et al.* (1997) observed maximum plant height, stem girth and canopy spread in plants treated with the highest level of nutrient (500 g N, 250 g P and 250 g K $tree^{-1}$) compared to control. The percentage of bisexual flowers also increased in plants provided with higher level of nutrients.

Application of N fertilizers increased leaf N content, while it decreased leaf P content. When P fertilizers were applied leaf P content increased, but N and K decreased. Potassium fertilizers had little effect on leaf nutrient composition (Prevel *et al.*, 1974). Ohler and Coaster (1979) observed higher concentration of P, K and Na in all parts of cashew with increased levels of K fertilizers.

Ghosh and Bose (1986) noticed slight increase in N content of leaf by P application up to 75 g $tree^{-1}$, however its increase to 100 g $tree^{-1}$ decreased the foliar N content. N concentration in leaf tissue increased with progressive levels of K and maximum N content was observed in plants treated with the highest dose of K, irrespective of the month of sampling. Progressive increase in P content of leaf was observed up to the highest level of N. Increase in N and P application slightly increased the K content of the leaf (Ghosh and Bose, 1986).Mathew (1990) observed that N application at higher levels decreased P content of leaves even when the level of P application was high.

d) Litter yield

Kumar and Hegde (1999) investigated the availability of cashew leaf litter from different age group plantation (10 to 40 years) and estimated that litter yield in cashew ranged from 7.86 kg (10-15 years old trees) to 29.60 kg $tree^{-1}$ $year^{-1}$ (25-40 year old trees).

2.3 Effect of lime and magnesium sulfate on growth and yield of cashew

Reports on the effect of lime and magnesium sulfate on growth and yield of cashew are very limited. Therefore available information on the effect of calcium, magnesium and sulfur on growth, productivity and tissue nutrient status of other tree crops are also reviewed briefly.

Badarinath *et al.* (1985) investigated the effect of lime at 2000 g $tree^{-1}$ in combination with 250:250:250 g or 500:250:375 g N:P:K $tree^{-1}$ along with either Zn or B and both at 50 g each on 20 year old cashew trees in slightly acidic soils (pH 6.4) of Ullal, Karnataka. The yield varied from 5.34 kg $tree^{-1}$ in control (250:250:250 g NPK) to 7.96 kg $tree^{-1}$ when lime as well as Zn was applied (500:250:250 g NPK + 200 g lime + 50 g Zn).

Ystaas and Froynes (1995) studied the effect of P (0,30 or 60 kg ha^{-1}) and Ca (0, 200 kg limestone + 2000 kg dolomitic limestone ha^{-1} or 6000 kg limestone + 200 kg dolomitic limestone ha^{-1}) on the growth of plum trees grown in a virgin, acid soil in Norway low in available P, exchangeable K, Ca and Mg. Liming with ground limestone and dolomitic limestone at 2000 kg each ha^{-1} significantly increased leaf Ca and Mg concentration and improved tree growth, yield, yield efficiency, fruit weight and fruit quality.

Investigating on the effect of soil and foliar application of calcium nitrate and calcium chloride on apple and pear trees at different locations and seasons in Washington State, Raese (1996) observed that calcium nitrate increased Ca concentration in leaves and fruits as well as yield of both apple and pear. Munro (1996) reported that application of gypsum at 5 t ha^{-1} to Valencia orange trees for a period of three years increased yield by 76 kg $tree^{-1}$ (17 per cent) compared to control.

Application of 3 kg complex fertilizers (36.44 per cent SiO_2, 15.58 per cent CaO and 2.17 per cent MgO) to 10 year old apple for three years increased the fruit production by 6 to 21.6 per cent, fruit firmness by 3.7 to 8.7 per cent and soluble solids by 2.6 to 5.2 per cent (Bai and Cheng, 1997). Field trials were conducted to optimize the biomass and crude protein production of *Leucaena leucocephala* in Southern Texas with treatment combination of three levels of P, two levels of Mg and two levels of soluble trace element mixture (Khan *et al.*, 1997). A combination of P, Mg and micronutrients increased biomass from 2555 kg to 3028 kg ha^{-1}. Biomass production was positively correlated with leaf Cu, N and Mg and negatively with Zn.

The effect of Mg and K on yield and nutritional status of pear trees was studied by Aizpurua *et al.* (1997). There was no significant difference in yield between control and rates of Mg at 20, 60 or 100 kg ha^{-1} and K at 70, 140, 210 or 280 kg ha^{-1}. Leaf Mg content was not affected by Mg treatment, but leaf K content was the lowest in control compared to K treatments. Leaf Ca and Mg were positively correlated, but K was negatively correlated with both these nutrients.

2.4 Varietal variation in growth, nut yield and leaf nutrient status of cashew

2.4.1 Growth and physiological characters

Considerable variation in growth, branching pattern, flushing and flowering habits between cashew types have been reported by many workers (Falade, 1981; Reddy, *et al.* 1989; Krishnappa *et al.*, 1996). Significant positive correlation between plant height and canopy spread with nut yield in cashew was observed by Nayar *et al.* (1981) and Parameswaran *et al.* (1984). Evaluating the performance of 18 clonally propagated cashew varieties for five years (five to nine years after planting) at Madakkathara, Salam *et al.* (1997) observed considerable variation in growth characters in terms of height, girth and canopy spread of the varieties. At nine years after planting (9 YAP) the variety M-44/3 was the shortest (5.5m) and V-3 was the tallest (8.03 m). Girth and canopy spread were the highest in the varieties H-1610 (109.5 cm) and V-3 (10.35 m). and the lowest in the variety M- 44/3 (66.5 cm and 10.35 m respectively).

Cashew is a polygamous tree producing perfect and staminate flowers in the same panicle. The floral biology of cashew has been studied by many workers (Rao and Hassan, 1957; Damodaran *et al.*, 1965; Northwood, 1966). According to Damodaran, *et al.* (1965) the total number of flowers in a panicle varied from 200 to 1600. Krishnappa *et al.* (1989) reported variation in the total number of flowers in a panicle from 157 to 1027 in 16 cashew selections.

The period and duration of flowering varied in different agro-climatic situations depending on altitude, temperature, relative humidity, rainfall and the genotype (Nambiar, 1974). Flowering period of four months from last week of November extending upto last week of March under the eastern dry tract of Karnataka was reported (Hanamshetti, *et al.* 1986). Variation in flowering season among cashew varieties under the humid tropical condition of Anakkayam was observed by Nalini and Santhakumari (1991). Early flowering (during middle of November) was seen in the variety BLA-139-1, whereas in late flowering types it was delayed upto the month of February.

The length of panicle in five cashew selections varied from 16.3 cm to 24.3 cm and the breadth varied from 17.0 cm to 23.3 cm (Krishnappa, *et al.*, 1989). However Anitha *et al.* (1991) did not obtain any correlation between panicle length and nut yield in cashew.

The opening of flowers in a panicle in cashew could be differentiated into three distinct phases, i.e. a first male phase, followed by a mixed phase which again is followed by a second male phase (Pavithran and Ravindranathan, 1974). Parameswaran, *et al.* (1984) grouped a population of 20 trees in to two based on their yield. They observed that the mixed phase was longer than both the male phases in trees above the median yield.

In a andromonoeceous crop like cashew, the percentage of bisexual flowers in a panicle is one of the most important aspects that decides the ultimate yield. According to Damodaran, *et al.* (1965) the percentage of hermaphrodite flowers in cashew varied from 0.45 to 24.9 per cent. Reddy and Rao (1985) reported 8 to 15 per cent bisexual flowers under coastal humid conditions of Bapatla, whereas Khan and Kumar (1988) observed 2.27 to 6.66 per cent bisexual flowers in cashew selections Ullal-1 and Ullal-2. The percentage of hermaphrodite flowers in five cashew types evaluated at Jhargram varied from 34.4 to 59.1 per cent (Chatopadhyay and Ghosh, 1993). In another study conducted by Krishnappa *et al.* (1989) the average number of bisexual flowers per panicle in different cashew selections in Karnataka ranged from 62.4 in the type Ansure-1 to 284.2 in the selection Guntur- 4/63 and the percentage of bisexual flowers from 10.13 (K-25-2) to 55.58 (T-1). Investigating the floral characters of 17 clonally propagated cashew genotypes at Bhubaneswar, Sena *et al.* (1995) recorded the lowest percentage of bisexual flowers in the variety H-1600 and the highest in BBSR-CII.

2.4.2 Leaf Nutrient Concentration

a) Nitrogen

Leaf nutrient content in perennial trees depends on the age of the tree, physiological stage of the crop, the genotype and the environment. In cashew, leaves contribute to 49 per cent of the total nitrogen pool in the plant, closely followed by petiole, bark and wood (Kumar, 1985).

In cashew seedlings, the leaf N concentration varied from 1.20 per cent (Gopikumar, *et al.*, 1978) to 3.24 per cent (Gopikumar and Aravindakshan, 1979). In mature cashew trees, leaf N concentration varied from 1.98 per cent (Calton, 1961) to 1.24 per cent (George *et al.*, 1984). Varietal variation in leaf N status ranged from 1.28 per cent in the variety BLA-39/4 (KAU, 1987) to 3.26 per cent in the variety M 26/2 at Cashew Research Station, Madakkathara (Bhaskar, 1993).

According to Mathew (1990) leaf N content was low (1.57 to 1.96 per cent) during 'fruiting and harvesting' phase and high (1.85 to 2.16 per cent) during 'flushing and early flowering' phase. Bhaskar (1993) observed leaf N content of 2.94 per cent at 'flushing and early flowering' phase, which declined to 2.21 per cent during 'fruiting phase' and again rose to 2.42 per cent at 'maturity and harvest' phase.

b) Phosphorus

Phosphorus concentration in leaves of cashew seedlings varied from 0.12 per cent (Falade, 1978) 0.81 per cent (Gopikumar, *et al.*, 1978). In mature trees it ranged from 0.06 per cent (George, *et al.*, 1984) to 0.21 per cent (Calton, 1961).

Reports on varietal variation in foliar P content from 0.09 per cent in the variety BPP-52 (Reddy and Reddy, 1988) to 0.15 per cent in the varieties NDR-2-1 and K-22-1 (KAU, 1987) are available. The leaf P concentration in six cashew varieties ranged from 0.06 per cent (BLA-139-1 and H-1600) to 0.08 per cent (Vengurla-3, Vengurla-5 and M 26/2) during the fifth year of planting (Bhaskar, 1993).

Leaf P concentration in cashew fluctuates between the physiological phases. Mathew (1990) reported that leaves of a 10 year old cashew tree contained 0.12 per cent P during 'flushing' stage and it decreased to 0.04 per cent during 'fruiting' and 'post harvest' phases. In cashew variety BLA-139-1, leaf P content was 0.06 per cent during 'early flowering' phase as well as 'harvesting' phase but declined to 0.04 per cent during 'fruiting' and 'post-harvest' phases respectively (Bhaskar 1993).

c) Potassium

In cashew seedlings, the leaf K concentration varied from 0.87 per cent (Gopikumar, *et al.*, 1978) to 3.17 per cent (Gopikumar and Aravindakshan, 1989). In mature trees it ranged from 0.28 per cent (Lefebvre, 1973) to 1.69 per cent (Calton, 1961).

Leaf K content varied with the variety. Reddy and Reddy (1988) reported low K (0.76 per cent) in the variety BPP-52 at Bapatla, whereas Sanyal and Mitra (1991) observed higher K concentration (1.82 per cent) in the variety Red Hazari at Jhargram. Variation in leaf K content among varieties ranging from 1.07 per cent (H-1598) to 1.34 per cent (Vengurla-3) was reported by Bhaskar (1993).

Reports on variation in leaf K concentration during the physiological phases of crop growth in cashew are also available. The leaves of ten year old tree contained 2.45 per cent K during 'flushing' and it decreased to 1.85 per cent during 'fruiting' and further to 1.45 per cent during 'post harvest' phase (Mathew, 1990). Lower leaf K concentration ranging from 0.85 to 0.90 per cent during 'maturity' and 'post harvest' phases and higher content of 1.00 to 1.17 per cent during 'flushing', 'flowering' and 'fruiting' phases was noticed in five year old trees of cashew variety BLA-139-1 (Bhaskar, 1993).

2.4.3 Yield attributes and nut yield

a) Panicle characters

Ghosh and Chatterjee (1987) evaluated the performance of 17 cashew types at Jhargram, West Bengal and observed that the number of nuts per panicle varied from 1.6 to 4.7 between types. Varietal difference in number of fruits per panicle in different cashew types have also been reported by various workers under different agro-climatic situations (Krishnappa, *et al.*, 1989; Reddy, *et al.*, 1989; Nalini and Santhakumari, 1991). Anitha *et al.* (1991) could establish significant positive correlation between number of nuts per panicle and nut yield in cashew.

Bhaskar (1993) attributed the higher tree to tree variability observed among the experimental trees for the lack of variation in number of nuts per panicle between the 18 varieties evaluated at fifth year of planting.

b) Nut Yield

Nut yield in cashew varies with the varieties, type of planting material, the soil type and climate. The average yield of seven cashew types at Cashew Research Station, Anakkayam ranged from 11.9 kg in the variety UL-21-2 to 34.7 kg tree^{-1} in BLA 139-1 (Nandini and James, 1984).

Evaluating the performance of five cashew selections (5/23 Coondapa, 8/46 Taliparamba, 9/66 Chinala, 1/11 Uallal and 6/21 Mudabidri) under the eastern dry tract condition of Karnataka state, Krishnappa *et al.* (1989) observed yield differences ranging from 1.70 to 6.36 kg tree^{-1} at the sixth year of planting. Yield difference in seedling progenies of six Bapatla varieties varied from 5.3 to 10.1 kg tree^{-1} at the tenth year of planting (Reddy *et al.*, 1989). Nalini and Santakumari (1991) observed that the average yield of 10 cashew selections for 10 years (1981-90) varied from

13.20 kg (K-16-1) to 29.3 kg tree^{-1} (BLA-139-1) in the lateritic soils of Anakkayam, Kerala. Salam *et al.* (1991b) evaluated the performance of fourteen hybrids in the oxisoils of Kerala and noticed variation in nut yield from 7.1 kg to 12.8 kg tree^{-1} year^{-1} at the fifteenth year of planting. Among the six hybrids (H-340, H-342, H-354, H-376, H-402, H-419) studied by Manoj *et al.* (1993) at Cashew Research Station, Madakkathara, H-342 had the highest nut yield (23.48 kg tree^{-1}) and H-340 had the lowest nut yield (19.55 kg tree^{-1}). Salam *et al.* (1997) evaluated the performance of eighteen cashew varieties under the lateritic condition of Madakkathara from fourth to tenth year after planting (YAP). The variety V-3 from Vengurla gave the highest yield of 15.7 kg tree^{-1} at 10 YAP and the cumulative yield per tree for seven years was the highest for the variety M 26/2 (67.2 kg) followed by M 44/3 (64.2 kg) and the lowest for the variety T. 129 (25.3 kg).

Available literature on cashew clearly demonstrates the wide variation in the nut weight between different cashew types (Aravindakshan *et al.* 1986; Nalini and Santakumari, 1991; Salam, *et al.*, 1991 a). The lowest nut weight in cashew was reported by Antarkar and Joshi (1987) for the variety V-5 (4.08 g) at Dapoli, Maharashtra and the highest nut weight by Salam *et al.* (1997) for the variety H-2/16 (10.08 g) at Madakkathara.

c) Shelling percentage

Shelling percentage in cashew varieties ranged from 20 per cent in type K-19-1 to 32.8 per cent in the variety BLA-139-1 (Aravindakshan *et al.*, 1986). According to Nalini and Santakumari (1991) shelling percentage of 10 cashew types at Cashew Research Station, Anakkayam varied from 25.8 per cent (K-25-2) to 28 per cent (BLA-139-1). Evaluating the performance of 18 cashew varieties from various states Salam, *et al.* (1997) reported the highest shelling percentage in the variety BLA-139-1 (37 per cent) and the lowest in H-1608 (29.8 per cent).

d) Kernel weight

Aravindakshan et al. (1986) reported variation in kernel weight from 1.41 g to 2.0 g in 13 cashew varieties. The highest kernel weight of 2.0 g was observed in the variety NDR 2-1. Among the nine cashew genotypes (BLA-139-1, BLA-39-4, K-22-1, NDR-2-1, H-3-17, H-1598, H-1602, H-1608 and H-1610) evaluated, George *et al.* (1991) reported the highest kernel weight in the hybrid H-1602 (2.76 g) and the lowest in the type K-22-1 (1.6 g). Salam *et al.* (1991 b) also observed the highest kernel weight of 2.76 g in the hybrid H-1602 among 14 hybrids evaluated. Kernel weight of 18 cashew varieties ranged from 1.38 g in V-5 to 2.46 g in H-2/16 from Bapatla (Bhaskar, 1993).

e) Cashew apple yield

Aravindakshan *et al.* (1986) observed significant difference in cashew apple yield in 13 types evaluated at Madakkathara. Hybrid H-3-17 gave the highest cashew apple production (358.52 kg tree^{-1}) followed by BLA-139-1 (323.43 kg tree^{-1}) and H-3-13 (239.64 kg tree^{-1}). Apple yield was the lowest in type K-28.2 (85.18 kg tree^{-1}).

f) Cashew apple weight

Considerable difference in weight of cashew apple between varieties has been reported by many researchers (Aravindakshan *et al.*, 1986; Krishnappa *et al.*, 1989; Nalini and Santakamari, 1991). Among 13 types evaluated by Aravindakshan *et al.* (1986) cashew apple weight was the highest (132.7 g) in the hybrid H-3-13 and the lowest (31.3 g) in the type K-28-2. Krishnappa *et al.* (1989) observed variation in the weight of cashew apple from 33.5 g to 62.0 g in five selections tested at Agricultural Research Station, Chintamani. Nalini and Santakumari (1991) found cashew apple weight to vary from 27.0 g to 80.0 g in 10 cashew selections. Weight of cashew apple varied from 32.9 g in the variety V 5 to 92.2 g in the variety T-59/2 among the 18 varieties evaluated by Bhaskar (1993) at fifth year of planting

g) Litter yield

Kumar and Hegde (1999) conducted studies on availability of cashew leaf litter from different age group plantations (10 to 40 years) in Ullal and reported average annual litter yield of 1.38 to 2.0 t ha^{-1}. The quantity of litter collected from each tree varied from 7.7 kg (10-15 year old trees) to 30.7 kg tree^{-1} year^{-1} (25-40 year old tree).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Three field experiments and one green house study were conducted at Cashew Research Station (CRS), Madakkathara, Thrissur, Kerala during 1997-99, to standardize the nutritional requirement of grafted cashew.

The study consisted of four experiments.

Exp. I Influence of nursery techniques on growth of cashew root stocks

b) Effect of potting media and nutrient supplements

b) Effect of lime incorporation in potting media

Exp. II Effect of soil nutrient regimes on leaf nutrient status and yield of graft raised cashew

Exp. III Effect of soil application of lime and magnesium sulphate on growth and productivity of graft raised cashew

Exp. IV Varietal variation in leaf nutrient status and its relation with nut yield

The details of materials and methods adopted for the experimentation are given below.

3.1 Location

The Experiments were conducted in the research farm at the Cashew Research Station, Madakkathara, Thrissur, Kerala located at 10° 32` N latitude and 76° 10` E longitudes, at an altitude of 22.5 m.

3.2 Climate

The location enjoys a tropical monsoon climate with an annual rainfall of 3000 mm and a monthly average relative humidity (RH) of 69 per cent. The data on daily maximum temperature, minimum temperature, RH, sunshine hours, wind velocity, total monthly rainfall and evaporation (agri-met observatory, Vellanikkara during 1997- '99) are given in Table 1and graphically represented in Fig.1 to 3.

During 1997, the average monthly maximum temperature ranged from 28.6°C to 35.7°C with a mean of 32.2°C. During 1998, the average daily maximum temperature ranged from 29.2°C to 36.5°C with a mean of 32.3°C. During 1999, the

Table 1. Abstract of weather (monthly mean) during 1997, 1998 and 1999

	1997		1998		1999	
	Mean	Range	Mean	Range	Mean	Range
Maximum temperature (°C)	32.2	28.6-35.7	32.3	29.2-36.5	31.5	28.4 – 35.5
Minimum temperature (°C)	23.3	21.8-24.5	23.2	22.8-25.6	23.4	22.7 – 24.7
Rainfall (mm) month^{-1}	253.5	0-979	265.0	0-809.3	218.3	0 – 823.3
Total rainfall per year (mm)	3042.8		3179.6		2619.5	
RH I (%)	87.3	78-95	88.1	77-96	86.8	72 – 96
RH II (%)	60.4	37-84	63.4	47-79	60.5	35 – 82
Mean RH (%)	73.0	57-89	75	62-87	73.0	53-89
Evaporation (mm)	148.8	89.6 - 203	135.2	81.2 – 180.5	124.6	73.3 – 177.7
Sunshine hours per day	6.8	1.9-9.6	6.8	3.3-10.0	6.9	2.4 – 10.3
Wind speed (km hr^{-1})	3.8	2.7-6.9	3.4	1.7-6.6	3.5	1.6-6.6

Fig. 1 Meteorological data - 1997

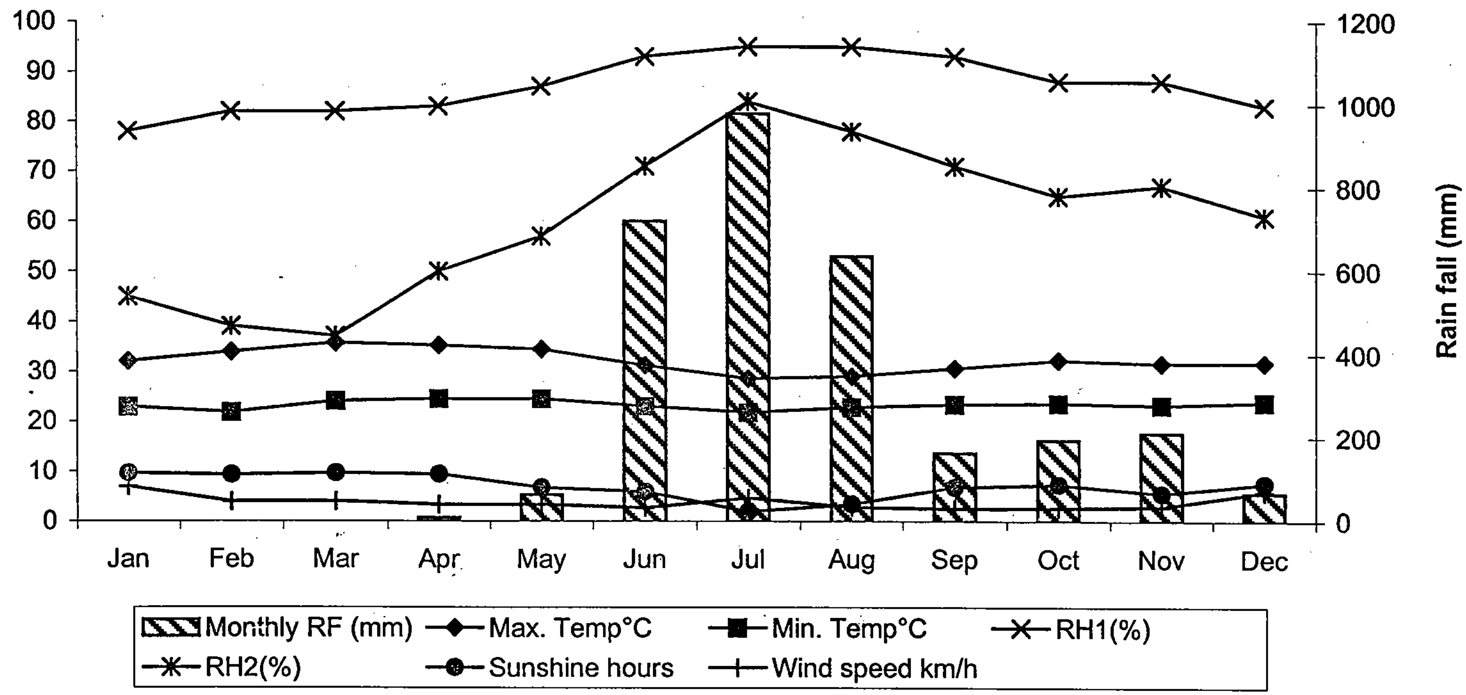


Fig. 2 Meteorological data - 1998

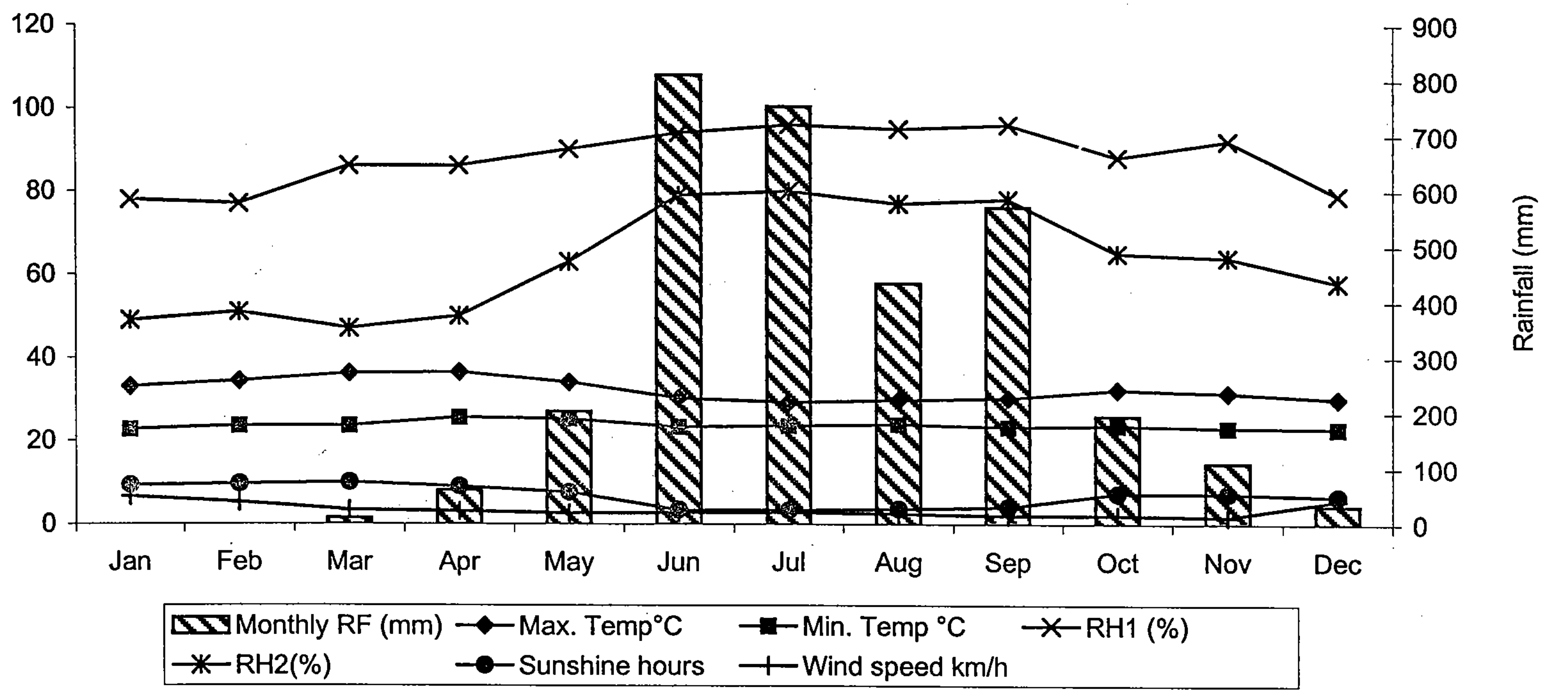
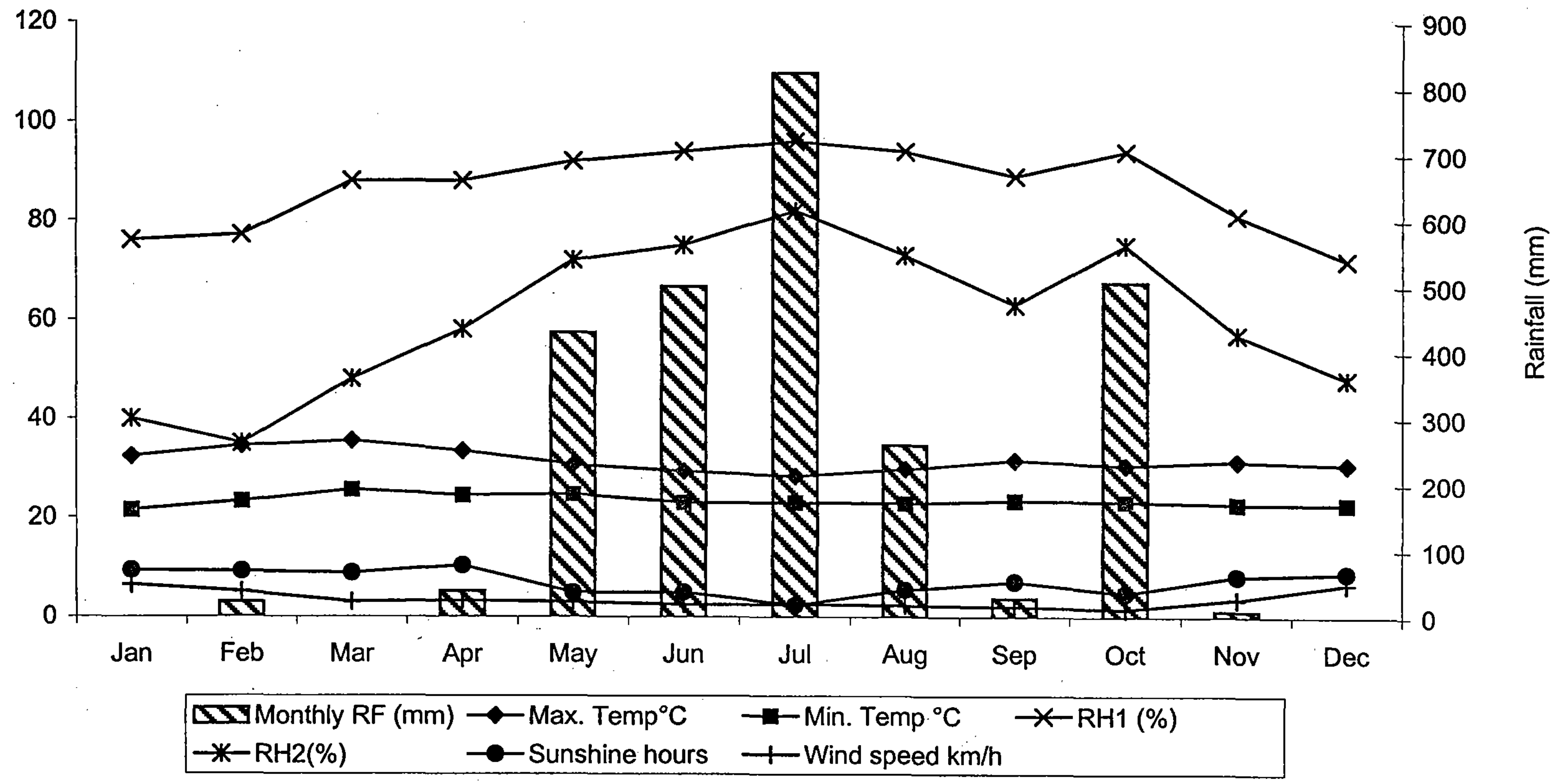


Fig. 3 Meteorological data - 1999



average daily maximum temperature ranged from 28.4°C to 35.5°C with a mean of 31.5°C.

The average daily minimum temperature ranged from 21.8°C to 24.5°C during 1997 with a mean of 23.3°C. During 1998,the minimum temperature ranged from 22.8 to 25.6°C with a mean of 23.2°C. The mean minimum temperature during 1999 was 23.4°C with the lowest being 21.5°C and the highest 24.7°C.

During 1997, the total monthly rainfall ranged from zero (during January, February and March) to 979 mm (July). The monthly rainfall in 1998 varied from zero (January and February) to 809.3 mm (July). The monthly rainfall during 1999 varied from zero (January, March and December) to 823.3 mm (July). The total rainfall of 1997 and 1998 were 3042.8 mm and 3179.6 mm respectively. The total annual rainfall was the lowest during 1999 (2619.5 mm).

During 1997, the average monthly RH values ranged from 60 to 90 per cent with a mean of 73.9 per cent. January, February and March were dry months (RH 59.5 to 61.5 per cent) and June, July, August and September were humid months (RH ranging from 82 to 89.5 per cent). During 1998, average monthly RH ranged from 63.5 per cent (January) to 88 per cent (July). January to April were dry months (RH less than 68 per cent) and June to September were humid months (RH more than 86 per cent). In 1999 the mean RH ranged from 61 to 89 per cent with an average of 75 per cent.

In 1997, total monthly evaporation was high during January to August (157 to 219 mm) and low during July to November (88 to 95 mm). The monthly evaporation in 1997 ranged from 89.6 to 203 mm with an average of 148.8 mm. Total monthly evaporation ranged from 81.2 mm to 180.5 mm in 1998. During 1999 monthly evaporation ranged from 73.3 mm to 177.7 mm.

The monthly average of sunshine hours ranged from 1.9 to 9.6 day^{-1} with an average of 6.8 hours day^{-1} during 1997. The months of July and August received low radiation of 2.7 and 3.7 hours day^{-1} respectively and January, February and March received considerably high solar radiation of 9.6, 9.3 and 10 hours day^{-1} respectively.

During 1998, sunshine hours ranged from 3.3 to 10 with an average of 6.8 hours day^{-1}. January to April received considerably high solar radiation (9-10 hours day^{-1}) whereas June to August recorded low radiation (3.3 to 3.6 hours day^{-1}). During

1999 the sunshine hours ranged from 2.4 to 9.7 hours day^{-1}. January, February, November and December received high amount of solar radiation (more than 8 hours day^{-1}) whereas June, July, August and October received low solar radiation (2.4 to 5.5 hours day^{-1}).

3.3 Soil

All the three field experiments (Exp. II, III and IV) were conducted in typical lateritic soil belonging to the soil order Oxisols. The mechanical composition and chemical properties of the soil are given in Table 2.

3.4 Technical programme

3.4.1 Exp. I Influence of nursery techniques on growth of cashew rootstocks

a) Effect of potting media and nutrient supplements

The technical programme consisted of treatment combinations involving three potting media and four nutrient supplements as indicated below.

Potting Media

i) Soil: Sand: FYM in 1:1:1 proportion (by volume)
ii) Soil: FYM in 1:1 proportion (by volume)
iii) Soil: Sand in 1:1 proportion (by volume)

Nutrient supplements

i) Control (No nutrient supplement)
ii) 200 g N per 100 kg of potting media
iii) 200 g N and 100 g P_2O_5 per 100 kg of potting media
iv) 200 g N, 100 g P_2O_5 and 200 g K_2O per 100 kg of potting media

Potting media was prepared using different proportions of soil, sand and FYM as per the treatments. Garden soil collected from the Cashew Research Station, Madakkathara, river sand and well-powdered, dried FYM were used for the preparation of potting mixture. The chemical properties of the soil, river sand and FYM used for the experiment are given in Table 3.

Nutrient supplements (N, P and K) were applied in the form of urea (46 per cent N), mussorie rock phosphate (21 per cent P_2O_5) and muriate of potash (60 per cent K_2O). Fertilizer nutrients as per the treatment were added to the potting media

Table 2. Physico - Chemical Properties of Soil

1. Mechanical composition

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

2. Chemical properties

Constituent	Content	Rating	Method used for estimation
Organic carbon (per cent)	1.05	Medium	Walkley and Black method
Available N (kg ha^{-1})	204.2	Medium	Alkaline permanganate method
Available P (kg ha^{-1})	15.42	Medium	Ascorbic acid method
Available K (kg ha^{-1})	213.4	Medium	Flame photometry
pH (1:2.5 soil-water suspension)	5.8	Moderately acidic	pH meter method
EC (1:2.5 soil-water suspension)	0.1	Safe	Conductivity bridge method
CEC (meq 100 g $soil^{-1}$)	4.0	-	Ammonium acetate method

Table 3. Chemical Properties of Soil, Sand and FYM

Constituent	Content	Rating
1. Soil		
Organic carbon (per cent)	0.97	Medium
Total nitrogen (per cent)	0.10	Medium
Available N (kg ha^{-1})	194.80	Low
Available P (kg ha^{-1})	13.20	Medium
Exchangeable K (kg ha^{-1})	203.50	Medium
pH (1:2.5 soil-water suspension)	5.5	Moderately acidic
2. River sand		
Available N (kg ha^{-1})	8.6	Low
Available P (kg ha^{-1})	0.89	Low
Available K (kg ha^{-1})	5.3	Low
pH (1:2.5 soil-water suspension)	7.5	Slightly alkaline
3. FYM		
Organic carbon (per cent)	4.18	High
Available N (per cent)	0.60	Medium
Available P (per cent)	0.18	Low
Available K (per cent)	0.42	Medium
pH (1:2.5 soil-water suspension)	6.70	Neutral

and mixed thoroughly and filled in polythene bags of 15 cm × 10 cm with one kg of potting media.

The experiment was laid out in Completely Randomised Design (CRD) with 12 treatments and four replications. There were 100 seedlings in each treatment. Seeds of uniform size of the variety Madakkathara-1 were selected and soaked for 24 hours in water prior to sowing. The polythene bags were irrigated regularly with micro- sprinklers. Germination was initiated from the 12th day; 90 per cent germination was attained in all the treatments by the 16th day. The seeds that germinated thereafter and those with abnormalities were rejected. The seedlings were maintained with periodical weeding and prophylactic plant protection operations during the period of the study. Ten seedlings in each treatment were tagged at random for periodical observation of growth characters.

Observations

i) Height

Height of the seedling was measured from ground level to the tip of the top most leaf.

ii) Girth

Girth just above the soil was measured using a vernier caliper.

iii) Number of leaves

The total number of leaves of plants under each treatment was counted and the mean worked out.

iv) Leaf area per seedling

Constants were worked out for large and medium and small leaves of similar sized seedlings relating the maximum length, breadth and area of leaves. The constant for small, medium and large size groups of leaves were 0.912, 0.725 and 0.665, respectively. The leaves of the treatment seedlings were also grouped into small, medium and large and the maximum length and breadth were taken and multiplied with the corresponding constant to get the leaf area and expressed in cm^2.

v) Root dry matter production

The observational plants were depotted at 90 days after sowing and washed keeping over a wire net, the shoot and root portions were separated. The root portion was dried in shade and dried in a hot air oven to constant weight and expressed in g plant^{-1}.

vi) Shoot dry matter production

The shoot portion of plants was first air- dried and then dried in a hot air oven at $70^{0}C$ to a constant weight. The weight of shoot portion was recorded as shoot dry matter production plant^{-1}.

vii) Root:Shoot ratio

From the dry weight of root and shoot, the root:shoot ratio was worked out.

viii) Total dry matter production

The total dry matter production was calculated from root dry matter production and shoot dry matter production and expressed in g plant^{-1}.

b) Effect of lime incorporation in potting media on growth of rootstock

Treatments

i) Control (No lime application)
ii) 100 g lime per 100 kg potting media
iii) 200 g lime per 100 kg potting media
iv) 300 g lime per 100 kg potting media
v) 400 g lime per 100 kg potting media
vi) 500 g lime per 100 kg potting media

The experiment was laid out in CRD with four replications and 100 seedlings in each treatment. The potting media was prepared with 1:1:1 mixture of garden soil, sand and cow dung. Lime as per the treatment was incorporated in the potting media and filled in polythene bags and seedlings raised as described under Exp. I (a)

Observations

Observations on the following characters were recorded using the procedure explained under Exp. I (a)

i) Height
ii) Girth
iii) Number of leaves
iv) Leaf area per seedling

v) Root dry matter production

vi) Shoot dry matter production

vii) Root:Shoot ratio

viii) Total dry matter production

3.4.2. Exp. II Effect of soil nutrient regimes on leaf nutrient status and yield of graft-raised cashew

The experiment was conducted for three years during 1997, 1998 and 1999. Twenty five trees of uniform growth in an existing plantation of graft-raised cashew variety Madakkathara – 1 planted at a spacing of 7.5 m × 7.5 m during September 1987 were chosen for the experiment. The treatments consisted of an unfertilised control and four levels of NPK combination.

Fertilizer levels

F_0 - No fertilizer

F_1 – 375 g N, 165 g P_2O_5 and 375 g K_2O tree^{-1} year^{-1}

F_2 - 750 g N, 325 g P_2O_5 and 750 g K_2O tree^{-1} year^{-1}

F_3 –1125 g N, 490 g P_2O_5 and 1125 g K_2O tree^{-1} year^{-1}

F_4 -1500 g N, 650 g P_2O_5 and 1500 g K_2O tree^{-1} year^{-1}

The experiment was laid out in Randomised Block Design (RBD) with five replications with single tree plots.

The fertilizers were applied in a single dose in the basin of trees in a circular band between 0.5 m and 1.5 m from the trunk and incorporated into the soil during September in each year. Nitrogen, phosphorus and potassium were applied in the form of urea (46 per cent N), mussorie rock phosphate (21 per cent P_2O_5) and muriate of potash (60 per cent K_2O) respectively. The cultural operations and plant protection measures were carried out as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1996).

Observations

a) Growth characters

i) Height

Tree height was measured from ground level to the tip of the top most flush and is expressed in metre.

ii) Girth

Girth of the tree was measured at a height of 50 cm from the ground level and expressed in centimetre.

iii) Canopy spread

The diameter of the canopy both in East- West and North- South directions were measured, the average worked out and expressed as canopy spread in metre.

iv) Number of flushes

The number of flushes was determined by using a one square metre quadrant from four sides of the tree canopy.

v) Number of panicles

The number of panicles was determined by adopting the same technique as above at 75 per cent flowering stage.

vi) Bisexual flowers

The number of bisexual flowers was assessed when the trees attained 50 per cent flowering. Ten panicles were selected at random and tagged before the commencement of opening of flowers. The number of opened male and bisexual flowers were counted and then clipped off once in two days. This process continued till the opening of all the flowers in the selected panicle. The number of bisexual flowers was expressed as percentage of total number of flowers in the panicle.

vii) Length and width of panicle

The length of panicle from base to the tip and the width at the widest point was measured from ten panicles selected at random in each tree and the mean worked out.

viii) Chlorophyll content of leaves.

Leaf samples were collected at flushing stage (3rd week of October) and flowering stage (3rd week of November) for the estimation of chlorophyll content. The top-most fully matured leaf of the current season flush was taken as the index leaf (Mathew, 1990) for the estimation of chlorophyll.

The leaves were collected between 8 and 9 A.M, immediately transferred to black polythene bags and taken to the laboratory for estimation of the chlorophyll content. The leaves were cut into very small pieces and one gram sample of the leaf was weighed into a mortar and ground with a pestle. The chlorophyll was extracted using 80 per cent acetone. The extract was filtered through Whatman No.1 filter paper and made up to 25 ml using 80 per cent acetone. The absorbance was read in a spectrophotometer at 663 and 645 nm wavelength. The chlorophyll *a*, chlorophyll *b* and total chlorophyll contents were calculated using the following formula and expressed in mg g^{-1} of fresh leaf (Starner and Hardley, 1967).

Chlorophyll *a*	= 12.7 (OD at 663 nm) – 2.69 (OD at 645 nm) v/w × 1000
Chlorophyll *b*	= 22.69 (OD at 645 nm) – 4.68 (OD at 663 nm) v/w × 1000
Total Chlorophyll	= 20.2 (OD at 645 nm) + 8.02 (OD at 663 nm) v/w × 1000

Where	OD	–	Optical density
	v	–	Volume of solvent (25 ml)
	w	–	Weight of sample (1 g)

b) Nut yield and yield components

i) Number of nuts

The number of immature, developing and mature nuts were counted from 10 randomly selected panicles on each tree during the maturity phase. The average was worked out and expressed as the number of nuts $panicle^{-1}$.

ii) Nut yield

The fallen nuts from individual trees were collected along with the apple on alternate days. The nuts were sun-dried for two consecutive days and the weight recorded. From each tree a composite sample of one kg nut was taken and separated into shell, kernel and testa and the weight recorded. The shell, kernel and testa were oven dried at 70°C to a constant weight. The dry matter yield of shell, kernel and testa were worked out from the data on nut yield and drying percentage.

iii) Nut weight

Samples of twenty five nuts were drawn randomly from each tree, weighed and the mean weight of nut was recorded.

iv) Shelling percentage

A sample of one kilogram nut was taken from the harvest of each tree and dried in a hot air oven at 70°C to constant weight. The nuts were then split open using 'hand cutters' and the weight of kernel, shell and testa recorded. The shelling percentage is expressed as weight of kernel and testa to the total nut weight.

v) Kernel yield

The nut yield per tree was multiplied by the shelling percentage and the kernel yield is expressed as kg $tree^{-1}$.

vi) Apple weight

Ten fresh cashew apples were randomly selected from each tree three times during the harvest season and the weight recorded. The average weight was calculated and is expressed as g $apple^{-1}$.

vii) Apple yield

The total apple yield (kg $tree^{-1}$) was worked out by multiplying the average apple weight with the number of nuts in the trees. The total number of nuts $tree^{-1}$ was computed by dividing the total nut yield (kg $tree^{-1}$) by the average weight of nut (g).

viii) Apple dry weight

Samples of one kg each of the apple was collected thrice during each season and dried to constant weight in a hot air oven at 70^0 C and the drying percentage worked out. From the apple yield and the drying percentage, the apple dry weight was worked out and expressed as kg $tree^{-1}$.

ix) Harvest duration

The period from the date of first harvest till the completion of harvest was worked out and expressed as harvest duration in days.

x) Litter yield

Litter traps were established under all the trees and the litter collected during every month. Litter traps of 0.24 m^2 surface were fabricated with stiff galvanised 3 mm wire and plastic bags as suggested by Hughes *et al* (1987). Five traps were set under the canopy of each tree. Litter was collected at the end of each month, sun-dried, weighed and the average litter fall per unit area calculated. The litter yield per tree was obtained by multiplying the weight of litter per unit area with the canopy area (ground coverage) of each tree and expressed as kg tree^{-1} year^{-1}.

Samples were drawn from the sun-dried litter and oven dried to constant weight at 70^{0} C and expressed as dry matter yield of litter kg tree^{-1}.

c) Chemical analysis

Soil

Soil samples were collected during July 1997, August 1998 and August 1999. Soil was collected from two diametrically opposite spots from the basin at a distance of 1.5 – 1.8 m away from the trunk and at a depth of 0-30 cm using a soil auger. These two samples were thoroughly mixed into a composite sample, air-dried, passed through a 2 mm sieve and used for analysis.

The soil samples were analysed for pH, organic carbon, mineralisable N, available P and exchangeable K. The analytical procedures are summarised in Table 4.

Plant

i) Leaf

Index leaves were collected two times every year, first at pre flushing stage (bud breaking stage) and second at the pre flowering stage (at the onset of panicle emergence). The top most fully matured leaf of the current season flush (index leaf as suggested by Mathew, 1990) was selected for analysis. The leaves were collected from the exposed region of the canopy in all the four directions of each tree. The collected samples were washed with water, air dried under shade and then dried in a hot air oven at 65-70°C to constant weight. The samples were finely ground and used for chemical analysis. The details of the methods followed in the chemical analysis of plant samples are summarised in Table 5.

ii) Kernel, shell and testa

Oven dried samples of kernel and testa were analysed for N, P, K, Ca and Mg and the concentration expressed on oven dry basis. For the determination of nutrient content in the shell, the samples were sun dried to constant weight, powdered and the nutrient concentration expressed on sun-dry basis.

Table 4. Details of methods followed in soil chemical analysis

Soil characteristics	Extractant used	Method of estimation	Instrument used
pH	1:2.5 soil water suspension	Direct reading	pH meter
Organic carbon		Walkley-Black Titrimetric	
Available P	Bray-1	Ascorbic acid blue colour	Spectronic 20
Exchangeable K	N. Ammonium acetate	Direct reading	Flame Photometer
Exchangeable Ca	N. Ammonium acetate	Direct reading	Atomic Absorption Spectrophotometer
Exchangeable Mg	N. Ammonium acetate	Direct reading	Atomic Absorption Spectrophotometer

Table 5. Details of methods followed in the analysis of plant samples

Nutrient	Digestion procedure	Method of estimation	Instrument used
N	H_2SO_4 digestion	Distillation and titration	Titrimetric
P	2:1 HNO_3-$HClO_4$ diacid digestion	Vanado molybdate yellow colour	Spectronic - 20 (Photoelectric colorimeter)
K	2:1 HNO_3-$HClO_4$ diacid digestion	Direct reading	Flame photometer
Ca	2:1 HNO_3-$HClO_4$ diacid digestion	Direct reading	Atomic Absorption Spectrophotometer
Mg	2:1 HNO_3-$HClO_4$ diacid digestion	Direct reading	Atomic Absorption Spectrophotometer
Fe	2:1 HNO_3-$HClO_4$ diacid digestion	Direct reading	Atomic Absorption Spectrophotometer
Zn	2:1 HNO_3-$HClO_4$ diacid digestion	Direct reading	Atomic Absorption Spectrophotometer
Mn	2:1 HNO_3-$HClO_4$ diacid digestion	Direct reading	Atomic Absorption Spectrophotometer

iii) Cashew apple

Oven dried samples of cashew apple were powdered and used for the determination of various nutrients and the concentration expressed on oven-dry basis.

iv) Litter

From the samples of litter collected during each month, a composite sample was prepared and a sub sample drawn at the end of each season, oven dried, powdered and used for estimation of nutrients and expressed on oven -dry basis.

d) Nutrient uptake

The nutrient uptake (kg $tree^{-1}$) was computed by multiplying the nutrient concentration (per cent) with total dry weight of the plant part.

3.4.3 Exp. III Effect of soil application of lime and magnesium sulphate on growth and productivity of graft raised cashew

The technical programme consisted of 16 treatments involving factorial combinations of four levels of lime and four levels of $MgSO_4$ as indicated below:

a) Levels of lime

L_0- Control (No lime)

L_1- 500 g $tree^{-1}$ $year^{-1}$

L_2- 1000 g $tree^{-1}$ $year^{-1}$

L_3- 1500 g $tree^{-1}$ $year^{-1}$

b) Levels of $MgSO_4$

Mg_0- Control (No $MgSO_4$)

Mg_1- 500 g $tree^{-1}$ $year^{-1}$

Mg_2- 1000 g $tree^{-1}$ $year^{-1}$

Mg_3- 1500 g $tree^{-1}$ $year^{-1}$

The experiment was laid out in factorial RBD with 16 treatments and three replications, in single tree plots. The treatments were imposed during August 1998 on five-year-old graft raised cashew trees of Variety Madakkathara –1 planted at a spacing of 7.5 m × 7.5 m.

Lime (CaO) was applied and incorporated in the tree basin (1.5 – 1.8 m radius from the trunk) during August 1998 as per the treatments. Magnesium sulphate was applied along with present recommended dose of NPK fertilizers (750 g N, 325 g P_2O_5 and 750 g K_2O tree^{-1} year^{-1}) during September 1998. All management practices including plant protection measures were adopted as per recommendation of Kerala Agricultural University (KAU, 1996).

Observations

Observations on growth characters (height, girth, canopy spread), flushing and flowering characters (number of flushes, number of panicles, percentage of bisexual flowers, flowering period) and yield components (number of nuts panicle^{-1}, nut yield, apple weight and nut weight) were recorded following the procedure described under Exp. II.

Chemical Analysis

a) Soil

Collection of soil samples and analysis for pH, organic carbon and available nutrients (N, P and K) were done as per the procedure described under Exp. II.

b) Plant

The leaf samples were collected at pre-flushing stage (October 1998) and analysed for N, P and K content following the procedure described under Exp. II.

3.4.4. Exp. IV Varietal variation in leaf nutrient status and its relation with nut yield

An existing multilocation trial under the AICRP on Cashew laid out at CRS, Madakkathara with eighteen varieties planted during September 1987 at a spacing of 7.5 m × 7.5 m was adopted for the study. The experiment was laid out in RBD with three replications. Each treatment was tried in plots of four trees. The trees were maintained with uniform dose of fertilizers, plant protection measures and other operations as per the package of practices recommendation (KAU, 1996). The details of the varieties are given in Table 6. For the purpose of leaf analysis and recording the nut yield, two trees were selected at random from each plot.

Table 6. Cashew varieties tested and their sources

Sl. No.	Variety	Selection / hybrid	Source
1.	H 1598	Hybrid	CRS, Madakkathara, KAU
2.	H 1600	Hybrid	CRS, Madakkathara, KAU
3.	H 1608	Hybrid	CRS, Madakkathara, KAU
4.	H 1610	Hybrid	CRS, Madakkathara, KAU
5.	Vittal 30/4 (VTL 30/4)	Selection	CPCRI, Vittal
6.	Vittal 59/2 (VTL 59/2)	Selection	CPCRI, Vittal
7.	Bapatla T 129 (T 129)	Selection	CRS, Bapatla
8.	Bapatla T 40 (T 40)	Selection	CRS, Bapatla
9.	Bapatla 2/15 (BPP 2/15)	Hybrid	CRS, Bapatla
10.	Bapatla 2/16 (BPP 2/16)	Hybrid	CRS, Bapatla
11.	Vengurla 2 (V2)	Selection	CRS, Vengurla
12.	Vengurla 3 (V3)	Selection	CRS, Vengurla
13.	Vengurla 4 (V4)	Selection	CRS, Vengurla
14.	Vengurla 5 (V5)	Selection	CRS, Vengurla
15.	Vridhachalam 33/3 (M 33/3)	Selection	CRS, Vridhchalam
16.	Vridhachalam 44/3 (M 44/3)	Selection	CRS, Vridhachalam
17.	Vridhachalam 26/2 (M 26/2)	Selection	CRS, Vridhachalam
18.	Anakkayam 1 (BLA139-1)	Selection	CRS, Anakkayam, KAU

CPCRI - Central Plantation Crops Research Institute

CRS - Cashew Research Station

KAU - Kerala Agricultural University

Observations

Observations on growth characters (height, girth, canopy spread), flushing and flowering characters (number of flushes, number of panicles, percentage of bisexual flowers, flowering period) and yield components (number of nuts panicle^{-1}, nut yield, apple weight and nut weight) were recorded during 1997 and 1998 following the procedure described under Exp. II.

a) Chemical analysis of plant samples

The leaf samples were collected for analysis at pre-flushing stage (bud breaking stage) during October – November 1997 and at pre- flowering stage (at the onset of panicle emergence) during November- December 1997 and analysed for N, P, K, Ca, Mg, Fe, Mn, Zn and Cu contents following the procedure described under Exp. II. The leaf nutrient status was analysed for two consecutive years, 1997 and 1998 (10 YAP and 11 YAP).

Statistical analyses

The data generated from all the experiments were analysed by the analysis of variance technique (Panse and Sukhatme, 1985). The correlation between nut yield and leaf nutrient status was estimated. Step wise multiple regression was done to identify the characters with the highest predictability. The joint relationship between the dependent variable and a set of independent variables were also arrived at by calculating the multiple correlation coefficient (Snedecor and Cochran, 1967).

An attempt was made to develop yield prediction models in cashew based on tissue nutrient status. Step wise regression was done with the concentration of N, P, K, Ca, Mg, Fe, Cu, Mn, Zn in leaf, chlorophyll content of leaves at pre flushing and post flushing stages with nut yield. For predicting the yield corresponding to different levels of nutrients a simple linear regression equation was fitted by estimating the parameters by the method of least squares (Nigam and Gupta, 1979).

RESULTS

4. RESULTS

The results of the green house study on the effect of potting media and nutrient supplements in the nursery on growth and vigour of cashew seedlings and field experiments to study the response of graft raised cashew to fertilizer nutrients and genotypic variation in yield and foliar nutrient status conducted at CRS, Madakkathara, KAU during 1997-99 are presented in this chapter. The data on interaction effects are given wherever significant and relevant.

4.1 Influence of nursery techniques on growth of cashew rootstocks

4.1.1 Exp. I a Effect of potting media and nutrient supplements

The results of the study conducted to identify the most suitable potting media for production of vigorous and uniform seedlings and the effect of mineral nutrient supplements on growth of cashew seedlings to be used as root stock for production of healthy grafts are presented below.

a) Growth characters

The data of the experiments on the effect of different potting media (PM_1-1:1:1 soil, sand and FYM; PM_2-1:1 soil, FYM; and PM_3-1:1 soil and sand) and nutrient supplements (N_0 : No nutrient supplement; N_1 : 200 g N; N_2 : 200 g N + 100 g P_2O_5; and N_3 : 200 g N + 100 g P_2O_5 + 200 g K_2O 100 kg^{-1} potting media) revealed significant influence of treatments on height of seedlings (Table 7). The height of seedlings was significantly higher in PM_2 and the values recorded were 13.40 cm, 30.11 cm and 38.02 cm at 30, 60 and 90 days after sowing (DAS), respectively. The lowest values were obtained in PM_3 with the height of 10.82 cm, 22.27 cm and 30.04 cm at 30, 60 and 90 DAS, respectively (Fig. 4).

Application of mineral nutrients increased the seedling height significantly (Fig.5). The highest values were recorded in the treatment N_3 at all stages of observation (12.98 cm, 28.48 cm and 35.73 cm respectively at 30, 60 and 90 DAS).

The treatment combination of $PM_2 \times N_1$ gave the highest values of seedling height (14.00 cm) at 30 DAS but its effect was on par with $PM_2 \times N_3$. The treatment $PM_2 \times N_3$ produced the tallest seedlings at 60 and 90 DAS (34.00 cm and 40.28 cm respectively). Height was the lowest in the treatment combination $PM_3 \times N_0$. The treatment combinations involving PM_2 recorded higher values for seedling height in all nutrient combinations.

Table 7. Effect of potting media and nutrient supplements on growth characters of cashew seedlings

Trt. No.	Potting media	Height (cm)			Girth (cm)		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
PM_1	Soil : Sand : FYM (1:1:1)	11.58^{b}	23.88^{b}	32.35^{b}	2.09^{ab}	2.96^{a}	3.51^{a}
PM_2	Soil : FYM (1:1)	13.40^{a}	30.11^{a}	38.02^{a}	2.16^{a}	3.11^{a}	3.67^{a}
PM_3	Soil : Sand (1:1)	10.82^{b}	22.27^{b}	30.04^{b}	1.99^{b}	2.95^{a}	3.15^{b}
Trt. No.	Nutrient supplement*						
N_0	No nutrient supplement	11.34^{b}	22.35^{c}	28.99^{b}	1.93^{b}	2.93^{a}	3.30^{b}
N_1	200 g N	12.05^{ab}	24.97^{bc}	34.63^{a}	2.07^{ab}	2.94^{a}	3.49^{ab}
N_2	200 g N + 100 g P_2O_5	11.35^{b}	25.86^{ab}	34.49^{a}	2.16^{a}	3.04^{a}	3.44^{ab}
N_3	200 g N + 100 g P_2O_5 +200 g K_2O	12.98^{a}	28.48^{a}	35.73^{a}	2.15^{a}	3.12^{a}	3.55^{a}
Trt. No.	Treatments						
T_1	$PM_1 \times N_0$	11.20^{bcd}	20.80^{ef}	26.70^{ef}	2.00^{ab}	2.94^{a}	3.29^{bcde}
T_2	$PM_1 \times N_1$	11.40^{bcd}	24.63^{cde}	32.98^{cde}	2.03^{ab}	2.87^{a}	3.60^{abcd}
T_3	$PM_1 \times N_2$	11.05^{bcd}	23.35^{cde}	33.85^{bcd}	2.24^{a}	3.00^{a}	3.55^{abcd}
T_4	$PM_1 \times N_3$	12.65^{abc}	26.73^{bcd}	35.88^{abcd}	2.11^{a}	3.03^{a}	3.61^{abcd}
T_5	$PM_2 \times N_0$	12.98^{ab}	28.55^{abc}	35.78^{abcd}	2.01^{ab}	2.90^{a}	3.57^{abcd}
T_6	$PM_2 \times N_1$	14.00^{a}	27.00^{abc}	37.10^{abc}	2.19^{a}	3.08^{a}	3.75ab
T_7	$PM_2 \times N_2$	12.83^{ab}	31.66^{ab}	38.90^{ab}	2.20^{a}	3.21^{a}	3.66^{abc}
T_8	$PM_2 \times N_3$	13.80^{a}	33.21^{a}	40.28^{a}	2.24^{a}	3.27^{a}	3.71^{abc}
T_9	$PM_3 \times N_0$	9.83^{d}	17.70^{f}	24.50^{f}	1.79^{b}	2.95^{a}	3.03^{e}
T_{10}	$PM_3 \times N_1$	10.75^{cd}	23.28^{cde}	31.43^{cde}	1.99^{ab}	2.86^{a}	3.11^{e}
T_{11}	$PM_3 \times N_2$	10.18^{d}	25.58^{def}	30.73^{de}	2.06^{ab}	2.91^{a}	3.13^{de}
T_{12}	$PM_3 \times N_3$	12.50^{abc}	25.50^{cde}	33.50^{bcd}	2.10^{a}	3.08^{a}	3.33^{bcde}

*per 100 kg potting media

Fig.4 Effect of different potting media on height of cashew seedlings

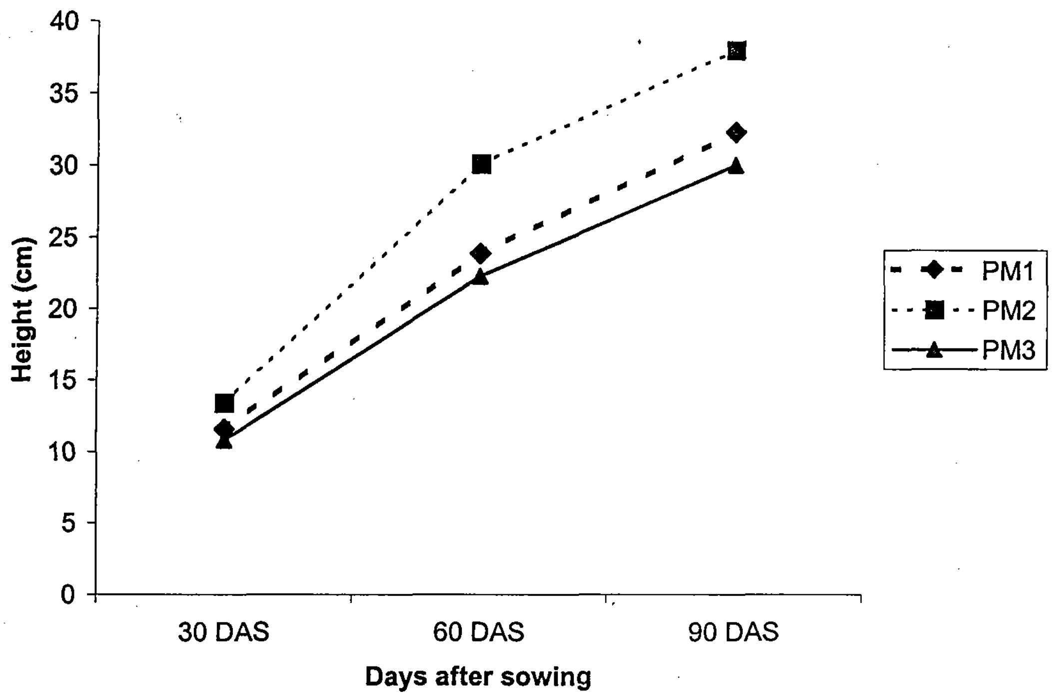
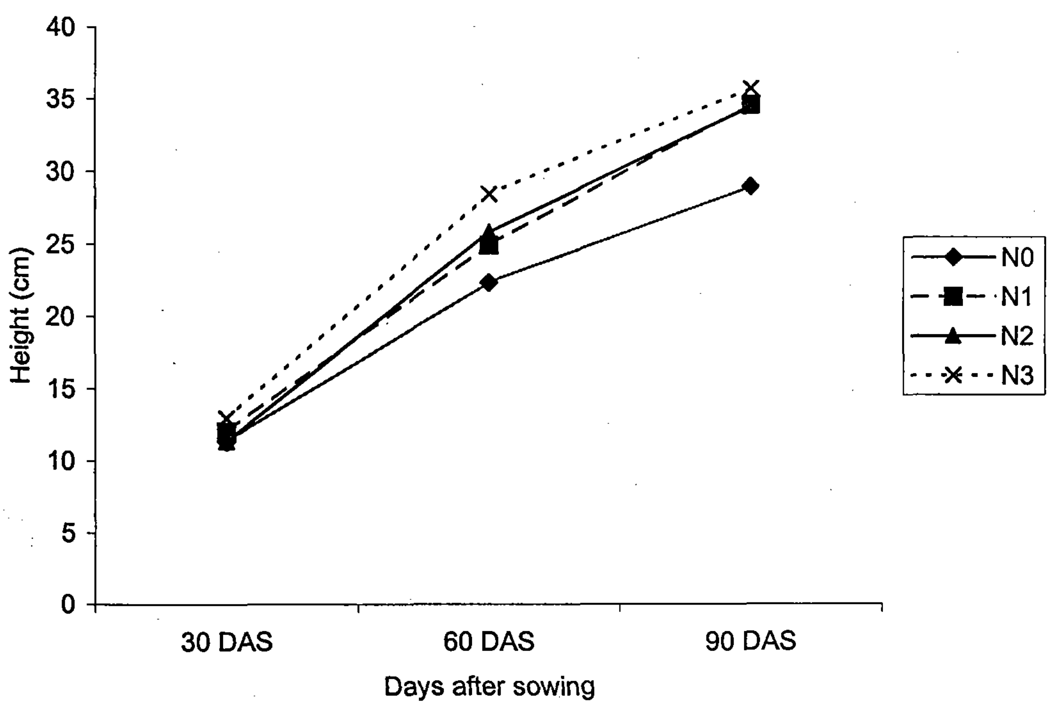


Fig.5 Effect of mineral supplements on height of cashew seedlings



Girth

Potting media had significant influence on girth of seedlings (Fig. 6). Girth was the highest in the treatment PM_2 (2.16 cm, 3.11 cm and 3.67 cm at 30, 60 and 90 DAS, respectively) and it was the lowest in PM_3 (1.99 cm, 2.95 cm and 3.15 cm respectively).

Nutrient supplements had significant influence on girth only at 30 DAS but not at 60 and 90 DAS (Fig.7). At 30 DAS, the treatments N_2 and N_3 were significantly superior to N_0. However, supplementation of P (N_2) or P and K (N_3) did not produce any additional benefit over N alone (N_1).

Combination of potting media and nutrient supplements influenced girth of seedlings only at 30 DAS and 90 DAS. At 30 DAS, $PM_1 \times N_2$ as well as $PM_2 \times N_3$ gave the highest girth (both 2.24 cm) and $PM_3 \times N_0$, the lowest girth (1.79 cm). At 90 DAS the highest girth was observed in $PM_2 \times N_1$ (3.75 cm) and the lowest in $PM_3 \times N_0$ (3.03 cm).

Potting media and nutrient supplements significantly influenced leaf production in cashew seedlings (Table 8). The number of leaves was highest in seedlings that were raised in PM_2, at all the stages of observation (10.27, 17.24 and 22.27 respectively). Leaf production was lowest in PM_3, at all the three dates of observation. At all days of observation the highest number of leaves were observed in seedlings treated with N_3 with corresponding values of 9.84, 17.52 and 22.17, respectively.

The combined effect of potting media and nutrient supplements on number of leaves was significant at all stages of seedling growth. The combination $PM_2 \times N_2$ (soil, FYM 1:1 with 200 g N + 100 g P) produced significantly more number of leaves at 30 DAS (11.30) and at 60 DAS (18.38). The treatment $PM_2 \times N_3$ resulted in the highest number of leaves (24.42) at 90 DAS. However, it was on par with $PM_2 \times N_2$ (23.48).

The effect of potting media and nutrient supplements on leaf area of seedling followed a similar trend as observed in the case of number of leaves. Seedlings grown in potting media with 1:1 soil and FYM (PM_2) gave the highest leaf area with the values 263.5, 458.2 and 618.2 cm^2 $seedling^{-1}$during the different stages of seedling growth observed (Fig.8).

Table 8. Effect of potting media and nutrient supplements on number of leaves and leaf area of cashew seedlings

Trt. No.	Potting media	Number of leaves			Leaf area (cm^2 seedling^{-1})		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
PM_1	Soil : Sand : FYM (1:1:1)	9.17^{b}	16.83^{ab}	20.60^{b}	229.0^{b}	405.6^{b}	578.7^{b}
PM_2	Soil : FYM (1:1)	10.27^{a}	17.24^{a}	22.27^{a}	263.5^{a}	458.2^{a}	618.2^{a}
PM_3	Soil : Sand (1:1)	8.83^{b}	16.17^{b}	19.76^{b}	229.2^{b}	417.2^{b}	548.5^{c}
Trt. No.	Nutrient supplement*						
N_0	No nutrient supplement	9.05^{a}	15.38^{b}	19.51^{b}	227.1^{b}	398.5^{e}	554.3^{c}
N_1	200 g N	9.16^{a}	16.60^{a}	20.35^{b}	238.8^{b}	421.0^{be}	579.8^{b}
N_2	200 g N + 100 g P_2O_5	9.64^{a}	17.42^{a}	21.48^{a}	235.1^{b}	436.9^{ab}	584.8^{ab}
N_3	200 g N + 100 g P_2O_5+200 g K_2O	9.84^{a}	17.52^{a}	22.17^{a}	261.1^{a}	451.6^{a}	608.2^{a}
Trt. No.	Treatments						
T_1	$PM_1 \times N_0$	9.08^{b}	15.30^{cd}	18.40^{f}	211.7^{f}	372.5^{e}	527.8^{f}
T_2	$PM_1 \times N_1$	9.10^{b}	17.23^{abc}	20.63^{cde}	232.6^{cdef}	401.5^{de}	588.9^{bcd}
T_3	$PM_1 \times N_2$	9.18^{b}	17.50^{ab}	21.67^{bc}	223.1^{def}	430.8^{bcd}	585.4^{bcde}
T_4	$PM_1 \times N_3$	9.33^{b}	17.27^{abc}	21.70^{bc}	248.4^{bcd}	417.5^{cde}	612.8^{abc}
T_5	$PM_2 \times N_0$	9.13^{b}	15.95^{bcd}	19.70^{cdef}	238.8^{bcdef}	416.6^{cde}	604.1^{abc}
T_6	$PM_2 \times N_1$	9.63^{b}	16.65^{abcd}	21.48^{bcd}	259.6^{abc}	451.5^{abc}	596.9^{abcd}
T_7	$PM_2 \times N_2$	11.30^{a}	18.38^{a}	23.48^{ab}	268.1^{ab}	474.5^{ab}	627.8^{ab}
T_8	$PM_2 \times N_3$	11.00^{a}	17.97^{ab}	24.42^{a}	287.3^{a}	490.3^{a}	644.1^{a}
T_9	$PM_3 \times N_0$	8.93^{b}	14.90^{d}	20.42^{cdef}	230.9^{cdef}	406.3^{cde}	531.1^{af}
T_{10}	$PM_3 \times N_1$	8.75^{b}	17.30^{abc}	18.95^{ef}	224.1^{def}	410.0^{cde}	553.7^{def}
T_{11}	$PM_3 \times N_2$	8.45^{b}	16.40^{abcd}	19.30^{def}	214.1^{ef}	405.4^{abcd}	541.3^{ef}
T_{12}	$PM_3 \times N_3$	9.18^{b}	16.10^{bcd}	20.38^{cdef}	247.6^{bcde}	447.1^{abcd}	567.8^{cdef}

*per 100 kg potting media

Fig.6 Effect of different potting media on collar girth of cashew seedlings

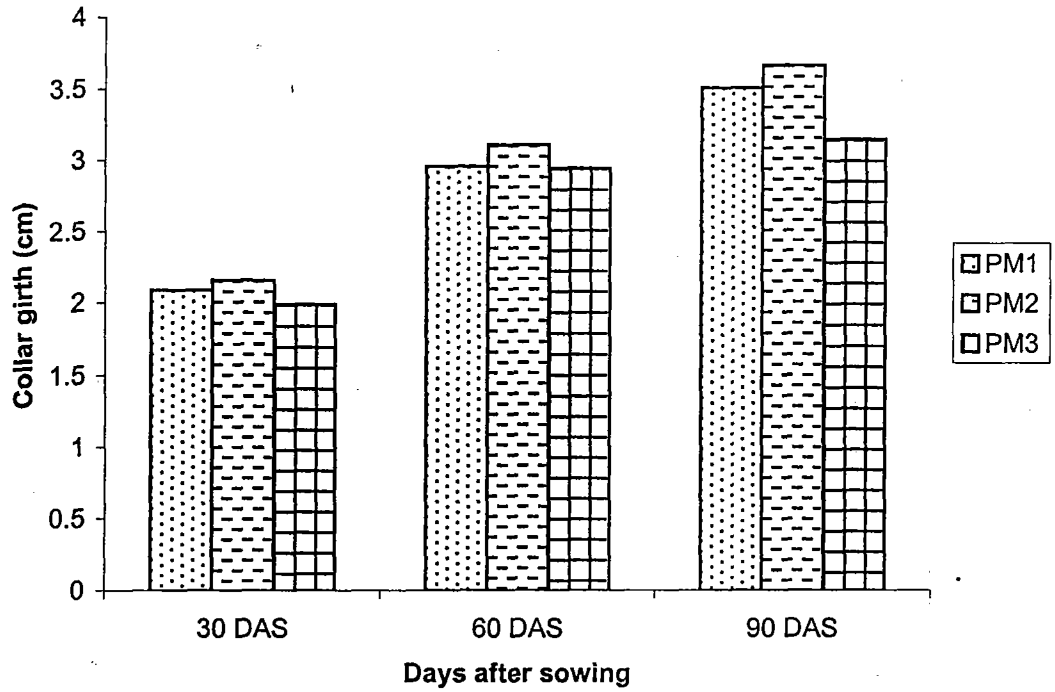


Fig.7 Effect of mineral supplements on collar girth of cashew seedlings

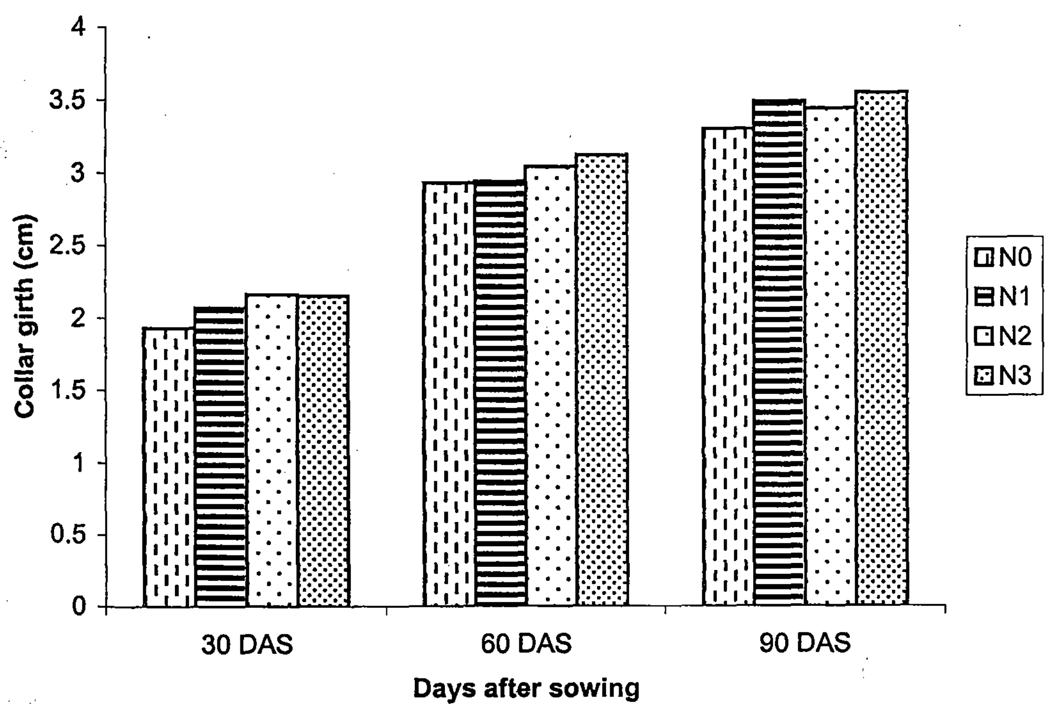


Fig.8 Effect of different potting media on leaf area of cashew seedlings

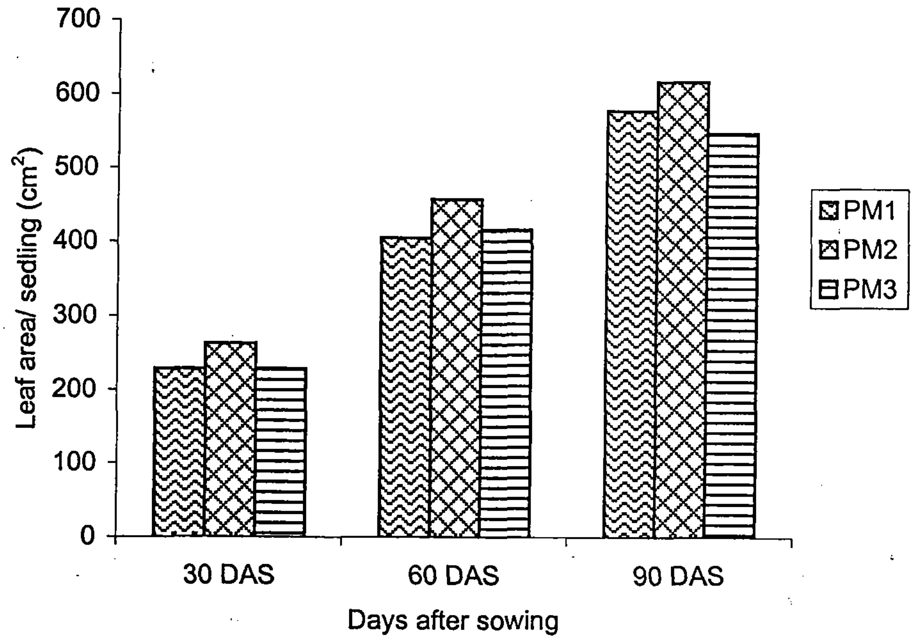
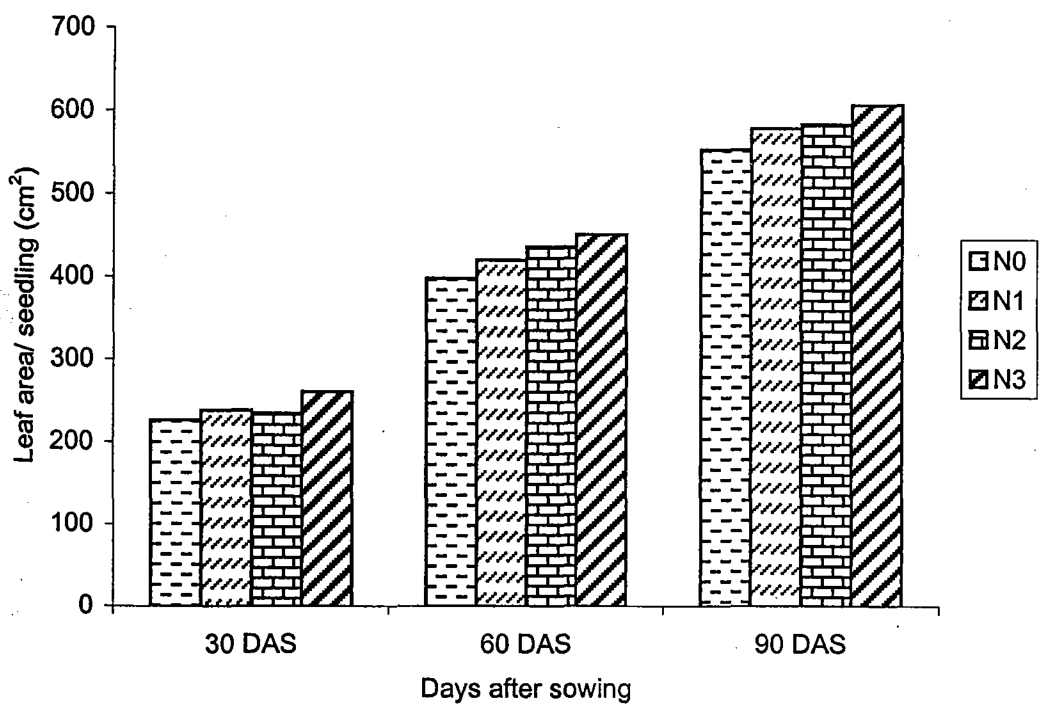


Fig.9 Effect of mineral supplements on leaf area of cashew seedlings



Leaf area was consistently high with the treatment N_3 at all stages (261.1, 451.6 and 608.2 cm^2 respectively) and the lowest in seedlings which did not receive any fertilizer, with corresponding values 227.1, 398.5 and 554.3 cm^2 at 30, 60 and 90 DAS respectively (Fig. 9).

Among the treatment combination, $PM_2 \times N_3$ resulted in the highest leaf area of 287.3 cm^2, 490.3 cm^2 and 644.1 cm^2 at 30, 60 and 90 DAS respectively, but its effect was on par with that of $PM_2 \times N_2$ with the values 268.1, 474.5 and 627.8 at the corresponding stages.

The overall data on growth characters reveals that the potting media with 1:1 soil and FYM (PM_2) was the best in terms of height, collar girth, leaf production and leaf area in cashew seedlings.

With regard to nutrient supplements, a complete mixture of N, P and K (200:100:200 g 100 kg^{-1}) was found better for all growth characters.

Among the treatment combinations, application of N and P (200 g N + 100 g P_2O_5) in 1:1 mixture of soil and FYM (PM_2) produced vigorous seedlings with higher number of leaves and leaf area.

b) Nutrient concentration

The data on nutrient concentration in shoot and root of seedlings at 90 DAS are given in Table 9. The concentration of major nutrients (N, P and K) in shoot portion of cashew seedlings differed significantly by potting media. The highest concentration of N (1.55 per cent), P (0.087 per cent) and K (1.33 per cent) was observed in seedlings raised in 1:1 mixture of soil and FYM (PM_2). The concentration of N, P and K in root tissues followed a pattern similar to that of shoot. The highest concentration of N (1.29 per cent) P (0.082 per cent) and K (1.09 per cent) were observed in roots of seedlings grown in a mixture of 50 per cent each of top soil and FYM (PM_2).

Although N concentration in shoot increased with mineral nutrients, the difference between the treatments were not significant. Phosphorus concentration in shoot was the highest (0.086 per cent) by the nutrient supplement N_2, but its effect was on par with that of N_3 (0.084 per cent). Potassium concentration was the highest (1.29 per cent) in seedlings supplemented with N, P and K whereas it was lowest (1.21 per cent) in those without any fertilizer. The concentration of both N and K (1.25

Table 9. Effect of potting media and nutrient supplements on nitrogen phosphorus and potassium content of cashew seedlings at 90 DAS

Trt. No.	Potting media	Shoot			Root		
		N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
PM_1	Soil : Sand : FYM (1:1:1)	1.48^{ab}	0.082^{b}	1.24^{b}	1.20^{b}	0.077^{b}	0.99^{b}
PM_2	Soil : FYM (1:1)	1.55^{a}	0.087^{a}	1.33^{a}	1.29^{a}	0.082^{a}	1.09^{a}
PM_3	Soil : Sand (1:1)	1.41^{b}	0.081^{b}	1.15^{c}	1.13^{c}	0.073^{c}	0.97^{b}
Trt. No.	Nutrient supplement*						
N_0	No nutrient supplement	1.46^{a}	0.082^{b}	1.21^{b}	1.20^{ab}	0.077^{ab}	1.00^{a}
N_1	200 g N	1.48^{a}	0.082^{b}	1.23^{b}	1.15^{b}	0.075^{b}	1.01^{a}
N_2	200 g N + 100 g P_2O_5	1.48^{a}	0.086^{a}	1.30^{b}	1.25^{a}	0.079^{a}	1.00^{a}
N_3	200 g N + 100 g P_2O_5 + 200 g K_2O	1.49^{a}	0.084^{a}	1.29^{a}	1.25^{ab}	0.078^{a}	1.06^{a}
Trt. No.	Treatments						
T_1	$PM_1 \times N_0$	1.48^{abc}	0.081^{cde}	1.20^{bc}	1.17^{bc}	0.081^{abc}	0.98^{de}
T_2	$PM_1 \times N_1$	1.50^{abc}	0.077^{e}	1.22^{bc}	1.17^{bc}	0.071^{d}	0.97^{de}
T_3	$PM_1 \times N_2$	1.50^{abc}	0.085^{bc}	1.22^{bc}	1.25^{abc}	0.081^{ab}	0.96^{de}
T_4	$PM_1 \times N_3$	1.42^{abc}	0.086^{abc}	1.31^{ab}	1.20^{abc}	0.077^{bc}	1.04^{abcd}
T_5	$PM_2 \times N_0$	1.51^{abc}	0.083^{cd}	1.38^{a}	1.29^{ab}	0.079^{abc}	1.10^{abc}
T_6	$PM_2 \times N_1$	1.58^{ab}	0.089^{ab}	1.26^{abc}	1.20^{abc}	0.083^{a}	1.03^{abcde}
T_7	$PM_2 \times N_2$	1.48^{abc}	0.090^{a}	1.30^{ab}	1.35^{a}	0.081^{ab}	1.12^{ab}
T_8	$PM_2 \times N_3$	1.61^{a}	0.086^{abc}	1.36^{a}	1.34^{a}	0.083^{a}	1.12^{a}
T_9	$PM_3 \times N_0$	1.40^{bc}	0.079^{de}	1.05^{d}	1.03^{bc}	0.071^{d}	0.94^{de}
T_{10}	$PM_3 \times N_1$	1.36^{c}	0.080^{de}	1.20^{bc}	1.08^{c}	0.072d	1.09^{bcde}
T_{11}	$PM_3 \times N_2$	1.43^{abc}	0.084^{bcd}	1.14^{cd}	1.14^{bc}	0.075^{cd}	0.93^{e}
T_{12}	$PM_3 \times N_3$	1.43^{abc}	0.082^{cd}	1.20^{bc}	1.15^{bc}	0.075^{cd}	1.00^{cde}

*per 100 kg potting media

and 1.06 per cent respectively) was highest in root tissues of seedlings applied with the treatment N_3. Seedlings grown in media supplemented with N_2 had the highest P content (0.079 per cent) but its effect was on par with that of N_3 (0.078 per cent).

Interaction between potting media and nutrient supplements had significant influence on N, P and K concentration in shoot tissues. Among the treatment combination $PM_2 \times N_3$ registered the highest concentration of nitrogen in shoot (1.61 per cent) and root $PM_2 \times N_2$ in root (1.34 per cent). In the case of P concentration, the treatment $PM_2 \times N_2$ gave the highest value in shoot whereas $PM_2 \times N_1$ and $PM_2 \times N_3$ gave the highest value in root. The K concentration in shoot was the highest (1.38 per cent) in treatment $PM_2 \times N_0$ whereas in root it was by $PM_2 \times N_3$ (1.12 per cent).

c) Dry matter production

The dry matter accumulation in seedlings was estimated only at 90 DAS and the data are given in Table 10. The dry matter accumulation in shoot (SDMP) as well as in roots (RDMP) was highest in seedlings grown in PM_2 with values of 12.87 and 3.39 g seedling^{-1}, respectively (Fig.10).

Seedlings supplemented with N and P (N_2) produced the highest dry matter in shoots (12.59 mg plant^{-1}) while those received N, P and K (N_3) gave the highest dry matter in roots (3.19 g plant^{-1}) at 90 DAS (Fig. 11).

Different potting media and nutrient supplements significantly influenced the total dry matter production (TDMP) in cashew seedlings. The highest TDMP (16.26 g plant^{-1}) was observed in seedlings raised in 1:1 mixture of soil and FYM (PM_2) and the lowest (13.23 g plant^{-1}) in 1:1 soil and sand (PM_3). Addition of N (N_1) in the potting media produced 14.69 g plant^{-1} while supplementation of both N and P (N_2) produced 15.75 g plant^{-1}. It was also found that the combination of NPK (N_3) did not have any significant benefit than that of NP (N_2).

The combination of $PM_2 \times N_2$ gave the highest TDMP (17.90 g plant^{-1}) while $PM_3 \times N_0$ gave the lowest value (11.19 g plant^{-1}).

d) Nutrient uptake

Potting media as well as nutrient supplements significantly influenced uptake of N, P and K by cashew seedlings (Table 11). Seedlings raised in PM_2 had

Table 10. Effect of potting media and nutrient supplements on dry matter production and uptake of N, P and K by cashew seedlings at 90 DAS

Trt. No.	Potting media	Dry matter production			Total uptake		
		Shoot (g plant^{-1})	Root (g plant^{-1})	Total (g plant^{-1})	N (mg plant^{-1})	P (mg plant^{-1})	K (mg plant^{-1})
PM_1	Soil : Sand : FYM (1:1:1)	11.46^{b}	3.00^{b}	14.46^{b}	204.97^{b}	11.77^{b}	171.32^{b}
PM_2	Soil : FYM (1:1)	12.87^{a}	3.39^{a}	16.26^{a}	241.72^{a}	13.97^{a}	207.15^{a}
PM_3	Soil : Sand (1:1)	10.45^{c}	2.77^{c}	13.23^{c}	178.11^{c}	10.53^{b}	147.16^{c}
Trt. No.	Nutrient supplement*						
N_0	No nutrient supplement	10.39^{b}	2.82^{b}	13.21^{b}	186.50^{b}	10.63^{c}	155.25^{b}
N_1	200 g N	11.65^{a}	3.04^{a}	14.69^{a}	207.79^{a}	11.91^{b}	173.47^{a}
N_2	200 g N + 100 g P_2O_5	12.59^{a}	3.16^{a}	15.75^{a}	224.78^{a}	13.40^{a}	185.99^{a}
N_3	200 g N + 100 g P_2O_5 + 200 g K_2O	11.76^{a}	3.19^{a}	14.95^{a}	213.99^{a}	12.43^{ab}	186.13^{a}
Trt. No.	Treatments						
T_1	$PM_1 \times N_0$	10.77^{cd}	3.06^{b}	13.83^{c}	196.61^{de}	11.19^{cde}	157.58^{c}
T_2	$PM_1 \times N_1$	10.73^{cd}	2.83^{c}	13.56^{c}	192.52^{de}	10.34^{ef}	158.15^{c}
T_3	$PM_1 \times N_2$	12.13^{bc}	2.97^{c}	15.10^{bc}	219.38^{bcd}	12.68^{bcd}	176.40^{bc}
T_4	$PM_1 \times N_3$	12.24^{abc}	3.14^{bc}	15.38^{bc}	211.39^{cde}	12.87^{bcd}	193.13^{b}
T_5	$PM_2 \times N_0$	11.58^{bc}	3.02^{bc}	14.60^{bc}	213.26^{cde}	12.00^{cd}	193.08^{b}
T_6	$PM_2 \times N_1$	13.34^{ab}	3.41^{ab}	16.75^{ab}	251.42^{ab}	14.67^{ab}	202.74^{ab}
T_7	$PM_2 \times N_2$	14.30^{a}	3.60^{a}	17.90^{a}	259.00^{a}	15.80^{a}	225.74^{a}
T_8	$PM_2 \times N_3$	12.25^{bc}	3.52^{a}	15.77^{abc}	243.22^{abc}	13.38^{bc}	207.02^{ab}
T_9	$PM_3 \times N_0$	8.81^{d}	2.38^{d}	11.19^{d}	149.65^{f}	8.69^{f}	115.10^{d}
T_{10}	$PM_3 \times N_1$	10.87^{cd}	2.89^{c}	13.76^{c}	179.44^{ef}	10.71^{def}	159.50^{c}
T_{11}	$PM_3 \times N_2$	11.34^{bc}	2.91^{c}	14.26^{bc}	195.97^{de}	11.71^{cde}	155.83^{c}
T_{12}	$PM_3 \times N_3$	10.79^{cd}	2.90^{c}	13.69^{c}	187.36^{de}	11.03^{de}	158.23^{c}

*per 100 kg potting media

Fig.10 Effect of potting media on dry matter production of cashew seedlings

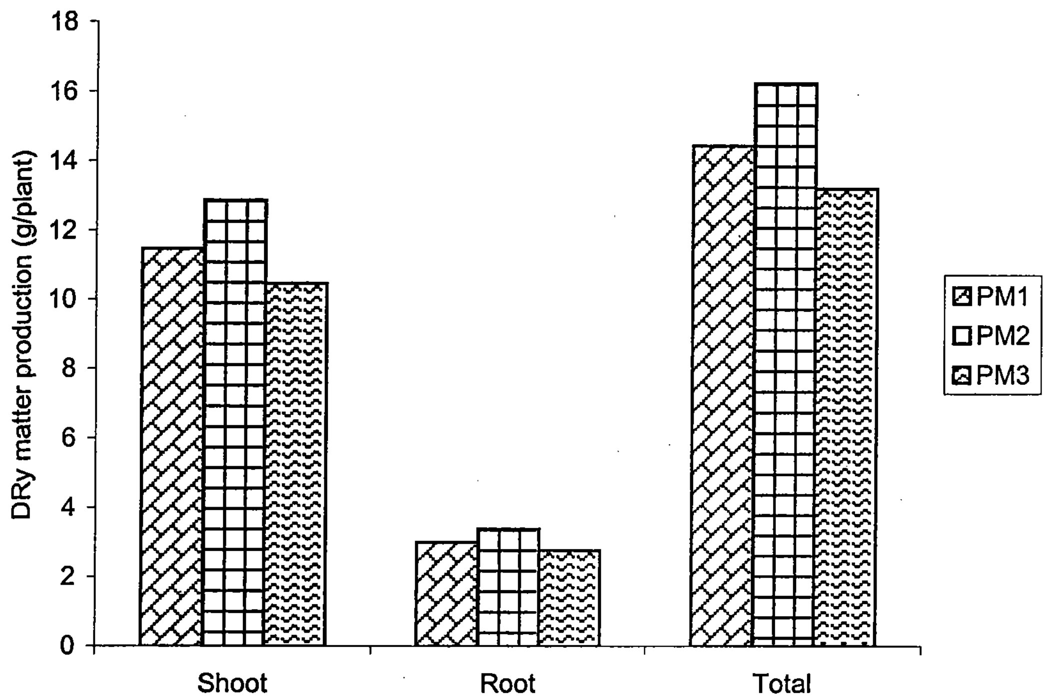


Fig.11 Effect of nutrient supplements on dry matter production of cashew seedlings

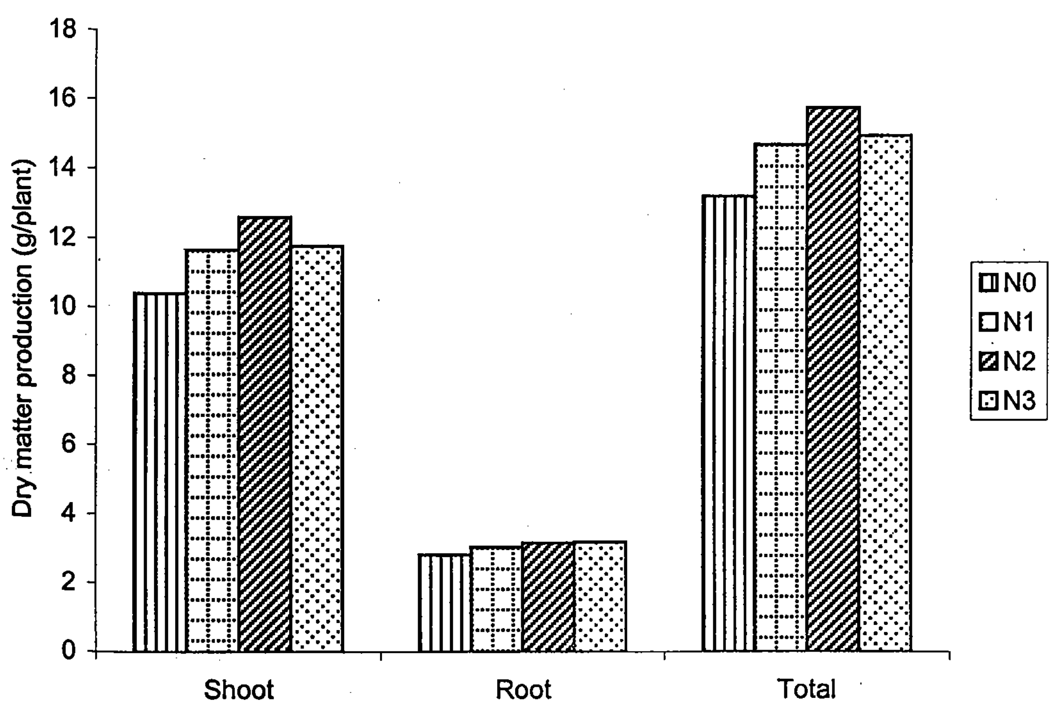


Table 11. Effect of potting media and nutrient supplements on uptake of N, P and K by shoot and root of cashew seedlings at 90 DAS

Trt. No.	Potting media	Shoot			Root		
		N (mg plant^{-1})	P (mg plant^{-1})	K (mg plant^{-1})	N (mg plant^{-1})	P (mg plant^{-1})	K (mg plant^{-1})
PM_1	Soil : Sand : FYM (1:1:1)	169.09^{b}	9.46^{b}	141.74^{b}	35.88^{b}	2.32^{b}	29.57^{b}
PM_2	Soil : FYM (1:1)	197.87^{a}	11.20^{a}	170.21^{a}	43.86^{a}	2.77^{a}	36.94^{a}
PM_3	Soil : Sand (1:1)	146.97^{c}	8.50^{c}	120.16^{c}	31.14^{b}	2.04^{c}	27.00^{c}
Trt. No.	Nutrient supplement*						
N_0	No nutrient supplement	152.56^{b}	8.44^{c}	126.83^{b}	33.94^{b}	2.18^{b}	28.43^{c}
N_1	200 g N	172.73^{a}	9.60^{b}	142.82^{a}	35.06^{b}	2.31^{ab}	30.65^{bc}
N_2	200 g N + 100 g P_2O_5	185.22^{a}	10.90^{a}	154.11^{a}	39.56^{a}	2.50^{a}	31.87^{ab}
N_3	200 g N + 100 g P_2O_5 + 200 g K_2O	174.72^{a}	9.92^{ab}	152.39^{a}	39.27^{a}	2.51^{a}	33.73^{a}
Trt. No.	Treatments						
T_1	$PM_1 \times N_0$	160.59^{bc}	8.75^{cde}	127.75^{c}	36.02^{bcd}	2.44^{bc}	29.84^{cde}
T_2	$PM_1 \times N_1$	159.70^{bc}	8.33^{de}	130.80^{c}	32.86^{cde}	2.01^{cd}	27.35^{e}
T_3	$PM_1 \times N_2$	182.42^{abc}	10.29^{bcd}	147.92^{bc}	36.96^{bcd}	2.40^{bc}	28.48^{de}
T_4	$PM_1 \times N_3$	173.68^{abc}	10.47^{bc}	160.51^{ab}	37.70^{bcd}	2.41^{bc}	32.63^{bcd}
T_5	$PM_2 \times N_0$	174.18^{abc}	9.59^{cd}	160.03^{ab}	39.07^{bc}	2.41^{bc}	33.05^{bc}
T_6	$PM_2 \times N_1$	210.52^{a}	11.83^{ab}	167.61^{ab}	40.90^{b}	2.84^{a}	35.14^{b}
T_7	$PM_2 \times N_2$	210.55^{a}	12.90^{a}	185.68^{a}	48.45^{a}	2.90^{a}	40.06^{a}
T_8	$PM_2 \times N_3$	196.22^{ab}	10.47^{bc}	167.51^{ab}	47.00^{a}	2.91^{a}	39.51^{a}
T_9	$PM_3 \times N_0$	122.90^{d}	6.99^{e}	92.71^{d}	26.74^{e}	1.69^{d}	22.30^{f}
T_{10}	$PM_3 \times N_1$	148.02^{cd}	8.64^{cde}	130.04^{c}	31.42^{de}	2.07^{bcd}	29.46^{cde}
T_{11}	$PM_3 \times N_2$	162.70^{bc}	9.51^{cd}	128.74^{c}	33.27^{cd}	2.20^{bc}	27.08^{e}
T_{12}	$PM_3 \times N_3$	154.26^{cd}	8.84^{cde}	129.17^{c}	33.10^{cde}	2.20^{bc}	29.06^{cde}

*per 100 kg potting media

significantly higher content of N, P and K in shoot and the values recorded were 197.87, 11.20 and 170.21 mg plant^{-1}, respectively. The treatment PM_3 gave relatively low uptake of N, P and K in shoot tissues and the corresponding values observed were 146.97, 8.50 and 120.16 mg plant^{-1}.

Among the nutrient supplements, the effect of N_1 was on par with that of N_2 and N_3 with regard to nutrient uptake. Treatment combinations of potting media and nutrient supplements produced significant differences in uptake of N, P and K by shoot tissues. Uptake of the three major nutrients studied was more in treatment combinations of PM_2 with different doses of nutrient supplements. The highest uptake was observed in the treatment combination $PM_2 \times N_2$ and the lowest uptake in the treatment combination which did not receive FYM as well as mineral supplements ($PM_3 \times N_0$).

The effect of treatment combination on uptake of N, P and K through roots followed a similar pattern to that of shoots. The highest uptake of N and K was noticed in seedlings under $PM_2 \times N_2$ treatment, with the values of 48.45 mg and 40.06 mg plant^{-1} respectively. The highest uptake of P (2.91 mg plant^{-1}) was observed in the treatment combination $PM_2 \times N_3$ but it was on par with $PM_2 \times N_2$ (2.90 mg plant^{-1}).

The treatment PM_2 gave the highest total uptake of N, P and K with the values of 241.72, 13.97 and 207.15 mg plant^{-1}, respectively. Total uptake of nutrients followed a trend similar to that of total dry matter production.

The highest total uptake of N, P and K was observed in seedlings grown in PM_2 and supplemented with 200 g N and 100 g P_2O_5 ($PM_2 \times N_2$) and the lowest in plants that received the treatment combination $PM_3 \times N_0$. Uptake of K increased gradually with addition of nutrients from the level N_0 to N_3, whereas in the case of N and P increase was noticed up to the treatment N_2 only.

4.1.2 Exp. I b Effect of lime incorporation in potting media on growth of cashew root stocks

The results of the experiment on the effect of lime incorporation in potting media on growth of cashew seedlings in the nursery are presented below. The data are furnished in Tables 12 to 16.

a) Growth characters

Incorporation of lime at different levels (100, 200, 300, 400 and 500 g per 100 kg potting media) did not produce any effect on height of seedlings at 30, 60 or 90 days after sowing (DAS). Height of seedlings varied from 13.33 cm to 15.05 cm at 30 DAS and from 24.0 cm to 27.3 cm at 90 DAS (Table 12).

Collar girth was not affected by lime at levels ranging from 100 g to 500 g. The collar girth at 30 DAS ranged from 2.51 cm to 2.70 cm, at 60 DAS from 2.67 to 2.94 cm and at 90 DAS from 3.19 cm to 3.36 cm. Leaf production in cashew seedlings did not vary by incorporation of lime.

Incorporation of lime in potting media did not exert any significant influence on either shoot dry matter production (SDMP) or root dry matter production (RDMP) of cashew seedling observed at 30, 60 and 90 DAS (Table 13). Shoot dry matter production varied from 2.59 to 2.78 mg plant^{-1} at 30 DAS, 5.33 to 5.73 mg plant^{-1} at 60 DAS and 11.5 to 12.1 mg plant^{-1} at 90 DAS. Root dry matter production varied from 0.89 to 1.02 mg plant^{-1} at 30 DAS, 1.80 to 2.07 mg plant^{-1} at 60 DAS and 3.36 to 3.87 mg plant^{-1} at 90 DAS. The root shoot ratio (RS ratio) at 30 DAS and 60 DAS was significantly influenced by different levels of lime (Table 14). Application of lime at 300 g 100 kg^{-1} potting media (L_3) gave the highest RS ratio at 30 DAS. At 60 DAS, the highest RS ratio was observed in the treatment L_2 (200 g lime 100 kg^{-1}) but its effect was on par with treatments L_3 and L_4 (300 g and 400 g 100 kg^{-1} potting media) respectively. The different levels of lime did not influence the RS ratio at 90 DAS.

The nutrient concentration (N, P and K) of shoot as well as roots was estimated at 90 DAS (Table 15). Incorporation of lime at various levels ranging from 100 g up to 500 g 100 kg^{-1} potting media did not show any spectacular change in the nutrient concentration of shoot as well as root.

Similar results were obtained in the uptake of nutrients also (Table 16). Even though the different levels were on par, seedlings that were applied with lime at 300 g 100 kg^{-1} potting media recorded the highest N uptake through shoot (156.2 mg plant^{-1}) and those applied with lime at 200 g or 400 g 100 kg^{-1} recorded the highest N uptake (77.7 mg plant^{-1}) through root. Phosphorus uptake in shoot ranged from 9.9 mg to 11.26 mg plant^{-1} and in root from 2.5 mg to 3.1 mg plant^{-1}. In the case of potassium, the values ranged from 136.8 to 144.1 mg plant^{-1} and from 34.7 to 44.4 mg plant^{-1} in shoot and root portions respectively.

Table 12. Effect of lime incorporation in potting media on growth characters of cashew seedlings

Treatment Notation	Levels of lime	Height (cm)			Collar girth (cm)			No. of leaves/seedling		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
L_0	Control (No lime)	13.33^{d}	21.72^{a}	25.88^{ab}	2.60^{a}	2.82^{ab}	3.19^{a}	10.78^{a}	15.27^{a}	17.73^{a}
L_1	Lime @ 100 g 100 kg potting media^{-1}	13.67^{cd}	22.28^{a}	27.23^{a}	2.61^{a}	2.85^{ab}	3.22^{a}	9.63^{a}	14.55^{a}	19.35^{a}
L_2	Lime @ 200 g 100 kg potting media^{-1}	15.05^{a}	21.14^{a}	24.85^{ab}	2.52^{a}	2.74^{ab}	3.36^{a}	10.32^{a}	14.66^{a}	17.04^{a}
L_3	Lime @ 300 g 100 kg potting media^{-1}	14.25^{bc}	20.94^{a}	25.68^{ab}	2.58^{a}	2.76^{ab}	3.32^{a}	10.21^{a}	15.80^{a}	17.88^{a}
L_4	Lime @ 400 g 100 kg potting media^{-1}	14.63^{ab}	19.74^{a}	24.05^{b}	2.51^{a}	2.67^{b}	3.28^{a}	10.83^{a}	14.91^{a}	18.92^{a}
L_5	Lime @ 500 g 100 kg potting media^{-1}	14.29^{bc}	21.91^{a}	27.25^{a}	2.70^{a}	2.94^{a}	3.34^{a}	10.38^{a}	15.19^{a}	19.25^{a}
SEm±		0.76	1.29	1.46	0.06	0.07	0.13	0.67	0.54	0.79

Table 13. Effect of lime incorporation in potting media on dry matter production of cashew seedlings

Treatment Notation	Levels of lime	Shoot DMP (g plant^{-1})			Root DMP (g plant^{-1})		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
L_0	Control (No lime)	2.74^{a}	5.69^{a}	12.10^{a}	0.90^{a}	1.80^{a}	3.36^{a}
L_1	Lime @ 100 g 100 kg potting media^{-1}	2.59^{a}	5.67^{a}	11.50^{a}	0.89^{a}	1.84^{a}	3.65^{a}
L_2	Lime @ 200 g 100 kg potting media^{-1}	2.78^{a}	5.50^{a}	12.10^{a}	0.96^{a}	2.07^{a}	3.87^{a}
L_3	Lime @ 300 g 100 kg potting media^{-1}	2.69^{a}	5.64^{a}	11.80^{a}	1.02^{a}	2.05^{a}	3.58^{a}
L_4	Lime @ 400 g 100 kg potting media^{-1}	2.60^{a}	5.33^{a}	11.60^{a}	0.98^{a}	1.89^{a}	3.85^{a}
L_5	Lime @ 500 g 100 kg potting media^{-1}	2.67^{a}	5.73^{a}	11.80^{a}	0.99^{a}	2.07^{a}	3.84^{a}
SEm±		0.12	0.24	0.35	0.05	0.09	0.24

Table 14. Effect of lime incorporation in potting media on root: shoot ratio of cashew seedlings and pH of potting media

Treatment Notation	Levels of lime	Root: Shoot ratio			pH		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
L_0	Control (No lime)	0.33^{c}	0.32^{b}	0.28^{a}	5.6^{c}	5.7^{c}	5.6^{a}
L_1	Lime @ 100 g 100 kg potting media^{-1}	0.35^{abc}	0.32^{b}	0.32^{a}	5.8^{b}	5.8^{bc}	5.7^{a}
L_2	Lime @ 200 g 100 kg potting media^{-1}	0.34^{bc}	0.37^{a}	0.32^{a}	6.1^{a}	6.2^{a}	5.8^{a}
L_3	Lime @ 300 g 100 kg potting media^{-1}	0.38^{a}	0.36^{a}	0.30^{a}	6.1^{a}	6.0^{ab}	5.8^{a}
L_4	Lime @ 400 g 100 kg potting media^{-1}	0.37^{ab}	0.35^{ab}	0.33^{a}	6.1^{a}	6.0^{ab}	5.7^{a}
L_5	Lime @ 500 g 100 kg potting media^{-1}	0.37^{ab}	0.36^{a}	0.33^{a}	6.1^{a}	6.1^{a}	5.8^{a}
SEm±		0.01	0.01	0.02	0.1	0.1	0.1

Table 15. Effect of lime incorporation in potting media on N, P and K concentration in cashew seedlings at 90 DAS

Treatment Notation	Levels of lime	Shoot			Root		
		N%	P%	K%	N%	P%	K%
L_0	Control (No lime)	1.23[a]	0.090[a]	1.19[a]	1.38[a]	0.078[a]	1.09[a]
L_1	Lime @ 100 g 100 kg potting media^{-1}	1.27[a]	0.097[a]	1.25[a]	1.26[a]	0.080[a]	0.95[a]
L_2	Lime @ 200 g 100 kg potting media^{-1}	1.26[a]	0.085[a]	1.13[a]	1.37[a]	0.080[a]	0.93[a]
L_3	Lime @ 300 g 100 kg potting media^{-1}	1.32[a]	0.086[a]	1.13[a]	1.27[a]	0.075[a]	1.02[a]
L_4	Lime @ 400 g 100 kg potting media^{-1}	1.28[a]	0.082[a]	1.18[a]	1.38[a]	0.072[a]	1.07[a]
L_5	Lime @ 500 g 100 kg potting media^{-1}	1.27[a]	0.089[a]	1.22[a]	1.38[a]	0.071[a]	1.16[a]
SEm±		0.07	0.006	0.12	0.05	0.004	0.10

Table 16. Effect of lime incorporation in potting media on uptake of N, P and K by cashew seedlings at 90 DAS

Treatment Notation	Levels of lime	Shoot nutrient uptake*			Root nutrient uptake*		
		N	P	K	N	P	K
L_0	Control (No lime)	149.3[a]	9.9[a]	144.1[a]	46.4[a]	2.7[b]	36.7[a]
L_1	Lime @ 100 g 100 kg potting media^{-1}	145.5[a]	11.2[a]	143.5[a]	45.8[a]	2.9[ab]	34.7[a]
L_2	Lime @ 200 g 100 kg potting media^{-1}	152.3[a]	10.3[a]	136.1[a]	53.0[a]	3.1[a]	36.0[a]
L_3	Lime @ 300 g 100 kg potting media^{-1}	156.2[a]	10.6[a]	133.7[a]	45.5[a]	2.9[ab]	36.5[a]
L_4	Lime @ 400 g 100 kg potting media^{-1}	148.9[a]	10.8[a]	136.8[a]	53.0[a]	2.7[b]	41.2[a]
L_5	Lime @ 500 g 100 kg potting media^{-1}	149.4[a]	10.5[a]	143.9[a]	52.8[a]	2.7[b]	44.5[a]
SEm±		5.8	0.7	15.4	4.9	0.1	6.3

*mg plant^{-1}

4.2 Exp. II Effect of soil nutrient regimes on leaf nutrient status and yield of graft-raised cashew

Results of the field experiment conducted during 1997-99 to study the response of graft raised cashew to varying nutrient regimes are furnished in this section.

4.2.1 Growth characters

i) Tree height

Tree height did not differ significantly due to the different levels of fertilizer application in any of the years studied (10^{th}, 11^{th} and 12^{th} year after planting). Therefore an attempt was made to compare the increase in height due to treatments between 10^{th} and 12^{th} YAP (Table 17). The increase in height was significantly different and the maximum increase was with the highest dose of fertilizer application at 1500 g N, 650 g P_2O_5 and 1500 g K_2O tree^{-1} (F_4), but it was on par with that of F_2 (750 g N, 325 g P_2O_5 and 750 g K_2O) and F_3 (1125 g N, 490 g P_2O_5 and 1125 g K_2O).

ii) Tree girth

As in the case of plant height, tree girth did not differ significantly between the various nutrient regimes in the year wise observation, but it ranged from 84.6 cm (F_1) to 98.7 cm (F_4) at 10 YAP and 95.0 cm (F_1) to 109.4 cm (F_4) during 12 YAP (Table 18). Girth increase from 10 to 12 YAP was statistically significant with the maximum increment in the treatment F_3 (11.7 cm), followed by F_4 (10.7 cm).

iii) Canopy spread

Canopy spread did not increase due to different nutrient regimes in any of the years studied (Table 19).

The results suggest that the growth characters in terms of height and girth differed due to change in fertility regimes up to the highest level.

iv) Number of flushes

The flush production differed significantly by levels of fertilizers during the first two years (10^{th} and 11^{th} YAP), but this effect was not observed during all the years. Number of flushes per unit area was the highest with the treatment F_4 (40.3 m^{-2}), but its effect was on par with that of the lower levels of F_2 and F_3 when the average of the

Table 17. Effect of levels of fertilizers on tree height (m)

Trt. No.	Fertilizer levels*	Years after planting			Increase in height (10-12 YAP) (m)
		10 YAP	11 YAP	12 YAP	
F_0	No fertilizer	7.30[a]	7.56[a]	8.14[a]	0.84[d]
F_1	375:165:375	6.88[a]	7.26[a]	7.98[a]	1.10[c]
F_2	750:325:750	6.94[a]	7.32[a]	8.26[a]	1.32[bc]
F_3	1125:490:1125	7.06[a]	7.48[a]	8.38[a]	1.32[ab]
F_4	1500:650:1500	6.68[a]	7.30[a]	8.16[a]	1.48[a]
SEm±		0.20	0.18	0.19	0.07

Table 18. Effect of levels of fertilizers on tree girth (cm)

Trt. No.	Fertilizer levels*	Years after planting			Increase in girth (10-12 YAP) (cm)
		10 YAP	11 YAP	12 YAP	
F_0	No fertilizer	88.6[a]	91.4[a]	96.0[a]	7.4[a]
F_1	375:165:375	84.6[a]	90.6[a]	95.0[a]	10.4[ab]
F_2	750:325:750	91.8[a]	96.8[a]	99.6[a]	7.8[bc]
F_3	1125:490:1125	89.7[a]	95.2[a]	101.4[a]	11.7[a]
F_4	1500:650:1500	98.7[a]	105.6[a]	109.4[a]	10.7[a]
SEm±		6.7	6.9	7.0	0.9

Table 19. Effect of levels of fertilizers on canopy spread (m)

Trt. No.	Fertilizer levels*	Years after planting			Increase in canopy size (10-12 YAP) (m)
		10 YAP	11 YAP	12 YAP	
F_0	No fertilizer	7.68[a]	8.52[a]	8.63[a]	0.95[a]
F_1	375:165:375	7.45[a]	7.65[a]	8.58[a]	1.13[a]
F_2	750:325:750	8.51[a]	9.24[a]	9.42[a]	0.91[a]
F_3	1125:490:1125	8.19[a]	8.75[a]	9.30[a]	1.11[a]
F_4	1500:650:1500	8.64[a]	8.89[a]	9.75[a]	1.11[a]
SEm±		0.54	0.54	0.60	0.15

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

three years was considered (Table 20). The lowest flush production was observed in trees that did not receive any fertilizer (28.3 m^{-2}).

v) Number of panicles

Panicle number differed significantly between treatments in all the three years and the highest value (27.7 m^{-2}) was noticed with the trees applied with fertilizers at the dose of 1500 g N, 650 g P_2O_5 and 1500 g K_2O (F_4), but the lower levels of F_2 and F_3 were on par with the highest dose in panicle production (Table 21).

vi) Panicle length

Effect of fertilizers on panicle length was significant only during the first and third years (10 and 12 YAP). The panicle length when averaged for three years was the highest (17.97 cm) with the trees treated with F_2 and its effect was on par with that of all the treatments except control. Increase in fertilizer beyond F_1 (375 g N, 165 g P_2O_5 and 375 g K_2O) did not produce any effect on length of panicle (Table 22).

vii) Panicle width

Fertilizer treatments did not produce any effect to change the width of panicle in any of the years studied (Table 23). The average width of panicle ranged from 22.31 cm (F_0) to 24.57 cm (F_4).

viii) Number of flowers per panicle

The effect of fertilizer treatments on flower production was evident during the second and third years of the study (Table 24). The number of flowers per panicle (average for three years) was the highest with F_3 (520.7) and it was on par with F_2 (519.4) and F_4 (503.7).

ix) Percentage of bisexual flowers

Production of bisexual flowers differed considerably due to levels of fertilizers and this effect was noticed in all the three years (Table 25). The percentage of bisexual flowers (mean for three years) was the lowest (9.38 per cent) in trees which received no fertilizer, and the highest (17.13 per cent) in trees applied with a dose of F_2 (750 g N, 325 g P_2O_5 and 750 g K_2O). Further increase in fertilizer application did not increase the production of bisexual flowers.

Table 20. Effect of fertilizer levels on number of flushes (m^{-2})

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	27.8^c	29.4^b	27.8^c	28.3^c
F_1	375:165:375	32.8^b	30.8^b	32.0^b	31.9^b
F_2	750:325:750	38.8^a	36.6^a	39.2^a	38.2^a
F_3	1125:490:1125	39.2^a	39.6^a	40.0^a	39.6^a
F_4	1500:650:1500	40.8^a	39.4^a	40.6^a	40.3^a
SEm±		1.4	1.6	1.2	1.0

Table 21. Effect of fertilizer levels on number of panicles (m^{-2})

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	18.2^b	19.4^c	19.2^b	18.9^b
F_1	375:165:375	21.8^b	22.4^{bc}	22.0^{ab}	22.1^b
F_2	750:325:750	26.2^a	26.4^{ab}	26.4^a	26.3^a
F_3	1125:490:1125	26.8^a	27.2^a	25.8^a	26.6^a
F_4	1500:650:1500	27.6^a	29.4^a	26.2^a	27.7^a
SEm±		1.4	1.5	1.8	1.2

* g N, P_2O_5, K_2O $tree^{-1}$ $year^{-1}$

Table 22. Effect of fertilizer levels on length of panicle (cm)

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	16.02[b]	17.54[a]	15.40[b]	16.32[b]
F_1	375:165:375	17.00[ab]	17.68[a]	15.52[b]	16.74[ab]
F_2	750:325:750	18.80[a]	17.52[a]	17.58[a]	17.97[a]
F_3	1125:490:1125	16.40[b]	17.14[a]	17.32[a]	16.95[ab]
F_4	1500:650:1500	18.10[a]	17.28[a]	16.65[ab]	17.34[ab]
SEm±		0.72	0.15	0.57	0.45

Table 23. Effect of fertilizer levels on width of panicle (cm)

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	21.38[a]	23.94[a]	21.60[b]	22.31[b]
F_1	375:165:375	24.62[a]	25.98[a]	22.69[ab]	24.43[a]
F_2	750:325:750	22.70[a]	24.52[a]	24.26[a]	23.83[ab]
F_3	1125:490:1125	23.96[a]	22.98[a]	23.29[ab]	23.41[ab]
F_4	1500:650:1500	23.90[a]	24.92[a]	24.89[a]	24.57[a]
SEm±		1.05	0.98	0.75	0.89

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Table 24. Effect of fertilizer levels on total number of flowers in a panicle

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	462.4^b	424.1^b	155.0^c	347.1^b
F_1	375:165:375	518.4^{ab}	490.2^b	194.9^{bc}	401.0^b
F_2	750:325:750	596.4^a	636.1^a	325.7^a	519.4^a
F_3	1125:490:1125	573.6^a	640.3^a	348.6^a	520.7^a
F_4	1500:650:1500	590.6^a	627.4^a	293.7^{ab}	503.7^a
SEm±		32.8	30.3	23.7	25.1

Table 25. Effect of fertilizer levels on percentage of bisexual flowers

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	11.80^b	9.60^b	6.74^c	9.38^c
F_1	375:165:375	12.00^b	12.80^b	6.90^c	10.57^c
F_2	750:325:750	16.80^a	20.20^a	15.30^a	17.53^a
F_3	1125:490:1125	17.80^a	18.60^a	13.80^{ab}	16.73^a
F_4	1500:650:1500	15.40^{ab}	17.00^a	10.34^{bc}	14.25^b
SEm±		1.16	1.27	1.29	0.79

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

The data on flowering characters (number of panicles, panicle length, panicle width, number of flowers and the percentage of bisexual flowers) reveal that flower production and floral characters in cashew did not improve beyond the fertilizer dose of F_2.

x) Chlorophyll content of leaves

Fertilizer treatments increased the chlorophyll *a* content of leaves at flushing stage only during the second and third years of the study (Table 26). During the second year (11 YAP), the highest chlorophyll *a* content (1.48 mg g^{-1}) in leaves was noticed in trees treated with a fertilizer dose of F_2 (750 g N, 325 g P_2O_5 and 750 g K_2O). Mean values of chlorophyll *a* for the three year period (10 to 12 YAP) was the highest in the leaves of trees treated with F_2 (1.43 mg g^{-1}). Enhancing the level of applied fertilizers beyond the dose of F_2 did not increase the chlorophyll *a* content of leaves (Fig. 14).

At flowering stage, chlorophyll *a* content was high in leaves of trees treated with fertilizers compared to trees that received no fertilizers (Table 27). Between stages chlorophyll *a* content was high during flushing stage (1.12 to 1.43 mg g^{-1}) than during flowering stage (0.78 to 0.97 mg g^{-1}). During the first year of the study, the leaf chlorophyll did not increase beyond the fertilizer level F_1 (375 g N, 165 g P_2O_5 and 375 g K_2O). But during the subsequent years (11 and 12 YAP), the chlorophyll *a* content increased with increase in fertilizer up to the dose of F_2 (750 g N, 325 g P_2O_5 and 750 g K_2O). The mean values of chlorophyll *a* content at flowering also did not increase beyond the treatment F_2.

Chlorophyll *b* content of leaves at flushing stage increased with fertilizer application and the trend was seen during the second and third years only (Table 28). In general, the chlorophyll *b* content increased with fertilizer treatment up to a dose of F_2.

As in the case of flushing, the chlorophyll *b* content of leaves at flowering stage also differed considerably due to fertilizer treatments (Table 29). It increased with fertilizer application up to a fertilizer dose of F_2. When the average values for the three years was considered chlorophyll *b* content was the highest (0.75 mg g^{-1}) in trees applied with fertilizers at the dose of F_2 and the lowest (0.65 mg g^{-1}) in trees that received no fertilizers. Between stages, the chlorophyll *b* content was high at flushing (0.75 to 0.96 mg g^{-1}) compared to flowering (0.65 to 0.75 mg g^{-1}).

Table 26. Effect of fertilizer levels on chlorophyll *a* content (mg g^{-1}) of leaves at flushing stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	1.00^{b}	1.18^{d}	1.17^{b}	1.12^{b}
F_1	375:165:375	1.01^{b}	1.26^{cd}	1.21^{ab}	1.16^{b}
F_2	750:325:750	1.41^{a}	1.48^{a}	1.39^{a}	1.43^{a}
F_3	1125:490:1125	1.34^{a}	1.43^{ab}	1.34^{ab}	1.41^{a}
F_4	1500:650:1500	1.37^{a}	1.33^{bc}	1.35^{a}	1.38^{a}
SEm±		0.11	0.04	0.06	0.05

Table 27. Effect of fertilizer levels on chlorophyll *a* content (mg g^{-1}) of leaves at flowering stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.77^{b}	0.84^{c}	0.74^{b}	0.78^{d}
F_1	375:165:375	0.84^{ab}	0.85^{bc}	0.82^{b}	0.83^{c}
F_2	750:325:750	0.90^{a}	1.01^{a}	0.99^{a}	0.97^{a}
F_3	1125:490:1125	0.90^{a}	0.91^{b}	0.98^{a}	0.93^{b}
F_4	1500:650:1500	0.88^{a}	1.02^{a}	0.95^{a}	0.96^{a}
SEm±		0.03	0.02	0.03	0.01

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Table 28. Effect of fertilizer levels on chlorophyll *b* content (mg g^{-1}) of leaves at flushing stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.86^{b}	0.69^{d}	0.70^{b}	0.75^{d}
F_1	375:165:375	0.90^{ab}	0.80^{c}	0.72^{b}	0.81^{c}
F_2	750:325:750	1.02^{a}	0.93^{ab}	0.90^{a}	0.96^{a}
F_3	1125:490:1125	1.00^{ab}	0.88^{b}	0.88^{a}	0.89^{b}
F_4	1500:650:1500	0.96^{ab}	0.96^{a}	0.87^{a}	0.91^{ab}
SEm±		0.05	0.03	0.03	0.03

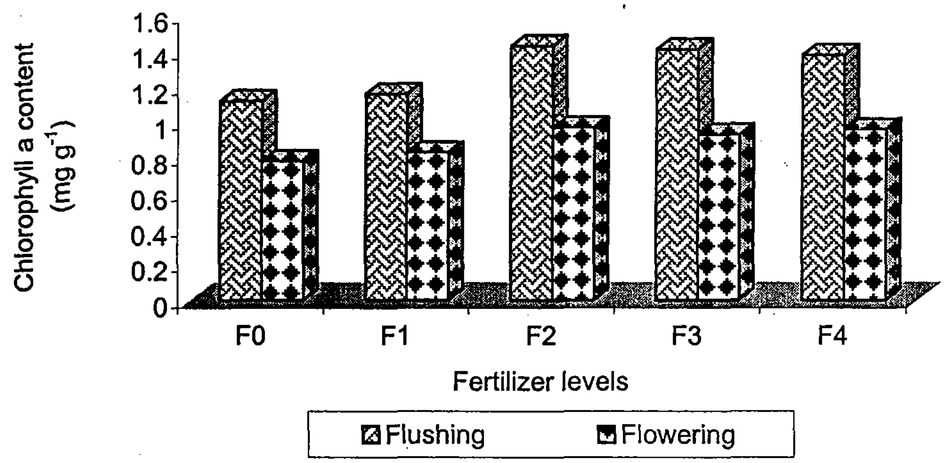
Table 29. Effect of fertilizer levels on chlorophyll *b* content (mg g^{-1}) of leaves at flowering stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.69^{b}	0.61^{a}	0.63^{b}	0.65^{c}
F_1	375:165:375	0.71^{b}	0.65^{a}	0.72^{a}	0.69^{b}
F_2	750:325:750	0.80^{a}	0.66^{a}	0.78^{a}	0.75^{a}
F_3	1125:490:1125	0.81^{a}	0.64^{a}	0.75^{a}	0.74^{a}
F_4	1500:650:1500	0.78^{a}	0.70^{a}	0.72^{a}	0.73^{a}
SEm±		0.01	0.05	0.03	0.01

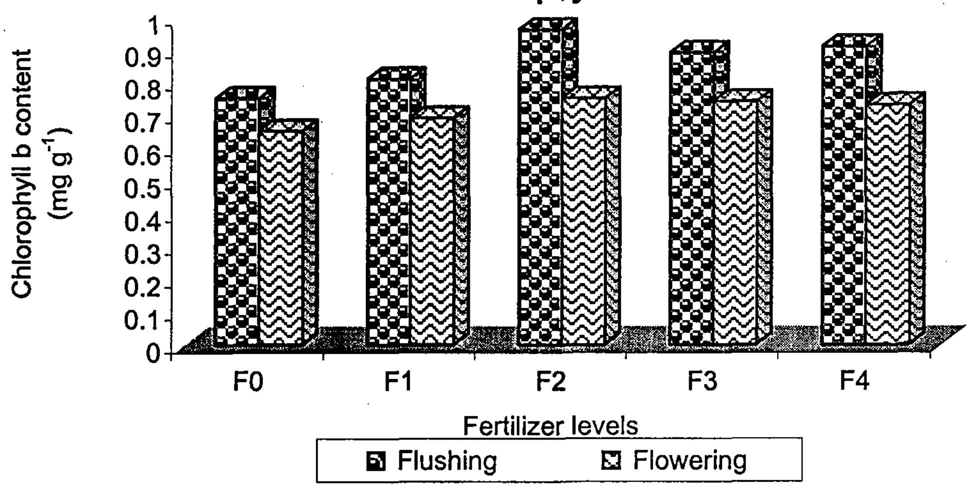
* g N, P_2O_5, K_2O $tree^{-1}$ $year^{-1}$

Fig.12. Effect of fertilizer levels on chlorophyll content of leaves at flushing and flowering stages

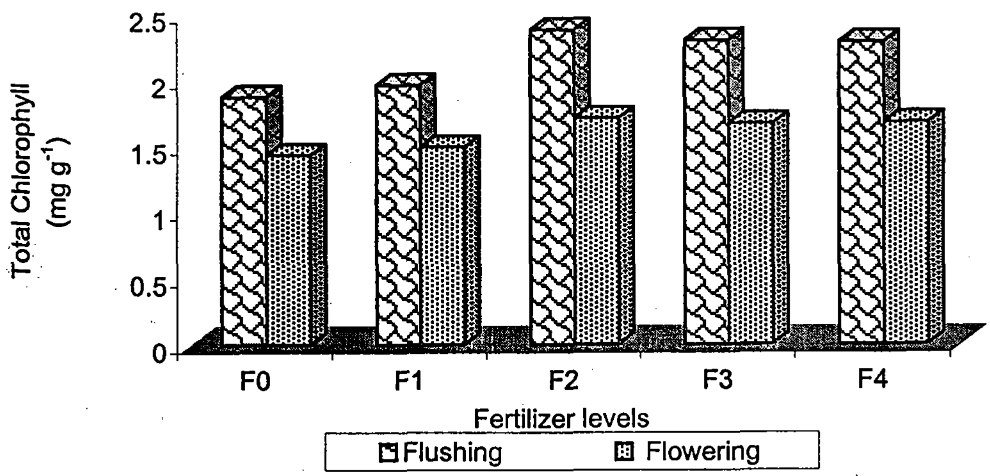
a. Chlorophyll *a*



b. Chlorophyll *b*



c. Total Chlorophyll



Total chlorophyll content at flushing stage increased with increase in fertilizer application up to a dose of F_2 (Table 30). Total chlorophyll content was the highest at the dose of F_2 (2.38 mg g^{-1}) and the lowest (1.87 mg g^{-1}) in leaves of trees that received no fertilizer.

Total chlorophyll content at flowering ranged from 1.43 mg g^{-1} (F_0) to 1.71 mg g^{-1} (F_2). Further increase in applied fertilizer above the dose of F_2 did not increase the total chlorophyll content at flowering (Table 31).

Between the stages, total chlorophyll content was high at flushing 1.87 to 2.38 mg g^{-1}) compared to flowering stage (1.43 to 1.71 mg g^{-1}).

4.2.2 Yield and yield components

i) Number of nuts per panicle

The number of nuts per panicle differed significantly with fertilizer application (Table 32) in all years under study. The number of nuts per panicle was the highest (6.71) in trees receiving fertilizers at 750 g N, 325 g P_2O_5 and 750 g K_2O and the lowest (5.23) in trees that received no fertilizers when the average over 3 years was taken into account.

ii) Harvest duration

The duration of harvest or spread of harvesting time changed with levels of fertilizer application excepting in the second year of the study (Table 33). When the average duration for three years was taken, harvest duration was the highest (60.4 days) in trees that received fertilizers at the level F_3 and the lowest (45 days) in unfertilized trees.

iii) Nut yield

Before introducing the fertilizer treatments (during 9 YAP), the trees selected for the study were grouped in to various plots and replication and the nut yield from individual plots were recorded. The data were subjected to statistical analysis. Although the nut yield of trees under different treatments (proposed) ranged from 7.24 kg $tree^{-1}$ to 11.27 kg $tree^{-1}$, they remained statistically on par.

During the first year after imposing fertilizer treatments, nut yield differed significantly between trees receiving different fertilizer levels. However, using the pre

Table 30. Effect of fertilizer levels on total chlorophyll content (mg g^{-1}) of leaves at flushing stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	1.86^b	1.88^c	1.86^b	1.87^b
F_1	375:165:375	1.90^b	2.05^b	1.93^b	1.96^b
F_2	750:325:750	2.43^a	2.45^a	2.29^a	2.38^a
F_3	1125:490:1125	2.25^a	2.31^a	2.32^a	2.30^a
F_4	1500:650:1500	2.33^a	2.34^a	2.22^a	2.29^a
SEm±		0.11	0.06	0.08	0.06

Table 31. Effect of fertilizer levels on total chlorophyll content (mg g^{-1}) of leaves at flowering stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	1.46^b	1.45^c	1.38^c	1.43^d
F_1	375:165:375	1.55^b	1.49^{bc}	1.54^b	1.49^c
F_2	750:325:750	1.69^a	1.68^a	1.77^a	1.71^a
F_3	1125:490:1125	1.71^a	1.56^b	1.74^a	1.67^b
F_4	1500:650:1500	1.66^a	1.71^a	1.67^a	1.68^{ab}
SEm±		0.03	0.03	0.04	0.02

* g N, P_2O_5, K_2O $tree^{-1}$ $year^{-1}$

Table 32. Effect of fertilizer levels on number of nuts per panicle

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	5.62^{b}	4.80^{b}	5.28^{b}	5.23^{c}
F_1	375:165:375	5.76^{b}	5.20^{b}	4.86^{b}	5.27^{c}
F_2	750:325:750	6.68^{a}	6.68^{a}	6.78^{a}	6.71^{a}
F_3	1125:490:1125	6.66^{a}	6.76^{a}	6.22^{ab}	6.55^{ab}
F_4	1500:650:1500	6.08^{ab}	6.72^{a}	5.80^{ab}	6.20^{b}
SEm±		0.18	0.15	0.43	0.15

Table 33. Effect of fertilizer levels on duration of harvest (days)

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	49.8^{d}	40.2^{b}	45.0^{b}	45.00^{b}
F_1	375:165:375	55.4^{c}	43.4^{b}	49.0^{ab}	48.27^{b}
F_2	750:325:750	69.4^{ab}	49.4^{a}	58.8^{a}	59.20^{a}
F_3	1125:490:1125	70.0^{a}	53.2^{a}	58.0^{a}	60.40^{a}
F_4	1500:650:1500	63.0^{b}	48.8^{a}	55.2^{a}	55.67^{a}
SEm±		1.4	1.8	1.5	1.92

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

treatment yield as co-variate, the yield data of treatment years were subjected to ANOCOVA and the adjusted means are presented in Table 34 a.

An increase in fertilizer dose increased the nut yield up to a level of F_2 and the yield did not increase further with increase in fertilizers. This effect of fertilizer was consistently noticed in all the years under the study (Fig. 13).

In all the years the lowest yield varying from 5.72 kg $tree^{-1}$ to 7.13 kg $tree^{-1}$ were noticed with trees which did not receive any fertilizer and the highest yield ranging from 10.97 kg $tree^{-1}$ to 15 kg $tree^{-1}$ were noticed in trees that received fertilizers at the dose of F_2 (750 g N, 325 g P_2O_5 and 750 g K_2O). The data on variation in nut yield from the pre treatment yield at 9 YAP is given in Table 34 b.

iv) Nut weight

The nut weight increased with increase in fertilizer application up to a dose of F_3 (1125 g N, 490 g P_2O_5 and 1125 g K_2O $tree^{-1}$) and this effect was seen only during one year (12 YAP). Although, the highest mean nut weight averaged over three years was observed with F_2, its effect was on par with all the other treatments except F_1 (Table 35).

v) Shelling percentage

Shelling percentage increased with fertilizer application up to a dose of F_2 and this effect was noticed only during the third year under study. Although the highest shelling percentage (31.99 per cent) was observed with the treatment F_2 when the average was taken, it was on par with F_3 and F_4. The lowest shelling percentage (27.53 per cent) was given by nuts from control plots (Table 36).

vi) Kernel yield

As in the case of nut yield, the kernel yield also increased with increase in fertilizer dose up to a level of F_2 (Table 37). Any further increase in fertilizer was not beneficial to improve the kernel yield. The lowest average kernel yield (1.56 kg $tree^{-1}$) was observed with trees that received no fertilizer, whereas the highest kernel yield (4.00 kg $tree^{-1}$) was observed with trees that received fertilizers at the dose of F_2.

Table 34a. Effect of fertilizer levels on nut yield (kg tree^{-1})

Trt. No.	Fertilizer levels*	Years after planting				Mean (10-12 YAP)
		9 YAP	10 YAP	11 YAP	12 YAP	
F_0	No fertilizer	7.24^a	5.00^b (5.91)	5.36^b (5.72)	6.87^b (7.13)	5.73^c (6.25)
F_1	375:165:375	11.27^a	8.56^{ab} (7.17)	7.17^{ab} (6.57)	7.69^{ab} (7.30)	7.81^{bc} (7.01)
F_2	750:325:750	8.80^a	12.88^a (12.90)	10.98^a (10.97)	15.00^a (15.00)	12.95^a (12.96)
F_3	1125:490:1125	7.45^a	12.04^a (12.83)	9.88^a (10.22)	11.72^a (11.94)	11.21^{ab} (11.66)
F_4	1500:650:1500	9.44^a	10.58^a (10.24)	9.32^a (9.17)	11.85^a (11.75)	10.58^{ab} (10.39)
SEm±		1.89	1.13	1.25	1.23	1.13

Values in parenthesis indicate means after ANOCOVA

Table 34b. Effect of fertilizer levels on variation in nut yield (kg tree^{-1}) from the pre treatment yield

Trt. No	Fertilizer levels*	Nut yield 9 YAP (kg tree^{-1})	Years after planting		
			10 YAP	11 YAP	12 YAP
F_0	No fertilizer	7.24^a	-2.24^c	-1.92^{bc}	-0.37^{bc}
F_1	375:165:375	11.27^a	-2.71^c	-4.10^c	-3.58^c
F_2	750:325:750	8.80^a	4.08^a	2.16^a	6.20^a
F_3	1125:490:1125	7.45^a	4.59^a	2.43^a	4.27^a
F_4	1500:650:1500	9.44^a	1.14^b	-0.12^{ab}	2.41^{ab}
SEm±		1.89	0.88	1.19	1.23

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Fig. 13 Effect of fertilizer levels on nut yield of cashew

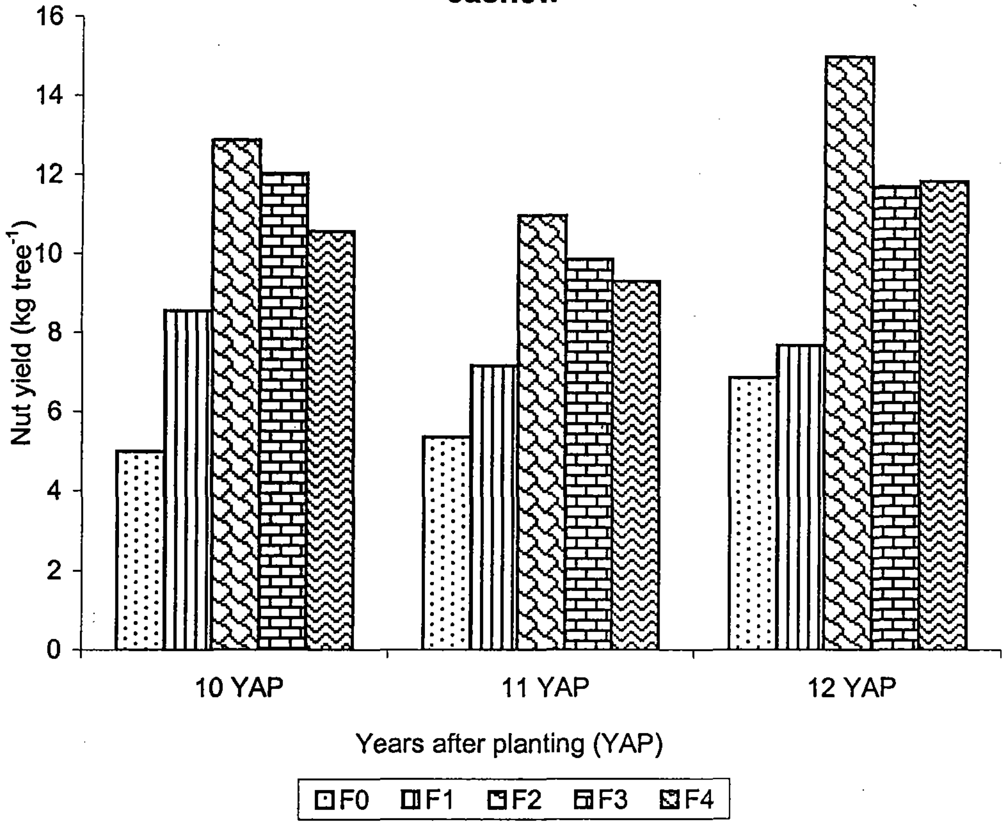


Table 35. Effect of fertilizer levels on nut weight (g)

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	6.17[a]	6.20[a]	5.62[c]	5.99[ab]
F_1	375:165:375	5.87[ab]	5.84[b]	5.68[bc]	5.80[b]
F_2	750:325:750	6.23[a]	6.20[a]	5.92[abc]	6.11[a]
F_3	1125:490:1125	5.80[b]	5.92[ab]	6.23[a]	5.98[ab]
F_4	1500:650:1500	5.93[ab]	5.90[ab]	6.10[ab]	5.98[ab]
SEm±		0.11	0.11	0.15	0.07

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Table 36. Effect of fertilizer levels on shelling percentage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	29.30[a]	26.58[b]	26.72[b]	27.53[c]
F_1	375:165:375	31.34[a]	28.34[ab]	28.15[b]	29.28[b]
F_2	750:325:750	30.85[a]	32.55[a]	32.58[a]	31.99[a]
F_3	1125:490:1125	29.95[a]	30.73[ab]	29.73[ab]	30.14[b]
F_4	1500:650:1500	29.45[a]	32.25[a]	29.00[ab]	30.24[b]
SEm±		1.00	0.29	1.20	0.56

Table 37. Effect of fertilizer levels on kernel yield (kg tree^{-1})

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	1.47[b]	1.43[b]	1.84[b]	1.56[b]
F_1	375:165:375	2.68[ab]	2.03[ab]	2.17[ab]	2.29[ab]
F_2	750:325:750	3.97[a]	3.46[a]	4.58[a]	4.00[a]
F_3	1125:490:1125	3.61[a]	3.04[a]	3.48[a]	3.35[a]
F_4	1500:650:1500	3.12[a]	3.01[a]	3.44[a]	3.19[a]
SEm±		0.41	0.31	0.42	0.31

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

vii) Cashew apple yield

Fertilizer treatments exerted considerable influence on cashew apple yield (Table 38). The yield of cashew apple averaged over the years was the highest (103.7 kg tree^{-1}) with trees that received NPK fertilizers at 750: 325: 750 g tree^{-1}. Apple yield was the lowest (37.61 kg tree^{-1}) in trees that received no fertilizer.

viii) Cashew apple weight

There was no significant effect by the levels of fertilizer to change the weight of cashew apple in any of the year under the study (Table 39). But data on pooled analysis revealed that apple weight increased with increase in fertilizer up to a dose of F_4 (1500 g N, 650 g P_2O_5 and 1500 g K_2O), but this was on par with all the other treatments except control.

4.2.3 Nutrient concentration in plant parts

i) Leaf

a) Nitrogen

Fertilizer application increased the leaf nitrogen content at pre-flushing stage up to a dose of F_2 (750 g N, 325 g P_2O_5 and 750 g K_2O) only and this effect was seen in all the three years (Table 40). The leaf nitrogen content averaged over three years was the lowest (1.33 per cent) in trees that received no fertilizer and it was the highest (1.84 per cent) in trees that received fertilizers at level F_2. Increasing the levels of fertilizers beyond F_2 did not increase the leaf nitrogen content (Fig.14 a).

There was difference in leaf N between the two physiological stages (pre-flushing and pre-flowering) of crop growth observed (Table 41). The leaf N content was high at the pre-flowering stage (1.65 to 1.94 per cent) compared to the pre-flushing stage (1.33 to 1.84 per cent).

b) Phosphorus

Fertilizer application did not change the leaf P content at pre-flushing stage (Table 42) as well as at pre-flowering stage (Table 43) and the effect was consistently noticed in all the three years of the study (Fig.14 b). The average P content of leaves was slightly higher at pre-flushing stage (0.11 to 0.12 per cent) compared to pre-flowering stage (0.09 to 0.11 per cent).

Table 38. Effect of fertilizer levels on cashew apple yield (kg tree^{-1})

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	34.58^{b}	40.78^{b}	37.46^{b}	37.61^{c}
F_1	375:165:375	63.26^{ab}	57.19^{ab}	48.16^{b}	56.20^{bc}
F_2	750:325:750	92.98^{a}	89.89^{a}	128.16^{a}	103.70^{a}
F_3	1125:490:1125	82.82^{a}	84.11^{a}	103.50^{a}	90.14^{a}
F_4	1500:650:1500	74.51^{a}	73.24^{ab}	101.50^{a}	83.08^{ab}
SEm±		12.35	8.40	9.54	9.08

Table 39. Effect of fertilizer levels on cashew apple weight (g)

Trt. No	Fertilizer levels	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	48.00^{a}	47.54^{ab}	40.98^{b}	45.51^{b}
F_1	375:165:375	47.36^{a}	46.76^{b}	46.04^{a}	46.72^{ab}
F_2	750:325:750	48.74^{a}	48.80^{ab}	43.78^{ab}	47.09^{ab}
F_3	1125:490:1125	47.58^{a}	47.80^{ab}	46.76^{a}	47.39^{ab}
F_4	1500:650:1500	48.70^{a}	49.41^{a}	47.10^{a}	48.39^{a}
SEm±		0.77	0.69	1.55	0.62

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Table 40. Effect of fertilizer levels on N concentration (%) in leaves at pre-flushing stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	1.20^{b}	1.47^{b}	1.33^{c}	1.33^{c}
F_1	375:165:375	1.23^{b}	1.44^{b}	1.49^{bc}	1.41^{c}
F_2	750:325:750	1.74^{a}	1.95^{a}	1.82^{a}	1.84^{a}
F_3	1125:490:1125	1.70^{a}	1.87^{a}	1.74^{a}	1.77^{a}
F_4	1500:650:1500	1.67^{a}	1.74^{a}	1.62^{ab}	1.66^{b}
SEm±		0.13	0.08	0.08	0.06

Table 41. Effect of fertilizer levels on N concentration (%) in leaves at pre-flowering stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	1.78^{b}	1.67^{b}	1.49^{d}	1.65^{c}
F_1	375:165:375	1.87^{ab}	1.75^{ab}	1.59^{cd}	1.74^{b}
F_2	750:325:750	2.09^{a}	2.15^{a}	1.88^{a}	2.04^{a}
F_3	1125:490:1125	2.16^{a}	2.05^{a}	1.82^{ab}	2.01^{a}
F_4	1500:650:1500	2.25^{a}	2.15^{a}	1.71^{bc}	2.04^{a}
SEm±		0.11	0.10	0.05	0.05

* g N, P_2O_5, K_2O $tree^{-1}$ $year^{-1}$

Table 42. Effect of fertilizer levels on P concentration (%) in leaves at pre-flushing stage

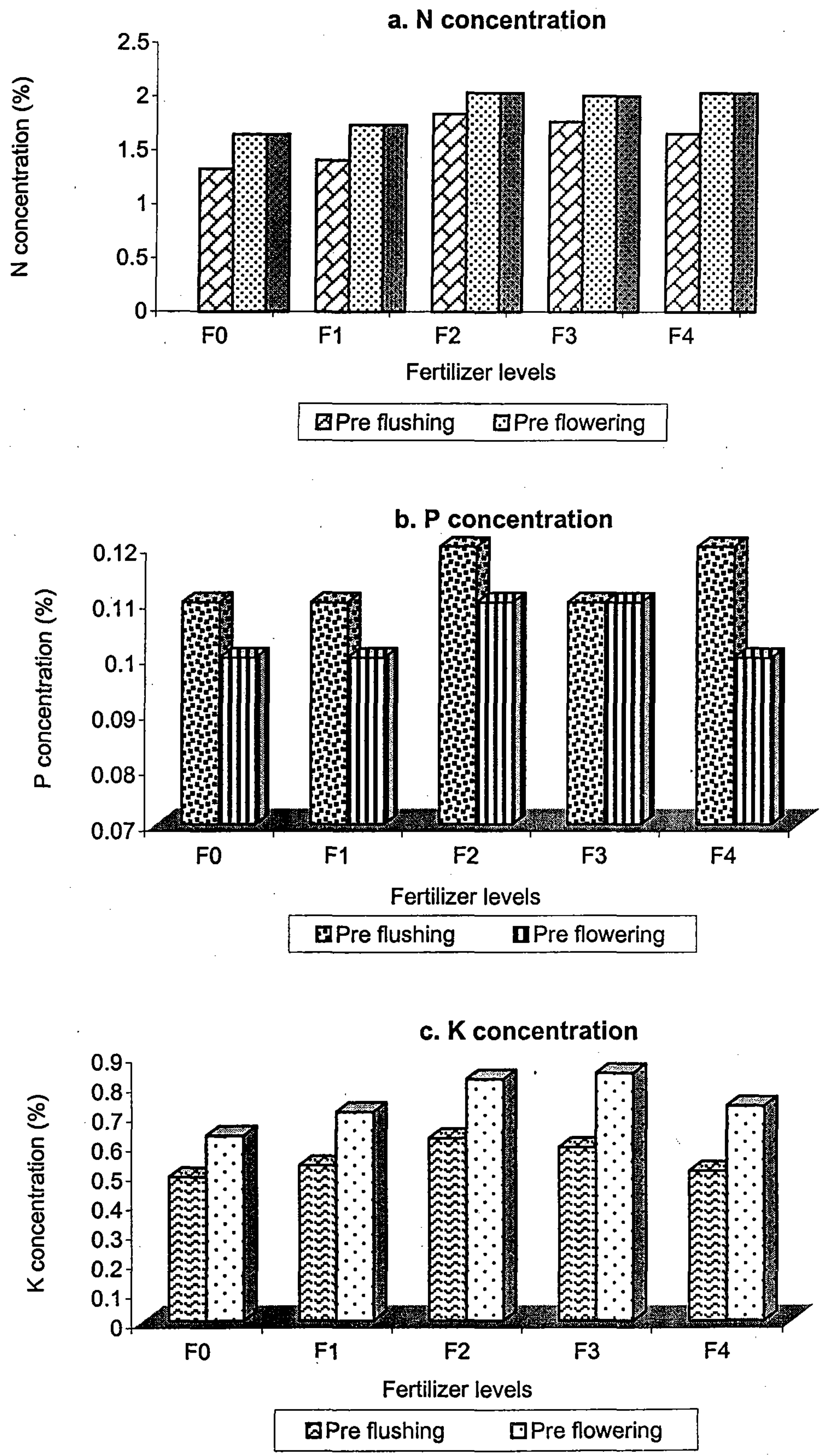
Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.131[a]	0.108[a]	0.093[d]	0.111[a]
F_1	375:165:375	0.149[a]	0.085[a]	0.098[c]	0.111[a]
F_2	750:325:750	0.160[a]	0.099[a]	0.101[bc]	0.120[a]
F_3	1125:490:1125	0.122[a]	0.108[a]	0.109[a]	0.113[a]
F_4	1500:650:1500	0.138[a]	0.111[a]	0.105[b]	0.118[a]
SEm±		0.012	0.005	0.004	0.008

Table 43. Effect of fertilizer levels on P concentration (%) in leaves at pre-flowering stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.121[ab]	0.100[a]	0.075[d]	0.099[a]
F_1	375:165:375	0.103[b]	0.096[ab]	0.080[c]	0.093[a]
F_2	750:325:750	0.152[a]	0.079[c]	0.092[a]	0.108[a]
F_3	1125:490:1125	0.129[ab]	0.092[b]	0.093[a]	0.105[a]
F_4	1500:650:1500	0.120[ab]	0.083[c]	0.087[b]	0.097[a]
SEm±		0.017	0.006	0.004	0.011

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Fig.14. Effect of fertilizer levels on N, P and K conten of leaves at pre flushing and pre flowering stages



c) Potassium

The leaf K concentration at pre-flushing stage differed due to fertilizers application only in one out of the three years under the study (Table 44). The average of the values for three years showed that the leaf K increased with increase in fertilizer dose up to F_2 (0.62 per cent) and beyond which the effect was not beneficial. The leaf K was the lowest (0.49 per cent) in trees that received no fertilizers.

But at pre-flowering stage, the effect of fertilizer on leaf K was found to be considerable in all the years (Table 45). The average of leaf K was the lowest (0.63 per cent) in trees that received no fertilizers and the highest (0.84 per cent) with trees that received F_3.Between stages, like leaf N, the leaf K concentration was high during pre-flowering stage compared to pre-flushing stage (Fig. 14c).

d) Micro nutrients

The concentration of Fe, Mn and Zn in leaves was estimated only at 11 YAP. The levels of fertilizers did not change the concentration of Fe, Mn or Zn in leaves at pre-flushing stage (Table 46) and at pre-flowering stage (Table 47).

ii) Cashew apple

The concentration of N, P and K in cashew apple, shell, kernel, testa and litter; and the uptake of these nutrients through the above parts was estimated during the second year of the study (11 YAP).

The N concentration in cashew apple increased with fertilizer dose up to F_2 only (Table 48). The N concentration was low (0.78 per cent) in apples of trees that received no fertilizers. As in the case of N, the P concentration of apple also increased with increase in fertilizer up to a dose of F_1 and it did not increase further with increase in fertilizer dose.

The K concentration of apple did not vary due to change in fertilizer dose. The N concentration was more in leaves than apple, but P and K contents were more in apple compared to leaves.

Table 44. Effect of fertilizer levels on K concentration (%) in leaves at pre-flushing stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.48^{a}	0.57^{ab}	0.41^{c}	0.49^{d}
F_1	375:165:375	0.51^{a}	0.62^{ab}	0.47^{c}	0.53^{c}
F_2	750:325:750	0.58^{a}	0.71^{a}	0.58^{ab}	0.62^{a}
F_3	1125:490:1125	0.56^{a}	0.59^{ab}	0.62^{a}	0.59^{b}
F_4	1500:650:1500	0.51^{a}	0.53^{b}	0.50^{bc}	0.51^{cd}
SEm±		0.04	0.05	0.03	0.02

Table 45. Effect of fertilizer levels on K concentration (%) in leaves at pre-flowering stage

Trt. No	Fertilizer levels*	Years after planting			
		10 YAP	11 YAP	12 YAP	Mean
F_0	No fertilizer	0.67^{ab}	0.63^{c}	0.59^{c}	0.63^{c}
F_1	375:165:375	0.66^{b}	0.83^{ab}	0.64^{bc}	0.71^{b}
F_2	750:325:750	0.81^{a}	0.86^{ab}	0.80^{a}	0.82^{a}
F_3	1125:490:1125	0.82^{a}	0.89^{a}	0.89^{a}	0.84^{a}
F_4	1500:650:1500	0.81^{a}	0.68^{bc}	0.69^{b}	0.73^{b}
SEm±		0.05	0.06	0.03	0.03

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Table 46. Effect of fertilizer levels on concentration of Fe, Mn and Zn in leaves at pre-flushing stage

Trt. No	Fertilizer levels*	Fe (ppm)	Mn (ppm)	Zn (ppm)
F_0	No fertilizer	203.6[a]	159.8[a]	26.5[a]
F_1	375:165:375	186.6[a]	185.2[a]	28.0[a]
F_2	750:325:750	202.0[a]	208.4[a]	28.4[a]
F_3	1125:490:1125	209.8[a]	230.0[a]	31.4[a]
F_4	1500:650:1500	254.4[a]	212.0[a]	30.0[a]

Table 47. Effect of fertilizer levels on concentration of Fe, Mn and Zn in leaves at pre-flowering stage

Trt. No	Fertilizer levels*	Fe (ppm)	Mn (ppm)	Zn (ppm)
F_0	No fertilizer	186.2[a]	188.0[a]	13.4[a]
F_1	375:165:375	209.2[a]	203.2[a]	17.8[a]
F_2	750:325:750	189.6[a]	178.0[a]	12.5[a]
F_3	1125:490:1125	226.0[a]	213.2[a]	11.8[a]
F_4	1500:650:1500	236.0[a]	232.0[a]	16.0[a]

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

iii) Litter

The concentration of N and P in litter did not differ due to change in levels of applied fertilizer (Table 49). Nitrogen concentration of litter ranged from 0.67 per cent (F_0) to 0.86 per cent (F_3). Like N and P, the K concentration of litter increased with increase in fertilizer application up to a level of F_3. The lowest K concentration (0.22 per cent) was noticed in litter collected from trees that received no fertilizers whereas the highest K concentration (0.34 per cent) was noticed in litter from trees that received the treatment F_3 (Fig. 15).

The concentration of Fe, Mn and Zn in litter did not vary significantly due to levels of NPK fertilizers (Table 50).

iv) Kernel

The N concentration of kernel increased with fertilizer treatment up to F_2 but it did not increase further due to increase in fertilizer application (Table 51). The lowest kernel N (3.39 per cent) was observed with trees that received no fertilizers whereas the kernel N was highest (3.83 per cent) with trees treated with a fertilizer dose of F_2 (Fig.16).

The P and K concentration of kernel also increased with increase in fertilizer application. The lowest kernel P (0.424 per cent) was observed with F_0 and the highest with F_4 (0.483 per cent). The lowest K concentration (0.56) was observed with F_0 and the highest with F_3 (0.70 per cent).

v) Shell

Nitrogen content of shell increased with increase in fertilizer dose (Table 52). Shell N was the lowest (0.53 per cent) with F_0 and the highest with F_2 (0.58 per cent). Phosphorous concentration in shell increased with fertilizer dose up to the level of F_3. The P concentration in shell was the lowest (0.032 per cent) with trees that received no fertilizers and the highest (0.049) with trees that received F_3 (Fig. 17).

The K content in shell did not change due to change in fertilizer dose. However the highest K concentration in shell (0.42 per cent) was observed when fertilizers were applied at the dose of F_2.

Table 48. Effect of levels of fertilizers on concentration of N, P and K in cashew apple

Trt. No.	Fertilizer levels	N (%)	P (%)	K (%)
F_0	No fertilizer	0.78[c]	0.121[b]	1.06[a]
F_1	375:165:375	0.99[a]	0.126[a]	1.07[a]
F_2	750:325:750	0.98[ab]	0.123[ab]	0.96[a]
F_3	1125:490:1125	0.85[bc]	0.106[c]	1.04[a]
F_4	1500:650:1500	0.86[abc]	0.095[d]	1.02[a]

Table 49. Effect of levels of fertilizers on concentration of N, P and K in litter

Trt. No	Fertilizer levels*	N (%)	P (%)	K (%)
F_0	No fertilizer	0.67[a]	0.043[c]	0.22[b]
F_1	375:165:375	0.71[a]	0.043[c]	0.23[b]
F_2	750:325:750	0.77[a]	0.046[c]	0.24[ab]
F_3	1125:490:1125	0.86[a]	0.066[a]	0.34[a]
F_4	1500:650:1500	0.69[a]	0.052[b]	0.27[ab]

Table 50. Effect of levels of fertilizers on concentration of Fe, Mn and Zn in litter

Trt. No.	Fertilizer levels	Fe (ppm)	Mn (ppm)	Zn (ppm)
F_0	No fertilizer	248.6[a]	310.2[a]	6.8[a]
F_1	375:165:375	232.7[a]	338.4[a]	5.9[a]
F_2	750:325:750	258.6[a]	287.8[a]	9.2[a]
F_3	1125:490:1125	249.8[a]	284.8[a]	8.1[a]
F_4	1500:650:1500	189.8[a]	288.4[a]	5.9[a]

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Fig. 15 Effect of fertilizer levels on N, P and K concentration in litter

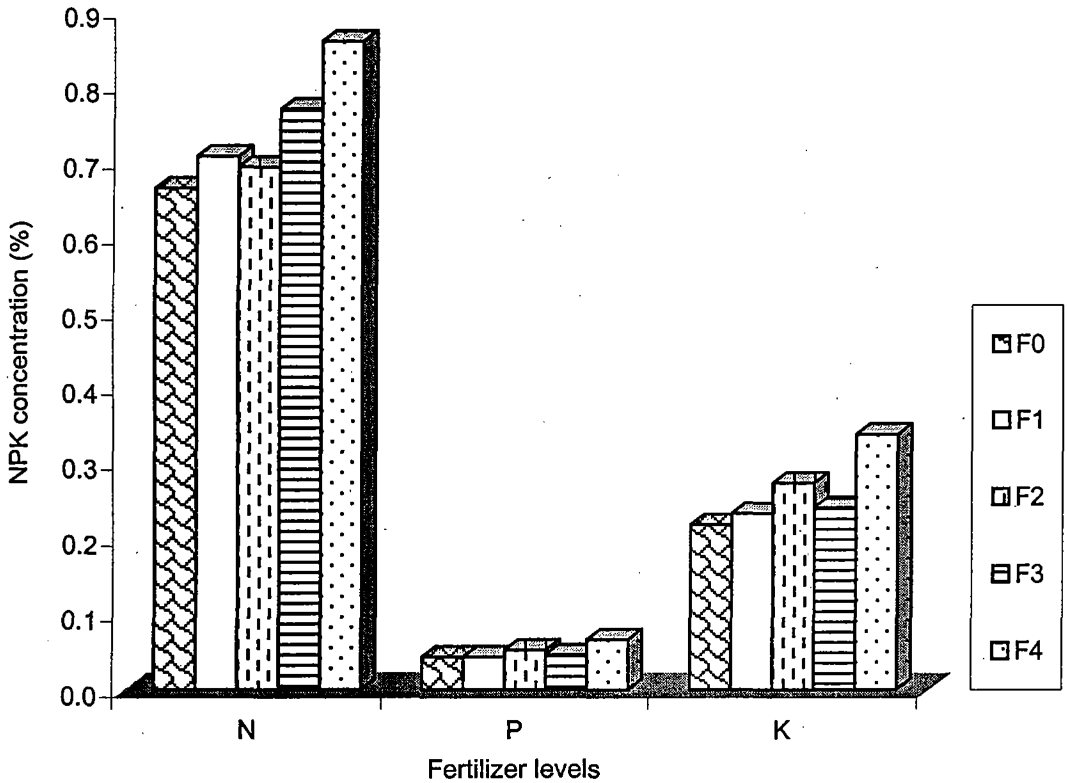


Table 51. Effect of fertilizer levels on concentration of N, P and K in kernel

Trt. No	Fertilizer levels*	N (%)	P (%)	K (%)
F_0	No fertilizer	3.39[c]	0.424[b]	0.56[c]
F_1	375:165:375	3.50[bc]	0.437[b]	0.60[bc]
F_2	750:325:750	3.83[a]	0.451[ab]	0.66[ab]
F_3	1125:490:1125	3.79[ab]	0.482[a]	0.70[a]
F_4	1500:650:1500	3.65[abc]	0.483[a]	0.67[ab]
SEm±		0.10	0.044	0.03

Table 52. Effect of fertilizer levels on concentration of N, P and K in shell

Trt. No	Fertilizer levels*	N (%)	P (%)	K (%)
F_0	No fertilizer	0.53[b]	0.032[b]	0.38[a]
F_1	375:165:375	0.55[ab]	0.042[a]	0.41[a]
F_2	750:325:750	0.58[a]	0.042[a]	0.42[a]
F_3	1125:490:1125	0.58[a]	0.049[a]	0.41[a]
F_4	1500:650:1500	0.58[a]	0.034[b]	0.41[a]
SEm±		0.01	0.0023	0.07

Table 53. Effect of fertilizer levels on concentration of N, P and K in testa

Trt. No	Fertilizer levels*	N (%)	P (%)	K (%)
F_0	No fertilizer	1.50[b]	0.11[c]	0.34[b]
F_1	375:165:375	1.55[ab]	0.11[b]	0.35[ab]
F_2	750:325:750	1.71[a]	0.12[a]	0.39[a]
F_3	1125:490:1125	1.72[a]	0.12[a]	0.39[ab]
F_4	1500:650:1500	1.69[ab]	0.12[a]	0.39[ab]
SEm±		0.06	0.01	0.01

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Fig.16 Effect of fertilizer levels on concentration of N, P and K in kernel

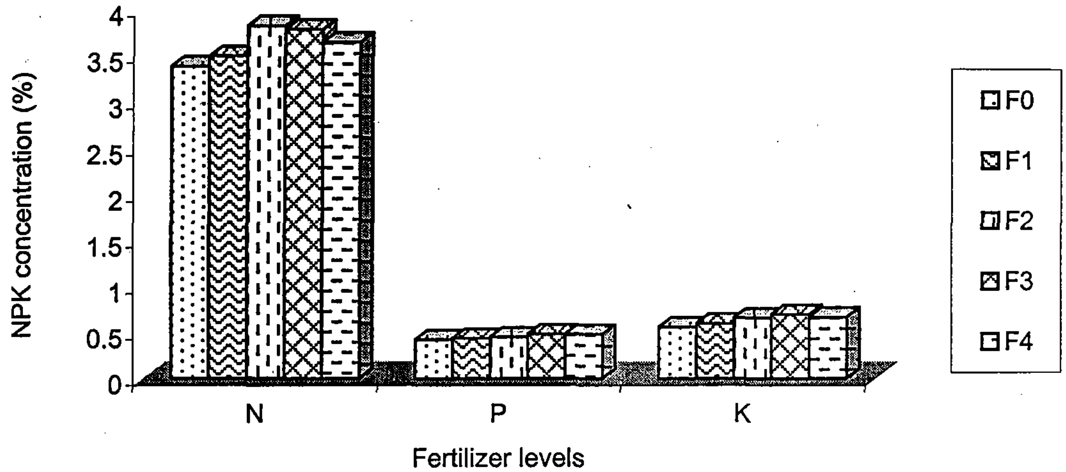


Fig.17 Effect of fertilizer levels on concentration of N, P and K in shell

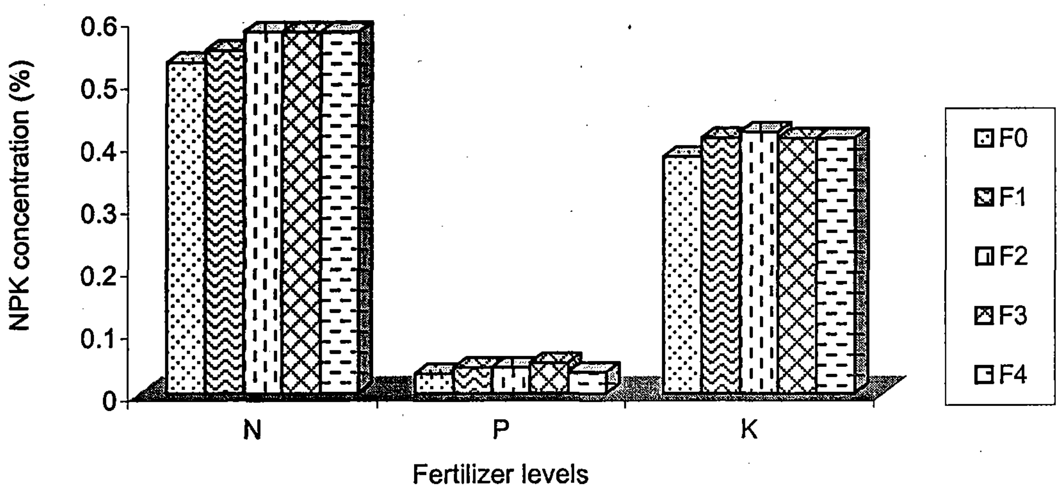
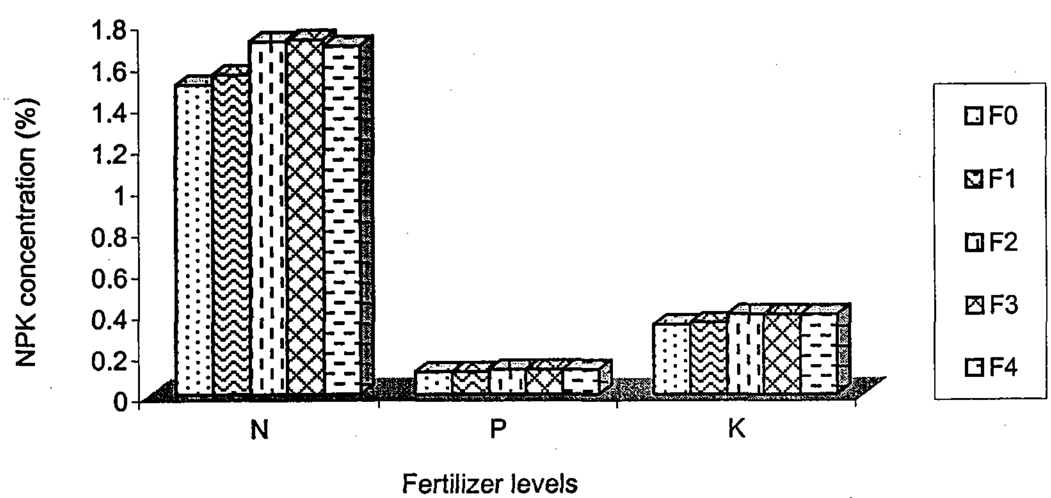


Fig.18 Effect of fertilizers levels on concentration of N, P and K in testa



vi) Testa

The N and K content of testa increased with fertilizer application up to a dose of F_2 only (Table 53). The lowest N (1.50 per cent) and the lowest K concentration in testa (0.34 per cent) was observed with F_0, whereas the highest N (1.71 per cent) and K (0.39 per cent) contents were observed in trees applied with F_2. The P concentration in testa did not change due to change in fertilizer doses (Fig. 18).

4.2.4 Nutrient uptake

i) Dry matter yield of cashew apple

The dry matter yield of cashew apple increased with increase in fertilizer application up to a fertilizer dose of F_2 (Table 54). The highest dry matter yield was observed with trees applied with F_2 (8.88 kg tree^{-1}) and the lowest (4.12 kg tree^{-1}) with trees that received no fertilizers.

ii) NPK uptake through cashew apple

The N removal through apple differed significantly due to change in fertilizer treatments. The highest amount of N uptake through apple (81.6 g tree^{-1}) was observed in trees given fertilizers at F_2 level (750 g N, 325 g P_2O_5 and 750 g K_2O) while the lowest N removal (32.06 g tree^{-1}) was observed in trees without any applied fertilizers (F_0). The P and K removal through apple did not differ due to change in fertilizer doses but the highest values were shown by trees applied with fertilizers at F_3 level (Fig.19).

iii) Litter yield

Leaf litter production in cashew was not affected by the levels of fertilizers (Table 55). The quantity of litter ranged from 8.68 kg (F_0) to 12.32 kg tree^{-1} (F_3).

iv) Nutrient removal through litter

The removal of N, P and K through litter did not differ due to change in fertilizer levels (Table 55). However N removal varied from 57.8 to 104.0 g tree^{-1}, P removal varied from 3.76 to 7.95 g tree^{-1} and K removal from 19.01 to 29.08 g tree^{-1} (Fig. 20).

Table 54. Effect of levels of fertilizers on dry weight of cashew apple and uptake of N, P and K

Trt. No.	Fertilizer levels	Dry weight (kg tree^{-1})	Nutrient uptake (g tree^{-1})		
			N	P	K
F_0	No fertilizer	4.12^{b}	32.06^{b}	4.91^{b}	44.41^{b}
F_1	375:165:375	5.62^{ab}	56.11^{ab}	7.21^{ab}	61.46^{ab}
F_2	750:325:750	8.88^{a}	81.60^{a}	10.30^{a}	88.08^{a}
F_3	1125:490:1125	8.34^{a}	69.63^{a}	8.82^{ab}	84.85^{a}
F_4	1500:650:1500	7.31^{ab}	61.82^{a}	6.84^{ab}	74.21^{ab}
SEm±		1.11	9.05	1.25	11.08

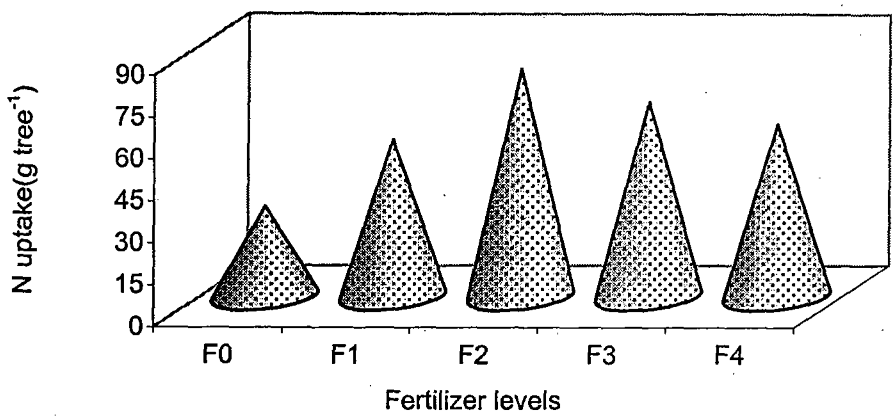
Table 55. Effect of levels of fertilizers on litter dry weight and removal of N, P and K

Trt. No.	Fertilizer levels	Dry weight of litter (kg tree^{-1})	Nutrient removal (g tree^{-1})		
			N	P	K
F_0	No fertilizer	8.68^{a}	57.80^{b}	3.76^{b}	19.49^{a}
F_1	375:165:375	8.19^{a}	57.54^{b}	3.83^{b}	19.01^{a}
F_2	750:325:750	10.68^{a}	83.77^{ab}	4.81^{ab}	25.76^{a}
F_3	1125:490:1125	12.32^{a}	104.00^{a}	7.95^{a}	29.08^{a}
F_4	1500:650:1500	10.17^{a}	77.05^{ab}	4.85^{ab}	27.51^{a}
SEm±		1.31	12.52	1.08	4.32

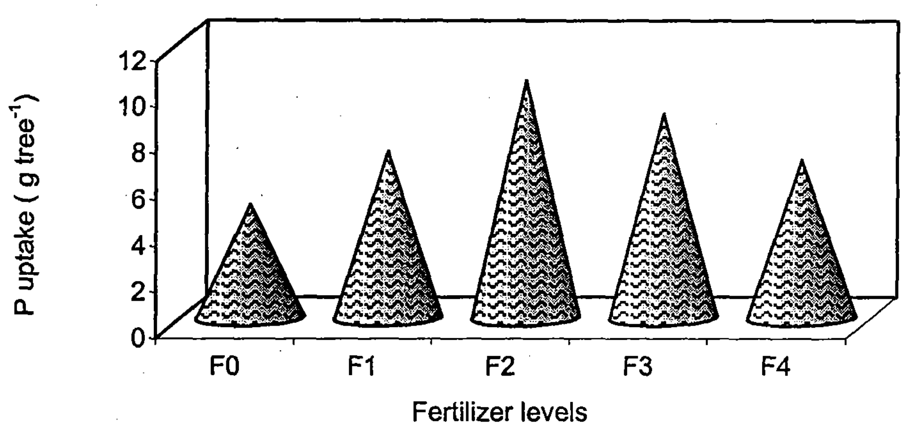
* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Fig.19 Effect of levels of fertilizers on N, P and K uptake through cashew apple

a. N uptake



b. P uptake



c. K uptake

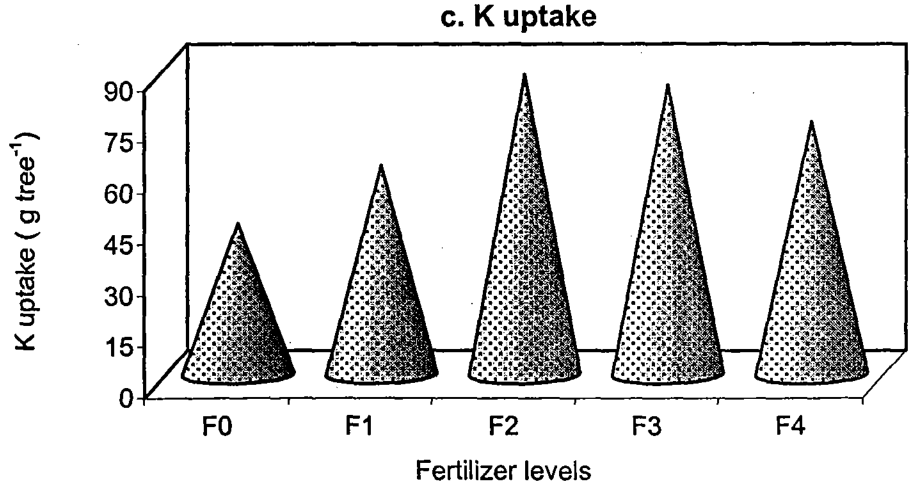
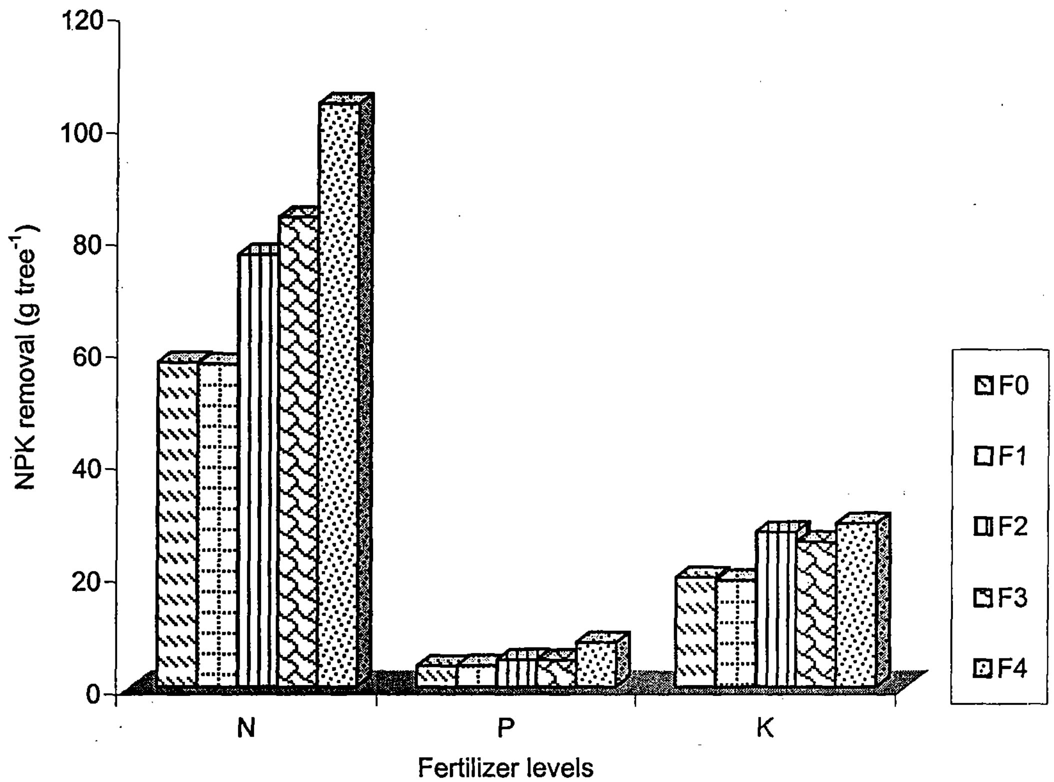


Fig. 20 Effect of fertilizer levels on N, P and K removal through litter



v) Shell, Kernel and Testa

Nitrogen uptake through shell did not differ due to levels of fertilizer application, while its uptake through kernel and testa increased with fertilizer up to a dose of F_2 (Table 56). The combined uptake of N through kernel, shell and testa also increased up to a dose of F_2 and further increase in fertilizer application did not increase the N uptake.

The P uptake through shell did not differ due to fertilizer treatments (Table 57). The highest P uptake through kernel (15.49 g tree^{-1}) as well as the highest total uptake (kernel, shell and testa) was observed with the fertilizer dose of F_3 (18.64 g tree^{-1}).

Potassium uptake through shell remained same irrespective of the fertilizer treatments (Table 58). The trees applied with fertilizers at the dose of F_3 gave the highest uptake of K through kernel (22.17 g tree^{-1}), whereas those treated with F_2 gave the highest K uptake through testa (0.96 g tree^{-1}). The uptake of K through shell, kernel and testa together was the highest (56.53 g tree^{-1}) in trees treated with F_2 and it did not increase with further increase in fertilizer dose.

vi) Nut and apple

Uptake of N through apple and nut combined together was the highest in the treatment F_2 (254.11 g tree^{-1}) followed by F_3 (Table 59). The lowest N uptake was observed in control plots (103.54 g tree^{-1}). The total uptake of P through apple and nut together was the highest (28.05 g tree^{-1}) in trees treated with a fertilizer dose of F_2 and the lowest (12.34 g tree^{-1}) in trees that received no fertilizers (Table 60). Potassium uptake through apple and nut was also the highest (144.60 g tree^{-1}) with the application of the treatment F_2 and the lowest (67.78 g tree^{-1}) in trees that received no fertilizers (Table 61).

vii) Total nutrient removal

The total uptake of N through apple, nut and removal through litter also increased with increase in fertilizer application up to a dose of F_2 only (Table 59). The total N uptake was the lowest at the fertilizer level F_0 (161.38 g tree^{-1}) and the highest with F_2 (337.88 g tree^{-1}). The total uptake of P (through apple, nut and litter) was the highest (35.41 g tree^{-1}) when the treatment F_3 (1125 g N, 490 g P and 1125 g K) and the lowest (16.10 g tree^{-1}) when no fertilizer was applied (Table 60). The total uptake

Table 56. Effect of fertilizer levels on N uptake by shell, kernel, and testa

Trt. No	Fertilizer levels*	N uptake (g tree^{-1})			
		Shell	Kernel	Testa	Total
F_0	No fertilizer	20.61^{b}	49.22^{b}	1.64^{b}	71.47^{c}
F_1	375:165:375	28.36^{ab}	71.56^{b}	2.34^{b}	102.27^{bc}
F_2	750:325:750	44.90^{a}	123.60^{a}	4.01^{a}	172.50^{ab}
F_3	1125:490:1125	38.19^{ab}	120.77^{a}	4.12^{a}	163.07^{a}
F_4	1500:650:1500	36.52^{ab}	110.29^{a}	3.75^{a}	150.56^{a}
SEm±		5.54	12.67	0.35	17.59

Table 57. Effect of fertilizer levels on P uptake by shell, kernel and testa

Trt. No	Fertilizer levels*	P uptake (g tree^{-1})			
		Shell	Kernel	Testa	Total
F_0	No fertilizer	1.25^{b}	6.07^{b}	0.11^{b}	7.43^{a}
F_1	375:165:375	2.09^{ab}	8.85^{b}	0.17^{b}	11.11^{a}
F_2	750:325:750	3.27^{a}	14.19^{a}	0.30^{a}	17.75^{a}
F_3	1125:490:1125	2.86^{a}	15.49^{a}	0.30^{a}	18.64^{a}
F_4	1500:650:1500	2.15^{ab}	14.42^{a}	0.27^{a}	16.85^{a}
SEm±		0.46	1.24	0.04	1.60

Table 58. Effect of fertilizer levels on K uptake by shell, kernel and testa

Trt. No	Fertilizer levels*	K uptake (g tree^{-1})			
		Shell	Kernel	Testa	Total
F_0	No fertilizer	14.90^{b}	8.10^{b}	0.37^{a}	23.37^{b}
F_1	375:165:375	20.72^{ab}	12.23^{b}	0.52^{a}	33.47^{b}
F_2	750:325:750	34.43^{a}	21.13^{a}	0.96^{b}	56.53^{a}
F_3	1125:490:1125	27.64^{ab}	22.17^{a}	0.93^{b}	50.73^{a}
F_4	1500:650:1500	26.00^{ab}	19.83^{a}	0.87^{b}	46.70^{a}
SEm±		4.97	1.92	0.09	6.44

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

Table 59. Effect of fertilizer levels on N uptake by cashew apple, nut and litter

Trt. No	Fertilizer levels*	N uptake				
		Apple and Nut (g tree^{-1})	Litter (g tree^{-1})	Total (g tree^{-1})	Total (kg ha^{-1})	Uptake (g kg^{-1} nut)
F_0	No fertilizer	103.54^{c}	57.80^{d}	161.33^{d}	28.56^{b}	30.37^{a}
F_1	375:165:375	158.38^{bc}	57.54^{d}	215.91^{c}	38.22^{b}	30.93^{a}
F_2	750:325:750	254.11^{a}	83.77^{b}	337.88^{a}	59.80^{a}	34.71^{a}
F_3	1125:490:1125	232.70^{ab}	104.02^{a}	336.72^{a}	59.60^{a}	35.16^{a}
F_4	1500:650:1500	212.38^{ab}	77.05^{c}	289.43^{b}	51.23^{a}	31.39^{a}
SEm±		26.04	12.52	23.44	4.15	2.83

Table 60. Effect of fertilizer levels on P uptake by cashew apple, nut and litter

Trt. No	Fertilizer levels*	P uptake				
		Apple and Nut (g tree^{-1})	Litter (g tree^{-1})	Total (g tree^{-1})	Total (kg ha^{-1})	Uptake (g kg^{-1} nut)
F_0	No fertilizer	12.34^{c}	3.76^{b}	16.10^{b}	0.67^{a}	3.03^{a}
F_1	375:165:375	18.32^{bc}	3.83^{b}	22.15^{ab}	0.68^{a}	3.13^{a}
F_2	750:325:750	28.05^{a}	4.81^{ab}	32.85^{a}	0.85^{a}	3.24^{a}
F_3	1125:490:1125	27.46^{a}	7.95^{a}	35.41^{a}	1.41^{a}	3.60^{a}
F_4	1500:650:1500	23.69^{ab}	4.85^{ab}	28.54^{ab}	0.86^{a}	3.10^{a}
SEm±		2.82	1.08	2.79	0.19	0.22

Table 61. Effect of fertilizer levels on K uptake by cashew apple, nut and litter

Trt. No	Fertilizer levels*	K uptake				
		Apple and Nut (g tree^{-1})	Litter (g tree^{-1})	Total (g tree^{-1})	Total (kg ha^{-1})	Uptake (g kg^{-1} nut)
F_0	No fertilizer	67.78^{b}	19.49^{d}	87.27^{d}	15.45^{d}	16.21^{a}
F_1	375:165:375	94.92^{ab}	19.01^{d}	113.94^{c}	20.17^{c}	16.21^{a}
F_2	750:325:750	144.60^{a}	25.76^{c}	170.36^{a}	30.15^{b}	15.80^{a}
F_3	1125:490:1125	135.59^{a}	29.08^{a}	164.66^{a}	29.15^{a}	16.80^{a}
F_4	1500:650:1500	120.92^{ab}	27.51^{b}	148.43^{b}	26.27^{a}	15.96^{a}
SEm±		17.27	4.32	18.26	3.23	0.83

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

of K through the harvested parts (nut and apple) and litter ranged from 87.27 g in trees applied with no fertilizers to 170.36 g in trees given the fertilizer dose of F_2 (Table 61).

4.2.5 Partitioning of nutrients between harvested parts

The total nutrient removal of graft raised cashew at 11th year of planting through nut, apple and litter was worked out. It was estimated that at 11 YAP, graft raised cashew variety Madakkathara -1 with nut yield of 8.5 kg $tree^{-1}$ removes 268.4 g N, 18.6 g P and 137.0 g K through apple, nut and litter. Cashew apple accounted for 22.4 per cent N, 28.1 per cent P and 51.5 per cent K, while nut removed 49.2 per cent N, 53.3 per cent P and 30.8 per cent K. Nutrient removal through litter was 28.8, 18.6 and 17.7 per cent of the total N, P and K removed from the plant system, respectively. The highest uptake of N and P was observed through nut and K through apple. The high protein content of cashew kernel explains the high rate of N removal through nut. The significance of recycling of apple and litter back into the system which helps to compensate about 50 per cent of the total nutrient removal is also evident from the results (Fig. 21).

4.2.6 Soil nutrient status

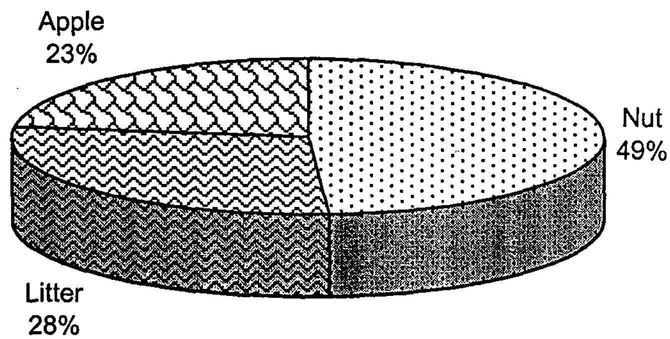
The data on soil chemical characteristics (pH, Organic carbon, Available N, Available P and Exchangeable K) at post harvest stages during the period of the study (1997 – 98 to 99-00) are given in Tables 62 to 64. It was found that pH of the soil did not vary due to different levels of fertilizers. The data also revealed that the fertilizer application did not have any influence on the organic carbon content and exchangeable K in the soil observed at the end of the fruiting season during all the years.

During the second and third years, there was significant variation in available N content of the soil. Available N content of the soil was high in the treatments with higher levels of fertilizers.

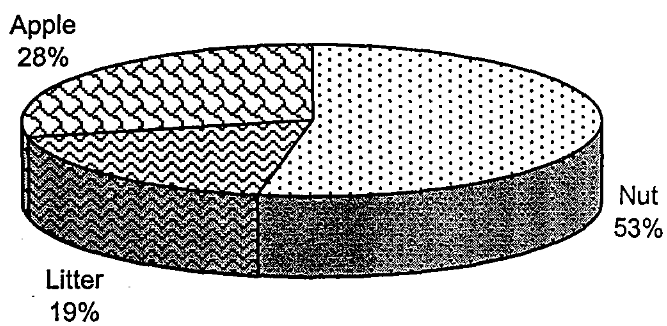
Nitrogen content of soil ranged from 152.0 kg (control) to 229.0 kg ha^{-1} (F_3) at the end of the second year (1998-'99) and from 161.8 kg (control) to 248.0 kg ha^{-1} (F_3) during the third year (1999-'00). During both the years the treatments with highest levels of fertilizers exhibited higher soil N status. Variation among the

Fig.21 Partitioning of N,P and K between harvested parts and litter in cashew

a) Nitrogen



b) Phosphorus



c) Potassium

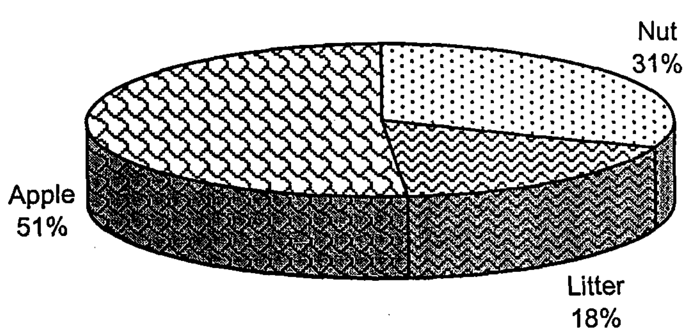


Table 62. Soil pH and organic carbon content of soil as influenced by fertilizer levels

Trt. No	Fertilizer levels	pH			Organic carbon (%)		
		97-98	98-99	99-00	97-98	98-99	99-00
F_0	No fertilizer	5.50^a	5.48^a	5.38^a	0.91^a	1.08^a	0.92^a
F_1	375:165:375	5.34^a	5.42^a	5.22^a	1.15^a	1.16^a	0.94^a
F_2	750:325:750	5.56^a	5.28^a	5.50^a	1.08^a	1.14^a	0.94^a
F_3	1125:490:1125	5.30^a	5.38^a	5.44^a	1.17^a	1.06^a	1.08^a
F_4	1500:650:1500	5.24^a	5.42^a	5.18^a	0.94^a	1.12^a	0.97^a
SEm±		0.12	0.10	0.09	0.09	0.06	0.06

Table 63. Available N and P content of soil as influenced by fertilizer levels

Trt. No	Fertilizer levels	Available N (kg ha^{-1})			Available P (kg ha^{-1})		
		97-98	98-99	99-00	97-98	98-99	99-00
F_0	No fertilizer	194.8^d	152.0^b	161.8^d	15.12^a	13.08^a	11.62^c
F_1	375:165:375	213.6^b	165.0^b	168.4^d	14.30^a	20.04^a	14.30^{bc}
F_2	750:325:750	231.5^a	186.6^b	205.2^c	11.16^a	15.46^a	11.90^c
F_3	1125:490:1125	185.3^e	221.4^a	248.0^a	16.24^a	21.26^a	17.90^a
F_4	1500:650:1500	195.8^c	229.0^a	220.2^b	15.78^a	19.56^a	15.30^{ab}
SEm±		31.06	15.69	19.15	2.89	2.63	0.99

Table 64. Exchangeable K content of soil as influenced by fertilizer levels

Trt. No	Fertilizer levels	Exchangeable K (kg ha^{-1})		
		97-98	98-99	99-00
F_0	No fertilizer	203.5^b	177.8^d	165.6^a
F_1	375:165:375	198.5^b	205.2^c	187.2^a
F_2	750:325:750	293.4^a	275.4^b	273.8^a
F_3	1125:490:1125	218.3^b	208.0^c	233.2^a
F_4	1500:650:1500	258.3^{ab}	295.2^a	302.0^a
SEm±		25.6	13.09	22.7

* g N, P_2O_5, K_2O tree^{-1} year^{-1}

treatments was similar during both years. The treatments F_0, F_1 and F_2 were on par while F_2, F_3 and F_4 were also on par.

Significant variation in P content could be observed only during the final year of the study. Available P content of soil ranged from 11.62 kg ha^{-1} in control to 17.90 kg ha^{-1} in F_3. However any definite trend in difference between the treatments in soil P content was not seen.

4.3 Exp. III Effect of soil application of lime and magnesium sulfate on growth and productivity of graft-raised cashew

i) Growth and physiological characters

Lime and $MgSO_4$ were applied to graft raised cashew at 5 YAP (1997) and 6 YAP (1998) and the observations on growth and flowering characters, yield attributes, nut yield and leaf nutrient concentration were recorded at 6 YAP (1998). The data are furnished in tables 65 to 71.

The trees that received lime or $MgSO_4$ (both at 500, 1000 or 1500 g $tree^{-1}$) did not differ in growth parameters viz. height, girth and canopy spread (Table 65). Though the effect of treatments on the production of flushes was not significant, a clear positive trend with the application of either lime or $MgSO_4$ or both was observed. The effect of the different levels of lime averaged over varied levels of $MgSO_4$ showed improvement in number of flushes when compared to no lime application. The very same trend was observed for $MgSO_4$ also at different levels of lime. In the combination treatments the highest number of flushes (34.67) was observed with the combination treatment of 1000 g lime and $MgSO_4$ each against 28.67 in control.

Application of lime and $MgSO_4$ at 500, 1000 or 1500 g $tree^{-1}$ did not change the chlorophyll content (chlorophyll *a*, chlorophyll *b* and total chlorophyll) in leaves at pre-flushing stage (Table 66). However application of lime improved the chlorophyll *a* and application of $MgSO_4$ improved chlorophyll *b* over the control treatments.

ii) Flowering characters

The data on flowering characters (percentage of flowering shoots, number and percentage of bisexual flowers $panicle^{-1}$ and number of nuts $panicle^{-1}$) are furnished in Table 67. The percentage of flowering shoots did not change due to

Table 65. Effect of lime and magnesium sulfate on growth characters

Treat. Notation	Levels of lime*	Height (cm)	Girth (cm)	Canopy spread (m)	No. of flushes m^{-2}
L_0	No lime	4.91^{a}	76.08^{a}	6.69^{a}	28.67^{a}
L_1	500 g lime	4.74^{a}	73.60^{a}	6.42^{ab}	29.17^{a}
L_2	1000 g lime	4.80^{a}	75.10^{a}	6.00^{b}	30.59^{a}
L_3	1500 g lime	4.66^{a}	75.80^{a}	6.12^{b}	30.75^{a}
SEm±		0.11	1.45	0.15	0.77
Treat. Notation	Levels of $MgSO_4$*				
Mg_0	No $MgSO_4$	4.59^{b}	74.58^{a}	6.50^{a}	28.67^{a}
Mg_1	500 g $MgSO_4$	4.82^{ab}	76.17^{a}	6.01^{b}	30.33^{a}
Mg_2	1000 g $MgSO_4$	4.73^{ab}	74.33^{a}	6.54^{ab}	30.67^{a}
Mg_3	1500 g $MgSO_4$	4.96^{a}	75.75^{a}	6.18^{ab}	29.50^{a}
SEm±		0.18	1.45	0.15	0.77
Treat. Notation	Treatments*				
L_0Mg_0	Control	4.43^{b}	74.33^{ab}	6.10^{cdef}	28.67^{b}
L_0Mg_1	500 g $MgSO_4$	5.08^{ab}	76.67^{ab}	6.83^{abc}	30.00^{ab}
L_0Mg_2	1000 g $MgSO_4$	4.73^{ab}	75.00^{ab}	6.70^{abcd}	28.33^{b}
L_0Mg_3	1500 g $MgSO_4$	5.40^{a}	78.33^{a}	7.13^{ab}	27.67^{b}
L_1Mg_0	500 g lime	4.76^{ab}	77.33^{a}	7.32^{a}	27.67^{b}
L_1Mg_1	500 g lime + 500 g $MgSO_4$	4.48^{b}	77.67^{a}	5.58^{f}	30.33^{ab}
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	4.77^{ab}	72.00^{ab}	7.18^{ab}	29.67^{ab}
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	4.93^{ab}	67.33^{b}	5.62^{f}	29.00^{b}
L_2Mg_0	1000 g lime	4.70^{ab}	69.67^{ab}	5.92^{cdef}	27.67^{b}
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	4.94^{ab}	77.33^{a}	5.75^{def}	29.00^{b}
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	4.67^{ab}	75.67^{ab}	6.05^{cdef}	34.67^{a}
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	4.90^{ab}	78.67^{a}	6.28^{bcdef}	31.00^{ab}
L_3Mg_0	1500 g lime	4.46^{b}	77.00^{ab}	6.65^{abcde}	30.67^{ab}
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	4.80^{ab}	73.00^{ab}	5.90^{cdef}	32.00^{ab}
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	4.78^{ab}	74.67^{ab}	6.23^{bcdef}	30.00^{ab}
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	4.62^{b}	78.67^{a}	5.68^{def}	30.33^{ab}
SEm±		0.22	2.90	0.31	1.53

* $tree^{-1}$ $year^{-1}$

Table 66. Effect of lime and magnesium sulfate on chlorophyll content of leaves at flushing stage

Treat. Notation	Levels of lime*	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Total chlorophyll (mg g^{-1})
L_0	No lime	1.23^{b}	0.75^{ab}	1.98^{a}
L_1	500 g lime	1.25^{b}	0.77^{ab}	2.03^{a}
L_2	1000 g lime	1.29^{ab}	0.68^{b}	1.97^{a}
L_3	1500 g lime	1.32^{a}	0.77^{a}	2.09^{a}
SEm±		0.03	0.03	0.06
Treat. Notation	Levels of $MgSO_4$*			
Mg_0	No $MgSO_4$	1.28^{a}	0.70^{a}	1.92^{a}
Mg_1	500 g $MgSO_4$	1.34^{a}	0.74^{a}	1.99^{a}
Mg_2	1000 g $MgSO_4$	1.31^{a}	0.79^{a}	2.08^{a}
Mg_3	1500 g $MgSO_4$	1.16^{b}	0.75^{a}	2.07^{a}
SEm±		0.03	0.03	0.06
Treat. Notation	Treatments*			
L_0Mg_0	Control	1.23^{bcde}	0.75^{ab}	1.94^{ab}
L_0Mg_1	500 g $MgSO_4$	1.23^{bcde}	0.68^{ab}	1.88^{ab}
L_0Mg_2	1000 g $MgSO_4$	1.28^{abcd}	0.76^{ab}	1.96^{ab}
L_0Mg_3	1500 g $MgSO_4$	1.20^{cde}	0.80^{a}	2.14^{ab}
L_1Mg_0	500 g lime	1.25^{bcd}	0.75^{ab}	1.95^{ab}
L_1Mg_1	500 g lime + 500 g $MgSO_4$	1.35^{abc}	0.79^{a}	2.03^{ab}
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	1.31^{abcd}	0.82^{a}	2.14^{ab}
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	1.09^{e}	0.71^{ab}	2.00^{ab}
L_2Mg_0	1000 g lime	1.26^{abcd}	0.59^{b}	1.79^{b}
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	1.37^{ab}	0.69^{ab}	1.93^{ab}
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	1.32^{abcd}	0.74^{ab}	2.05^{ab}
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	1.20^{cde}	0.71^{ab}	2.11^{ab}
L_3Mg_0	1500 g lime	1.38^{ab}	0.72^{ab}	2.01^{ab}
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	1.42^{a}	0.79^{a}	2.11^{ab}
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	1.34^{abc}	0.82^{a}	2.08^{a}
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	1.16^{de}	0.76^{ab}	2.06^{ab}
SEm±		0.05	0.06	0.11

*$tree^{-1}$ $year^{-1}$

Table 67. Effect of lime and magnesium sulfate on flowering characters

Treat. Notation	Levels of lime*	Per cent of flowering shoots	Per cent of bisexual flowers	No. of bisexual flowers panicle^{-1}	Nuts panicle^{-1}
L_0	No lime	74.30^{a}	13.81^{a}	16.30^{a}	5.45^{a}
L_1	500 g lime	74.40^{a}	13.24^{a}	23.63^{a}	4.89^{b}
L_2	1000 g lime	76.43^{a}	14.62^{a}	19.73^{a}	5.24^{ab}
L_3	1500 g lime	76.34^{a}	15.33^{a}	19.49^{a}	5.47^{a}
SEm±		3.85	0.87	2.60	0.17
Treat. Notation	Levels of $MgSO_4$*				
Mg_0	No $MgSO_4$	66.74^{b}	10.81^{c}	13.66^{b}	4.53^{c}
Mg_1	500 g $MgSO_4$	76.29^{ab}	11.99^{c}	21.03^{ab}	4.90^{c}
Mg_2	1000 g $MgSO_4$	80.29^{a}	15.38^{b}	25.33^{a}	6.13^{a}
Mg_3	1500 g $MgSO_4$	78.14^{ab}	18.83^{a}	21.30^{ab}	5.50^{b}
SEm±		3.85	0.87	2.60	0.17
Treat. Notation	Treatments*				
L_0Mg_0	Control	78.43^{ab}	12.37^{cdef}	15.97^{abc}	5.03^{bc}
L_0Mg_1	500 g $MgSO_4$	65.53^{ab}	11.13^{def}	16.53^{abc}	4.77^{bcd}
L_0Mg_2	1000 g $MgSO_4$	76.57^{ab}	13.93^{bcdef}	19.93^{abc}	6.23^{a}
L_0Mg_3	1500 g $MgSO_4$	76.67^{ab}	17.80^{abc}	13.07^{bc}	5.77^{ab}
L_1Mg_0	500 g lime	60.77^{b}	10.13^{ef}	20.73^{abc}	3.90^{de}
L_1Mg_1	500 g lime + 500 g $MgSO_4$	73.40^{ab}	10.67^{def}	27.60^{ab}	5.47^{ab}
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	77.83^{ab}	16.07^{bcd}	22.87^{abc}	5.43^{ab}
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	85.60^{ab}	16.10^{bcd}	23.33^{abc}	4.77^{bcd}
L_2Mg_0	1000 g lime	65.87^{ab}	9.37^{f}	6.33^{c}	5.07^{bc}
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	80.83^{ab}	11.10^{def}	27.00^{ab}	3.57^{e}
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	90.70^{a}	16.20^{bcd}	26.37^{ab}	6.47^{a}
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	68.30^{ab}	21.80^{a}	19.20^{abc}	5.87^{ab}
L_3Mg_0	1500 g lime	61.90^{b}	11.37^{def}	11.63^{bc}	4.10^{cde}
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	85.40^{ab}	15.07^{bcdef}	13.00^{bc}	5.80^{ab}
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	76.07^{ab}	15.30^{bcde}	32.13^{a}	6.37^{a}
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	82.00^{ab}	19.60^{ab}	21.20^{abc}	5.80^{ab}
SEm±		7.70	1.73	5.20	0.35

* tree^{-1} year^{-1}

different levels of lime or $MgSO_4$ from 500 to 1500 g $tree^{-1}$ $year^{-1}$ or due to the combined application.

The number of bisexual flowers $panicle^{-1}$ was not affected by the levels of lime, but it increased with increase in $MgSO_4$ up to a level of 1000 g $tree^{-1}$. Further increase in applied $MgSO_4$ up to 1500 g $tree^{-1}$ did not influence the number of bisexual flowers produced in a panicle. The percentage of bisexual flowers increased with increase in $MgSO_4$ application up to the highest dose of 1500 g $tree^{-1}$ $year^{-1}$ (Mg_3). The highest (18.83) percentage of bisexual flowers was observed in trees that received $MgSO_4$ at 1500 g $year^{-1}$ (Mg_3) and the lowest (10.81 per cent) in trees that were not applied with $MgSO_4$.

The combined application of different levels of lime and $MgSO_4$ significantly influenced the percentage of bisexual flowers. The combination treatments gave the highest (21.80) percentage of bisexual flowers when 1000 g lime was applied along with 1500 g $MgSO_4$. The highest dose of lime and $MgSO_4$ (1500 g each) also showed considerable improvement in the character. The treatment combination involving 500 g lime along with 1000 or 1500 g $MgSO_4$, 1000 g each of both and 1500 g $MgSO_4$ alone also produced comparatively higher percentage of bisexual flowers (16.07 to 17.80).

Levels of $MgSO_4$ at 1000 g and 1500 g $tree^{-1}$ $year^{-1}$ significantly increased the number of nuts $panicle^{-1}$ over the control as well as the dose of 500 g $tree^{-1}$ $year^{-1}$. The highest of number of nuts (6.13 $panicle^{-1}$) was observed in trees that received 1000 g $MgSO_4$ and the lowest (4.53 $pancile^{-1}$) in trees that did not receive any $MgSO_4$.

Different levels of lime did not change the number of nuts $panicle^{-1}$. Interaction effect was significant with the highest number of nuts (6.47 $panicle^{-1}$) in trees that were applied with 1000 g each of lime and $MgSO_4$ $tree^{-1}$ (L_2Mg_2) closely followed by those with the treatment 1500 g lime and 1000 g $MgSO_4$ (L_3Mg_2) which produced 6.37 nuts $panicle^{-1}$. Perusal of the effect of combination treatment on number of nuts shows that the treatment which received lime alone resulted in lesser nuts $panicle^{-1}$, some times lower than the control.

Application of lime at 1500 g $tree^{-1}$, gave the longest duration (53 days) of harvest but the effect was on par with that of 500 g and 1000 g lime $tree^{-1}$. The duration of harvest did not change due to levels of $MgSO_4$. The interaction between lime and $MgSO_4$ was significant with the trees that received the combination of 1500 g lime and 1000 g $MgSO_4$ (L_3Mg_2) recording the longest duration (59.67 days).

c) Nut yield and nut characters

Levels of lime or $MgSO_4$ did not exert any significant influence on either the nut yield or nut weight (Table 68). However, the application as well as the increasing levels of lime or $MgSO_4$ showed an increasing trend in the nut yield. The combination treatments exerted significant influence on nut yield. The highest yield of 5.70 kg tree^{-1} was observed for the treatment 500 g lime and 1500 g $MgSO_4$ tree^{-1} followed by $MgSO_4$ alone at 1000 g tree^{-1} (5.38 kg) and 1500 g lime and 500 g $MgSO_4$ (5.22 kg).

Shelling percentage was influenced by levels of lime independently as well as in combination with $MgSO_4$. However on averaging the effect of $MgSO_4$ alone, the levels did not show any effect. Shelling percentage was the highest (32.90) in nuts from trees that received the treatment L_2Mg_3 (1000 g lime + 1500 g $MgSO_4$). The treatment combination of L_2Mg_2 (32.63 per cent) and L_3Mg_1 (32.60 per cent) also gave similar results.

d) Nutrient concentration in leaves

The effect of lime application averaged over the levels of $MgSO_4$ did not produce any significant effect on the concentration of any of the critical nutrient in leaf except Zn (Table 69, 70 and 71). Similar trend was observed when the effect of $MgSO_4$ was averaged over different levels of lime also. However, the data reveal a definite trend in the variation in leaf nutrient concentration with respect to major, secondary and micro nutrients due to treatment effects. Leaf N content showed a step wise increase with increasing doses of lime from 1.52 per cent in control to 1.65 per cent at 1500 g lime tree^{-1}. Similarly, the N content increased from 1.45 per cent in trees without $MgSO_4$ application to 1.66 per cent when 1500 g $MgSO_4$ tree^{-1} was applied. Such a phenomenon is observed in the case of P content of leaves with lime application, but with $MgSO_4$ application the P content showed a step wise reduction. A similar result as that of P was observed for leaf K content.

A perusal of the effect of combination treatments shows that non application of either lime or $MgSO_4$ resulted in the lowest concentration of leaf N, P or K contents. Higher N content was observed for combination of lime and $MgSO_4$. Lime

Table 68. Effect of lime and magnesium sulfate on nut yield and nut characters

Treat. Notation	Levels of lime*	Harvest duration (Days)	Nut yield (kg $tree^{-1}$)	Nut weight (g)	Shelling per cent
L_0	No lime	42.75^{b}	3.67^{a}	6.18^{a}	30.99^{a}
L_1	500 g lime	45.75^{ab}	3.77^{a}	5.91^{b}	29.80^{b}
L_2	1000 g lime	50.00^{ab}	4.29^{a}	5.94^{b}	31.47^{a}
L_3	1500 g lime	53.00^{a}	4.00^{a}	6.04^{ab}	31.18^{a}
SEm±		2.40	0.47	0.07	0.41
Treat. Notation	Levels of $MgSO_4$*				
Mg_0	No $MgSO_4$	45.58^{a}	3.43^{a}	5.98^{ab}	29.88^{b}
Mg_1	500 g $MgSO_4$	50.25^{a}	4.35^{a}	5.86^{b}	31.11^{a}
Mg_2	1000 g $MgSO_4$	50.58^{a}	4.77^{a}	6.16^{a}	31.30^{a}
Mg_3	1500 g $MgSO_4$	47.08^{a}	4.58^{a}	6.08^{a}	31.15^{a}
SEm±		2.40	0.47	0.07	0.41
Treat. Notation	Treatments*				
L_0Mg_0	Control	36.67^{c}	3.20^{cde}	5.90^{bcd}	31.47^{bc}
L_0Mg_1	500 g $MgSO_4$	40.33^{b}	2.62^{cde}	6.40^{a}	31.40^{bc}
L_0Mg_2	1000 g $MgSO_4$	47.67^{abc}	5.38^{ab}	6.27^{ab}	30.43^{bc}
L_0Mg_3	1500 g $MgSO_4$	46.33^{abc}	3.47^{bcd}	6.17^{abc}	30.67^{bc}
L_1Mg_0	500 g lime	52.33^{abc}	3.62^{bcd}	6.17^{abc}	30.10^{bc}
L_1Mg_1	500 g lime + 500 g $MgSO_4$	52.33^{abc}	4.68^{abc}	5.60^{d}	29.00^{c}
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	49.67^{abc}	4.25^{bcd}	6.03^{abcd}	29.60^{c}
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	36.67^{c}	5.70^{a}	5.83^{bcd}	30.50^{abc}
L_2Mg_0	1000 g lime	38.33^{c}	3.80^{bcd}	5.80^{cd}	28.90^{c}
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	58.67^{a}	4.90^{abc}	5.60^{d}	31.43^{abc}
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	45.33^{abc}	4.53^{abc}	6.13^{abc}	32.63^{ab}
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	57.67^{a}	4.50^{abc}	6.23^{abc}	32.90^{a}
L_3Mg_0	1500 g lime	55.00^{ab}	3.11^{cde}	6.03^{abcd}	29.03^{c}
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	49.67^{abc}	5.22^{ab}	5.83^{bcd}	32.60^{ab}
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	59.67^{a}	4.92^{abc}	6.20^{abc}	32.55^{ab}
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	47.67^{abc}	4.63^{abc}	6.10^{abc}	30.53^{abc}
SEm±		4.80	0.94	0.13	0.82

* $tree^{-1}$ $year^{-1}$

Table 69. Effect of soil application of lime and magnesium sulfate on N, P and K content of leaves at pre-flushing stage

Treatment Notation	Levels of lime*	N (%)	P (%)	K (%)
L_0	No lime	1.52[a]	0.130[b]	0.51[a]
L_1	500 g lime	1.52[a]	0.139[a]	0.53[a]
L_2	1000 g lime	1.58[a]	0.133[b]	0.57[a]
L_3	1500 g lime	1.65[a]	0.142[a]	0.57[a]
SEm±		0.06	0.003	0.02
Treatment Notation	Levels of $MgSO_4$			
Mg_0	No $MgSO_4$	1.45[b]	0.140[a]	0.53[a]
Mg_1	500 g $MgSO_4$ tree^{-1}	1.55[ab]	0.136[b]	0.56[a]
Mg_2	1000 g $MgSO_4$ tree^{-1}	1.61[ab]	0.134[b]	0.56[a]
Mg_3	1500 g $MgSO_4$ tree^{-1}	1.66[a]	0.134[b]	0.53[a]
SEm±		0.06	0.003	0.02
Treatment Notation	Treatments*			
L_0Mg_0	Control	1.40[a]	0.113[f]	0.46[b]
L_0Mg_1	500 g $MgSO_4$	1.45[a]	0.126[h]	0.53[ab]
L_0Mg_2	1000 g $MgSO_4$	1.60[a]	0.145[abc]	0.55[ab]
L_0Mg_3	1500 g $MgSO_4$	1.64[a]	0.138[def]	0.50[ab]
L_1Mg_0	500 g lime	1.40[a]	0.150[a]	0.58[ab]
L_1Mg_1	500 g lime + 500 g $MgSO_4$	1.46[a]	0.140[cde]	0.53[ab]
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	1.48[a]	0.131[g]	0.52[ab]
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	1.73[a]	0.136[efg]	0.48[ab]
L_2Mg_0	1000 g lime	1.47[a]	0.148[ab]	0.57[ab]
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	1.52[a]	0.143[bcd]	0.57[ab]
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	1.70[a]	0.120[i]	0.58[ab]
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	1.63[a]	0.119[i]	0.57[ab]
L_3Mg_0	1500 g lime	1.52[a]	0.147[ab]	0.51[ab]
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	1.75[a]	0.134[fg]	0.62[a]
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	1.67[a]	0.143[bcd]	0.59[ab]
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	1.64[a]	0.143[bcd]	0.56[ab]
SEm±		0.12	0.007	0.04

* tree^{-1} year^{-1}

Table 70. Effect of lime and magnesium sulfate on Ca, Mg and S content of leaves at pre-flushing stage

Treatment Notation	Levels of lime*	Ca (%)	Mg (%)	S (%)
L_0	No lime	0.20^{b}	0.22^{a}	0.11^{a}
L_1	500 g lime	0.21^{ab}	0.22^{a}	0.12^{a}
L_2	1000 g lime	0.22^{ab}	0.25^{a}	0.11^{a}
L_3	1500 g lime	0.25^{a}	0.23^{a}	0.12^{a}
SEm±		0.02	0.01	0.01
Treatment Notation	Levels of $MgSO_4$*			
Mg_0	No $MgSO_4$	0.23^{a}	0.22^{a}	0.11^{a}
Mg_1	500 g $MgSO_4$	0.22^{a}	0.23^{a}	0.11^{a}
Mg_2	1000 g $MgSO_4$	0.22^{a}	0.23^{a}	0.12^{a}
Mg_3	1500 g $MgSO_4$	0.22^{a}	0.24^{a}	0.12^{a}
SEm±		0.02	0.01	0.01
Treatment Notation	Treatments*			
L_0Mg_0	Control	0.18^{ab}	0.20^{a}	0.11^{cde}
L_0Mg_1	500 g $MgSO_4$	0.25^{ab}	0.22^{a}	0.10^{e}
L_0Mg_2	1000 g $MgSO_4$	0.20^{ab}	0.21^{a}	0.13^{ab}
L_0Mg_3	1500 g $MgSO_4$	0.16^{b}	0.25^{a}	0.13^{ab}
L_1Mg_0	500 g lime	0.22^{ab}	0.19^{a}	0.11^{cde}
L_1Mg_1	500 g lime + 500 g $MgSO_4$	0.18^{ab}	0.22^{a}	0.12^{bcd}
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	0.26^{ab}	0.23^{a}	0.12^{bcd}
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	0.20^{ab}	0.23^{a}	0.12^{bcd}
L_2Mg_0	1000 g lime	0.26^{ab}	0.27^{a}	0.10^{e}
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	0.23^{ab}	0.24^{a}	0.11^{cde}
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	0.16^{b}	0.25^{a}	0.13^{ab}
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	0.22^{ab}	0.23^{a}	0.11^{cde}
L_3Mg_0	1500 g lime	0.25^{ab}	0.20^{a}	0.11^{cde}
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	0.21^{ab}	0.24^{a}	0.13^{ab}
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	0.26^{ab}	0.25^{a}	0.12^{bcd}
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	0.28^{a}	0.23^{a}	0.12^{bcd}
SEm±		0.03	0.03	0.02

* $tree^{-1}$ $year^{-1}$

Table 71. Effect of lime and magnesium sulfate on Fe, Mn and Zn content of leaves at pre-flushing stage

Treat. Notation	Levels of lime*	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
L_0	No lime	323.3^{a}	318.7^{a}	19.6^{ab}	6.4^{a}
L_1	500 g lime	355.4^{a}	286.8^{ab}	21.7^{a}	6.1^{a}
L_2	1000 g lime	364.3^{a}	299.3^{ab}	22.2^{a}	5.1^{a}
L_3	1500 g lime	317.1^{a}	253.3^{b}	16.2^{b}	5.0^{a}
SEm±		21.7	19.5	1.3	0.7
Treat. Notation	Levels of $MgSO_4$*				
Mg_0	No $MgSO_4$	361.8^{a}	291.0^{a}	24.3^{a}	6.3^{a}
Mg_1	500 g $MgSO_4$	311.2^{a}	283.3^{a}	19.6^{b}	6.2^{a}
Mg_2	1000 g $MgSO_4$	335.3^{a}	271.6^{a}	18.3^{b}	5.9^{a}
Mg_3	1500 g $MgSO_4$	351.9^{a}	312.3^{a}	17.5^{b}	5.9^{a}
SEm±		21.7	19.5	1.3	0.7
Treat. Notation	Treatments*				
L_0Mg_0	Control	447.0^{a}	313.7^{ab}	26.0^{ab}	8.7^{a}
L_0Mg_1	500 g $MgSO_4$	327.0^{abc}	297.3^{ab}	21.7^{abc}	8.0^{ab}
L_0Mg_2	1000 g $MgSO_4$	251.7^{bc}	261.3^{b}	18.0^{abcd}	5.0^{ab}
L_0Mg_3	1500 g $MgSO_4$	267.3^{bc}	402.3^{a}	12.7^{d}	4.0^{b}
L_1Mg_0	500 g lime	267.7^{bc}	232.3^{b}	24.3^{ab}	5.3^{ab}
L_1Mg_1	500 g lime + 500 g $MgSO_4$	271.3^{bc}	287.0^{ab}	18.7^{abcd}	7.0^{ab}
L_1Mg_2	500 g lime + 1000 g $MgSO_4$	452.7^{a}	290.7^{ab}	19.7^{abcd}	7.3^{ab}
L_1Mg_3	500 g lime + 1500 g $MgSO_4$	430.0^{a}	337.0^{ab}	24.0^{ab}	4.7^{ab}
L_2Mg_0	1000 g lime	389.0^{abc}	339.7^{ab}	26.3^{a}	6.7^{ab}
L_2Mg_1	1000 g lime + 500 g $MgSO_4$	362.3^{abc}	337.3^{ab}	20.7^{abcd}	5.0^{ab}
L_2Mg_2	1000 g lime + 1000 g $MgSO_4$	390.7^{abc}	265.3^{b}	21.0^{abcd}	6.3^{ab}
L_2Mg_3	1000 g lime + 1500 g $MgSO_4$	315.3^{abc}	255.0^{b}	20.7^{abcd}	5.7^{ab}
L_3Mg_0	1500 g lime	343.3^{abc}	278.3^{ab}	20.3^{abcd}	4.7^{ab}
L_3Mg_1	1500 g lime + 500 g $MgSO_4$	284.0^{bc}	211.3^{b}	17.3^{bcd}	4.7^{ab}
L_3Mg_2	1500 g lime + 1000 g $MgSO_4$	246.0^{c}	269.0^{b}	14.3^{cd}	4.7^{ab}
L_3Mg_3	1500 g lime + 1500 g $MgSO_4$	395.0^{ab}	254.7^{b}	12.7^{d}	6.0^{ab}
SEm±		43.5	38.9	2.6	1.3

*$tree^{-1}$ $year^{-1}$

alone treatments resulted in lower N content than $MgSO_4$ alone treatments. As in the case of N, the combination treatments resulted in high P content in leaves, but $MgSO_4$ alone treatments resulted in high leaf P content than lime alone treatments. The leaf K concentration was the highest (0.62 per cent) in the combination treatment of 1500 g lime + 500 $MgSO_4$ and the lowest (0.46 per cent) in trees that did not receive both the nutrients (control). Here also lime alone treatments resulted in higher K content than $MgSO_4$ alone treatments.

Both Ca and Mg content of leaf showed an increasing trend with application of lime when its effect was averaged over different levels of $MgSO_4$. However the Ca content was found to be decreasing with higher levels of $MgSO_4$, while Mg content was found to be increasing.

The Fe content of leaves reduced with increasing levels of $MgSO_4$ application. Lime application at higher levels tended to increase Fe content. The Fe concentration was as high as 447 ppm in the control against 327, 251 and 267 ppm in graded levels of $MgSO_4$ from 500 to 1500 g tree^{-1}. Leaf Mn content was found to be decreasing with increasing levels of either lime or $MgSO_4$. Zinc content tended to increase with moderate levels of lime, but decreased with increasing $MgSO_4$ application. Copper content of leaves was found to decrease with increasing levels of both lime and $MgSO_4$.

4.4 Exp. IV Varietal variation in leaf nutrient status and its relation to yield

Eighteen cashew varieties (graft raised) were evaluated during 10th and 11th year after planting (10 YAP and 11 YAP) for various growth, yield characters and tissue nutrient status. The results of the study are presented below.

a) Growth and physiological characters

i) Tree height

Tree height differed significantly between varieties and it ranged from 6.10 m (H-2/16) to 7.23 m (H-1598) at 10 YAP and from 6.83 m (BLA 139-1) to 9.17 m (V-3) at 11 YAP. Trees of four varieties (H-1610, H-1598, V-4 and V-3) had average height more than 7.5 m. The varieties M-44/3, BLA 139-1 and H-1608 had comparatively less tree height when the average of two years was considered. However the varieties did not differ statistically in terms of tree height (Table 72).

Table 72. Tree height, girth and canopy spread of cashew varieties

Sl. No.	Variety	Height (m)			Girth (cm)			Canopy spread (m)		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	6.20^{a}	6.80^{a}	6.50^{a}	69.3^{m}	75.2^{f}	72.3^{l}	7.80^{k}	8.32^{k}	8.06^{n}
2.	VTL-59/2	6.53^{a}	7.07^{a}	6.80^{a}	92.3^{d}	101.3^{d}	96.8^{de}	9.30^{fgh}	9.84^{fg}	9.57^{hi}
3.	V- 2	6.73^{a}	7.47^{a}	7.10^{a}	71.0^{l}	74.3^{j}	72.7^{l}	7.33^{l}	8.72^{f}	8.03^{h}
4.	M- 33/3	6.57^{a}	7.13^{a}	6.85^{a}	79.7^{f}	84.5^{i}	82.1^{k}	8.80^{ij}	9.42^{hi}	9.11^{l}
5.	H-1598	7.23^{a}	8.07^{a}	7.65^{a}	89.0^{f}	96.2^{e}	92.6^{g}	9.77^{e}	11.10^{cd}	10.44^{f}
6.	V-4	7.20^{a}	8.00^{a}	7.60^{a}	86.7^{g}	92.7^{f}	89.7^{h}	9.17^{ghi}	10.93^{d}	10.05^{f}
7.	T-129	6.53^{a}	7.57^{a}	7.05^{a}	92.0^{d}	102.3^{d}	97.2^{d}	10.20^{bc}	11.96^{b}	11.08^{b}
8.	M-26/2	6.83^{a}	7.43^{a}	7.13^{a}	91.3^{de}	97.0^{e}	94.2^{fg}	9.03^{hi}	9.99^{fg}	9.51^{ij}
9.	VTL-30/4	6.50^{a}	7.27^{a}	6.89^{a}	92.7^{d}	98.3^{e}	95.5^{ef}	9.77^{de}	10.52^{e}	10.15^{ef}
10.	V-5	6.70^{a}	7.40^{a}	7.05^{a}	84.7^{h}	92.0^{fg}	88.4^{hi}	8.87^{ij}	9.71^{gh}	9.29^{k}
11.	H-1608	6.30^{a}	6.97^{a}	6.64^{a}	82.0^{i}	89.0^{h}	85.5^{j}	9.00^{hij}	9.71^{gh}	9.36^{jk}
12.	H-1600	6.33^{a}	7.20^{a}	6.77^{a}	99.3^{c}	106.0^{c}	102.7^{c}	9.63^{ef}	10.97^{cd}	10.30^{de}
13.	H-1610	6.17^{a}	8.90^{a}	8.04^{a}	110.0^{a}	127.5^{a}	118.8^{a}	11.47^{a}	14.08^{a}	12.78^{a}
14.	H-2/15	6.27^{a}	7.03^{a}	6.65^{a}	85.3^{gh}	90.2^{gh}	87.8^{i}	9.27^{fgh}	10.17^{ef}	9.72^{gh}
15.	T-40	6.67^{a}	7.27^{a}	6.97^{a}	89.0^{f}	96.7^{e}	92.9^{g}	9.47^{efg}	10.13^{f}	9.80^{g}
16.	H- 2/16	6.10^{a}	7.60^{a}	6.85^{a}	90.3^{ef}	96.3^{e}	93.3^{g}	10.13^{cd}	11.35^{c}	10.74^{c}
17.	V- 3	6.83^{a}	9.17^{a}	7.50^{a}	102.3^{b}	109.0^{b}	105.7^{b}	10.50^{b}	11.11^{cd}	10.81^{c}
18.	BLA-139-1	6.20^{a}	6.83^{a}	6.52^{a}	77.0^{k}	88.8^{h}	82.9^{j}	8.63^{j}	9.18^{i}	8.91^{m}
SEm±		0.39	0.39	0.38	5.1	5.9	5.9	0.48	0.76	0.75

ii) Tree girth

The tree girth differed significantly between the varieties. The tree girth was the highest in the variety H-1610 during both the years (110 cm and 127.5 cm at 10 YAP and 11 YAP respectively). Tree girth was the lowest in the variety M- 44/3 (69.3 cm) at 10 YAP and V-2 (74.3 cm) at 11 YAP.

iii) Canopy spread

There was considerable difference in the canopy spread between the varieties. Among the 18 varieties H-1610 had the widest canopy with 11.47 m and 14.08 m at 10 and 11 YAP respectively. The canopy spread was the lowest in the variety V-2 with 7.33 m and 8.72 m at 10 and 11 YAP respectively.

iv) Number of flushes

The flush production in terms of number of flushes per m^2 differed significantly between the varieties (Table 73). The variety H-1600 produced the highest number of flushes (38.00 m^{-2}) at 10 YAP while the variety M-26/2 produced the highest number of flushes per unit area (32.50 m^{-2}) at 11 YAP. Flush production was the lowest in the varieties M-44/3 (27.67 $m^{-2)}$ and H-2/16 (23.67 m^{-2}) during the first and second years of the study respectively. The average flush production for the two year period was the highest in the variety M-26/2 (34 m^{-2}) and it was on par with the varieties H-1600, H-1608, H-2/15 and V-4 .The lowest flush production (28.67 m^{-2}) was noticed in the variety T-129 when the average for two years was considered.

v) Number of panicles

Number of panicles m^{-2} differed significantly between the varieties (Table 73). Panicle production was the highest in the variety M-26/2 at 10 YAP (25.5 m^{-2}) and in V-2 (27.7 m^{-2}) at 11 YAP. The varieties T-129 and V-3 produced lesser number of panicles per unit area during the initial and final years of the study respectively. The variety M-26/2 had the highest average number of panicles for the two years (25 m^{-2}) and it was on par with that of M-44/3, VTL-30/4, V-5, H-1600, and T-40. The varieties V-3, H-1610, H-1598, T-129 and H-2/16 produced lesser number of panicles in unit area (18.58 to 19.75 m^{-2}) when the average of the values for two years was taken into account.

Table 73. Number of flushes and panicles in unit area in cashew varieties

Sl. No.	Variety	Flushes m^{-2}			Number of panicles m^{-2}		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	27.67^{c}	32.00^{a}	29.83^{ab}	21.33^{abc}	24.67^{a}	23.00^{ab}
2.	VTL-59/2	35.33^{ab}	27.67^{abcd}	31.50^{ab}	21.67^{abc}	20.67^{ab}	21.17^{abc}
3.	V- 2	34.67^{ab}	27.83^{abcd}	31.25^{ab}	21.33^{abc}	27.17^{ab}	21.25^{abc}
4.	M-33/3	34.83^{ab}	28.33^{abcd}	31.58^{ab}	20.50^{bc}	20.50^{ab}	20.50^{bc}
5.	H-1598	29.33^{bc}	31.00^{ab}	30.17^{ab}	18.50^{bc}	20.00^{ab}	19.25^{bc}
6.	V-4	36.83^{a}	27.83^{abcd}	32.33^{ab}	20.83^{abc}	21.47^{ab}	21.15^{abc}
7.	T-129	29.33^{bc}	28.00^{abcd}	28.67^{b}	17.67^{c}	21.00^{ab}	19.33^{bc}
8.	M-26/2	35.50^{ab}	32.50^{a}	34.00^{a}	25.50^{a}	24.50^{a}	25.00^{a}
9.	VTL-30/4	34.00^{ab}	25.00^{cd}	29.50^{ab}	23.00^{ab}	21.67^{ab}	22.33^{abc}
10.	V-5	33.67^{ab}	29.17^{abcd}	31.42^{ab}	22.67^{ab}	21.67^{ab}	22.17^{abc}
11.	H-1608	36.67^{a}	29.33^{abcd}	33.00^{ab}	21.67^{abc}	20.67^{ab}	21.17^{abc}
12.	H-1600	38.00^{a}	29.83^{abc}	33.92^{a}	22.17^{abc}	22.17^{ab}	22.17^{abc}
13.	H-1610	33.00^{sbc}	25.50^{bcd}	29.25^{ab}	19.17^{bc}	18.17^{b}	18.67^{bc}
14.	H-2/15	34.67^{ab}	30.33^{abc}	32.50^{ab}	20.33^{bc}	21.50^{ab}	20.92^{abc}
15.	T-40	34.67^{ab}	28.83^{abcd}	31.75^{ab}	21.33^{abc}	21.83^{ab}	21.58^{abc}
16.	H-2/16	34.17^{ab}	23.67^{a}	28.92^{b}	20.83^{abc}	18.67^{b}	19.75^{bc}
17.	V-3	35.00^{ab}	23.83^{d}	29.42^{ab}	19.83^{bc}	17.33^{b}	18.58^{c}
18.	BLA-139-1	34.33^{ab}	27.17^{abcd}	30.75^{ab}	20.83^{abc}	20.67^{ab}	20.75^{abc}
SEm±		1.83	1.69	1.44	1.33	1.44	1.28

vi) Chlorophyll content of leaves

Chlorophyll *a* content of leaves at flushing stage differed considerably between varieties in both years studied (Table 74). The varieties M-26/2 and BLA-139-1 had the highest chlorophyll *a* content (1.47 mg/g each) in leaves at flushing stage at 10 YAP, whereas the variety V-5 had the highest content (1.69 mg/g) at 11 YAP. Chlorophyll *a* content at flushing stage was low in the variety VTL-59/2 during both the years. When the average of the two years was considered, the highest chlorophyll *a* was observed in V-5 (1.44 mg/g) and the lowest (0.79 mg/g) in VTL-59/2 (Fig.22). Six other varieties namely, V-3, VTL-30/4, BLA 139-1, M-26/2, H-1598 and M-44/3 also maintained high chlorophyll *a* (1.28 to 1.41 mg g^{-1}) when the average for two years was considered.

As in the case of flushing, chlorophyll *a* content at flowering also differed significantly with the varieties (Table 74). The variety M-26/2 had the highest chlorophyll *a* content (0.96 mg g^{-1}) and VTL-59/2 had the lowest content (0.65 mg g^{-1}) at 10 YAP. During 11 YAP the varieties did not differ in chlorophyll *a* content at flowering stage. Chlorophyll *a* was the highest (0.98 mg g^{-1}) in the variety M-26/2 and the lowest (0.77 mg g^{-1}) in VTL-59/2 when the average for two years was taken in to account (Fig.23). Between flushing and flowering stages, chlorophyll *a* content was high at flushing compared to flowering.

The varieties differed considerably in the chlorophyll *b* content of leaves both at flushing as well as at flowering stages (Table 75). The varieties M-33/3 and H-1598 had the highest chlorophyll *b* content (0.89 mg g^{-1}) at flushing stage during the 10 th and 11th YAP respectively. The lowest content was noticed in the variety T-129 (0.53 mg g^{-1}) at 10 YAP and V-2 (0.42 mg g^{-1}) at 11 YAP. The average value for two years was the highest in the variety M-44/3 (0.82 mg g^{-1}) while it was the lowest in the varieties VTL-59/2 and H-1608 (0.58 mg g^{-1} each).

As in the case of flushing, the varieties differed significantly in chlorophyll *b* content of leaves at flowering stage also. Chlorophyll *b* content at flowering ranged from 0.49 mg g^{-1} (V-2) to 0.60 mg g^{-1} (M-26/2) at 10 YAP and from 0.51 mg g^{-1} (VTL-59/2) to 0.79 mg g^{-1} (M-26/2) at 11 YAP. When the average for the successive years was considered, the variety M-26/2 had the highest (0.69 mg g^{-1}) and VTL-59/2 had the lowest (0.51 mg g^{-1}) chlorophyll *b* content at flowering stage (Fig. 25).

Table 74. Chlorophyll *a* content of leaves (mg g^{-1}) at flushing and flowering stages of cashew varieties

Sl. No.	Variety	Flushing stage			Flowering stage		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	1.27^{abc}	1.35^{abc}	1.31^{abc}	0.81^{ab}	1.00^{a}	0.91^{ab}
2.	VTL-59/2	0.87^{cd}	0.72^{d}	0.79^{d}	0.65^{c}	0.88^{a}	0.77^{b}
3.	V-2	1.21^{abcd}	0.72^{d}	0.96^{cd}	0.77^{bc}	0.89^{a}	0.83^{ab}
4.	M-33/3	1.33^{ab}	1.11^{cd}	1.22^{abc}	0.76^{bc}	0.93^{a}	0.85^{ab}
5.	H-1598	1.11^{abcd}	1.57^{ab}	1.34^{ab}	0.82^{ab}	0.96^{a}	0.89^{ab}
6.	V-4	1.26^{abc}	1.22^{bc}	1.24^{abc}	0.83^{ab}	0.96^{a}	0.90^{ab}
7.	T-129	0.81^{d}	1.41^{abc}	1.11^{abcd}	0.85^{ab}	1.00^{a}	0.93^{a}
8.	M-26/2	1.47^{a}	1.18^{bc}	1.32^{abc}	0.96^{a}	1.00^{a}	0.98^{a}
9.	VTL-30/4	1.25^{abc}	1.22^{bc}	1.24^{abc}	0.76^{bc}	0.92^{a}	0.84^{ab}
10.	V-5	1.18^{abcd}	1.69^{a}	1.44^{a}	0.86^{ab}	1.02^{a}	0.94^{a}
11.	H-1608	0.95^{bcd}	1.08^{cd}	1.01^{bcd}	0.84^{ab}	0.92^{a}	0.88^{ab}
12.	H-1600	1.29^{abc}	1.12^{cd}	1.20^{abc}	0.84^{ab}	0.94^{a}	0.89^{ab}
13.	H-1610	1.21^{abcd}	1.18^{bc}	1.19^{abc}	0.82^{ab}	0.95^{a}	0.89^{ab}
14.	H- 2/15	1.15^{abcd}	1.23^{bc}	1.19^{abc}	0.79^{bc}	0.97^{a}	0.88^{ab}
15.	T-40	1.24^{abc}	1.20^{bc}	1.22^{abc}	0.86^{ab}	0.99^{a}	0.93^{a}
16.	H-2/16	1.20^{abcd}	1.18^{bc}	1.19^{abc}	0.89^{ab}	0.98^{a}	0.94^{a}
17.	V-3	1.14^{abcd}	1.42^{abc}	1.28^{abc}	0.80^{abc}	1.03^{a}	0.92^{ab}
18.	BLA-139-1	1.47^{a}	1.16^{bc}	1.32^{abc}	0.87^{ab}	1.00^{a}	0.94^{a}
SEm±		0.12	0.13	0.11	0.04	0.06	0.05

Fig. 22 Chlorophyll *a* content at flushing stage of cashew varieties

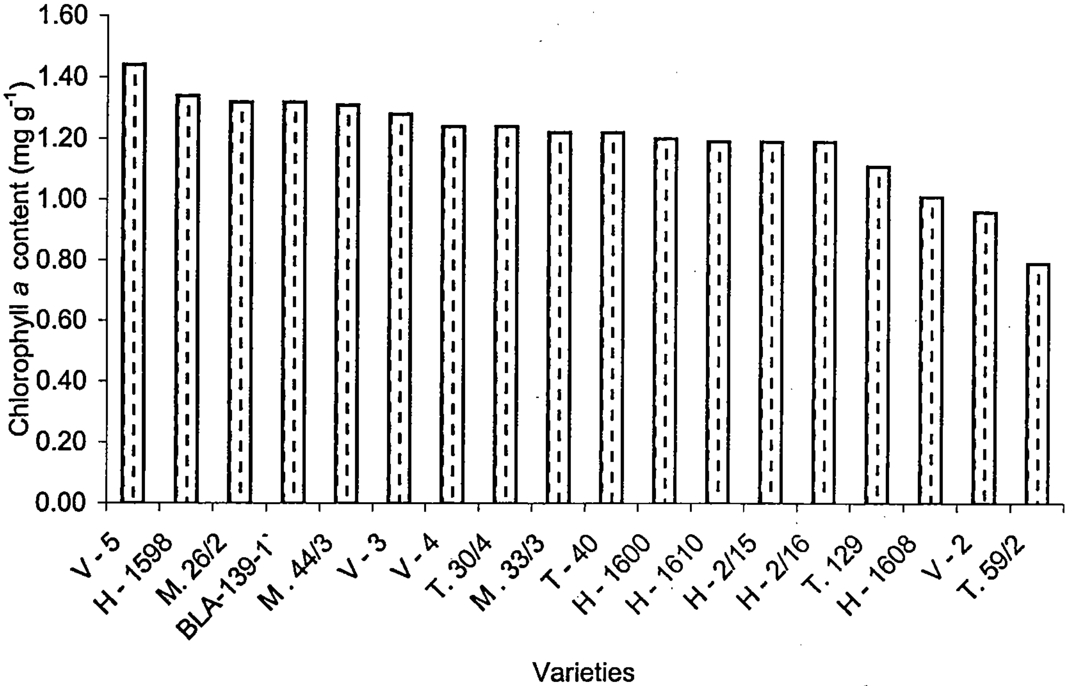


Fig. 23 Chlorophyll *a* content at flowering stage of cashew varieties

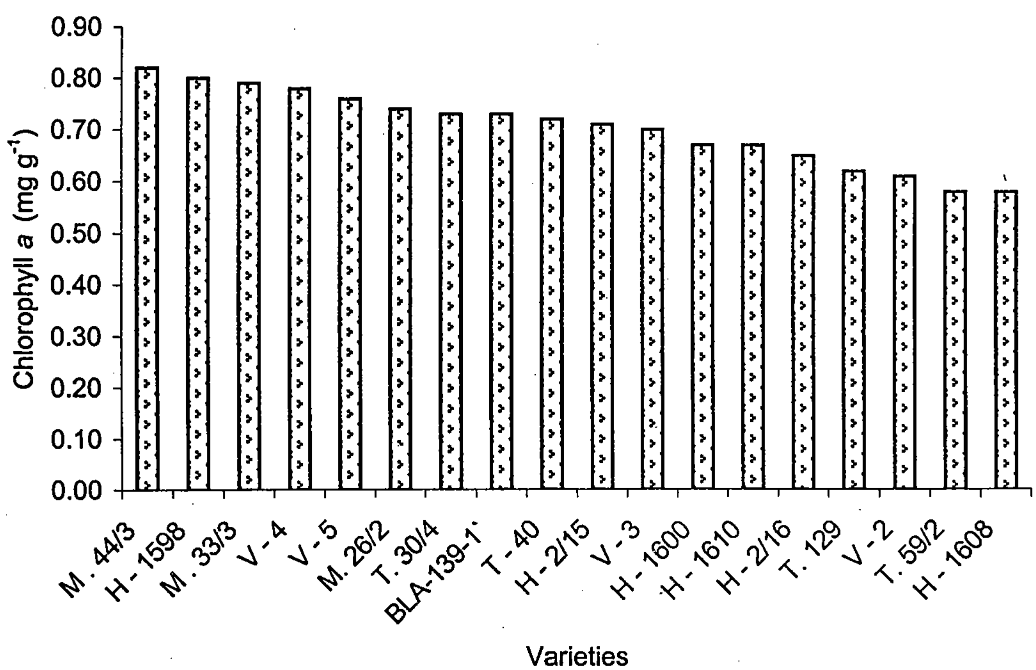


Table 75. Chlorophyll *b* content of leaves (mg g^{-1}) at flushing and flowering stages of cashew varieties

Sl. No.	Variety	Flushing stage			Flowering stage		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	0.81^{abc}	0.83^{ab}	0.82^{a}	0.55^{ab}	0.67^{ab}	0.61^{abc}
2.	VTL-59/2	0.62^{abcd}	0.55^{cde}	0.58^{ef}	0.51^{ab}	0.51^{b}	0.51^{c}
3.	V-2	0.79^{abc}	0.42^{e}	0.61^{def}	0.49^{b}	0.67^{ab}	0.58^{abc}
4.	M-33/3	0.89^{a}	0.69^{abcd}	0.79^{ab}	0.54^{ab}	0.61^{ab}	0.57^{bc}
5.	H-1598	0.70^{abcd}	0.89^{a}	0.80^{ab}	0.56^{ab}	0.67^{ab}	0.61^{abc}
6.	V-4	0.83^{ab}	0.74^{abcd}	0.78^{abc}	0.55^{ab}	0.65^{a}	0.60^{abc}
7.	T-129	0.53^{d}	0.71^{abcd}	0.62^{cdef}	0.54^{ab}	0.75^{a}	0.65^{ab}
8.	M-26/2	0.81^{abc}	0.68^{abcd}	0.74^{abcde}	0.60^{a}	0.79^{a}	0.69^{a}
9.	VTL-30/4	0.77^{abc}	0.69^{abcd}	0.73^{abcdef}	0.50^{b}	0.65^{a}	0.58^{bc}
10.	V-5	0.73^{abcd}	0.80^{abc}	0.76^{abcd}	0.55^{ab}	0.73^{a}	0.64^{ab}
11.	H-1608	0.59^{cd}	0.57^{bcde}	0.58^{f}	0.54^{ab}	0.70^{a}	0.62^{abc}
12.	H-1600	0.70^{abcd}	0.64^{abcde}	0.67^{abcdef}	0.53^{ab}	0.71^{a}	0.62^{abc}
13.	H-1610	0.72^{abcd}	0.61^{bcde}	0.67^{abcdef}	0.56^{ab}	0.70^{a}	0.63^{ab}
14.	H-2/15	0.74^{abcd}	0.68^{abcd}	0.71^{abcdef}	0.54^{ab}	0.70^{a}	0.63^{ab}
15.	T-40	0.78^{abc}	0.66^{abcde}	0.72^{abcdef}	0.58^{ab}	0.71^{a}	0.64^{ab}
16.	H-2/16	0.80^{abc}	0.50^{de}	0.65^{bcdef}	0.55^{ab}	0.77^{a}	0.66^{ab}
17.	V-3	0.73^{abcd}	0.67^{abcde}	0.70^{abcdef}	0.56^{ab}	0.68^{ab}	0.62^{abc}
18.	BLA-139-1	0.79^{abc}	0.67^{abcde}	0.73^{abcdef}	0.58^{ab}	0.70^{a}	0.64^{ab}
SEm±		0.07	0.08	0.05	0.04	0.06	0.04

Fig. 24 Chlorophyll *b* content at flushing stage of cashew varieties

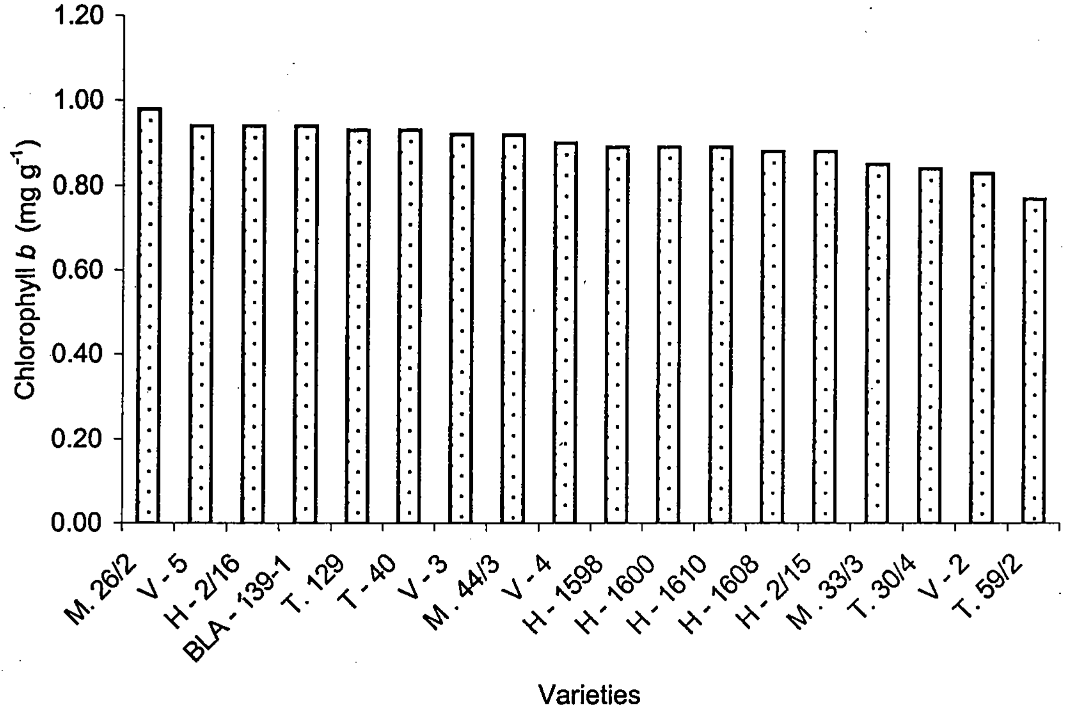
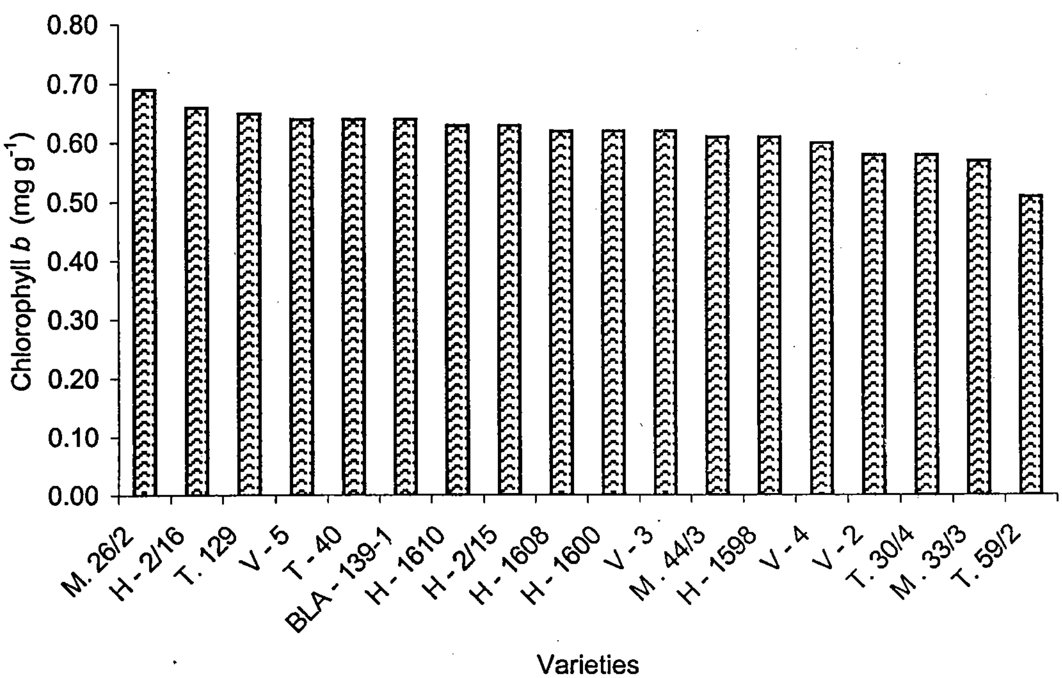


Fig. 25 Chlorophyll *b* content at flowering stage of cashew varieties



During the initial year of the study (10 YAP) total chlorophyll at flushing stage was the highest in the variety M-26/2 (2.23 mg g^{-1}) and the lowest in the variety T-129 (1.34 mg g^{-1}). But, during the second year (11 YAP) the variety V-5 had the highest (2.53 mg g^{-1}) total chlorophyll content and V-2 had the lowest (1.15 mg g^{-1}) content (Table 76). The average for two years (Fig. 26) was the highest in V-5 (2.22 mg g^{-1}) and the lowest in VTL-59/2 (1.39 mg g^{-1}).

At flowering stage, total chlorophyll was the highest in the variety M-26/2 during both years (1.55 and 1.79 mg g^{-1} respectively). The lowest content was observed in VTL-59/2 (1.16 and 1.39 mg g^{-1}) during both the years. The average values of total chlorophyll content of the 18 varieties are depicted in Fig. 27.

b) Nut yield and yield components

i) Number of nuts per panicle

The number of nuts per panicle ranged from 3.93 (T-129) to 7.40 (M-44/3) at 10 YAP and 2.93 (V-2) to 7.10 (V-3) at 11 YAP (Table 77). The average for two years was the highest in M-44/3 (7.07 nuts panicle $^{-1}$) and the lowest in V-2 (3.90).

ii) Harvest duration

The varieties differed considerably in the duration of harvest. The duration of harvest was the longest (62.3 days) in the variety V-5 and the shortest (41 days) in V-2 at 10 YAP. At 11 YAP the variety M-44/3 had the longest duration (57 days) and the variety H-1608 (45 days) had the shortest period of harvest.

iii) Nut yield

The varieties differed significantly in nut yield (Table 78). In general the nut yield at 10 YAP was more than that at 11 YAP. The variety M-26/2 gave the highest nut yield (13.23 kg $tree^{-1}$) and VTL-59/2 gave the lowest (4.20 kg $tree^{-1}$) at 10 YAP. During the second year of the study the variety V-5 produced the highest nut yield (12.41 kg $tree^{-1}$) and the variety V-2 gave the lowest yield (0.80 kg).

The average nut yield during the period of the study was the highest in V-5 (10.89 kg $tree^{-1}$) and the lowest in the variety VTL-59/2 (3.64 kg $tree^{-1}$). The varieties V-4, M-26/2, V-3, H-1598 and M-44/3 also gave comparatively higher nut yield ranging from 9.15 kg to 10.41 kg $tree^{-1}$ whereas the varieties V-2, H-1610, H-1600

Table 76. Total chlorophyll content of leaves (mg g^{-1}) at flushing and flowering stages of cashew varieties

Sl. No.	Variety	Flushing stage			Flowering stage		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	2.08^{abc}	2.18^{abc}	2.13^{ab}	1.36^{abc}	1.67^{ab}	1.52^{ab}
2.	VTL-59/2	1.49^{cd}	1.30^{de}	1.39^{e}	1.16^{c}	1.39^{b}	1.27^{b}
3.	V-2	1.99^{abc}	1.15^{e}	1.57^{de}	1.25^{bc}	1.55^{ab}	1.40^{ab}
4.	M-33/3	2.23^{a}	1.82^{bcd}	2.03^{abcd}	1.30^{bc}	1.54^{ab}	1.42^{ab}
5.	H-1598	1.81^{abcd}	2.38^{ab}	2.10^{ab}	1.38^{ab}	1.63^{ab}	1.50^{ab}
6.	V-4	2.09^{ab}	1.95^{abc}	2.02^{abcd}	1.38^{ab}	1.62^{ab}	1.50^{ab}
7.	T-129	1.34^{d}	2.13^{abc}	1.74^{bcde}	1.40^{ab}	1.75^{a}	1.58^{a}
8.	M-26/2	2.27^{a}	1.86^{bcd}	2.07^{abc}	1.55^{a}	1.79^{a}	1.67^{a}
9.	VTL-30/4	2.02^{abc}	1.92^{bcd}	1.97^{abcd}	1.26^{bc}	1.57^{ab}	1.41^{ab}
10.	V-5	1.91^{abc}	2.53^{a}	2.22^{a}	1.41^{ab}	1.74^{ab}	1.58^{a}
11.	H-1608	1.53^{bcd}	1.64^{cde}	1.59^{cde}	1.37^{abc}	1.62^{ab}	1.50^{ab}
12.	H-1600	1.98^{abc}	1.76^{bcd}	1.87^{abcd}	1.37^{abc}	1.65^{ab}	1.51^{ab}
13.	H-1610	1.93^{abc}	1.78^{bcd}	1.86^{abcd}	1.38^{ab}	1.65^{ab}	1.52^{ab}
14.	H-2/15	1.89^{abcd}	1.90^{bcd}	1.90^{abcd}	1.34^{abc}	1.67^{ab}	1.50^{ab}
15.	T-40	2.02^{abc}	1.89^{bcd}	1.96^{abcd}	1.45^{ab}	1.70^{ab}	1.57^{a}
16.	H-2/16	2.00^{abc}	1.69^{cde}	1.85^{abcd}	1.44^{ab}	1.75^{a}	1.59^{a}
17.	V-3	1.87^{abcd}	2.09^{abc}	1.98^{abcd}	1.36^{abc}	1.71^{ab}	1.53^{ab}
18.	BLA-139-1	2.26^{a}	1.83^{bcd}	2.05^{abcd}	1.45^{ab}	1.70^{ab}	1.58^{a}
SEm±		0.17	0.19	0.14	0.04	0.10	0.08

Fig. 26 Total chlorophyll content of leaves at flushing stage of cashew varieties

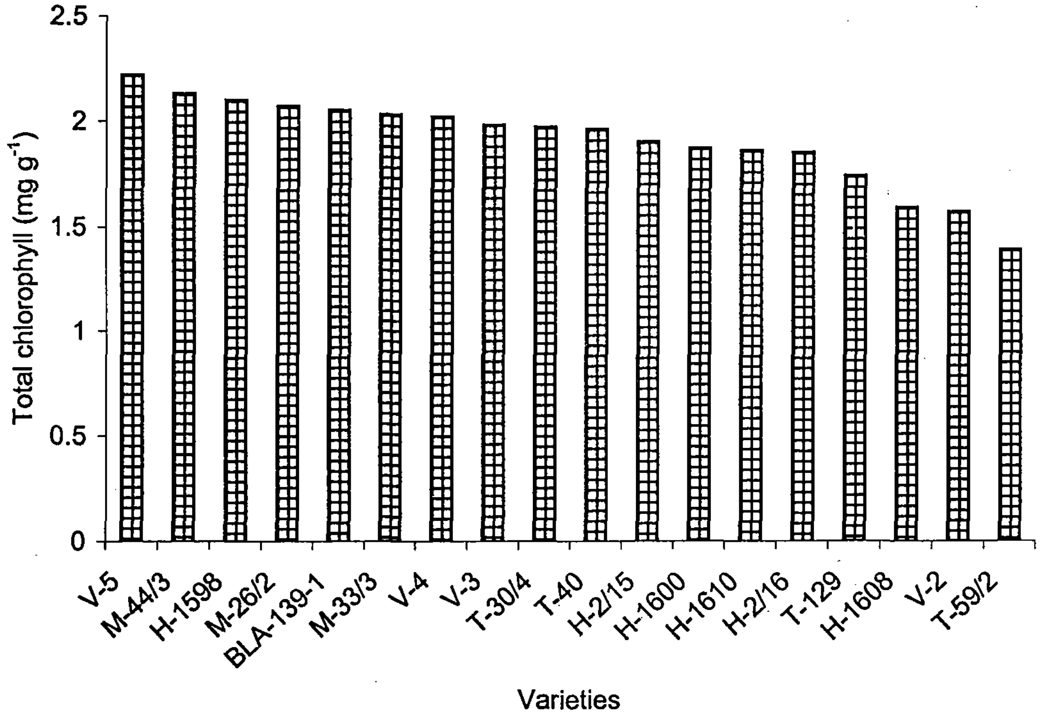


Fig. 27 Total chlorophyll content of leaves at flowering stage of cashew varieties

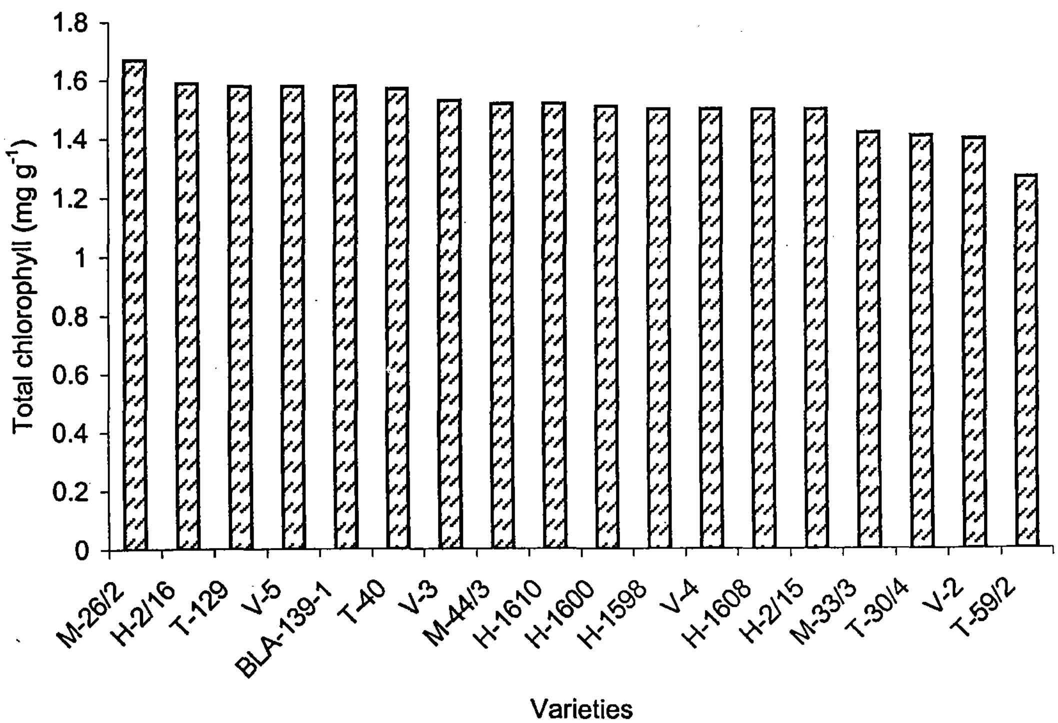


Table 77. Number of nuts per panicle and harvest duration of cashew varieties

Sl. No.	Variety	Number of nuts panicle^{-1}			Harvest duration (days)		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	7.40^{a}	6.73^{abc}	7.07^{a}	59.0^{ab}	57.0^{a}	58.0^{a}
2.	VTL-59/2	4.13^{e}	3.83^{efg}	3.98^{f}	44.7^{de}	45.5^{e}	45.1^{fg}
3.	V-2	4.83^{bcde}	2.93^{g}	3.90^{f}	41.0^{de}	45.1^{e}	45.1^{fg}
4.	M-33/3	5.97^{abcd}	4.80^{bcdefg}	5.38^{bcdef}	47.0^{cde}	45.7^{e}	46.3^{efg}
5.	H-1598	6.57^{abc}	6.23^{abcd}	6.40^{abc}	52.3^{cde}	51.5^{abcd}	51.9^{bcde}
6.	V-4	6.63^{ab}	5.70^{abcde}	6.17^{abcd}	59.0^{ab}	56.3^{a}	57.8^{ab}
7.	T-129	3.93^{e}	5.50^{cdefg}	4.72^{def}	42.7^{e}	46.2^{de}	44.4^{g}
8.	M-26/2	6.67^{ab}	4.57^{cdefg}	5.62^{abcde}	58.0^{ab}	53.0^{ab}	55.5^{abc}
9.	VTL-30/4	6.17^{abcd}	5.40^{abcde}	5.78^{abcd}	52.0^{abcde}	54.0^{b}	53.0^{abcd}
10.	V-5	6.23^{abcd}	7.03^{ab}	6.63^{ab}	62.3^{a}	52.3^{abc}	57.3^{ab}
11	H-1608	6.20^{abcd}	5.40^{abcde}	5.80^{abcd}	45.3^{de}	45.0^{e}	45.2^{fg}
12.	H-1600	4.93^{bcde}	3.13^{fg}	4.03^{ef}	46.0^{de}	46.0^{de}	46.0^{fg}
13.	H-1610	4.47^{de}	5.20^{abcdef}	4.83^{cdef}	42.3^{e}	46.0^{de}	44.2^{g}
14.	H-2/15	5.13^{bcde}	4.73^{cdefg}	4.93^{cdef}	49.3^{bcde}	46.3^{de}	47.8^{defg}
15.	T-40	5.47^{bcde}	4.03^{defg}	4.75^{def}	43.3^{de}	45.3^{e}	44.3^{g}
16.	H-2/16	5.53^{bcde}	4.40^{defg}	4.97^{cdef}	57.0^{abc}	52.7^{abc}	54.8^{abc}
17.	V-3	4.80^{cde}	7.10^{a}	5.95^{abcd}	53.7^{abcd}	48.0^{bcde}	50.8^{cdef}
18.	BLA-139-1	5.70^{abcde}	5.17^{abcdef}	5.43^{bcdef}	42.7^{e}	47.3^{cde}	45.0^{fg}
SEm±		0.47	0.53	0.47	3.13	1.72	1.85

Table 78. Nut yield and nut weight of cashew varieties

Sl. No.	Variety	Nut yield (kg tree^{-1})			Nut weight (g)		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	9.88^{abc}	8.42^{abcd}	9.15^{abc}	4.63^{j}	4.27^{h}	4.43^{i}
2.	VTL-59/2	4.20^{f}	3.08^{ef}	3.64^{i}	7.23^{def}	7.83^{bc}	7.53^{d}
3.	V-2	7.07^{cdef}	0.80^{f}	3.93^{hi}	6.63^{fg}	6.80^{de}	6.72^{ef}
4.	M-33/3	9.97^{abc}	5.42^{cdef}	7.69^{cdef}	8.33^{abc}	7.83^{bc}	8.08^{bc}
5.	H-1598	9.22^{bcd}	9.58^{abc}	9.40^{abc}	7.07^{def}	6.93^{c}	7.00^{e}
6.	V-4	12.20^{ab}	8.63^{abcd}	10.41^{ab}	8.17^{abc}	8.43^{ab}	8.30^{b}
7.	T-129	5.09^{ef}	8.28^{abcd}	6.69^{defg}	5.63^{hi}	5.30^{fg}	5.47^{g}
8.	M-26/2	13.23^{a}	7.52^{abcde}	10.38^{ab}	6.70^{efg}	6.30^{e}	6.50^{f}
9.	VTL-30/4	9.98^{abc}	6.46^{cde}	8.22^{cde}	5.67^{h}	5.40^{fg}	5.50^{g}
10.	V-5	9.37^{abc}	12.41^{a}	10.89^{a}	4.93^{ij}	5.00^{g}	4.97^{h}
11.	H-1608	9.75^{abc}	6.97^{bcde}	8.36^{bcd}	7.92^{bcd}	8.10^{bc}	8.02^{bc}
12.	H-1600	5.70^{def}	5.08^{cdef}	5.39^{ghi}	8.07^{bc}	7.93^{bc}	8.00^{bc}
13.	H-1610	4.97^{ef}	4.26^{def}	4.61^{ghi}	7.50^{cde}	7.97^{bc}	7.75^{cd}
14.	H-2/15	7.11^{cdef}	5.20^{cdef}	6.16^{efg}	8.40^{ab}	8.20^{bc}	8.30^{b}
15.	T-40	8.25^{cde}	4.08^{def}	6.16^{efg}	5.77^{h}	5.67^{f}	5.72^{g}
16.	H-2/16	7.42^{cdef}	4.56^{cdef}	5.99^{fgh}	9.03^{a}	9.00^{a}	9.02^{a}
17.	V-3	7.48^{cdef}	11.83^{ab}	9.66^{abc}	7.78^{bcd}	7.63^{c}	7.67^{cd}
18.	BLA-139-1	8.28^{cde}	5.07^{cdef}	6.68^{defg}	6.03^{gh}	5.63^{f}	5.82^{g}
SEm±		1.18	1.11	0.94	0.26	0.23	0.21

and H-2/16 were poor yielders with nut yield ranging from 3.93 kg to 5.99 kg tree^{-1} when the average yield for two years was taken in to account (Fig. 28).

iv) Nut weight

The varieties differed significantly in nut weight. Nuts of varieties H-1600, V-4, M-33/3, H-2/15 and H-2/16 were comparatively bigger in size with weight ranging from 8.07 g to 9.03 g at 10 YAP. The varieties T-40 (5.77 g), T-129 (5.63 g), VTL-30/4 (5.67 g), V-5 (4.93 g) and M-44/3 (4.63 g) produced nuts weighing less than 6.0 g at 10 YAP. At 11 YAP, nut weight was more than 8.0 g in the varieties H-1608 (8.10 g), H-2/15 (8.20 g), V-4 (8.43 g) and H-2/16 (9.0 g). The average nut weight (for two years) was the highest in the variety H-2/16 and the lowest in M-44/3 with 9.02 g and 4.43 g respectively (Fig. 29).

v) Shelling percentage

The varieties differed significantly in shelling percentage (Table 79). During the first year of the experimentation the variety V-2 gave the highest shelling percentage (31.8 per cent) and the variety M-33/3 the lowest (20.4 per cent). At 11 YAP the varieties VTL-30/4 (34.70 per cent) and M-33/3 (25.02 per cent) gave the highest and the lowest values for shelling percentage respectively. The average values were the highest in the variety VTL-30/4 (33.05 per cent) and the lowest in M-33/3 (22.71 per cent).

vi) Kernel weight

Kernel weight differed significantly between the varieties. Kernel weight ranged from 1.39 g (V-5) to 2.41 g (H-2/16) at 10 YAP and from 1.34 g (V-5) to 2.66 g (H-2/15) at 11 YAP. When the average of two years was considered the varieties VTL-59/2, V-3, H-1598, V-4, M-26/2, H-1600, H-2/15, H-2/16 and V-3 recorded kernel weight ranging from 2.03 g to 2.53 g and the varieties V-5 and M-44/3 had low kernel weight ranging from 1.37 g to 1.41 g (Fig. 30).

vii) Cashew apple yield

The yield of cashew apple was the highest in the variety M-26/2 (99.10 kg tree^{-1}) and the lowest in the variety VTL-59/2 (29.83 kg tree^{-1}) at 10 YAP and the corresponding values observed at 11 YAP were 80.17 kg (V-4) and 7.48 kg (V-2) respectively. When the average data for two years was taken, the yield of cashew

Fig. 28 Nut yield of cashew varieties

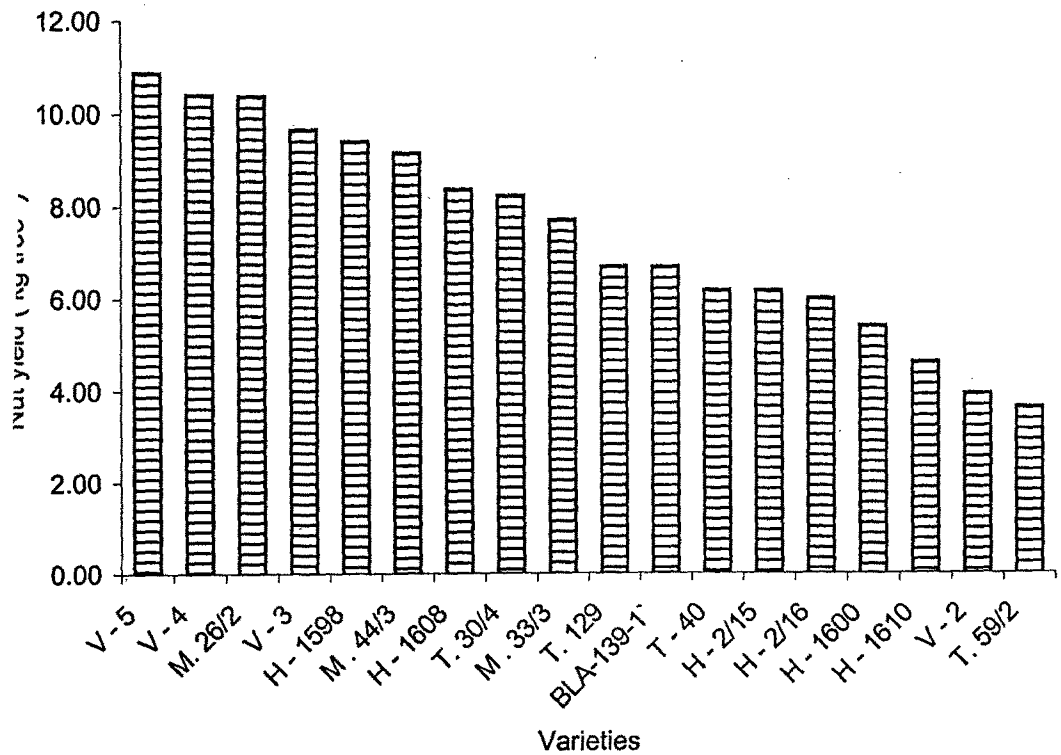


Fig. 29 Nut weight of cashew varieties

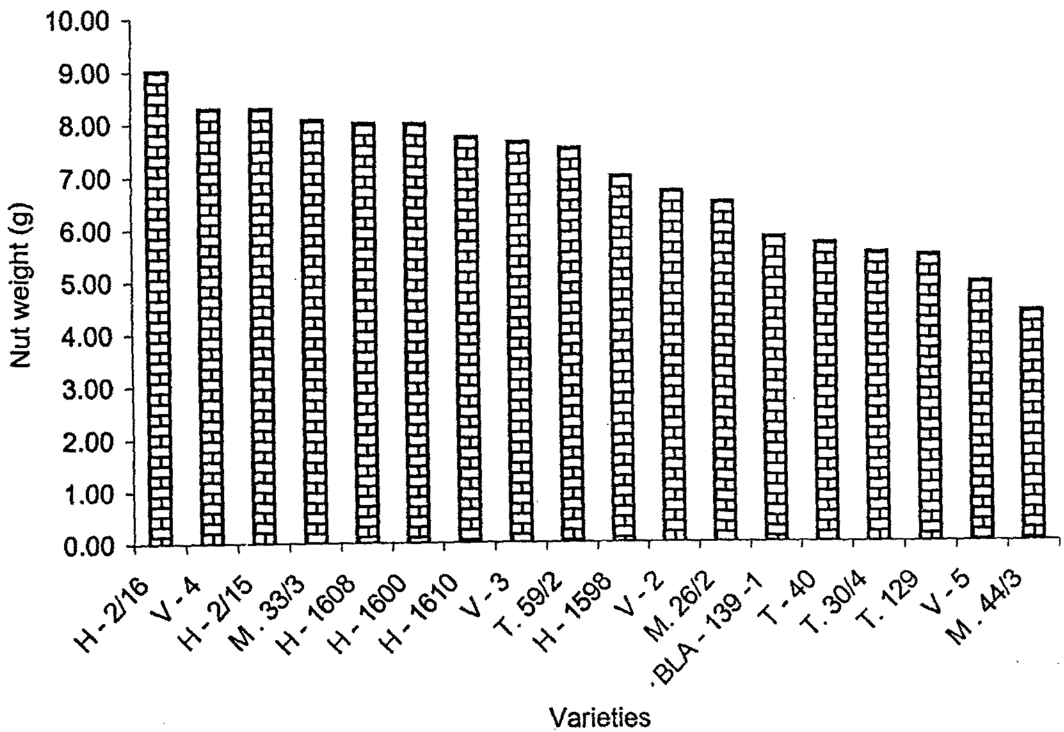


Table 79. Shelling percentage and kernel weight of cashew varieties

Sl. No.	Variety	Shelling per cent			Kernel weight (g)		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	30.9^{ab}	32.45^{abc}	31.68^{ab}	1.44^{hi}	1.39^{f}	1.41^{g}
2.	VTL-59/2	28.6^{abcd}	26.60^{efg}	27.60^{ef}	2.07^{cde}	2.09^{bc}	2.08^{c}
3.	V-2	31.8^{a}	29.17^{def}	30.48^{bcd}	2.11^{bcd}	1.98^{bcd}	2.05^{c}
4.	M-33/3	20.4^{e}	25.02^{g}	22.71^{h}	1.70^{fghi}	1.96^{bcd}	1.83^{def}
5.	H-1598	29.4^{abc}	31.52^{bcd}	30.46^{bcd}	2.08^{bcd}	2.17^{b}	2.13^{c}
6.	V-4	28.0^{abcd}	29.55^{cde}	28.78^{def}	2.28^{abc}	2.49^{a}	2.39^{b}
7.	T-129	29.0^{abc}	33.82^{ab}	31.41^{abc}	1.63^{ghi}	1.80^{de}	1.72^{f}
8.	M-26/2	30.5^{ab}	31.97^{abcd}	31.23^{abc}	2.04^{cde}	2.02^{bcd}	2.03^{c}
9.	VTL-30/4	31.4^{ab}	34.70^{a}	33.05^{a}	1.78^{defg}	1.87^{cde}	1.83^{ef}
10.	V-5	28.3^{abcd}	27.07^{efg}	27.68^{ef}	1.39^{i}	1.34^{f}	1.37^{g}
11.	H-1608	24.9^{d}	26.25^{fg}	25.58^{fg}	1.97^{cdef}	2.12^{b}	2.05^{e}
12.	H-1600	27.3^{bcd}	26.18^{fg}	26.74^{fg}	2.20^{abc}	2.07^{bc}	2.13^{c}
13.	H-1610	26.0^{cd}	25.13^{g}	25.57^{g}	1.95^{cdefg}	2.00^{bcd}	1.98^{cd}
14.	H-2/15	28.8^{abcd}	32.43^{abc}	30.62^{bcd}	2.41^{ab}	2.66^{a}	2.53^{ab}
15.	T-40	31.1^{ab}	34.63^{a}	32.87^{a}	1.79^{defg}	1.96^{bcd}	1.88^{de}
16.	H-2/16	27.6^{bcd}	29.48^{cde}	28.54^{def}	2.49^{a}	2.65^{a}	2.57^{a}
17.	V-3	28.1^{abcd}	27.15^{efg}	27.63^{ef}	2.16^{bc}	2.07^{bc}	2.12^{c}
18.	BLA-139-1	28.8^{abcd}	30.27^{cd}	29.54^{cde}	1.74^{efgh}	1.71^{e}	1.73^{f}
SEm±		1.16	0.94	0.91	0.10	0.08	0.07

Fig. 30 Kernel weight of cashew varieties

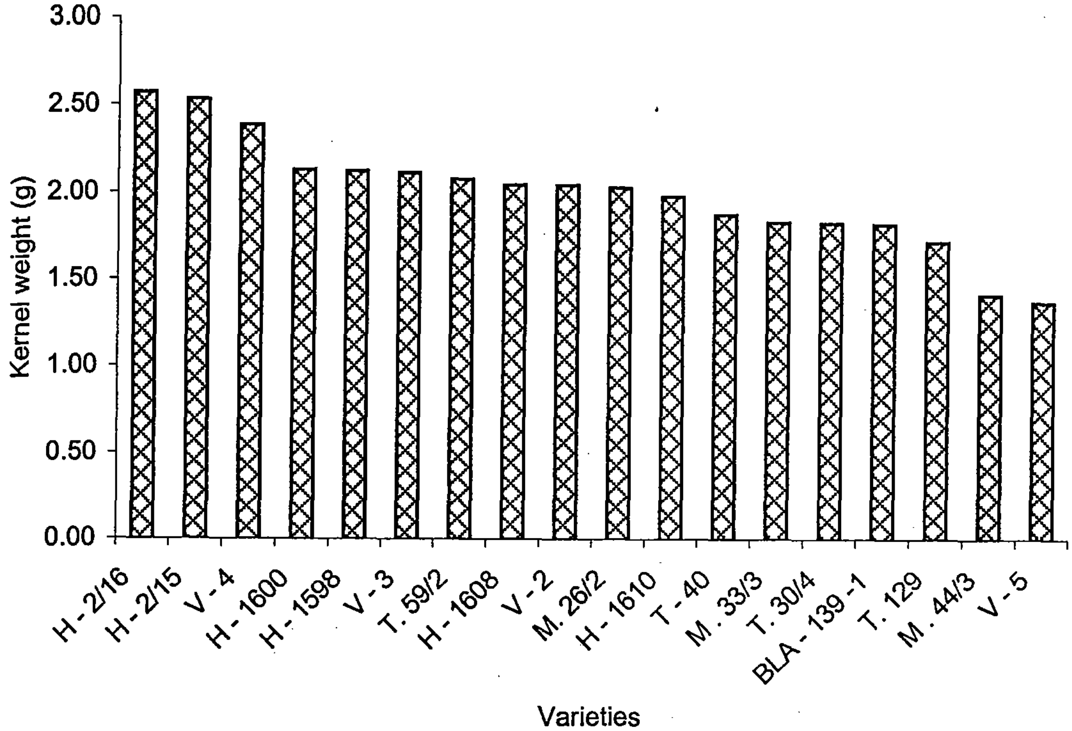
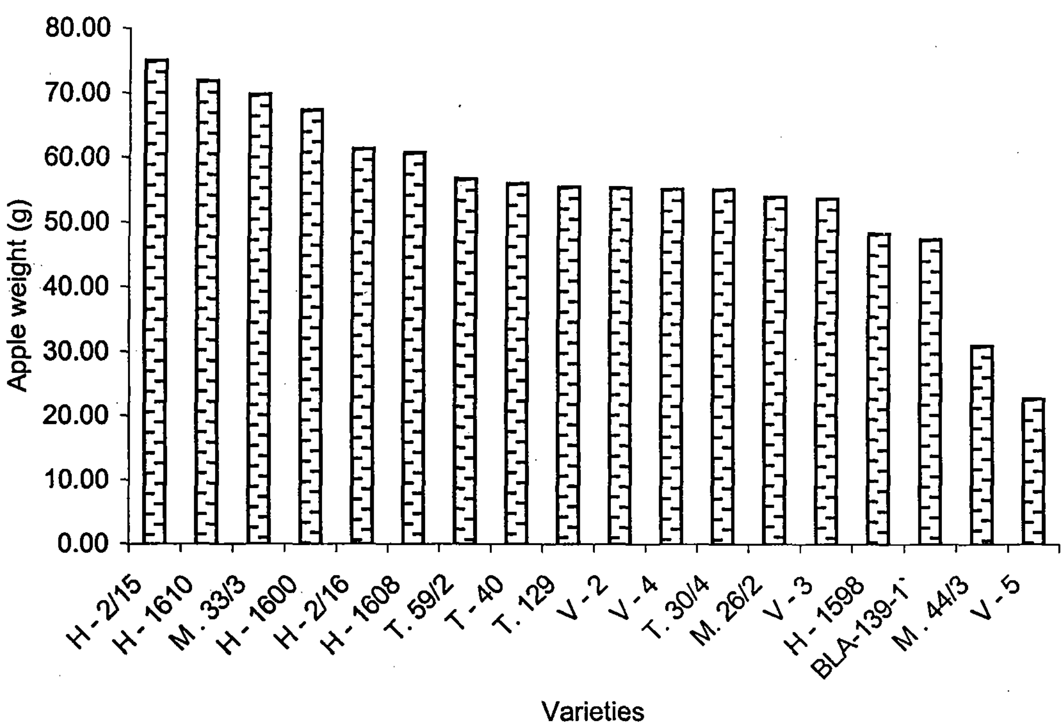


Fig. 31 Cashew apple weight of varieties



apple was the highest (78.90 kg $tree^{-1}$) in the variety VTL-30/4 and the lowest (26.16 kg $tree^{-1}$) in VTL-59/2 (Table 80).

viii) Cashew apple weight

The 18 varieties evaluated differed significantly in weight of cashew apple. The variety H-2/15 produced the heaviest apples (74.08 g and 75.30 g at 10 and 11 YAP respectively) and V-5 produced apples with low weight (22.0 g and 23.63 g respectively). The weight of cashew apples of the varieties H-1608, H-2/16, H-1600, M-33/3 and H-1610 were also comparatively high (60.78 g to 71.93 g) when the average of two years was taken. Only four varieties (H-1598, BLA 139-1, M-44/3 and V-5) produced apples with average weight less than 5.0 g (Fig. 31).

c) Leaf nutrient concentration

i) Nitrogen

The varieties M-44/3, H-1598 and VTL-30/4 had consistently high N content in leaf at pre-flushing stage during both years of study (Table 81). Leaf N was low in the varieties V-2, H-1600, H-2/16 and BLA-139-1 during all the years at pre-flushing stage. When averaged over the years, the variety H-1598 had the highest concentration (1.69 per cent) and VTL-59/2 had the lowest (1.16 per cent) concentration (Fig. 32).

As in the case of pre-flushing stage, the varieties differed in leaf N at pre-flowering stage also. Leaf N concentration at pre-flowering was high in the varieties M-44/3, H-15 98, V-5, H-1608 and M-33/3 (1.74 to 1.97 per cent) during both the years. The varieties V-2, H-1600 and H-2/16 recorded low leaf N (1.28 to 1.42 per cent) at pre-flushing stage at both 10 and 11 YAP. When the average of two years was considered the highest values were noticed in the variety V-5 (1.97 per cent) and lowest in the variety H-1600 (1.34 per cent). The average values of leaf N in the varieties M-26/2, M-33/3, H-1608, H-1598 and M-44/3 ranged from 1.74 per cent to 1.90 per cent (Fig. 33). Comparing the stages, leaf N at pre-flowering stage was higher than that at pre-flushing stage in all the varieties.

ii) Phosphorus

Significant variation in leaf P content was observed among the 18 varieties at pre-flushing stage (Table 82). At 10 YAP the variety BLA 139-1 contained the highest leaf P (0.212 per cent) and H-1600, the lowest (0.104 per cent). The highest P

Table 80. Cashew apple yield and apple weight of cashew varieties

Sl. No.	Variety	Cashew apple yield (kg $tree^{-1}$)			Cashew apple weight (g)		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	68.65^{abcd}	57.25^{abc}	62.95^{abcd}	31.00^{f}	31.13^{f}	31.07^{e}
2.	VTL-59/2	29.83^{d}	22.48^{cd}	26.16^{d}	51.77^{de}	61.80^{bcd}	56.78^{cd}
3.	V-2	47.07^{bcd}	7.48^{d}	27.27^{cd}	54.80^{de}	56.17^{cde}	55.48^{cd}
4.	M-33/3	71.20^{abcd}	47.62^{abcd}	59.41^{abcd}	70.47^{ab}	69.20^{ab}	69.83^{ab}
5.	H-1598	63.77^{abcd}	76.50^{ab}	70.13^{ab}	46.83^{e}	50.03^{e}	48.43^{d}
6.	V-4	78.20^{abcd}	50.42^{abcd}	64.31^{abcd}	54.67^{de}	55.83^{cde}	55.25^{cd}
7.	T-129	45.23^{bcd}	52.25^{abc}	48.74^{abcd}	54.17^{de}	56.97^{cde}	55.57^{cd}
8.	M-26/2	99.10^{a}	56.80^{abc}	77.95^{a}	52.63^{de}	55.37^{de}	54.00^{cd}
9.	VTL-30/4	94.00^{ab}	63.80^{abc}	78.90^{a}	54.90^{de}	55.53^{de}	55.22^{cd}
10.	V-5	52.27^{abcd}	58.40^{abc}	55.33^{abcd}	22.00^{f}	23.63^{f}	22.82^{e}
11.	H-1608	82.50^{abc}	52.00^{abc}	67.25^{abc}	60.47^{cd}	61.10^{bcd}	60.78^{bc}
12.	H-1600	44.37^{bcd}	19.40^{cd}	31.88^{bcd}	68.17^{abc}	66.10^{abc}	67.43^{ab}
13.	H-1610	51.33^{abcd}	32.33^{bcd}	41.83^{abcd}	70.70^{ab}	73.17^{a}	71.93^{a}
14.	H-2/15	66.57^{abcd}	46.72^{abcd}	56.64^{abcd}	74.80^{a}	75.30^{a}	75.05^{a}
15.	T-40	77.90^{abcd}	40.58^{abcd}	59.24^{abcd}	55.67^{de}	56.43^{cde}	56.05^{cd}
16.	H-2/16	47.73^{bcd}	31.43^{cd}	39.58^{abcd}	61.17^{bcd}	61.60^{bcd}	61.38^{bc}
17.	V-3	52.37^{abcd}	80.17^{a}	62.28^{abc}	52.87^{de}	54.73^{de}	53.80^{cd}
18.	BLA-139-1	63.47^{abcd}	38.68^{abcd}	51.08^{abcd}	47.53^{e}	47.50^{e}	47.52^{d}
SEm±		14.64	13.01	11:92	3.18	3.10	3.04

Table 81. Leaf N concentration (%) at pre-flushing and pre-flowering phases of cashew varieties

Sl. No.	Variety	Pre flushing stage			Pre flowering stage		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	1.71^{ab}	1.59^{abc}	1.65^{a}	1.93^{cd}	1.87^{a}	1.90^{ab}
2.	VTL-59/2	1.36^{cdef}	1.16^{e}	1.26^{ef}	1.53^{h}	1.34^{de}	1.44^{g}
3.	V-2	1.18^{f}	1.23^{de}	1.21^{f}	1.41^{i}	1.30^{e}	1.36^{h}
4.	M-33/3	1.62^{abcde}	1.29^{cde}	1.45^{bcd}	1.76^{e}	1.74^{ab}	1.75^{c}
5.	H-1598	1.64^{abcd}	1.74^{a}	1.69^{a}	1.94^{bcd}	1.84^{a}	1.89^{b}
6.	V-4	1.39^{bcdef}	1.58^{abcd}	1.48^{bc}	1.58^{gh}	1.79^{ab}	1.69^{cd}
7.	T-129	1.29^{f}	1.63^{abc}	1.46^{bcf}	1.31^{j}	1.84^{ab}	1.57^{ef}
8.	M-26/2	1.73^{a}	1.36^{bcde}	1.54^{ab}	2.03^{ab}	1.45^{de}	1.74^{c}
9.	VTL-30/4	1.67^{abc}	1.62^{abc}	1.65^{a}	1.62^{g}	1.64^{bc}	1.63^{de}
10.	V-5	1.41^{abcdef}	1.70^{ab}	1.56^{ab}	2.05^{a}	1.88^{a}	1.97^{a}
11.	H-1608	1.45^{abcdef}	1.36^{bcde}	1.40^{bcde}	1.92^{d}	1.75^{ab}	1.83^{b}
12.	H-1600	1.27^{f}	1.34^{cde}	1.31^{def}	1.40^{ij}	1.28^{e}	1.34^{h}
13.	H-1610	1.43^{cdef}	1.54^{abcde}	1.48^{bc}	1.77^{ef}	1.39^{de}	1.55^{f}
14.	H-2/15	1.31^{def}	1.40^{abcde}	1.36^{cdef}	1.48^{hi}	1.40^{de}	1.44^{g}
15.	T-40	1.46^{abcdef}	1.34^{cde}	1.40^{bcde}	2.02^{abc}	1.33^{e}	1.68^{cd}
16.	H-2/16	1.25^{f}	1.33^{cde}	1.29^{ef}	1.42^{i}	1.40^{de}	1.41^{gh}
17.	V-3	1.38^{bcdef}	1.72^{a}	1.56^{ab}	1.52^{h}	1.75^{ab}	1.64^{de}
18.	BLA-139-1	1.38^{bcdef}	1.31^{cde}	1.35^{cdef}	1.65^{fg}	1.54^{cd}	1.59^{ef}
SEm±		0.12	0.09	0.09	1.00	0.11	0.07

Fig. 32 Leaf N concentration at pre-flushing stage of cashew varieties

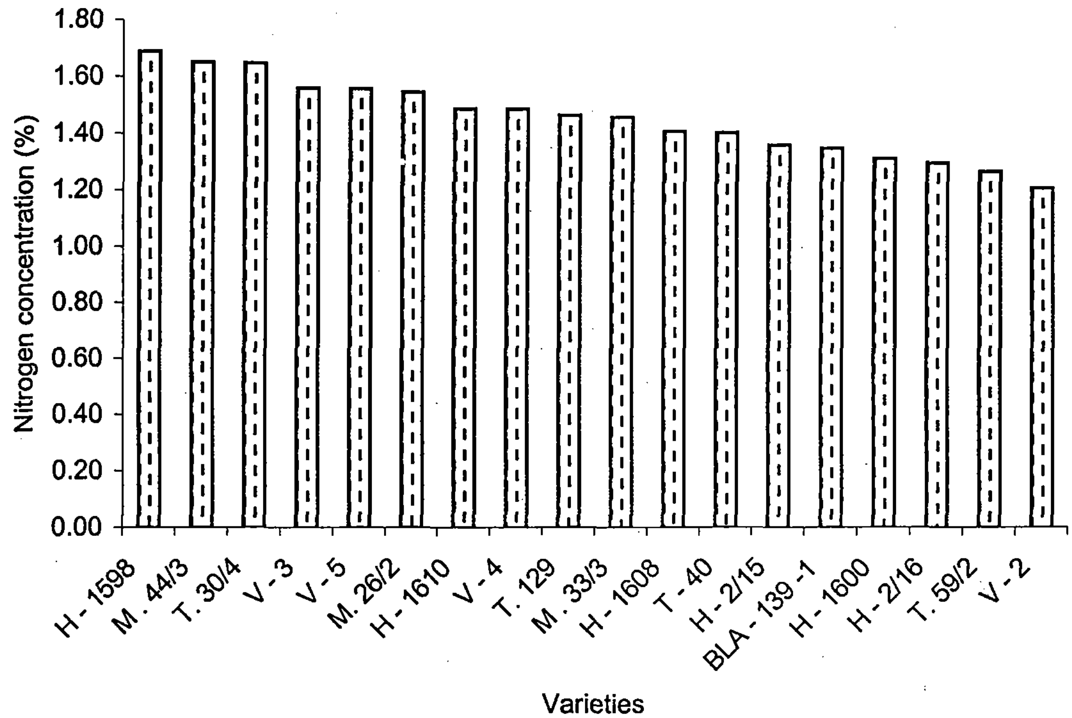


Fig. 33 Leaf N concentration at pre-flowering stage of cashew varieties

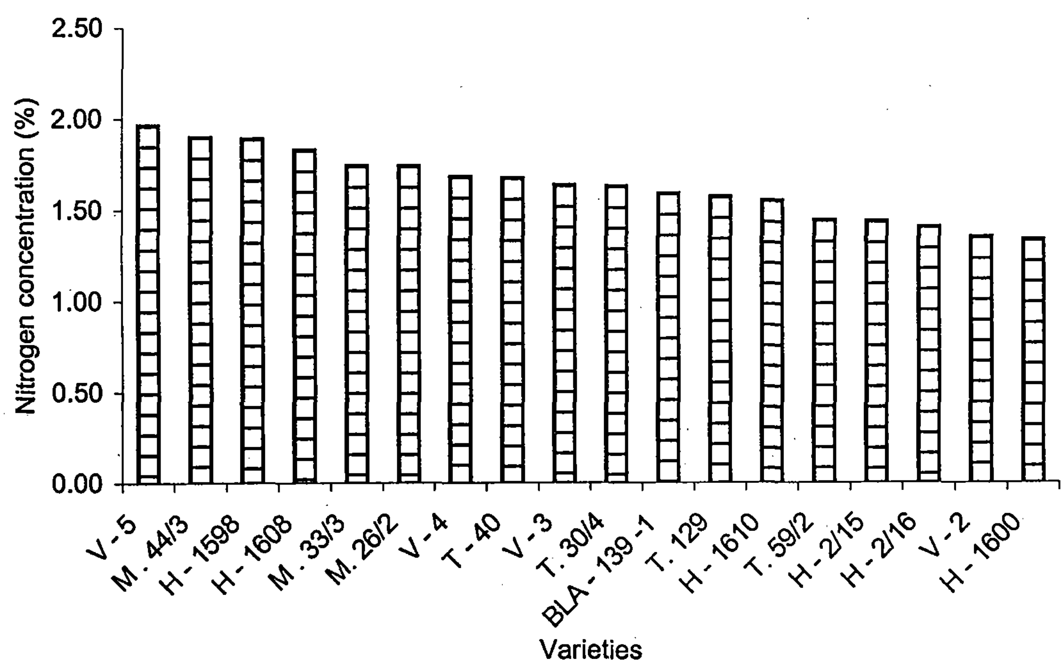


Table 82. Leaf P concentration (%) at pre-flushing and pre-flowering phases of cashew varieties

Sl. No.	Variety	Pre-flushing stage			Pre-flowering stage		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	0.133[b]	0.098[b]	0.115[cde]	0.082[j]	0.082[ef]	0.082[hi]
2.	VTL-59/2	0.110[b]	0.095[bc]	0.103[h]	0.085[ij]	0.105[a]	0.095[cd]
3.	V-2	0.152[b]	0.098[b]	0.125[b]	0.097[f]	0.080[fg]	0.089[ef]
4.	M-33/3	0.141[b]	0.057[f]	0.099[hi]	0.091[gh]	0.084[def]	0.088[fg]
5.	H-1598	0.136[b]	0.082[d]	0.109[fg]	0.083[j]	0.087[cde]	0.085[gh]
6.	V-4	0.165[ab]	0.082[d]	0.123[b]	0.108[bcd]	0.081[ef]	0.095[cd]
7.	T-129	0.143[b]	0.071[e]	0.107[g]	0.120[a]	0.091[bc]	0.106[a]
8.	M-26/2	0.116[b]	0.072[e]	0.094[j]	0.096[fg]	0.085[cdef]	0.091[ef]
9.	VTL-30/4	0.146[b]	0.080[d]	0.113[de]	0.086[hij]	0.075[g]	0.081[i]
10.	V-5	0.103[b]	0.095[bc]	0.099[h]	0.099[ef]	0.084[def]	0.092[cdef]
11.	H-1608	0.152[b]	0.085[d]	0.118[c]	0.106[cd]	0.080[fg]	0.093[cde]
12.	H-1600	0.107[b]	0.083[d]	0.095[ij]	0.089[hi]	0.090[bcd]	0.089[ef]
13.	H-1610	0.151[b]	0.083[d]	0.117[cd]	0.104[de]	0.087[cde]	0.096[c]
14.	H-2/15	0.123[b]	0.108[a]	0.115[cde]	0.105[d]	0.094[b]	0.100[b]
15.	T-40	0.139[b]	0.091[c]	0.115[cde]	0.112[b]	0.089[bcd]	0.101[b]
16.	H-2/16	0.151[b]	0.074[e]	0.112[ef]	0.111[bc]	0.087[cde]	0.099[b]
17.	V-3	0.147[b]	0.051[g]	0.099[hi]	0.076[k]	0.081[ef]	0.079[i]
18.	BLA-139-1	0.212[a]	0.082[d]	0.146[a]	0.097[fg]	0.086[cdef]	0.091[def]
SEm±		0.018	0.002	0.001	0.002	0.008	0.029

Fig. 34 Leaf P concentration at pre-flushing stage of cashew varieties

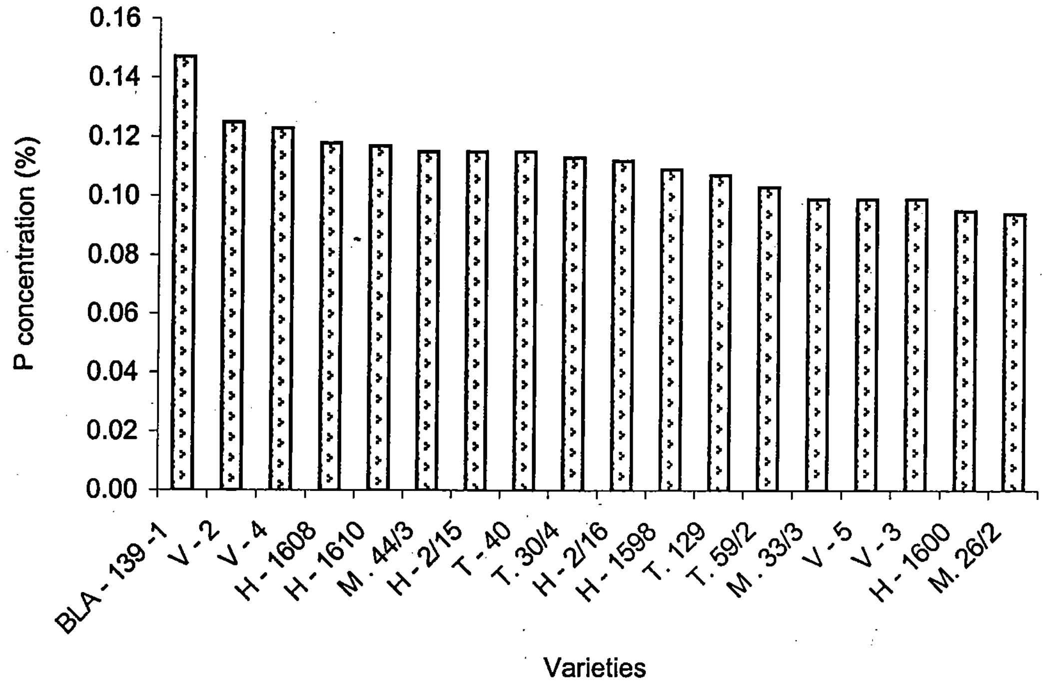
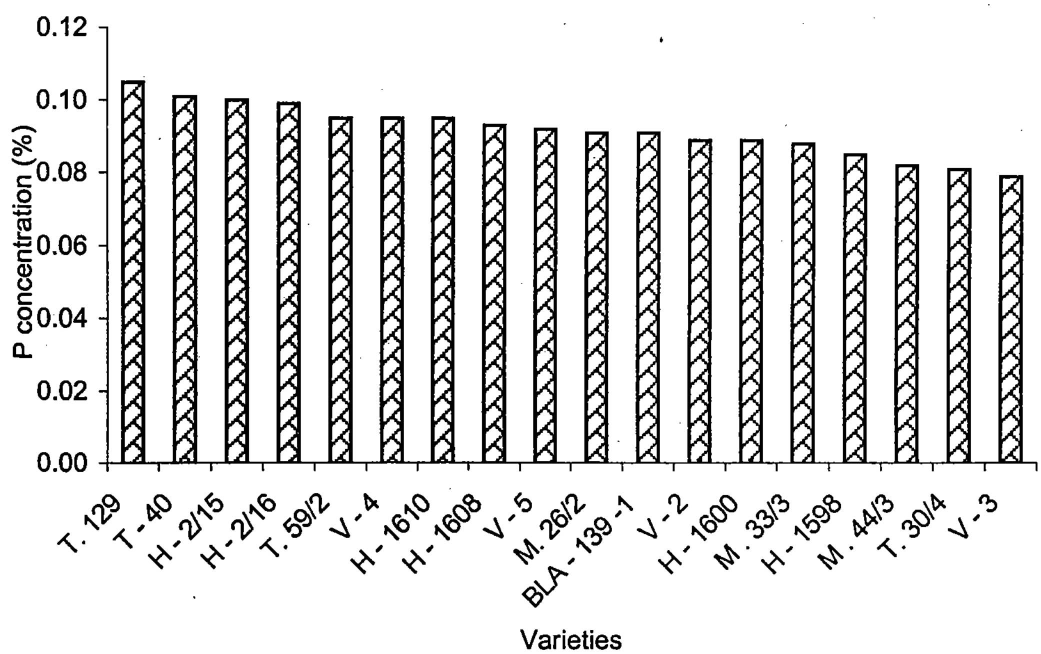


Fig. 35 Leaf P concentration at pre-flowering stage of cashew varieties



concentration at 11 YAP was observed in the variety H-2/15 (0.108 per cent) and the lowest in M-33/3 (0.057 per cent). On averaging the P concentration over the years it was seen that the varieties V-2 and V-4 also maintained high leaf P (0.125 and 0.123 per cent respectively) whereas the varieties H-1600, V-3, V-5 and M-33/3 had low leaf P concentration ranging from 0.095 to 0.099 per cent (Fig. 34)

The varietal variation in leaf P content at pre-flowering stage was also significant. Concentration of P in leaves at pre-flowering stage ranged from 0.076 per cent (V-3) to 0.120 per cent (T-129) at 10 YAP and from 0.075 per cent (VTL-30/4) to 0.105 per cent (VTL-59/2) at 11 YAP. When the average for the two years was taken the highest values was noticed in the variety T-129 (0.106 per cent) and the lowest values in the variety V-3 (0.079 per cent). Leaf P concentration was higher in all the varieties at pre-flushing stage than that at pre-flowering stage.

iii) Potassium

The varieties differed significantly in leaf K concentration at pre-flushing stage (Table 83). The highest concentration of K was observed in the varieties M-26/2 (0.66 per cent) and H-1598 (0.80 per cent) during the initial and second years of the study, respectively. The lowest K concentration at pre-flushing stage was seen in the varieties H-2/16 and V-5 (both 0.48 per cent at 10 YAP) and H-1610 (0.50 per cent at 11 YAP). The average K concentration in leaf was the highest (0.69 per cent) in the variety H-1598 and the lowest (0.50 per cent) in the varieties H-1610 and H-2/16 (Fig.36).

As in the case of pre-flushing stage, leaf K content at pre-flowering stage also differed significantly between the varieties. Leaf K concentration ranged from 0.64 per cent (H-1600) to 1.10 per cent (H-1598) at 10 YAP and from 0.61 per cent (T-40) to 1.08 per cent (V-5 and H-1598) at 11 YAP. The average values were the highest in H-1598 (1.09 per cent) and the lowest in H-1600 (0.66 per cent). When averaged over the years, the varieties V-4 and H-1608 also had high leaf K (1.06 and 1.05 per cent respectively) where as the varieties H-1610, T-40, T-129, H-2/15, V-2 and H-2/16 had very low leaf K concentration (less than 0.75 per cent) at pre-flowering stage (Fig.37). Comparing the stages, leaf K was higher at pre-flowering stage than that at pre-flushing stage in all the varieties.

Table 83. Leaf K concentration (%) at pre-flushing and pre-flowering phases of cashew varieties

Sl. No.	Variety	Pre-flushing stage			Pre-flowering stage		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	0.62^{a}	0.53^{hij}	0.57^{cd}	0.85^{abcdef}	0.89^{abcd}	0.87^{cd}
2.	VTL-59/2	0.56^{a}	0.52^{j}	0.54^{def}	0.79^{cdef}	0.76^{cdef}	0.78^{cdef}
3.	V-2	0.53^{a}	0.51^{j}	0.52^{fg}	0.78^{def}	0.66^{ef}	0.72^{def}
4.	M-33/3	0.58^{a}	0.57^{fg}	0.58^{cd}	0.78^{def}	0.91^{abc}	0.84^{cdef}
5.	H-1598	0.59^{a}	0.80^{a}	0.69^{a}	1.10^{a}	1.08^{a}	1.09^{a}
6.	V-4	0.53^{a}	0.74^{bc}	0.63^{b}	1.07^{ab}	1.05^{ab}	1.06^{ab}
7.	T-129	0.54^{a}	0.56^{fgh}	0.55^{def}	0.71^{ef}	0.70^{def}	0.71^{def}
8.	M-26/2	0.66^{a}	0.58^{f}	0.62^{b}	0.97^{abcde}	0.74^{cdef}	0.86^{cde}
9.	VTL-30/4	0.54^{a}	0.75^{b}	0.65^{b}	1.06^{abc}	0.85^{bcde}	0.95^{abc}
10.	V-5	0.48^{a}	0.64^{de}	0.56^{cd}	0.79^{cdef}	1.08^{a}	0.93^{abc}
11.	H-1608	0.55^{a}	0.71^{c}	0.63^{b}	1.05^{abcd}	1.06^{ab}	1.05^{ab}
12.	H-1600	0.52^{a}	0.52^{j}	0.52^{fg}	0.64^{f}	0.67^{ef}	0.66^{f}
13.	H-1610	0.55^{a}	0.50^{j}	0.50^{efg}	0.65^{f}	0.68^{def}	0.67^{ef}
14.	H-2/15	0.53^{a}	0.55^{ghi}	0.54^{def}	0.70^{ef}	0.72^{cdef}	0.71^{def}
15.	T-40	0.55^{a}	0.55^{fghi}	0.55^{cdef}	0.73^{ef}	0.61^{f}	0.67^{ef}
16.	H-2/16	0.48^{a}	0.52^{ij}	0.50^{g}	0.83^{bcdef}	0.66^{f}	0.75^{def}
17.	V-3	0.50^{a}	0.67^{d}	0.59^{c}	0.78^{cdef}	1.00^{ab}	0.89^{bcd}
18.	BLA-139-1	0.49^{a}	0.63^{e}	0.56^{cde}	0.80^{bcdef}	0.86^{bcde}	0.83^{def}
SEm±		0.03	0.06	0.03	0.08	0.07	0.06

Fig. 36 Leaf K concentration at pre-flushing stage of cashew varieties

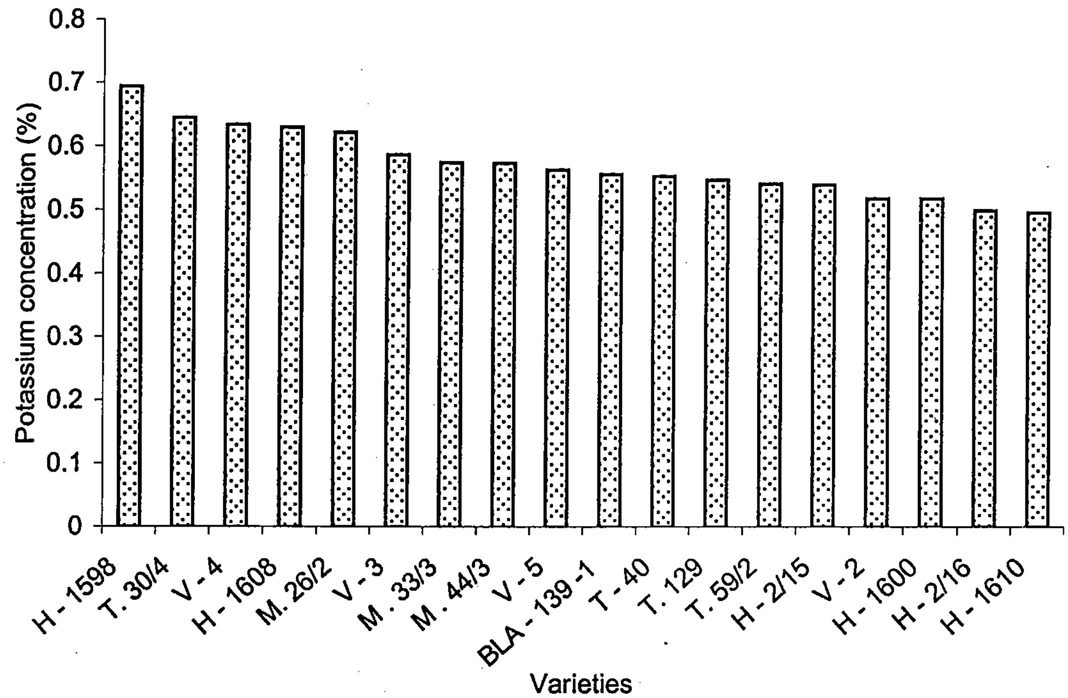
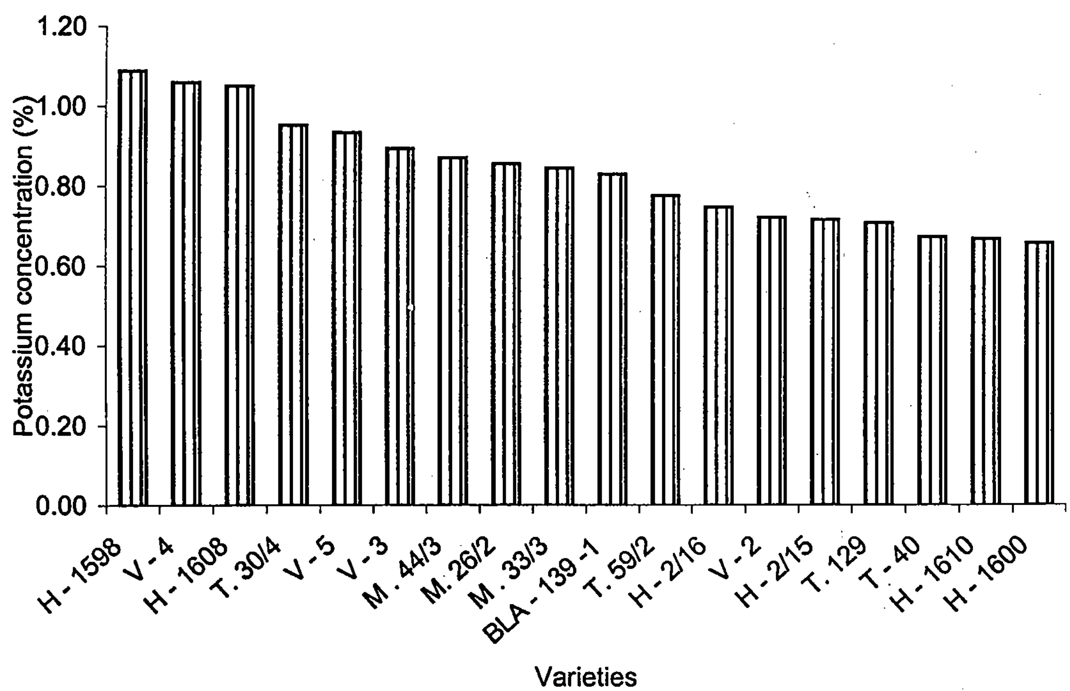


Fig. 37 Leaf K concentration at pre-flowering stage of cashew varieties



iv) Calcium

The varieties differed in calcium content of leaves at pre-flushing stage during both the years (Table 84). Concentration of Ca ranged from 0.08 per cent (M-26/2) to 0.17 per cent (VTL-59/2) at 10 YAP and 0.10 per cent (H-1598) to 0.16 per cent (T-40) at 11 YAP. The average values were the highest and the lowest in the varieties VTL-59/2 (0.16 per cent) and M-26/2 (0.09 per cent), respectively (Fig.38).

v) Magnesium

Varietal variation in magnesium content of leaves at pre-flushing stage was not significant. The average values ranged from 0.10 per cent in the variety H-1600 to 0.16 per cent in H-2/16 (Fig.39).

vi) Micro nutrients

The concentration of Fe in leaves at pre-flushing stage ranged from 66 ppm (VTL-30/4) to 114 ppm (VTL-59/2) at 10 YAP and 149.3 ppm (H-1610) to 251.3 ppm (V-4) at 11 YAP (Table 85). The concentration of Fe in leaves when averaged over the years ranged from 111.3 ppm in the variety H-2/16 to 186.5 ppm in H-2/15 (Fig. 14). Manganese concentration was the highest in the varieties VTL-59/2 (119.3 ppm) and V-3 (239 ppm) and the lowest in the varieties V-4 (72.3 ppm) and H-2/16 (58.3 ppm) at 10 and 11 YAP respectively. The average values for the two years are depicted in Fig. 41.

The eighteen varieties did not differ significantly in Zn and Cu concentration in leaves at pre-flushing stage (Table 86). The Zn concentration averaged over the years ranged from 10.5 ppm to 14.7 ppm (Fig. 42) and Cu from 6.4 ppm to 9.2 ppm (Fig. 43).

Table 84. Leaf Ca and Mg concentration (%) at pre flushing stage of cashew varieties

Sl. No.	Variety	Ca			Mg		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	0.16^{ab}	0.14^{abc}	0.15^{ab}	0.14^{a}	0.14^{a}	0.14^{a}
2.	VTL-59/2	0.17^{a}	0.15^{ab}	0.16^{a}	0.16^{a}	0.16^{a}	0.16^{a}
3.	V-2	0.15^{abc}	0.14^{abc}	0.15^{ab}	0.14^{a}	0.15^{a}	0.14^{a}
4.	M-33/3	0.15^{abc}	0.13^{abcd}	0.14^{abc}	0.15^{a}	0.15^{a}	0.15^{a}
5.	H-1598	0.09^{ef}	0.10^{d}	0.10^{de}	0.10^{a}	0.10^{a}	0.10^{a}
6.	V-4	0.11^{def}	0.13^{abcd}	0.13^{cd}	0.14^{a}	0.12^{a}	0.13^{a}
7.	T-129	0.13^{bcd}	0.14^{abc}	0.14^{abc}	0.15^{a}	0.14^{a}	0.15^{a}
8.	M-26/2	0.08^{f}	0.10^{d}	0.09^{e}	0.11^{a}	0.10^{a}	0.10^{a}
9.	VTL-30/4	0.13^{bcd}	0.12^{bcd}	0.13^{bc}	0.15^{a}	0.14^{a}	0.15^{a}
10.	V-5	0.12^{cde}	0.13^{abcd}	0.13^{bc}	0.14^{a}	0.14^{a}	0.14^{a}
11.	H-1608	0.13^{bcd}	0.13^{abcd}	0.13^{bc}	0.15^{a}	0.16^{a}	0.16^{a}
12.	H-1600	0.09^{ef}	0.11^{cd}	0.10^{de}	0.10^{a}	0.10^{a}	0.10^{a}
13.	H-1610	0.14^{abcd}	0.13^{abcd}	0.14^{abc}	0.14^{a}	0.14^{a}	0.14^{a}
14.	H-2/15	0.13^{bcd}	0.13^{abcd}	0.13^{bc}	0.15^{a}	0.14^{a}	0.15^{a}
15.	T-40	0.15^{abc}	0.16^{a}	0.15^{ab}	0.15^{a}	0.16^{a}	0.15^{a}
16.	H-2/16	0.16^{ab}	0.14^{abc}	0.15ab	0.16^{a}	0.16^{a}	0.16^{a}
17.	V-3	0.12^{cde}	0.14^{abc}	0.13^{bc}	0.13^{a}	0.13^{a}	0.13^{a}
18.	BLA-139-1	0.13^{bcd}	0.12^{bcd}	0.12^{cd}	0.13^{a}	0.13^{a}	0.13^{a}
SEm±		0.02	0.01	0.02	0.01	0.01	0.01

Fig. 38 Leaf Ca concentration at pre-flushing stage of cashew varieties

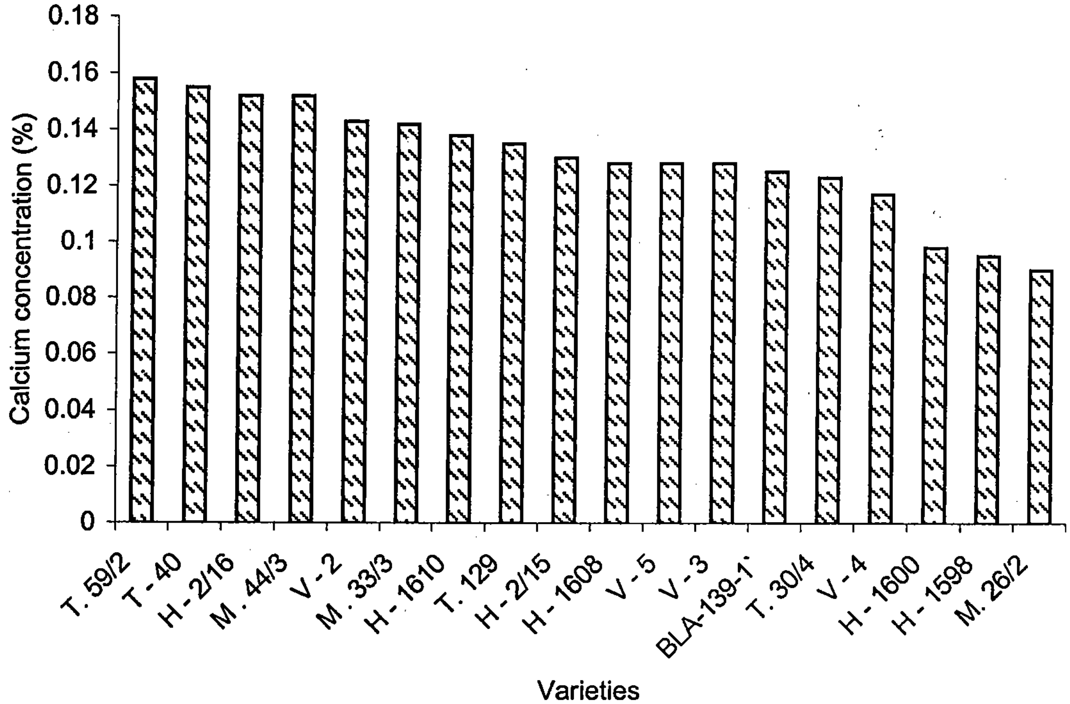


Fig. 39 Leaf Mg concentration at pre- flushing stage of cashew varieties

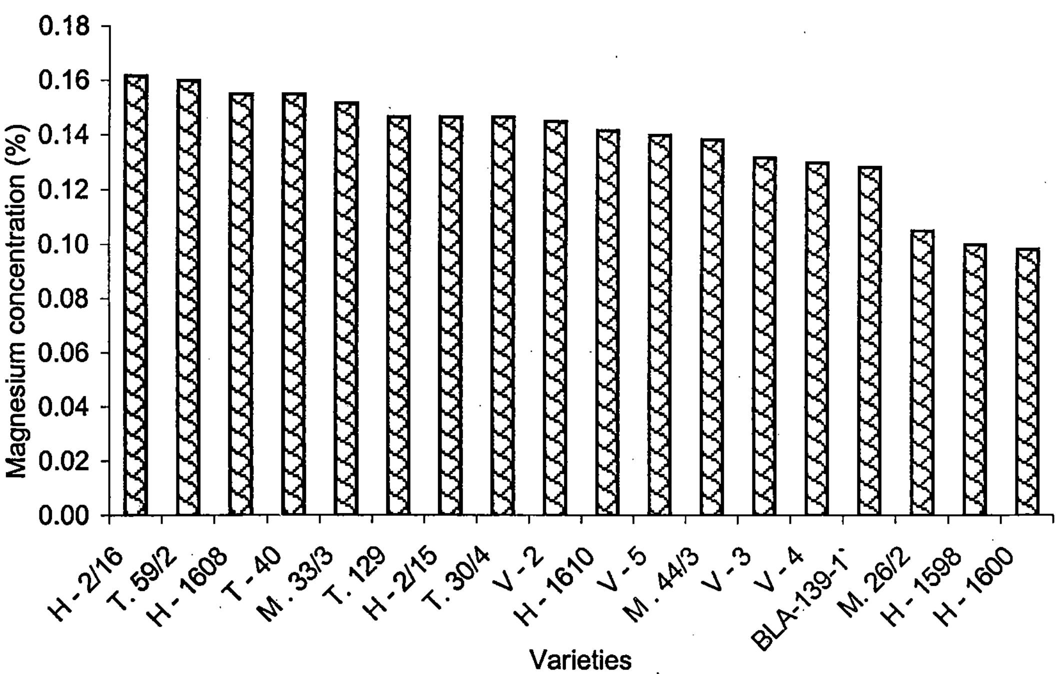


Table 85. Leaf Fe and Mn concentration (ppm) at pre-flushing stage of cashew varieties

Sl. No.	Variety	Fe			Mn		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	106.7^{b}	202.2^{f}	154.5^{d}	92.6^{a}	188.0^{abc}	140.4^{abc}
2.	VTL-59/2	114.0^{a}	178.0^{j}	146.0^{f}	119.3^{a}	225.0^{ab}	172.2^{a}
3.	V-2	96.7^{c}	183.7^{i}	146.0^{g}	80.0^{a}	166.3^{abcd}	123.2^{bcde}
4.	M-33/3	93.3^{cd}	187.0^{hi}	140.2^{g}	95.3^{a}	194.0^{abc}	144.7^{abc}
5.	H-1598	82.4^{f}	175.0^{j}	128.7^{h}	77.7^{a}	158.7^{abcde}	118.2^{bcde}
6.	V-4	71.5^{hi}	251.3^{c}	161.3^{c}	72.3^{a}	97.0^{defg}	84.7^{de}
7.	T-129	81.7^{f}	207.3^{e}	144.5^{f}	100.0^{a}	185.3^{abc}	142.7^{abc}
8.	M-26/2	74.2^{gh}	165.0^{k}	119.7^{i}	78.3^{a}	85.7^{efg}	82.0^{e}
9.	VTL-30/4	66.0^{k}	188.3^{gh}	127.2^{h}	84.3^{a}	193.7^{abc}	139.0^{abc}
10.	V-5	88.7^{e}	191.7^{g}	140.2^{g}	86.3^{a}	207.7^{ab}	147.0^{abc}
11.	H-1608	106.8^{b}	217.3^{d}	162.0^{bc}	77.3^{a}	180.0^{abc}	128.7^{abcd}
12.	H-1600	88.0^{e}	216.0^{d}	152.0^{e}	72.7^{a}	114.7^{cdefg}	93.7^{de}
13.	H-1610	90.5^{de}	149.3^{f}	145.0^{f}	68.0^{a}	147.3^{bcdefg}	107.7^{cde}
14.	H-2/15	87.6^{e}	285.3^{a}	186.5^{a}	101.3^{a}	219.0^{ab}	160.2^{ab}
15.	T-40	80.0^{f}	159.0^{l}	119.5^{i}	102.0^{a}	70.3^{fg}	86.2^{de}
16.	H-2/16	67.8^{jk}	155.3^{l}	111.3^{f}	104.3^{a}	58.3^{g}	81.3^{e}
17.	V-3	70.0^{ij}	158.0^{b}	164.0^{b}	74.3^{a}	239.0^{a}	156.7^{ab}
18.	BLA-139-1	75.0^{g}	201.7^{f}	138.4^{g}	104.7^{a}	71.3^{fg}	88.0^{de}
SEm±		17.2	31.0	18.7	16.1	36.9	13.5

Fig.40 Leaf Fe concentration at pre-flushing stage of cashew varieties

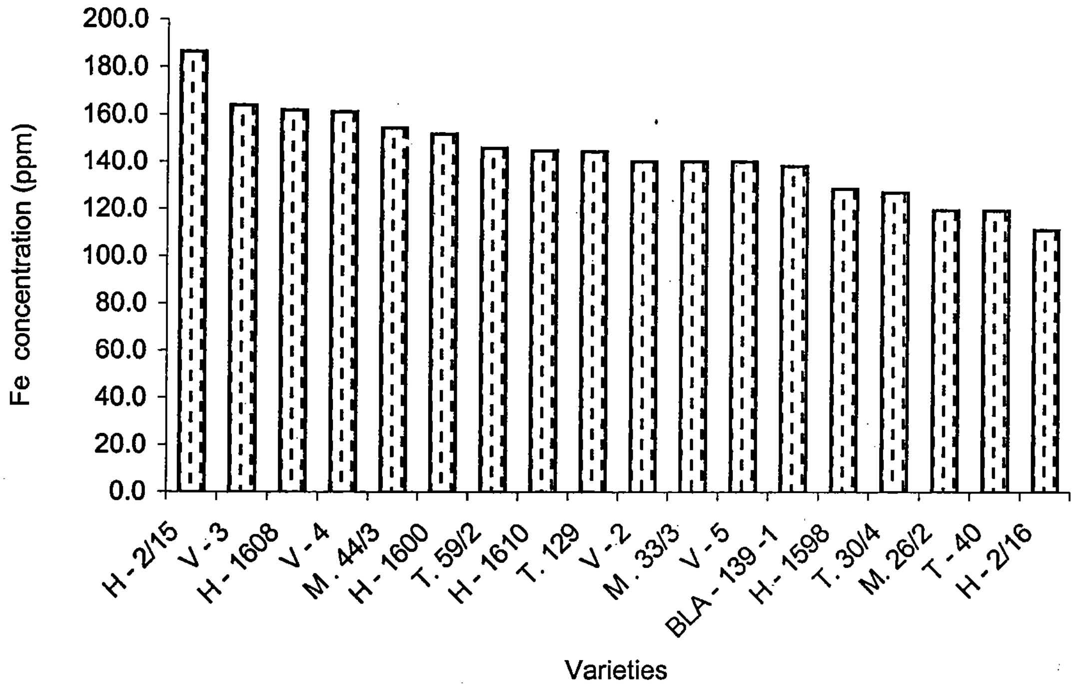


Fig. 41 Leaf Mn concentration at pre-flushing stage of cashew varieties

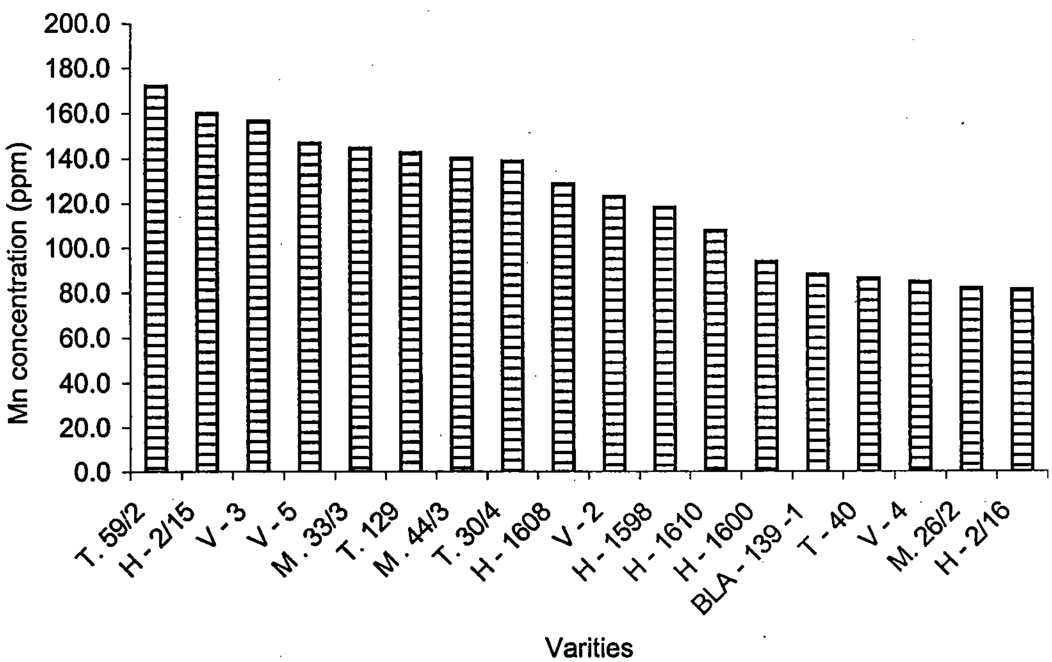


Table 86. Leaf Zn and Cu concentration (ppm) at pre flushing stage of cashew varieties

Sl. No	variety	Zn			Cu		
		10 YAP	11 YAP	Mean	10 YAP	11 YAP	Mean
1.	M-44/3	12.7[a]	10.7[a]	11.7[a]	8.67[a]	9.3[a]	9.0[a]
2.	VTL-59/2	15.3[a]	10.0[a]	12.7[a]	8.00[a]	9.0[a]	8.5[a]
3.	V-2	13.0[a]	9.0[a]	11.0[a]	7.67[a]	10.0[a]	8.9[a]
4.	M-33/3	11.7[a]	11.3[a]	11.5[a]	7.00[a]	8.0[a]	7.5[a]
5.	H-1598	12.3[a]	10.0[a]	11.2[a]	7.67[a]	8.3[a]	8.0[a]
6.	V-4	14.0[a]	11.3[a]	12.7[a]	7.32[a]	10.3[a]	8.8[a]
7.	T-129	9.3[a]	12.0[a]	10.7[a]	6.00[a]	8.7[a]	7.4[a]
8.	M-26/2	12.7[a]	9.0[a]	10.9[a]	6.35[a]	9.3[a]	7.8[a]
9.	VTL-30/4	9.0[a]	11.7[a]	10.4[a]	6.00[a]	7.0[a]	6.5[a]
10.	V-5	17.0[a]	12.3[a]	14.7[a]	7.00[a]	5.7[a]	6.4[a]
11.	H-1608	9.7[a]	11.3[a]	10.5[a]	7.00[a]	9.7[a]	8.4[a]
12.	H-1600	13.0[a]	12.1[a]	12.5[a]	7.00[a]	10.3[a]	8.7[a]
13.	H-1610	10.7[a]	9.3[a]	10.5[a]	5.68[a]	8.7[a]	7.2[a]
14.	H- 2/15	14.3[a]	13.3[a]	13.8[a]	8.65[a]	9.7[a]	9.2[a]
15.	T-40	9.3[a]	11.7[a]	10.5[a]	7.68[a]	8.0[a]	7.9[a]
16.	H-2/16	12.7[a]	9.3[a]	10.8[a]	8.00[a]	9.7[a]	8.9[a]
17.	V-3	11.7[a]	13.7[a]	12.7[a]	7.67[a]	9.7[a]	8.7[a]
18.	BLA-139-1	12.0[a]	11.7[a]	11.9[a]	8.00[a]	7.3[a]	7.7[a]
SEm±		1.8	1.4	1.4	1.22	1.3	1.1

Fig. 42 Leaf Zn concentration at pre-flushing stage of cashew varieties

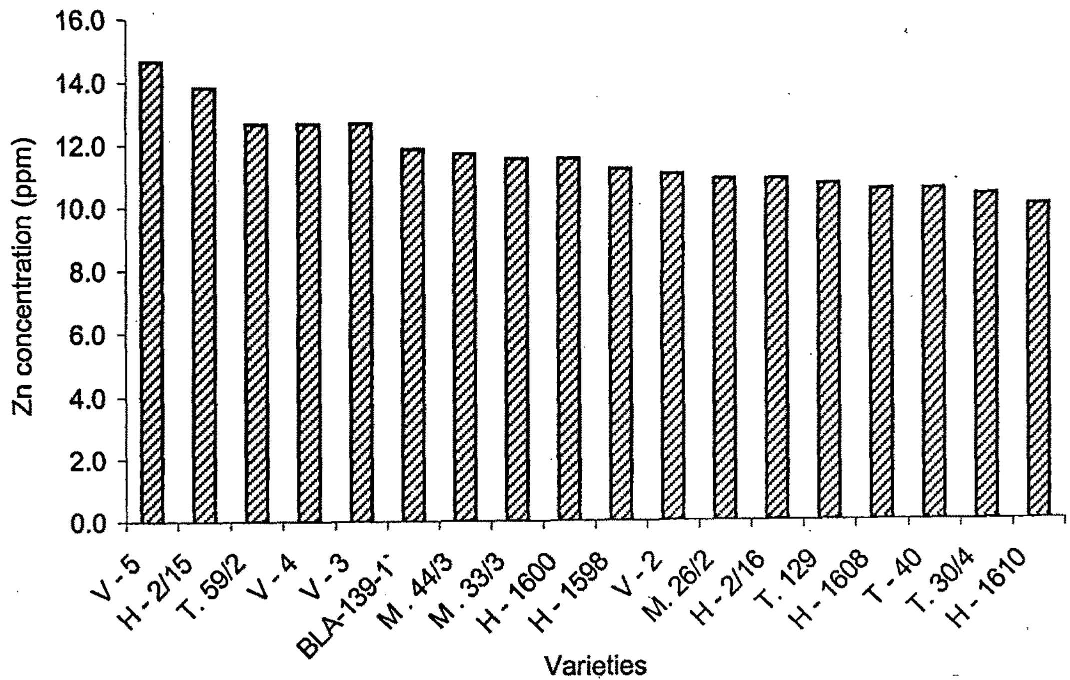
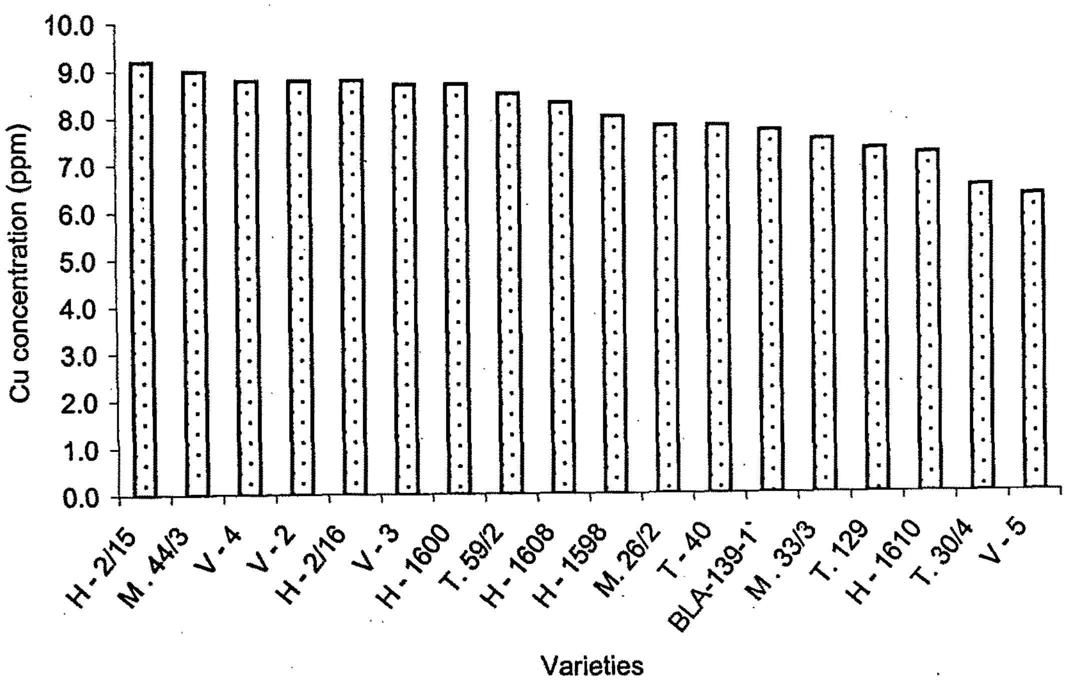


Fig. 43 Leaf Cu concentration at pre-flushing stage of cashew varieties



DISCUSSION

5. DISCUSSION

Results obtained from the field and pot culture experiments conducted to study the response of graft raised cashew to fertilizer nutrients, genotypic variation in yield and foliar nutrient contents, and effect of supplementation of secondary nutrients for cashew in laterite soil; and also standardisation of potting media for efficient root stock production are discussed in this chapter.

5.1 Exp. I a. Effect of potting media and nutrient supplements on growth of cashew root stocks

Pot culture experiments were conducted to study the effect of different potting media and nutrient supplements on growth and vigour of cashew seedlings intended to be used as root stocks. The results are discussed briefly here.

5.1.1 Effect of potting media on growth of seedlings

The biometric characters of cashew seedlings varied with the nature of the potting media and the plant nutrients supplemented in the media (Tables 7 and 8). Among the three potting media compared, performance of seedlings was the best with 1:1 soil : FYM mixture followed by that in 1:1:1 soil, sand and FYM mixture. The seedlings grown in 1:1 soil and sand mixture showed relatively poor height, girth, number of leaves, leaf area and dry matter production compared to 1:1 soil : FYM mixture.

The dominant influence of FYM in stimulating the growth of seedling is evident from the results. This has been demonstrated in experiments conducted on various other tree species. Dhar *et al.* (1992) in their studies on the influence of growing media on growth and dry matter accumulation of seedlings of forest tree species observed that farmyard manure (FYM) was the best medium for raising healthy and vigorous seedlings. The superiority of potting media containing cattle manure in obtaining vigorous seedlings of various tree crops was reported earlier (Anon, 1989). Sudheesan (1996) obtained better growth (seedling height, collar girth, number of leaves and dry matter accumulation) in seedlings of different tree species by treatments with FYM than those without FYM.

The favourable influence of the medium containing FYM may be attributed to its ability to provide an optimum moisture and aeration besides supplying the essential plant nutrients. The higher nutrient supplying capacity of the media containing higher proportion of FYM is clearly reflected on the growth characters which has shown marked improvement in the media containing 50 per cent (PM_2) and 33 per cent (PM_1) FYM compared to that without FYM (PM_3). The results of the present experiment also suggest that apart from the nutrient contents of the media, FYM improves the physical, chemical and biological properties of the growing media. The findings of the present investigation are in conformity with the results reported by Bahuguna *et al.* (1987) and Sudheesan (1996). Addition of either organic matter or mineral nutrient supplements resulted in higher collar diameter, better root development and higher dry matter production of seedlings than untreated control (Peixoto *et al.*, 1999).

5.1.2 Nutrient supplements to the potting media

Supplementing the potting media with N, P and K fertilizers influenced the growth of the seedlings. The influence of N and K were more prominent than that of P. The height, girth, number of leaves and leaf area of the seedlings were higher with 200 g N + 100 g P + 200 g K supplement to the potting media. However, in most observations the differences between the seedlings supplemented with 200 g N were not significantly different from the seedling supplement with N + P or N + P + K. Investigation on the effect of different potting media on growth of teak seedlings also gave similar results (Hassan and Dey, 1979). The influence of mineral nutrients, especially N in increasing the height, number of leaves, leaf area etc is well established.

There exists a positive relationship between leaf area and overall plant growth. As leaves are the photosynthesizing units of a plant, higher total leaf area through higher number of leaves or by increased area of individual leaves will result in improved benefit to the plant in the form of stored food materials. The mineral nutrient supplements have improved the nutrient supplying capacity of the media with increased uptake and assimilation.

The interactions between potting media and the mineral nutrient supplement were significant in many combinations. However, a firm conclusion is not possible because of the unpredictable drop in values. At various stages of seedling growth the treatment combination $PM_2 \times N_1$ gave the highest value of height, the lowest being in $PM_3 \times N_0$. On the other hand, the girth of the seedling was the highest with $PM_1 \times N_2$

as well as $PM_2 \times N_3$. As observed in height, $PM_3 \times N_0$ gave the lowest value of girth also. The number of leaves per plant was superior in the treatment combination $PM_2 \times N_2$, but it was on par with $PM_2 \times N_3$. The leaf area also showed almost similar pattern, $PM_2 \times N_2$ and $PM_2 \times N_3$ were on par. The dry matter production also showed similar pattern.

The nutrient concentration in seedlings also follows the above pattern. The highest concentration of N, P and K were observed in seedlings raised in 1:1 soil : FYM mixture. Among the treatment combinations $PM_2 \times N_3$ recorded the highest concentration of N both in shoot and root, P concentration being the highest in $PM_2 \times N_2$ and K concentration being the highest in $PM_2 \times N_0$. The nutrient uptake by the seedlings also followed more or less same pattern.

So, considering the overall results a potting media containing 1:1 soil: FYM mixture is the best for producing good quality cashew seedlings. Addition of sand improves the drainage and aeration of the potting media. But it can be seen from the data in Table 2 that the soil used for the experiment contains more than 65 per cent sand and can be classified as sandy loam soil. The results of the present investigation suggest that in a coarse textured soil, where the proportion of sand is around 65 per cent, cashew seedlings can be grown in 1:1 soil : FYM mixture. Obviously the costly input of sand can be dispensed with and quality seedlings of cashew could be prepared in 1:1 soil FYM mixture. The application of nutrient supplements becomes necessary only when the potting media is devoid of FYM because soil: sand mixture alone was found to be inferior in all the biometric observations on growth characters as well as in concentration and uptake of nutrients.

5.1.3 Exp. I b Effect of lime incorporation in potting media on growth of cashew root stocks

The data on the effect of incorporation of different levels of lime in potting media on the growth characters of cashew seedlings viz., height, girth, number of leaves, leaf area, dry matter production are presented in Tables 12 to 16. Incorporation of 100 to 500 g lime per 100 kg of the potting media showed no significant response on height, collar girth and number of leaves per seedling. The shoot dry matter and root dry matter production also did not vary significantly. The root: shoot ratio recorded at 30 DAS and 60 DAS showed significant variation.

However, the variation in root: shoot ratio recorded at 90 DAS was not significant. So it is obvious that lime application may not improve the growth of the seedlings, except for a short term as observed in the root: shoot ratio at 30 and 60 DAS. This improvement in root : shoot ratio is mainly due to the improved root growth. Though the variations were not significant, a consistent numerical superiority was observed in the plants applied with lime up to 200g per 100 kg potting media (Table 13). This may be because of the increase in pH due to the application of lime. Increase in root growth due to the application of lime has been reported (Bai and Cheng, 1997). However, the influence of lime was short-lived, probably due to the buffering action of soil and FYM. The absence of significant variation in the concentration and the uptake of N, P and K due to the incorporation of lime in the potting media also corroborates the lack of response in biometric characters. The lack of response for the application of lime to cashew seedlings in acid soil media may be due to the buffering action of organic matter, which occupies 33 per cent of the potting media. It may also be inferred that the cashew seedlings are probably adapted to acidic conditions of laterite soils.

5.2 Exp. II Effect of soil nutrient regimes on leaf nutrient status and yield of graft raised cashew

Results of the experiment conducted to investigate the response of graft raised cashew to fertilizer nutrients and to study the effect of nutrient regimes on leaf nutrient status are discussed hereunder.

a) Growth characters

The response of ten year old graft raised cashew variety Madakkathara-1 to a base level of 375-165-375 g N, P_2O_5 and K_2O tree^{-1} year^{-1} and its increments and no fertilizer control, was studied. Measures of growth expression viz., height, girth, canopy size and the number of flushes have been improved by mineral fertilization. Except canopy spread all these growth characters showed a linear increase.

The improvement in growth expressions is primarily the net result of enhanced photosynthesis and accumulation of photosynthates. Laterite soil is inherently low in organic carbon and N. Application of N particularly at higher rates has increased the available N in soil and resulted in greater absorption. This results in higher N content in tissue, consequently greater chlorophyll content and enhanced the rate of photosynthesis, which has been reflected in the height and seasonal flushes. A very high rate of N application necessarily need not result in high absorption due to defective external nutritional environment, so also higher N absorption need not enhance photosynthesis since photosynthesis will increase only up to 6 mg N per dm^2 of leaf area (Zelitch, 1973).

The significant response to increasing rates of P in terms of size of the crop and production of flushes can be attributed to its functional role in structure, metabolism and reproduction. The effect of P in increasing the height and flushes in cashew in laterite soils has already been reported (Nambiar, 1983 and Latha, 1992). The response of cashew to P in this experiment is suggestive of the low capacitive factor of P in the experimental area as the thin layer of surface soil is underlaid with hard laterite. The enhanced supply of P by the higher levels of fertilizers might have increased the capacitive factor of P in the soil.

The role of K in plants is attributed mainly to the improvement of internal nutritional environment, which influence growth and development. Latha (1992) observed significant response to K up to 750 g K_2O $tree^{-1}$ for cashew grown in laterite soil. The improvement in growth characters due to K application may be attributed to the indirect role of K in influencing translocation of other nutrients. Higher K application in laterite soil is found to decrease the toxic level of Fe and Mn in plant tissues (Bridgit, 1999) and also maintain cationic balance between Mg and Ca which are very important as structural component of chlorophyll in plant cells. Potassium is reported to promote the growth of meristematic tissue (Tisdale *et al.,* 1996) which can be primarily responsible for greater production of flushes.

b) Chlorophyll content of leaves

Chlorophyll *a, b* and total chlorophyll were found to increase with increments of N, P and K fertilizers. The positive role of N and P nutrition in chlorophyll development and functioning have been reported earlier by Bridgit and Potty (1992).

Chlorophyll *b* is the main acceptor of radiant energy, which is funnelled to P 700 of chlorophyll *a*. The increase in chlorophyll *b* indicated more efficient photosynthetic assimilation, which is reflected in the greater production of flushes. However Mayers and French (1960) reported that photosynthetic efficiency would be maximum only in the two-pigment system process. A deficiency in one will bring about more than proportionate reduction in assimilation rate. In the present study both the pigments increased almost linearly up to the F_2 level, declined thereafter, indicating the inefficiency of higher levels towards contribution to the production of photosynthates. A relative reduction of both the chlorophyll pigments and total chlorophyll at flowering stage indicates the diversion of the absorbed nutrients towards meeting the structural formation of reproductive parts and at all possibilities it could be a temporary phenomenon. Chlorophyll can be considered as the index of metabolic synthesis of proteins. Chlorophyll has not increased beyond the treatment F_2. The production pattern of nuts is in tune with chlorophyll synthesis.

c) Yield attributes and Yield

In cashew, yield is directly related to the number of panicles, bisexual flowers, nuts per panicle and also individual nut weight. All these parameters were the lowest in the case of non-fertilizer treatment and the highest at application of 750-325-750 g NPK tree^{-1} (F_2). At this level the flush production has been increased by 35 per cent over control. Flushes are the real progenitor of panicles, which showed an improvement of 39 per cent at F_2 level over control. Milthorpe and Moorby (1979) reported stimulation of the development of new meristems and hence an increase in demand for more mineral ions due to a high internal concentration of minerals especially N in the plant system. A concomitant increase in total chlorophyll and its constituent components in flushes due to sufficient ionic balance enhanced photosynthesis. Potassium is identified to play important roles in the production of co-factors and enzymes and promote the meristematic activity. All these have contributed to increased panicle production.

The number of bisexual flowers produced in a panicle is the determinant of the number of nuts per panicle. There was an increase of 49 per cent of the flowers in a panicle and 87 per cent increase in the number of bisexual flowers at F_2 level over control, which contributed to the higher yield. Only well balanced mineral ion composition in tissues will physiologically regulate the growth and development process within the plant. Mineral ion concentration determines the plant metabolism and hormone production, which ultimately decide the production and retention of flowers in the panicle. The average nut yield for three years increased from 5.73 kg to 12.95 kg tree^{-1} with 107 per cent improvement at F_2 level over control. The individual nut weight increased from 5.99 to 6.11 g. Yield is the ultimate expression of source sink relationship. The positive effect of applied mineral nutrients on flush production and attributes have been already discussed. The increase in test weight may be attributed to greater sink strength maintained by balanced mineral ion concentration. Latha (1992) observed quadratic response in cashew yield to various levels of nutrients tried up to 1000 g N, 500 g P_2O_5 and 1000 g K_2O tree^{-1} in a long term trial and worked out optimum doses of 750-325-750 g N, P_2O_5 and K_2O tree^{-1} year^{-1} for seedling raised cashew trees grown in laterite soils.

d) Leaf nutrient content

Application of fertilizers showed significant increase in concentration of N and K in leaves at both pre-flushing and pre-flowering stages over unfertilized plants. However, this increase was manifested only up to 750-325-750 g N, P_2O_5 and K_2O level after which a gradual decline was observed. Linear increase in nutrient contents, particularly N with increasing doses up to 1000 and 1500 g N tree^{-1} have been reported by Latha (1992) and Ghosh and Bose (1986) respectively in seedling raised cashew trees in laterite soil. The quadratic response observed in this experiment could probably be due to genotypic characters.

The leaf N content at pre-flowering stage was higher at all levels of fertilizers compared to that at pre-flushing stage. The high N content at pre-flowering stage might be due to the accumulation of nutrients in leaves for growth and production during current season. Current season growth in cashew is manifested by generation of new flushes. In cashew the flushing commences usually with the cessation of North East monsoon. The process of flushing involves the initiation of new twigs from the existing laterals and the growth of new twigs usually ends in a terminal panicle. The whole process of new shoot initiation, tissue development and the emergence of panicle is completed within a period of three to four weeks. The most active growth phase in cashew is the period from flushing to the initiation of flowering. There is a great demand for all the nutrients especially N, P and K which play a vital role in the metabolic process of the plant including cell division, multiplication and elongation. The increased growth of the plant occurs with enhanced production of carbohydrates, proteins, lipids and other metabolites.

The higher concentration of N is probably due to the increased demand for N in the newly formed flushes for formation of chlorophyll and other metabolic processes due to enhanced meristamatic activity and higher absorption of nutrients. The increased concentration of N in leaf tissue at pre-flowering stage compared to the pre-flushing stage observed in the present investigation corroborates the findings of the previous workers (Kumar, 1983; Mathew, 1990 and Bhaskar, 1993).

Although the leaf P content improved with increase in nutrient levels, the effect was not significant. The results reveal that leaf P content at pre- flushing as well as pre-flowering stages was not much influenced by the application of fertilizers upto the highest level also. The variation in leaf P content in the present study was very narrow. Lefebvre (1973) could observe only very low P content in cashew leaves in Madagascar. The soil with 18 kg available P_2O5 ha^{-1} is rated as good in available P content for Kerala soils.

Leaf N has not increased beyond a particular level of application. Further supplementation of nutrients failed to bring about improvement in elements in the seat of chlorophyll. The advantage of higher input could not be manifested in leaf nutrient content at pre-flushing stage.

The inability of plants to transport N, P and K from leaf might be due to high content of Fe and Mn. Increase in the acidity of soil might have released the native Fe and Mn. This might have nullified the effect of higher levels of N, P and K. The yield improvement did not occur since the uptake did not improve beyond 750:325:750 g. The case is same with P and K. The K content was more at pre-flowering stage than pre-flushing stage obviously due to enhanced uptake caused by the newly formed flushes.

e) Nutrient removal

The annual litter fall in cashew variety Madakkathara-1 did not differ significantly by the nutrient regimes. The quantity of litter removed ranged from 8.68 kg to 12.32 kg $tree^{-1}$ $year^{-1}$ at 11 YAP. The findings of Kumar and Hedge (1999) who investigated leaf litter fall and litter nutrient content of cashew trees of different age groups support the above results.

Nutrient concentration in leaf declined drastically prior to shedding. The concentration of N in litter did not differ significantly between the treatments. However it was considerably higher in leaf tissues at pre-flushing as well as at pre-flowering stages in trees applied with higher levels of fertilizers. Translocation of N from leaf to the developing fruits and nuts have taken place at a faster rate in plants with higher demand in the sink, which led to the decline in leaf N just prior to shedding in plants applied with higher levels of fertilizers.

The higher concentration of P and K in leaf litter in trees applied with the highest levels of fertilizers (F_3 and F_4) over the lower dose of F_2, explains that the sink was probably not better developed at the highest levels of fertilizers to properly utilise the absorbed nutrients. This also explains the low concentration of N, P and K in leaf tissues at the highest levels of fertilizers (F_3 and F_4) compared to the optimum level observed in the study (F_2).

The increase in N concentration in litter was about 10 per cent but in the case of P it was 50 per cent. The mobilisation of P was very low from leaf prior to shedding. It was metabolically inactivated by Fe and Mn. The lack of response is due to enhanced uptake of Fe and Mn that binds P and keeps it off from the metabolic stream. The metabolic use does not increase and the metabolic efficiency did not improve.

The total nutrient uptake through cashew apple and nut was the highest with the fertilizer level F_2 (Tables 59 to 61). Comparing the nutrient removal through different harvested parts, the highest quantity of N, P and K was removed through kernel, followed by litter (N removal) and apple (P and K uptake).

It was estimated that at 11 YAP, graft raised cashew (variety Madakkathara-1) removes on an average 32.5 g N, 3.2 g P and 16.2 g K through apple, nut and litter in producing one kg nut. The present findings are in conformity with the results of Mohapatra *et al.* (1973) and Bhaskar (1993).

The results obtained from this experiment also emphasises the importance of mineral fertilization in adequate quantity and balance for higher productivity. It is evident from the results that the growth and physiological characters in graft-raised cashew did not improve beyond the dose of F_2. The average nut yield for three years was the highest with the application of fertilizers at the dose of 750: 325: 750 g N, P_2O_5 and K_2O tree^{-1}. The highest variation in nut yield from pre treatment yield was also observed with the fertilizer dose of F_2. It also suggests that the level of 750-325-750 g N, P_2O_5 and K_2O tree^{-1} year^{-1} for seedling grown cashew is valid for graft raised cashew trees.

f) Yield prediction model

A probe into the factor analysis of cashew productivity presented in Table 87 and Fig. 44 will show that as is normally expected N content of the index leaf as well as its utilization constitute the key factor. A direct relationship of N and its metabolic utilization represented by chlorophyll content would mean that critical factor governing realized yield is N. The apparent positive relation of N also follows the concept of limiting nutrient management. However a closer scrutiny of the equation points out to metabolic inhibition involved in yield expression. This is particularly pertinent in the context of realizing up to 15 kg nut yield per tree under the management system in 1998, but subsequent failure to realize such yield levels either in the same treatment or under progressively higher levels of application. A yield level of 15 kg tree^{-1} at one time is an index of its capacity for yield. Failures to realize such high yield thereafter even under higher levels of nutrition would seem to be the direct evidence of some inhibiting influences limiting production.

The equations 1 and 2 (Table 87) really suggest that N factor minus a constant is the prediction component of yield, in spite of the positive relationship with N. The negative factor seems to be a real index of the inhibiting effect on the positive effect of N. This hypothesis is confirmed by the observations in the same work presented else where specifically on Fe, Mn and Cu effects. Together between these two results, it seem probable to conclude that productivity enhancement measures should now be shifted from evaluation of effect of graded levels to ameliorative management based on identification of limiting influences. Yield limiting influences of native factors due to their excess levels in soil and consequent absorption have been reported in coconut (Mathewkutty, 1994), in pepper (Sreekumaran, 1998) and in rice (Bridgit, 1999). The present results in its totality would seem to indicate that ameliorating the ill effects of Fe, Mn and Cu would help to raise the yield levels substantially at the present level of recommendation.

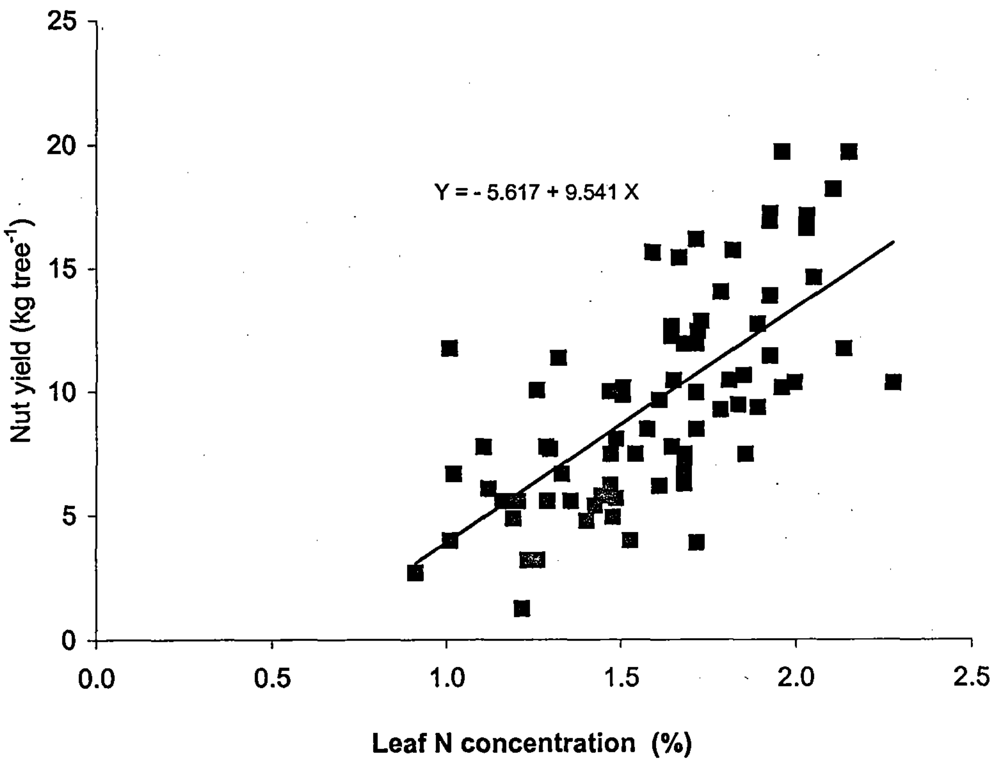
A perusal of the equation -1 based on pre-flush N concentration of the index leaf has also brought out another significant indication. It does not stand to reason that pre-flush N is the result exclusively of nutrients applied in the current season. Normally the fertilizers are applied to the crop in June-July or August-September. Markose (1975) have reported that the effect of applied N lasts for three months. Thus the pre-flush N of the leaf is at least in part reflecting the N absorbed earlier or to the basic soil fertility status. This would mean that productivity expression at least in a perennial crop like cashew is dependent not merely on the current season application of nutrients but on the basic fertility status of the soil. This is especially so because flushing is a sudden spurt of the resurgence of the plant where in stored

Table 87. Yield prediction model in cashew

Model	Coefficient	R^2	S.E
Model-1			
Constant	-5.617	0.467	3.179
Pre-flush N	9.541		
Model-2			
Constant	-9.921	0.499	3.103
Pre-flush N	7.526		
Total chlorophyll	3.520		

Equation 1: $Y = -5.617 + (9.541 \times a)$
Equation 2: $Y = -9.921 + (7.526 \times a) + (3.52 \times b)$
Y = Nut yield (Kg $tree^{-1}$)
a = Leaf N concentration at pre-flushing stage (%)
b = Total chlorophyll content of leaves at flushing stage (mg g^{-1})

Fig. 44 Relationship between leaf N concentration at pre-flushing stage and nut yield



food including minerals are remobilized and utilized; thus improvement of soil fertility status holds the key for productivity enhancement.

Current season fertilizer application may be likely to have a disadvantage also. These synthetic materials are bound to enhance soil acidity in the rhizosphere, which in turn will increase the release of native elements like Fe, Mn, Cu etc which have proved themselves harmful to cashew. Thus it is probable that the positive factor of nutrition with major nutrients is counter balanced or the advantage is offset through induced release of harmful native elements. Similar results have also been reported by Mathewkutty (1994) and Sreekumaran (1998) in coconut and pepper respectively. Mathewkuttty (1994) have further shown through the analysis of direct and indirect effect of elements that absence or negative effect of N in coconut yields is not actually due to the real lack of response to N but was an induced expression of S deficiency, which was again a net effect of Fe content.

Thus the overall results indicate that productivity enhancement of cashew is possible with ameliorative management to contain the excess effect of Fe, Mn, etc. Higher inputs of major nutrients are not required to realize higher productivity. What is important in the present context is increasing the use efficiency of applied inputs and not increasing their levels.

However, in any system where specific nutritional environment in soil is generated through continuous application of fertilizers as in the case of perennial crop, revalidation of existing practices is required. This implies that formulation of objective oriented management system of cashew and its judicious application in field will enable us not only to meet the entire requirement of cashew nut at present but also boost the cashew industry to further heights.

5.3 Exp. III Effect of soil application of lime and $MgSO_4$ on growth and productivity of graft raised cashew

Data on the yield attributes and nut yield of trees in the experiment showed that combined application of Ca and Mg have significantly increased the yield of nuts. The increase in yield had been of the order of 78 per cent over control. These results indicate the importance of the secondary elements in increasing the functional efficiency of primary nutrients in the yield process of the plant. Similar results have also been reported by Bridgit (1999).

A closer scrutiny of the data into the process of the yield formation in the treatments showed that the primary factor regulating the productivity of cashew is the number of reproductive flushes per unit area. The level of 500 g lime and 1500 g $MgSO_4$ have registered 85 per cent reproductive flushes, which was the highest in the present trial. Growth and development of perennial trees is through recurring annual flushes, which may either be vegetative or reproductive in nature. Vegetative flushes are stable and contribute to canopy expansion, where as reproductive flushes wither out at maturity. Minimum canopy spread associated with maximum realised yield would indicate the role of secondary elements in diverting the photosynthates to reproductive processes.

The observation that number of total flushes per unit area has not changed significantly but percentage of reproductive flushes as well as number of bisexual flowers have showed wide variation under different combinations of Ca and Mg further confirmed the role of Ca and Mg in realising better yield of cashew. Near inverse tendencies between number of reproductive shoots and number of bisexual flowers appear to be indicative of quantum requirement and utilization of these two elements in the process.

Results of the present study have further pointed out to the optimal quantitative and proportional requirement of Ca and Mg for better yields. Avoidance of application would lead to reduced number of reproductive shoots. Lower dose of lime and higher Mg may lead to more of reproductive flushes and increased number of bisexual flowers per panicle. Increase in Ca appeared to reduce bisexual flowers. Application of 1500 g lime and 1000 g $MgSO_4$ $tree^{-1}$ increased bisexual flowers, nuts per panicle and nut weight. Possibly relatively lower number of reproductive flushes with high Ca and Mg may be indication of relative deficiency of N, P and K.

Nutritional relation to productivity

A comparison of the control vs. rest of the treatments will indicate yield increase as the resultant of substantial reduction in the Fe, Zn, Mn and Cu content and then increase in the content of N, P, K, Ca and Mg in the leaves. Negative influence of higher foliar concentration of native elements on productivity has been reported in coconut (Mathewkutty, 1994), in rice (Bridgit, 1999) and in pepper (Sreekumaran,1998) in laterite soils. The inherent high content of these elements is the natural consequence of intense laterization process and can only be rectified through amelioration. Decrease in the contents of Fe, Mn, Zn and Cu by application of secondary elements would indicate their efficiency in this regard. Increase in the contents of N, P and K associated with decrease in the contents of Fe, Mn, Zn and Cu would mean that the latter ones restrict the uptake of primary elements and as such yield improvement due to secondary elements shall be due to increased metabolic availability of these elements through higher concentration. However, it can be seen that yield improvement had been far higher than the mere increase in the content of major elements could account for, but was also due to the increased efficiency in the use of these elements as well. This would imply that a higher concentration Fe, Mn, Zn and Cu in the leaves reduced the efficiency of major nutrients through metabolic interferences.

An observation of the foliar concentration of elements in the context of growth and yield attributes has brought out the significance of Ca and Mg in the nutrition of cashew. The highest number of bisexual flowers, nuts per panicle, nut weight and canopy spread have been recorded in the treatment receiving the highest level of Ca and medium level Mg viz., 1500g and 1000 g respectively. This treatment has also recorded the highest foliar content of Ca and Mg and the lowest content of Fe, Cu and Zn. The fact that growth and development of nuts require more of Ca and Mg as 70 per cent of the yield is the shell and it would suggest that the yield improvement in the rest of the treatment should be due to the twin effects of increased Ca and Mg and the decreased Fe, Mn, Zn and Cu contents.

A comparison of the treatments has shown a yield variation of the order of 17 per cent. This virtually has to be the effect of variation in the foliar content of the elements. It appeared that these variations are linked to N content as well as balance between K and Ca or K and other cations in general.

Yield expression in perennial crop like cashew is linked basically to reproductive flushes. Flushes are outburst of growth and are natural consequences of readily assimilable energy sources stored in the bark and not the exclusive effect of nutrients applied during the season. As such the influence of current season manuring on foliar elemental composition may be only marginal. This would mean that more than the levels of any element especially insolubles applied, change in foliar concentration will be important. Application levels would have to be decided on the effectiveness over time. This shall be further illustrated from the increase in the Ca content over control in L_1Mg_3 and additional increase in treatment L_3Mg_1 over this.

5.4 Exp. IV Varietal variation in leaf nutrient status and its relation to yield

The productivity of cashew is decided by the variety, environment, age of the plant and the management. Being clonally propagated the root stock will be similar and the varieties differ in their ability to respond to weather, nutrients and management depending upon the scion material used.

The variation in nut yield among the varieties with different bearing habits and its possible causes and relationship with the various parameters observed during the 10^{th} and 11^{th} year of planting are briefly discussed. The overall results of the experiment show that four types of bearing habits have been observed in the present study. The varieties can be grouped in to four categories:

i) Fairly stable high yielders

It can be seen from the data on nut yield (Table 78) that the varieties M-44/3, H-1598 and H-1608 gave nearly constant high yields throughout the study and can be classified as fairly stable high yielders. Nut yield of the varieties in the group ranged from 7.00 kg $tree^{-1}$ (H-1608 at 11 YAP) to 9.88 kg $tree^{-1}$ (M-44/3 at 10 YAP).

ii) Fairly high unstable yielders

The varieties which produced fairly high nut yield (mean yield more than 6 kg $tree^{-1}$), but the variation in nut yield between the years was more than 30% and were classified as fairly high unstable yielders. The varieties T-30/4, M-33/3, T-129, BLA-139-1, H-2/15, H-2/16 and T-40 can be included in this group.

iii) High unstable yielders

The four varieties V-5, V-4, M-26/2 and V-3 are ranked high in the average yield for the two years. But the variation in nut yield between the years was always more than 30 per cent in the above varieties which are classified as high yielders, but unstable in their production.

iv) Stable low yielders

The varieties H-1600, H-1610, V-2 and T-59/2 recorded consistently low yield during both years of the study and are classified as stable low yielders.

The plants classified as high unstable yielders and fairly high unstable yielders can be managed for realizing steady high production. The data also suggests that 50 per cent of the plants were vulnerable to variations in microenvironment. Low stable yielders are evidently low producers and conspicuously with poor nutrient use efficiency.

The lowest yield and the lowest nutrient content were observed in the varieties H-1600, H-1610 and T-59/2. Absorption of N is low in some cases (H-1600) while the nutrient use efficiency was low in some varieties (T-59/2). From the nutrition point of view the stable low yielders can be considered as those with poor absorption as well as with metabolic inability to utilize the absorbed nutrients. This is not due to lack of native or applied nutrients in the rhizosphere. Native nutrients have not been critical for production. The varieties that gave consistently low yield were inherently inferior in absorption and utilization of nutrients especially N, P and K

The consistently low bearing habit in the variety H-1610, can be due to the excessive vegetative growth. The height and girth were the highest in the variety H-1610. This can be attributed possibly to the inhibition of differentiation that resulted in the lesser development of reproductive organs.

The increment in vegetative characters was comparatively low in the stable high yielding group. But this was very high in the stable low yielders. Excessive increase in tree height and trunk girth results in low diversion of nutrients for spread of the canopy. The higher rate of increase in canopy spread with low increase in height and girth appears to be one of the important parameters contributing to yield.

The data on flushing also show that the flushes, which are the most important vegetative index were high in the stable low yielders. For realizing high yield about 70 per cent of the flushes should produce panicles. Number of nuts per panicle is a critical factor, which is directly related to the number of flowers and the percentage of bisexual flowers in a panicle. In cashew, the number of bisexual flowers that can be produced decides the yield potential. The number of nuts per panicle is reflection of the percentage of bisexual flowers and the subsequent fertilization and development of hermaphrodite flowers.

Formation of female flowers being the potential of any cashew variety, the realized yield is the proportion of bisexual flowers fertilized which in turn is reflected in number of nuts produced in a panicle. The female flower production may be low due to the failure to form female flowers during the differentiation phase that can be due to physiological causes. This effect can be aggravated by weather aberrations. Thus the cause of variation in productivity between the years in fairly high unstable and high unstable yielders can be attributed mainly to physiologic variability either independently or supplemented with weather effects.

A perusal of the data show that stable yielders are never very high yielders and that when the yield improves beyond the fairly high level the plant become unstable with variation of about 30 per cent or more between years. This may be because of the fact that growth and productivity are confined to a limited period of about three months. When the process of bearing is continuous as in coconut, the crop can adjust the variation in bearing within the cycle in a year. Thus, in the present study year to year variability observed in cashew varieties can possibly be due to the fact that there is only one time flushing and fruiting confined to a period of about three months.

The data on shelling per cent, kernel weight and apple weight show that marginal variation from year to year observed in the stable high yielders is due to the variation in partitioning of photosynthates between these three parts. Higher variation in yield is always due to the variation in the number of nuts produced in a panicle.

The performance of the low yielders has been characterized by a reduction in the nuts per panicle. The reduction has not been due to a reduced photosynthetic rate but might be due to failure in fertilization or production of female flowers themselves. Observation on growth characters showed that these plants had put on more growth in terms of height and girth. Thus, the low yield of these plants can be attributed to diversion of carbohydrates to growth rather than reproduction. These results would further imply that difference in productivity in cashew arise mainly through utilization of carbohydrates between growth and reproduction. This is evident from the data on chlorophyll content of leaves at flushing as well as flowering stages.

Once the number of nuts per panicle has been decided the high yield is decided by the combination of number of nuts per panicle and nut weight. The ratio between canopy spread and girth as well as canopy spread and height is important since it was observed that widening the ratio was found to improve the productivity.

Nutritional relations to the productivity of varieties have indicated that broadly two factors operate in productivity expression namely:

i) Varietal variation in the capacity to absorb nutrients and

ii) Nutrient balances

The stable low yielders are basically inefficient absorbers of applied elements especially N and P; very often their translocation from flushes to flowers is also marginal. These two possibly creates an induced deficiency of the element in the inflorescence, which in turn might affect female flower production. The induced deficiency of applied elements is aggravated by native essential nutrients especially Fe, Mn and Cu. The failure in female flower production may be one indirect cause or effect of the comparatively higher vegetative growth. Thus low yielding types should be considered as genetically poor yielders.

On the other hand the fairly high stable yielders do not suffer from inhibition of absorption of the applied nutrients or its translocation from flushes to flowers, as evident from consistently high N and P concentration in the leaves of these plants. This high content of N and P in turn had been able to counteract the adverse effect of Fe, Mn and Cu by effectively neutralizing their contents possibly through anion-cation neutralization. Experiments on rice have indicated that more than the content of these elements it is the balances between N and Fe that leads to yield expression. The present data show that K content of these types (fairly high stable yielders) was also higher than the stable low yielders. Bridgit (1999) have reported that the role of K in the plant system is to neutralize the yield inhibiting influence of Fe and Mn.

In the case of fairly high unstable yielders as well as high unstable yielders, the instability can be attributed to the inhibiting influence of Fe, Mn and Cu either alone or together, combined with variation in the content of major nutrients in the flushes as well as its translocation to the flowers. In these two cases, the metabolic exhaustion after a heavy bearing may also be one of the causes of the instability in yield. The above contention arose from the fact that the vegetative expansion of these plants was unrelated to low productivity and had continued in the normal course. The same seem to have been held good in the case of fairly high unstable yielders also.

The overall results indicated that of the 18 varieties, only three had been really poor yielders, which were unable to absorb nutrients. Fifteen of the 18 varieties were having potential for higher productivity. The low yield of these types could be improved upon by better management. The difference between realized and realizable yield is considered as the yield gap. The present observation that 15 out of 18 varieties had a high potential, but exhibited low yield, suggested that the concept of nutritional management should change from testing the different levels of a compact technology to identifying the causes of the yield gap and finding out means of their amelioration. In the present study the cause of the yield gap had largely been due to the excess content of Fe, Mn and Cu in the plant, which had naturally resulted from their high content in the soil. The problem of high content cannot be reduced, as it is inherent in soil. Ameliorative management to restrict their absorption alone is possible. Thus the data indicate that ameliorative management is the key to improvement in production irrespective of the variety in cashew.

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

Investigations were carried out at Cashew Research Station Madakkathara during 1997-99 with the objective to develop nutritional strategy for production of healthy root stocks and to study the variation in leaf nutrient status and the response of graft raised cashew to different nutrient regimes; the varietal variation in leaf nutrient content of different cashew varieties; to assess the effect of lime and $MgSO_4$ on growth and productivity of cashew. One green house study and three field experiments were taken up as part of the investigation.

Green house experiments concentrated on the studies to standardize a nutrient management strategy in the nursery to produce vigorous root stocks. The experiment was laid out in CRD with treatments comprising of factorial combination of three different potting media and four nutrient supplements (N_0 – No nutrient, N_1 – 200 g N, N_2 – 200 g N + 100 g P_2O_5, N_3 – 200 g N + 100 g P_2O_5 + 200 g K_2O 100 kg potting media^{-1}) and replicated four times. The nutrient supplements were added to the different potting media as per treatments and observation on growth, dry matter production, nutrient concentration and uptake were recorded at 30, 60 and 90 DAS (days after sowing).

To study the influence of lime incorporation in potting media on growth of cashew seedlings in the nursery, a trial was conducted with five levels of lime (100, 200, 300 400 and 500 g 100 kg^{-1} potting media) and one control in completely randomized design with four replications.

To study the effect of soil nutrient regimes on leaf nutrient status and yield of cashew, four different levels of fertilizers (F_1 - 375:165:375; F_2 - 750:325:750, F_3 - 1125:490:1125 and F_4 - 1500:650:1500 g N, P_2O_5 and K_2O tree^{-1} year^{-1}) and an absolute control (F_0) was applied for three consecutive years to 10 year old graft raised cashew variety Madakkathara-1. The experiment was laid out in RBD with five replication and single tree as a plot.

Observations on the biometric characters, panicle characters, chlorophyll content of leaves at flushing and flowering stages, leaf nutrient content (NPK) at pre-flushing and pre-flowering stages, nut yield and yield attributes were recorded during 10^{th} 11^{th} and 12^{th} YAP. The dry matter production, litter fall, the nutrient uptake through harvested parts and total nutrient removal were worked out at 11 YAP only.

Response of five year old graft raised cashew variety Madakkathara-1 to a factorial combination of four levels of lime (0, 500, 1000 and 1500 tree^{-1}) and four levels of $MgSO_4$ (0, 500, 1000, 1500) was investigated in a RBD with three replications. Observations on biometric characters, chlorophyll content of leaves, leaf nutrient content, yield attributes and nut yield were recorded.

Eighteen clonally propagated cashew varieties were evaluated at 10th and 11th year after planting to assess the variation in leaf nutrient status and its possible relation with growth and yield attributes. The experiment was in RBD with three replication and two trees in each plot. The data on growth, physiological characters, nut and apple characters, N, P and K content of leaves and nut yield were recorded.

The biometric characters of the cashew seedlings in terms of height, girth, number of leaves and leaf area were significantly influenced by the nature of the potting media. Among the three potting media compared, the best performance was observed with 1:1 soil:FYM mixture followed by 1:1:1 soil:sand:FYM mixture. Seedlings grown in 1:1 soil:sand mixture exhibited relatively poor height, girth, number of leaves and leaf area.

Significant improvement in height, number of leaves and leaf area was observed at all stages when the potting media was supplemented with 200 g N + 100 g P and 200 K 100 kg^{-1} (N_3). Nutrient supplements had significant effect on girth only at 30 DAS.

The treatment combination of $PM_2 \times N_1$ gave the highest values of height on 30 DAS, $PM_2 \times N_3$ at 60 and 90 DAS, the lowest being by $PM_3 \times N_0$. On the other hand the girth of seedling was the highest with $PM_2 \times N_3$. The lowest values of girth were recorded in the combination $PM_3 \times N_0$. The number of leaves per plant was highest in $PM_2 \times N_2$ and $PM_2 \times N_3$. Leaf area was the highest in treatment $PM_2 \times N_3$.

The highest concentration of N, P and K were observed at 90 DAS in shoot as well as root tissues of seedlings raised in 1:1 soil:FYM mixture.

Supplementation of N, NP or NPK recorded higher N concentration compared to control. NP or NPK recorded higher concentration of P and K in shoot tissues estimated at 90 DAS.

Among the treatment combinations $PM_2 \times N_3$ recorded the highest concentration of N both in shoot and root, P concentration in shoot was the highest in $PM_2 \times N_2$ and K concentration highest in both shoot and root by $PM_2 \times N_3$.

The overall results of the experiment suggest that a potting media containing 1: 1 soil : FYM mixture is the best for producing cashew seedlings, if the soil contains around 60 per cent sand.

Incorporation of lime at varying doses from 100 to 500 g 100 kg^{-1} of potting media (1:1:1 soil:sand:FYM) did not influence the growth characters of cashew seedlings in terms of height, girth, number of leaves or dry matter production.

Application of lime at 300 g 100 kg^{-1} potting media (L_3) gave the highest root : shoot ratio (RS ratio) at 30 DAS, while lime at 200 g (L_2) gave the highest RS ratio at 60 DAS. Lime application did not influence the RS ratio of seedlings at 90 DAS.

The concentration of N, P and K in shoot and root tissues of seedlings as well as the uptake of these nutrients remained unaffected irrespective of the levels of lime incorporated in potting media.

In the experiment to study the response of cashew to nutrient regimes, consecutive application of high levels of NPK fertilizers for three years brought about significant improvement in growth characters in terms of height, girth, number of flushes in 10 year old graft raised cashew trees of the variety Madakkathara-1.

Flower production and floral characters (number of panicles, number of flowers, percentage of bisexual flowers) improved upto a dose of 750 : 325 : 750 g N, P_2O_5 and K_2O $tree^{-1}$ (F_2).

Chlorophyll *a*, *b* and total chlorophyll content in leaves were the highest at flushing and flowering stages with the treatment F_2.

The average nut yield as well as the kernel yield for the three years of the study was the highest in trees applied with NPK at 750 : 325 : 750 g $tree^{-1}$ $year^{-1}$. The highest variation in nut yield from pre treatment yield (9 YAP) was observed when fertilizers were applied at the level F_2.

The levels of fertilizers did not influence the nut weight in cashew variety Madakkathara-1. The highest shelling percentage, kernel yield and apple yield were recorded at 750 : 325 : 750 g NPK tree^{-1}.

Application of fertilizers significantly increased the leaf N and K contents at pre-flushing as well as pre-flowering stages upto the dose of F_2, beyond which there was no response. The different levels of fertilizers did not influence phosphorus content of leaves at both stages of crop growth observed in any of the years.

N and P contents of apple were increased by fertilizers upto 375 : 165 : 375 g NPK tree^{-1} (F_1) but K content was unaffected.

Annual litter removal of cashew as well as N content of litter remained unaffected irrespective of the level of applied fertilizers. The highest P and K content in litter was observed with NPK fertilizers at 1125 : 490 : 1125 g tree^{-1} (F_3).

N, P and K content of kernel did not improve significantly beyond the dose F_2. The highest uptake of N and K through nut was observed with the treatment F_2, whereas P content was the highest with the treatment F_3. Dry matter yield and nutrient removal through apple did not increase beyond the fertilizer level F_1 (375 : 165 : 375 g NPK).

Total nutrient removal through harvested parts and litter was the highest (59.80 kg ha^{-1}) with the application of fertilizers at 750 : 325 : 750 g NPK tree^{-1} year^{-1}.

The quantity of nutrients removed through harvested parts and litter in producing one kg nut remained on par irrespective of the level of fertilizer applied.

The results of the study on the response of five year graft raised cashew trees to lime and $MgSO_4$ revealed that growth parameters viz. height, girth and canopy spread of cashew were not influenced by application of lime or $MgSO_4$.

Addition of lime and $MgSO_4$ at 500, 1000 or 1500 g did not change the chlorophyll content (chlorophyll *a*, chlorophyll *b* and total chlorophyll) of leaves at pre-flushing stage.

The percentage of bisexual flowers increased with increase in application of $MgSO_4$ upto the highest dose of 1500 g tree^{-1}.

Different levels of lime did not change the number of nuts per panicle, but $MgSO_4$ at 1000 and 1500 g tree^{-1} significantly increased the number of nuts over the lower dose of 500 g as well as non applied control. Interaction effect was significant with the highest number of nuts in the combination treatment of 1000 g each of lime and $MgSO_4$.

Levels of lime or $MgSO_4$ did not exert any influence on either nut yield or nut weight. The combination treatment of 500 g lime with 1500 g $MgSO_4$ produced the highest nut yield.

Leaf N content showed a stepwise increase with increase in dose of lime or $MgSO_4$.

Phosphorus and potassium content of leaves increased with application of lime, but decreased with application of $MgSO_4$.

Calcium and Magnesium content of leaves showed an increasing trend with application of lime when its effect was averaged over levels of $MgSO_4$.

Iron content of leaves was found to reduce with increasing levels of $MgSO_4$ application while lime application at higher levels tended to increase the Fe content.

Eighteen promising cashew varieties evaluated at 10th and 11th year of planting differed considerably in growth characters in terms of height, girth, canopy spread. The variety H-1610 was found superior and M-44/3 and V-2 inferior in the growth characters in terms of height, girth and canopy spread.

The varieties M-26/2, M-44/3, V-5 exhibited comparatively better performance in panicle characters and yield attributes.

Considerable variation in chlorophyll *a*, chlorophyll *b* and total chlorophyll content in leaves was observed between the eighteen varieties.

Leaf chlorophyll content was higher at flushing stage than that at flowering stage in all the varieties. Chlorophyll *a* content was higher in all the varieties than chlorophyll *b* at all stage of observation.

Chlorophyll content of leaves at flushing stage gave positive correlation with yield in most of the varieties.

Nut yield per tree of 18 varieties ranged from 4.20 kg (VTL-59/2) to 13.23 kg (M-26/2) at 10 YAP, 0.80 kg (V-2) to 12.41 kg (V-5) at 11 YAP. The highest average nut yield during the period of study was recorded by the variety V-5 (10.89 kg tree^{-1}) and the lowest by the variety VTL-59/2 (3.64 kg tree^{-1}).

The average nut weight in 18 cashew varieties ranged from 4.43 g (M-44/3) to 9.02 g (H-2/16) and kernel weight from 1.37 g (V-5) to 2.57 g (H-2/16).

Leaf N and K contents were higher at pre-flowering stage than that at pre-flushing stage in all the varieties. Phosphorous concentration was higher at pre-flushing stage than pre-flowering stage.

Considerable variation in leaf N and K content between the varieties was observed at all stages of observation during both years of the study. The varieties differed in P content at pre-flowering stage only.

The eighteen varieties tested differed significantly in the concentration of Ca, Fe. The concentration of Cu and Zn in leaves at pre-flushing stage did not vary significantly among the 18 varieties.

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NUTRITIONAL CHARACTERISTICS IN RELATION TO GROWTH AND PRODUCTIVITY OF CASHEW (*Anacardium occidentale* L.)

By

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ABSTRACT OF A THESIS

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ABSTRACT

Three field experiments and one green house study were conducted at Cashew Research Station (CRS), Madakkathara, Thrissur, Kerala during 1997-99 with the objective to study the response of graft raised cashew to varying levels of nutrient regimes and to assess the variation in leaf nutrient status in relation to nutrient regimes and to develop yield prediction model based on tissue nutrient status; to study the varietal variation in tissue nutrient status of eighteen promising varieties in relation to yield; to assess the effect of lime and Mg SO_4 on the growth and productivity of cashew in laterite soils; to develop a nutritional strategy in the cashew nursery for the production of healthy root stocks.

Exp. I Influence of nursery technique on growth of cashew root stocks

a) Effect of potting media and nutrient supplements

b) Effect of lime incorporation in potting media

A study was also carried out to standardize a nutrient management strategy in the nursery to produce vigorous root stock. Three different potting media (soil, sand and FYM in 1:1:1; soil and FYM in 1:1; soil and sand in 1:1 ratio) and four nutrient supplements (control, 100 g N; 200 g N + 100 g P_2O_5; 200 g N, 100 g P_2O_5 and 200 g K_2O 100 kg^{-1} potting media) in a factorial combination. The potting media containing 1:1 soil : FYM mixture supplemented with 200 g N, 100 g P_2O_5, 200 g K_2O per 100 kg potting media is best for producing good quality cashew seedlings.

Investigation conducted to study the effect of incorporation of lime in potting media at different levels varying from 0 to 500 g 100 kg^{-1} potting media revealed that the response of cashew seedlings to the application of lime was limited.

Exp. II Effect of soil nutrient regimes on leaf nutrient status and yield of graft raised cashew

This study involving four nutrient regimes - namely, 375:165:375; 750:325:750; 1125:390:1125 and 1500:650:1500 g N, P_2O_5 and K_2O tree^{-1} year^{-1} and an absolute control was conducted for three years on graft raised cashew variety Madakkathara-1.

Flower production and yield characters were significantly influenced up to a level of 750:325:750 g NPK tree^{-1} year^{-1} .The chlorophyll *a* and *b* was highest both at flushing and flowering stages with the application of 750:325:750 g NPK tree^{-1} year^{-1}. At pre-flushing and pre-flowering stages, N and K concentration in leaf, the total uptake of N and K, the highest nut yield as well as kernel yield was highest with the application of 750:325:750 g NPK tree^{-1} year^{-1}.

Exp. III Effect of soil application of lime and magnesium sulphate on growth and productivity of graft raised cashew

Investigation was carried out on five year old cashew grafts of variety Madakkathara-1, to study the effect of application of lime and $MgSO_4$ at four levels each (0, 500, 1000 and 1500 g tree^{-1} year^{-1}) in a factorial combination on growth and productivity of cashew.

The results showed that primary factors regulating the productivity of cashew was the number of flushes per unit area and application 500 g lime and 1500 g $MgSO_4$ has registered 85 per cent reproductive flushes. Application of 1500 g lime and 1000 g $MgSO_4$ increased bisexual flowers, nut panicle^{-1} and nut weight. Increase in the contents of N, P and K was associated with decrease in the contents of Fe, Mn, Zn and Cu, which explains the fact that these micronutrients restricted the uptake of primary elements.

Exp. IV Varietal variation in leaf nutrient status and its relation with nut yield

Among the 18 varieties tested in the varietal evaluation trial, three varieties namely V-5 and V-4 (Vengurla selections) and M-26/2 (Vridhachalam selection) were found to be promising in terms of nut yield, the most important commercial criteria in cashew. In most of the parameters related to yield, the above varieties were found comparatively better. Photosynthetic efficiency measured in terms of leaf chlorophyll content was also higher in these varieties. Leaf nutrient concentration (N and K) was also comparatively high in the high yielders.