EFFECT OF NPK ON SEED PROGENY AND AIR LAYERS IN CASHEW

(*ANACARDIUM OCCIDENTALE L.*)

By

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1985

CERTIFICATE

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I. INTRODUCTION

Cashew (Plate 1) the dollar spinner of tropical climates was introduced into India by the Portuguese and Spanish sailors in the sixteenth century. It has established well on an area of 4.81 lakh ha chiefly in Kerala, Karnataka, Goa, Maharashtra, Andhra Pradesh and Tamil Nadu.

For quite some period, India held the prime position in the export of processed kernels with more than 95 per cent of the world supply of about 50,000 tonnes to the International market.

Till recently, the crop had not gained its due importance in research and development and thus the national productivity of cashew remained comparatively low (0.5 kg/tree/year).

It has been thought over to increase the area of cashew plantation and the surveys conducted revealed that land for cashew planting was not substantially available because of the pressure on the land due to other crops in various states.

All along cashew industry has been built up by and large on the strength of the imported raw nuts from the

African countries. From 1957, the influx of raw nuts to India has been increasing steadily and reached the peak of 2,03,517 tonnes in 1968. Thereafter, the import has declined steeply and reached a negligible level of 3,212 tonnes in 1982. The acute shortage of imported nuts has led to an alarming situation for the processing units and India is forced to rely upon her own production for making the industry alive.

In this connection, it has been thought over to increase the share of indigenously produced raw cashew nuts for making available for export trade.

With the above back ground, long term strategies have been drawn to boost up the internal production of raw cashew nuts (Swaroop, 1976). Under this strategy, it was decided to grow clonally propagated and fertiliser responsive high yielding varieties for extensive cultivation.

The minikit trials conducted all over cashew tracts with timely application of fertilisers showed substantial increase in the productivity of unthrifty cashew plantations at farmers fields. Many of the earlier experiments conducted at Cashew Research Centres, viz., Vengurla (Maharashtra), Bapatla (Andhra Pradesh), Madakkathara (Kerala), and Jhagram (West Bengal) in general indicated response to applied NPK under different

Plate 1. Pseudo apple with cashew nut

agroclimates. But the extent of response varied from place to place making difficult for a comprehensive recommendation of fertiliser applications. Moreover, it will be pertinent to draw the conclusions only from the manurial experiments using clonally propagated material as test plants, rather than the non descriptive plant material in the experiment. In addition, information is yet to be generated on the effects of fertilisers on various quality parameters such as shelling percentage and protein and fruit (pseudo apple) in terms of juice, sugar, ascorbic acid contents and acidity of the juice which would play a major role in alcoholic and non-alcoholic beverage industries.

Thus, in order to generate information on the productivity of cashew, in relation to fertilisation through various physiological processes and their effects on quality and quantity attributes of nuts and apples, the experiment was laid out with the following objectives.

(1) To study the effect of NPK nutrition on growth and production of seed progeny and air layers

(2) To find out the effect of nutrition on quality of nuts and apples from air layers

(3) To work out the effect of fertilisers on leaf physiological parameters such as chlorophyll pigments, cuticular resistance, soluble sugars, leaf water content, and specific leaf weight

(4) To relate nutrient concentrations of leaf tissue to growth, yield and quality characters of fruits

(5) To work out critical concentrations of NPK in leaf.

II. REVIEW OF LITERATURE

The literature on various aspects of NPK fertilisers in relation to crop productivity in cashew and some other relevant woody perennials is briefly reviewed hereunder.

2.1 Growth parameters

2.1.1 Tree shape

The most important characteristic feature that might be of influence on both yield per tree and per hectare is the shape of the canopy.

Wickham (1971) further points the variation in cashew tree shape. He pointed out that growing conditions influence the tree canopy to a larger extent followed by the genetic make up of the plant.

2.1.2 Tree height

Growing conditions influence the appearance of the cashew trees to a larger extent. In Tanzania, Tsakaria (1967) measured the canopy development of young cashew trees growing on a loamy to sandy loam soil and reported that under reasonably favourable conditions, young trees might grow up at a rate of about one metre per year. Lefebvre (1973) reported

that mineral fertilisation was important for cashew growth. He observed that nitrogen and phosphorus application increased plant growth. However, he failed to record any increase in plant growth due to potassium application.

Nambiar (1983) reported that application of 1000g N to cashew trees grown on sandy soils of Bapatla recorded significantly taller trees (4.73 m) compared to 500g N application (4.33 m) or control (4.11 m). He also reported that application of phosphorus @ 200g and 400g recorded a plant height of 4.41 m and 4.52 m respectively, compared to 4.24 m in control plots. However, application of potassium did not show any significant influence on tree growth.

From the foregoing literature, it seems that cashew responds in terms of plant height to applied nitrogen and phosphorus.

2.1.3 Canopy radius

Tsakaris (1967) observed that the young cashew trees grow at a rate increasing their canopy diameter by about 1.5 to 2.0 m per year on a sandy loam soil for the first 5-6 years after which growth slows down. Ohler (1979) pointed out that the growth of the tree depended on the soil physical conditions and also on

the fertility status of the soil.

2.1.4 Surface area

In many of the perennial tree crops, yields are dependent on canopy surface area. Efforts have been made to increase the canopy size by fertiliser application and to relate with the production in crops like cashew, citrus and mango. Nambiar (1980) reported that nitrogen and phosphorus had a significant effect in increasing the canopy area in cashew. Application of 1000 g/tree/year increased canopy surface area to 56.1 m^2 when compared to control (42.71 m^2). Phosphorus application at the rate of 400 g P_2O_5 recorded the maximum canopy surface area (47.7 m^2). Potassium application did not show any significant effect.

Koo and Reese (1974) did not find any influence on canopy enlargement due to different sources and rates of potassium application to citrus trees. Mote [illegible] (1974) reported that mineral fertilizer application i.e. NPK+FYM, NPK or FYM could alone increase the tree growth by 83, 53, and 33 per cent respectively. Reese and Koo (1975) reported an increase in tree size of Hamlin pineapple and Valencia orange trees due to nitrogen application. However, potassium did not show any effect on tree size. Koo (1979) reported that fruit production increased with NK

fertilisers and irrigation mainly through the increase in surface area of the canopy.

From the above reports, it could be deducted that the tree canopy increases with the application of nitrogen and phosphorus fertilisers.

2.1.5 Leader branches

The previous growth of one year old shoots is called as leaders in cashew. The growth of the canopy depends upon the number of viable leader shoots. Nambiar (1983) reported that the number of leader shoots produced per plant showed significant increase due to application of higher levels of nitrogen, phosphorus and potassium.

2.1.6 Lateral shoots

During the flushing time, each leader shoot gives rise to 2-3 lateral shoots which bear panicles or may end as vegetative shoots. Nambiar (1983) recorded that under West Bengal conditions, application of 400g N, 300g P_2O_5 and 300g K_2O recorded maximum number of laterals per plant per year.

Though the literature on the production of leaders and laterals as influenced by fertilisation is very scanty, the indications are that the viability of leader

2.2 Light interception

A healthy cashew tree,not suffering from mineral deficiency or pest attack or other unfavourable conditions will have a dense foliage that provides a heavy shade even at the end of the dry season and almost totally suppresses weed growth. A tree having sparse foliage, through which light can be seen indicates some unfavourable conditions (Plate 7,c). Panicles are produced on the terminal growth on the periphery of the tree receiving maximum sunlight. Normally, the innermost branches where the shade is dense, do not produce any panicles (Cull ane , 1971).

The observations made by these authors indicate that the hemispherical and spreading tree crops are less efficient in utilising the radiation compared to tall growing compact trees with dense foliage.

2.3 Leaf characteristics

2.3.1 Leaf area index

To arrive at exact measurement of leaf area per

nutritional status of the tree.

2.2 Light interception

A healthy cashew tree, not suffering from mineral deficiency or pest attack or other unfavourable conditions will have a dense foliage that provides a heavy shade even at the end of the dry season and almost totally supresses weed growth. A tree having sparse foliage, through which light can be seen indicates some unfavourable conditions (Plates 7,8). Panicles are produced on the terminal growth on the periphery of the tree receiving maximum sunlight. Normally, the innermost branches where the shade is dense, do not produce any panicles (Chadwar., 1971).

The observations made by these authors indicate that the peripherial spreading tree crops are less efficient in utilising the radiation compared to tall growing compact trees with dense foliage.

2.3 Leaf characteristics

2.3.1 Leaf area index

To arrive at a correct measurement of leaf area per tree in cashew is a tedious process. Destructive sampling methods go a long way in deriving at the total leaf area production per unit time. Murthy et al.(1979) developed a rapid non-destructive method for estimating leaf area in cashew by measuring the product of maximum

length and breadth of cashew leaf. They presented a regression equation $\hat{Y}$ = 1.8721+0.6824 ab, where $\hat{Y}$ = estimated leaf area, ab=product of maximum length and breadth for non-descriptive cashew progenies. Later, Bhagawan et al. (1983) recommended the mean of 3rd, 4th and 5th leaf measurement for assessing the leaf area in cashew irrespective of genotype.

2.3.2 Chlorophyll pigments

Nitrogen is one of the main inorganic constituents of chlorophyll molecules and hence, any increment in the nitrogen nutrition would help to maintain the chlorophyll content of leaf tissue. High level of chlorophyll in any plant system by and large, has been reported to be associated with high productivity. Though much literature is not available on this aspect with reference to cashew, the literature available on perennial crops like citrus and mango is reviewed for a general understanding.

Ankaiah and Rao (1983) studied the comparative performance of low and high yielders of cashew in relation to chlorophyll content at Cashew Research Station, Bapatla and reported that the total chlorophyll ranged between 8.58 - 11.71 mg/l (with a mean of 9.83 mg/l) in the case of high yielders where as it ranged from 6.61 - 8.46 mg/l (with a mean of 7.90 mg/l) in case of

poor yielders. The average mean yield of high yielders was 37.0 kg nuts/tree/year whereas the poor yielders yielded only 2.0 kg/tree/year. The regression value for chlorophyll with yield was 0.746 indicating that the chlorophyll content of matured cashew leaves would give a fair indication of the bearing capacity of the tree. They also inferred that chlorophyll in cashew trees influences the yielding capacity of the genotype.

Pirtskhalaishvili (1972) recorded maximum chlorophyll a and b in citrus leaves due to balanced application of NPK fertilisers compared to control. Shimizu and Torikata (1972) studied the chlorophyll content of Satsuma orange leaves and reported that leaf chlorophyll ranged from 5-15 mg/g of leaf in the cultivars examined. Leaf chlorophyll content was correlated with leaf nitrogen and both chlorophyll a and b were increased by nitrogen fertilization. Chlorophyll content, however, did not increase after the leaf nitrogen content increased to 3.5 per cent. Working with $^{14}CO_2$ under field conditions Buttery and Buzzell (1977) established a positive correlation between chlorophyll and Pn rate of soybean leaves. Ishii and Nagai (1981) establishing relationship between photosynthetic characteristics and the nitrogen content of apple leaves observed that leaf Pn rate and leaf chlorophyll increased with the increase in nitrogen levels.

In nut shell, nitrogen fertilisation had a significant impact in increasing the chlorophyll content of many tree crops. The increase in chlorophyll content established relation with the increase in photosynthetic efficiency of apple leaves and the higher contents of chlorophyll in cashew leaves were associated with higher yield bearing capacity.

It could be inferred that high yield bearing capacity of cashew trees was the products of high chlorophyll content associated with elevated photosynthetic rates.

2.3.3 Total sugars

Yields of crops in regularly bearing cashew trees are mainly dependent on the current photosynthates. High level of carbohydrate accumulation in leaf tissue during flowering substantially contribute to the developing sinks. In turn, the rate of accumulation of carbohydrate depends on the active metabolic phase of the system under unlimited supply of inputs. Many researchers have established a relation between nutrient input, carbohydrate content and yields of crop plants.

Ankaiah and Rao (1983) working with cashew trees observed that all the high yielders (37.0 kg/tree/year) of cashew contained 7.19 per cent starch (20.0 kg/tree/year) and low yielders 6.90 per cent starch in leaf.

They reported that the significant association of starch content with yield was an indication of the current photosynthates contribution to the yield in cashew.

Kacharava (1975) studying the metabolism of N-containing compounds in satsuma orange leaves in relation to dates of nitrogen application observed that leaf sugars rose sharply in January and February and dropped to minimum in May-June. He also observed that sugar content of leaves of prolifically cropping trees was 3-5 times lower than in leaves of trees with high crop. Young mandarin trees accumulated more leaf carbohydrates due to an increase in the nitrogenous fertilisers from 100g to 200g/tree/year. Working on mango, Suryanarayana and Rao (1976, 1978) recorded a reduction in glucose and fructose levels in mango leaves during flower bud formation stage but then these sugar contents rose sharply reaching maximum during inflorescence development.

2.3.4 Cuticular resistance

The adaptability of cashew to rainfed agriculture throws light on the internal physiology of leaf to control the loss of water. Cashew leaves are well packed with cuticular waxes and resins offering a high degree of cuticular resistance to transpiration losses. During dry and sunny periods stomata close thus arresting the loss of water through the plant system. High cuticular

resistance in dryland crops helps in maintaining the desired levels of water potential to meet the plant's metabolic demands in acute water stress. To a certain extent high degrees of cuticular resistance are also reported to be associated with high yields in rubber and rice. Brag (1972) reported that wheat and pea plants with highest leaf potassium contents had the lowest rate of transpiration suggesting that increased level of potassium content in tissue regulates the moisture loss to a greater extent.

Szarek and Ting (1974) showed that the stomata in two species of cacti are very sensitive to lowered water potential and that water loss was very slight once the stomata were closed. Although the advantage of high epidermal resistance for survival is evident, the importance of this mechanism in drought resistance of crops, where productivity is important is less clear. Yoshida and Coronel (1976) studied nitrogen nutrition of rice in relation to leaf photosynthetic rates and leaf resistance. Photosynthetic rates were associated with leaf resistance and nitrogen content, and showed highest correlation. The high correlation between Pn and leaf conductance suggests that nitrogen nutrition affects leaf photosynthetic rates largely through its influence on stomatal resistance and associated changes in mesophyll or carboxylation. Yoshida and Reyes (1976) measured the cuticular resistance in

rice and considered it as resistance of leaf surface to water vapour transfer when all the stomata were closed. They also observed that plants showing high cuticular resistance are drought tolerant. Salisbury and Ross (1977) reported that the rate of water loss of detached leaf for some time or soon after detachment is generally taken as typical of the rate of water loss in intact leaf. The degree of resistance offered by the cuticle is influenced by nutrition is lacking in tree crops.

2.3.5 Specific leaf weight

Specific leaf weight (SLW) on dry weight basis is one of the important physiological traits in deciding the productivity of crop plants. The fact that SLW is independent of leaf area and related to photosynthetic rates, it has become handy for the researchers to establish a production based link between photosynthetic rates and SLW in many crop species.

Murata (1961) working on rice reported that high leaf area per unit leaf weight was associated with low photosynthetic rates and low productivity. Barnes et al. (1969) noted that SLW was independent of leaf area and leaf age in alfalfa. Pearce et al. (1969) recommended SLW as a selection criterion for increasing yield in alfalfa. They observed that the photosynthetic capability of leaves was positively correlated with SLW.

Regression analysis showed that variation for SLW accounted for about 64% of the variation in net photosynthesis. Bowes et al. (1972) reported an increase in the SLW with a corresponding increase in photosynthetic rates under high light intensities during the growth period of Soybean. Yoshida and Coronel (1976) studying the nitrogen nutrition, leaf resistance and leaf photosynthetic rates of the rice plant established significant correlation between leaf nitrogen content, SLW and net photosynthetic rates. Marini and Barden (1981) observed that in apples, SLW was a reliable index of the previous environment of leaf. They could also establish a positive and significant relation between SLW and net photosynthetic rates.

It is thus seen that SLW is directly related to net photosynthetic rate or CER though it does not form an index to forecast the productivity in some crops. The role of nutrients at different levels has yet to be identified in increasing the SLW and its relation in the productivity of woody perennial tree crops like cashew.

2.4 Yield attributes

2.4.1 Flushing behaviour

Normally shoot growth occurs in cashew through out the year under well distributed rainfall. Usually 2-3

periods of major shoot growth are distinguished according to the seasonal periodicity. Galang and Lazo (1936) observed several flushes of cashew growing in Bataan, Philippines, the first flushes were produced in March after the fruiting season was over. Jordan and Crone (1942) have mentioned a third seasonal growth stage in India, that may coincide with heavy rains. Bigger (1960) studying young trees in Tanzania, observed that maximum growth took place during the rain season from January to April. Rao and Hasan (1957) noted two main active growth phases on west coast of India, one beginning in October and lasting until January, prior to the flowering stage and another one between March and May. Massive shoot growth at the end of the rainy season or at the beginning of the dry season, just before flowering is a general phenomenon in climates with marked dry and wet seasons. The length of the shoot depends on the growth vigour of the tree and consequently on growing conditions.

2.4.2 Precocity of flowering

Precocity plays a major role in boosting the yield of young cashew plantations. Although precocity is a genetic factor, it is highly influenced by the growing conditions and general health of the tree. Such trees produce their first crop worth harvesting at the age of three years. Northwood (1967) from the observations that

he had collected on cashew trees, concluded that some trees appeared to be early bearers and some late bearers. Lefebvre (1973) showed that during vegetative stage, nitrogen and phosphorus were the most important elements where as potassium played only a minor role. There was a strong interaction between nitrogen and phosphorus. Seedlings receiving nitrogen and phosphorus developed much more vigorously and flowered much earlier than untreated ones. At 2.5 years age, 35 per cent of trees flowered due to N and P application over null per cent under control. At 3.5 years age, it was 87 per cent over 8 per cent in control and at 4.5 years age 100 per cent flowering was observed at N, P application over 31 per cent in control. Motskobili (1973) studied the growth and development of mandarin trees in relation to fertiliser application and reported that the trees receiving NPK and Ca advanced cropping.

In general, it is observed that the precocity of cashew could be influenced through proper management of fertiliser application. A compact duration of flowering period is important in cashew in view of the chemical control of insect pests and harvesting of the ripe nuts. Wide variations have been reported in cashew with respect to the flowering phenomenon.

Rao and Hasan (1957) studied the flowering phenomenon of five cashew trees and reported that from the

date of appearance of the first flowers, there was an average period of thirty two days for all panicles to start flowering. However, between the trees the period varied greatly viz., 17, 17, 19, 41 and 65 days respectively. Ohler (1979) reported from the observations made in Jamaica that the flowering period was for two and a half months and that the flowering peak reached about four weeks after the appearance of the first flowers.

The wide variations in the degree of flowering might probably be due to the genetic variability among the population observed by various workers. The scope of narrowing the stretch over flowering period due to manipulations in the nutritional status of the crop involving a single genotype is yet to be studied.

2.5 Fruit characteristics

2.5.1 Fruit volume

Though fruit volume is genetically a dominant feature among different genotypes, within the given cultivar, the apple volume depends mainly on the growing conditions and the number of fruits produced.

Koo and Reese (1973) observed that application of potassium to various citrus cultivars increased the fruit size. They also observed that increasing levels of nitrogen application decreased fruit size in Hamlin, pineapple and valancia oranges (Reese and Koo,

1975a). Forshey and Elfving (1977) working with McIntosh apples established the relationship between fruit size and fruit number. Increased number of fruits per tree significantly brought down the fruit size in these apples. Koo and Reese (1977) recorded small fruits of citrus when fertilised with higher rates of nitrogen, whereas potassium application increased the fruit size.

The results indicate that application of nitrogenous fertilisers reduces the fruit size by way of increasing fruit number in apples and citrus where as the same was increased with the increase in the levels of potassium.

2.5.2 Fruit weight

Quality of the apple determines the marketability of produce for industrial purposes. Hence, an average to heavier fruits in cashew fetch a good market price compared to filthy and lighter fruits. Though fruit size is a dependent factor on the number of fruits produced under normal management, the same could be maintained at higher levels of fertilisation without hampering the production of fruits.

In general, different varieties of cashew produce different weight of fruits. Though fruit weight among the varieties is a genetic trait, it is also influenced by the growing conditions. Under a given set of genetic

material, trees yielding higher number of fruits normally produce smaller fruits (Ohler, 1979). Kiely et al. (1972) reported varying effects in the fruit weight with the increase in the application of nitrogen to Valencia orange trees. They observed that increasing levels of potassium increased individual fruit weight. Hernandez (1979) working with valencia oranges reported that higher levels of nitrogen reduced individual fruit weight.

From the foregoing literature, it is understood that nitrogen increases the total number of fruits at the cost of individual fruit size.

2.5.3 Juice

Juicy fruits are well preferred in squash and fenny industries than pulpy fruits.

Lopes (1972) reported that juice content of cashew apple ranged from 35.9 - 87.9 per cent and the differences in colour of the pseudo apple did not bring marked variation in juice per cent. Reitz and Koo (1960) working with Valencia oranges could not increase the juice content per fruit by increased nitrogen and phosphorus application, whereas, Azzony et al. (1970) reported an increase in the juice content of naval orange fruits due to application of 100g urea/tree/year. Moss (1972) observed that high leaf potassium content was associated with low fruit juice content of naval oranges. However,

high leaf phosphorus was positively correlated with juice content of oranges. Increasing the level of nitrogen application to Hamlin, pineapple and valencia oranges (Reese and Koo, 1975, 1975a) and to satsuma orange trees (Kodama et al. 1977) increased the same. Koo and Reese (1977) reported that N and K increased juice content of temple oranges while Embleton, et al. (1980) observed that an increase in leaf nitrogen content of Valencia orange trees brought down fruit juice content whereas an increase in leaf potassium content increased the same. Thus, centroversial reports exist on the effect of fertilisers on juice content of fruits.

2.5.4 Total soluble solids (T.S.S)

Estimation of T.S.S. is an easy and handy tool to identify the general quality of the fruits.

Sites and Deszyck (1952) reported that increased application of potassium to valencia and hamlin oranges increased the T.S.S. in fruit juice. Reitz and Koo (1960) found that T.S.S. was increased with the increase in nitrogen and potassium fertilisers while Stewart et al. (1965) did not report any significant differences in T.S.S. of Valencia orange fruit juice by the application of different levels of nitrogen.

Kiely, et al. (1972) did not observe any consistent trend in T.S.S. of Valencia orange juice due to increased

levels of nitrogen whereas T.S.S. was reduced due to application of increased levels of potassium. Reese and Koo (1975 and 1975a) and Koo (1979) reported that T.S.S. was increased in oranges due to increased levels of nitrogen whereas increased potassium rates were associated with low soluble solids.

Krishna et al. (1978) reported that T.S.S. in Kagzi lime fruit juice came down with the increase of nitrogen levels beyond 400g/tree/year. Embleton et al. (1980) reported that an increase in leaf phosphorus content reduced T.S.S. in valencia orange juice.

Nitrogen in general seems to have an effect in increasing T.S.S. in fruits, whereas potassium had the reverse trend.

2.5.5 Reaction of juice

Juice reaction is one of the criteria for the palatability and marketability of any fruit. Though cashew apple production in India is about one million tonnes per year, consumption of apple in its original nature is very much limited due to high acidity and tannins present in the fruit juice. Hence, any effort by way of reducing the acidity of the fruit juice, would definitely fetch a higher degree of consumption in most of the tropical countries.

Lopes (1972) analysed various types of cashew apples from different parts of Mozambique and reported that the fruit juice acidity varied from 4.1 to 4.7. Moss (1972) studied the role of potassium in determining the fruit quality and observed that high leaf potassium was associated with high acidity in Washington and late Valencia oranges. High leaf phosphorus content was associated with low acidity and positively correlated, where as high leaf potassium levels were associated with high acidity. Moss (1975) reported that leaf potassium was increased due to high dose of nitrogen application and higher K and Mg in turn were associated with fruit acidity of citrus cultivars. Reese and Koo (1975 and 1975a) studied the response of hamlin, pineapple and valencia oranges and reported that high acidity in the fruit was associated with high level of potassium application. Koo and Reese (1977) and Embleton et al. (1980) confirmed that potassium application increased the acidity of orange fruits.

The results show that application of nitrogen and potassium in general increased acidity where as phosphorus decreased the same.

2.5.6 Sugar content in fruit

Palatability of cashew apples, mainly depends upon the sugar-acid ratio. Sugar content of the apples

is further important in fenny making industries. Thus any attempt to increase the sugar content of apple juice would definitely increase the consumption of raw apple and marketability for fenny making on industrial basis. This would help the farmer to dispose off their raw fruit on an economical price structure.

Ventura and Lima (1958) identified glucose, fructose and sucrose as the principle soluble sugars in fleshy peduncle of cashew. Yellow cashew apples were found to be more sweet and less astringent compared to red ones (Albuquerque et al. 1963). They attributed the reason for sweetness to the higher content of soluble sugars and lower levels of tannins.

Lopes (1972) analysed cashew apples for their chemical constituents from various cashew growing tracts of Mozambique and found that the total sugars varied from 7.7 to 10.5 per cent. Moss (1972) reported that higher content of leaf phosphorus reduced soluble sugars in Washington navel orange. Limura et al. (1974) observed that increased leaf nitrogen in persimmon orange trees increased fruit sugars. Haq et al. (1975) reported fructose, glucose and maltose besides some acidic substances as the principle sugars in cashew apple. Describing the chemical composition of the pseudo apple, Ohler (1979) reported up to ten per cent sugars in cashew fruit juice, mostly in the form of inverted sugars.

Singh et al. (1977) observed an increase in total soluble sugars in langra mangoes with increasing levels of nitrogenous fertilisers from 200g to 400g/tree/year in Bangladesh. Hernandez (1979) reported a decrease in sugar content of Valencia oranges due to increased levels of phosphorus.

Though some literature is available on fruit sugar in cashew, no literature is available as to how the fruit sugars are influenced by fertiliser application.

2.5.7 Ascorbic acid content of apples

Cashew fruits are a rich source of ascorbic acid. On an average, the cashew apple is found to contain ascorbic acid at the rate of 140-600 mg/100g of fresh fruit. Lopes (1972) reported about 350 mg of ascorbic acid/100g fresh fruit. He opined that ascorbic acid content varies depending on the agroclimate. Champakam (1983) working on the development of cashew apples, recorded a progressive increase in ascorbic acid content up to 278.75 mg/100g fruit within 55 days after pollination. Embleton et al. (1980) reported that for Valencia oranges increasing leaf potassium increased ascorbic acid content. Singh et al. (1977) from Bangladesh reported that ascorbic acid content of langra mangoes was increased due to application of nitrogen.

2.6 Nut characteristics

For any cashew industry, medium sized nuts are of paramount importance for international markets for fetching a high premium. Hence, the international price structure mainly depends upon the average size of the nut and kernel.

2.6.1 Nut weight

Large variations in the nut weight exist among the genotypes of cashew and the variation within the genotype is mainly attributed to the growing conditions.

From Brazil, Peixoto (1960) reported nuts as big as 30g. Correia (1963) estimated the average weight of nut to be about 5g with a range of 3-7g. Lefebvre (1963) from Madagascar observed nuts varying from 3.95-4.67g. Bocchetti and Monelli (1967) recorded weight of nuts to vary from 2.6 to 6.2g with an average weight of 4.8g per nut in Somalia. Giuliano and Armolian (1975) collected the nuts from nine countries and reported that the nut weight varied from 3.6 to 5.4g. Nambiar (1983) reported that increasing levels of nitrogen from 0-1000g or phosphorus from 0-400g or potassium from 0-1000g did not influence the weight of individual nuts on the sandy loam soils of Bapatla.

The data on nut size as influenced by fertilisers are meagre.

2.6.2 Nut density

In any planting programme heavier nuts are preferred for various seedling production than lighter nuts and on industrial value always heavier nuts record more shelling percentage and thus yielding more kernel.

In this context, Auckland(1961) investigating nuts for planting programme from different cashew varieties, found that larger nuts were of lower density than medium nuts. Northwood(1967) reported that the density of nuts depended upon growing conditions apart from genetic characters. He identified nuts ranging from 1.025 to 1.050g/ml under healthy condition. Ohler (1979) reviewing the work on cashew opined that research aspects on improving the density of nuts had not gone thoroughly.

In general, genotypic variations exists in cashew in regard to the density of the nuts. The variation within genotype is accounted due to improper filling of the cavity of the nut with developing cotyledons.(Plate 1).

2.6.3 Shelling percentage

From the industrial point of view, kernel to nut ratio is an important trait in cashew for harnessing more edible kernel. As the kernel is the most important part of the nut, a marginal difference in shelling percentage can dwindle the cashew industry.

Auckland (1961) reported that in cashew the kernel to nut ratio varied up to 34 per cent in India. Rocchetti and Moselle (1967) analysed cashew nuts from Tanzania and reported the average kernal percentage to be 29 but varying from 23-43. However, Ohler (1979) felt that once the plantations were established from vegetatively propagated material, a much higher general average of kernel might be achieved than from a heterogenous population. He further expressed that literature on the effects of growing conditions on shelling percentage was limited.

2.6.4 Kernel protein

The quality of the kernel is decided by its protein and lipid contents. Though literature on this aspect is scanty as to how the protein content vary with the nutritional status of the plantation, some general information is reviewed here under.

Cashew kernel protein was reported to be 21 per cent by Adriano (1926), Pillai and Subramanyam (1959). Mohapatra, et al. (1972) analysed cashew kernels collected from the existing cashew varieties in India and reported that the kernels of different genotypes varied from 13.13 to 25.03 per cent in their protein content. Ankaiah (1980) reported an increase in protein content of the kernels from 22.3 per cent in control to 27.4 per cent due to application of fertilizers to cashew trees.

Thus the protein content of cashew kernels could be increased by proper management of the plantations with timely and adequate manuring.

2.7 Effect of nitrogen, phosphorus and potassium on nut yield in cashew

Normally cashew is grown on the denuded hill slopes as a soil conservation practice. Of late, the commercial exploitation of cashew for industrial purposes, made the growers to produce more cashew nuts by short term strategies like application of fertilizers and adopting plant protection measures. Cashew was found to respond profusely to applied nutrients (Anonymous, 1976). The degree of response depends upon the nature and amount of fertiliser applied to.

2.7.1 Nitrogen

Nair, et al.(1972) could not record any increase in cashewnut yields by the application of 0.2?14 kg nitrogen/tree/year. Lefebvre (1973) observed a response in cashew to applied nitrogen specially in the presence of phosphorus. Fujii (1977) reported differential response of cashew to fertiliser application. Maximum cashew yields were obtained by an application of 500g ammonium sulphate with 1250g of single super phosphate on sandy loam soil. Ankaiah (1980) opined that fertilisation of cashew had definite advantage in increasing the yields. He felt that soil application of

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2.7.1 Nitrogen

Nair, et al.(1972) could not record any increase in cashewnut yields by the application of 0.2214 kg nitrogen/tree/year. Lefebvre (1973) observed a response in cashew to applied nitrogen specially in the presence of phosphorus. Pujari (1977) reported differential response of cashew to fertiliser application. Maximum cashew yields were obtained by an application of 500g ammonium sulphate with 1250g of single super phosphate on sandy loam soil. Ankaiah (1980) opined that fertilisation of cashew had definite advantage in increasing the yields. He felt that soil application of

fertilisers would be better than foliar application. At Vridhachalam, Pappaiah (1980) recorded maximum cashew yields by application of 600g N and 480g P_2O_5 before the start of north-east monsoon for four years. Nambiar (1983) reported that application of 1000g N sufficiently out-yielded (6.82 kg) the treatments with 500g N application (5.03), no application of N in the control (3.83 kg). During 1983, N at 1000 g/tree/ year recorded maximum yield (6.44 kg) compared to 500g N (5.52 kg) or control (5.12 kg) under sandy coastal soils of Bapatla.

At Jhargram (West Bengal), application of 400g N recorded significantly higher yields (2.45 kg/tree) compared to 200 g N (0.93 kg/tree). Yields were increased in all the treatments, recording significantly higher yields (5.3 kg/tree) under 400g N application, compared to 300g or 200g N application. Reddy et al. (1982) reported that application of nitrogen at 500g, 1000g and 1500g/tree/year recorded an increase of 42, 80 and 90 per cent yields respectively over control.

2.7.2 Phosphorus

Phosphorus application had a significant role in cashew production. From all the coordinating centres in India, the results indicated that phosphate application invariably brought up the yields. At Bapatla,

application of 400g P_2O_5/tree/year recorded maximum yield of 6.44 kg per tree compared to 200g P2O5 application and also control (Anonymous, 1983). At Vengurla, phosphorus application also showed a significant increase in yield. Highest level of phosphate significantly recorded more weight of nuts compared to control (Anonymous, 1981). At Jhagram, cashew yields were significantly influenced by phosphate application. Phosphorus at 300g/tree/year recorded maximum nuts which was significantly superior to 200g and 100g P_2O_5.

2.7.3 Potassium

Lefebvre (1973) from the experiments conducted on already bearing cashew trees reported that application of potassium had a significant effect in increasing the production particularly in the presence of nitrogen. Nambiar (1983) reported that potassium application did not show any significant effect on yields of cashew at Bapatla and also at Vengurla. The effect of potassium was more pronounced only at Jhagram in Midnapur tracts of West Bengal.

Cashew yields are mainly dependent on the canopy shape and size. Application of fertilisers substantially bring about changes in the canopy development, in turn bringing up the production attributes. The extent of increase in the production depends upon genotype used, the soil physico-chemical conditions and the nutrient

element tested. Thus the response to applied fertilisers was relatively low in sandy to sandy loam soils as seen in Bapatla (A.P) and Jargham (W.B), while the response was quite satisfactory with low levels of fertilisers under lateritic belt as seen at Vengurla (Maharashtra). Nitrogen had a definite role in increasing cashew yields. Application of Nitrogen up to 1000g/tree/year significantly increased nut yields in cashew. Phosphorus though had a relatively low progressive effect in increasing the yield in some centres, it was pronounced only at Jhargam.

2.8 Leaf nutrient composition

Leaf nutrient contents largely depend upon the age, genotype, type of the soil and management practices in many of the deep rooted perennial crops. Literature available in cashew on these aspects suffer particularly from lack of descriptive analysis of the genotype to be of relevance in comparison.

2.8.1 Nitrogen

Calton, et al. (1961) analysed cashew trees grown under unfavourable physical conditions of soil wetness and found that thrifty trees contained 1.98 per cent and unthrifty trees 1.52 per cent of leaf nitrogen. Lefebvre (1973) investigating deficiency symptoms of cashew in Madagascar reported that cashew leaf contained 1.73 per cent nitrogen on oven dry weight basis.

Haag et al. (1975) studying sufficient and deficient ranges for cashew reported that 2.4 to 2.58 per cent leaf nitrogen to be sufficient range and 0.98-1.38 per cent leaf nitrogen to be deficient range under pot culture studies. However, the range for hidden hunger was not mentioned. They also established that leaf nitrogen content was independent of age of the tree.

Working on cashew, Fulade (1978) reported that at least 1.24 per cent leaf nitrogen was essential for maximum growth in a sand culture experiment. Partitioning the total nutrients present in cashew, Kumar (1982) reported that cashew leaf comprises of 48.18 per cent of total nitrogen present in the plant system. Reddy et al. (1982) studying the growth in relation to cashew nutrition, employing single tree plot from an unreplicated experimental data for one year, reported that application of nitrogen from 0 g to 1500g/tree/year increased leaf nitrogen from 1.02 to 1.15 per cent during August and from 1.73 to 1.99 per cent during December. Increasing levels of nitrogen application to cashew decreased leaf phosphorus content from 0.149 to 0.124 per cent during August and from 0.187 to 0.171 per cent during December, while it decreased leaf potassium content from 0.660 to 0.575 per cent.

Reese and Koo (1975a) observed an increase in leaf nitrogen content of Hamlin, Pineapple and Valencia oranges to increased level of nitrogen fertilisers. High level of nitrogen application to Valencia and Shamnonti oranges in Lebanon brought down leaf phosphorus and potassium contents as reported by Kazak and Khalidy (197[illegible] In a detailed study on Eureka lemon trees, Khalidy and Nayyal (1976) observed that increasing level of nitrogen application reduced leaf phosphorus and potassium and increased leaf nitrogen. Increased levels of nitrogen showed positive correlations with leaf nitrogen, calcium and magnesium. Mitella Deidda (1976) reported that increasing levels of nitrogen up to 100g/tree/year incre leaf nitrogen and magnesium whereas leaf phosphorus and potassium levels decreased in Avana mandarin trees on a sandy clay soil. In temple orange trees, increasing levels of nitrogen increased leaf nitrogen content as reported by Reese and Koo (1977). Hernandez (1979) recorded highest leaf nitrogen content of Persian lime trees at the highest rate of nitrogen application, whereas P and K contents were highest in control plots. In Kagzi lime, leaf nitrogen increased with the increase in the level of nitrogen application from 400 to 800 g/tree/year (Murthy and Prasad, 1979).

2.8.2 Phosphorus

Calton et al. (1961) working on thrifty and unthrifty cashew trees recorded leaf phosphorus content as 0.21 and 0.10 per cent respectively. In Madagascar, Lefebvre (1973) studied the deficiency symptoms and reported that cashew trees were having 0.082 per cent leaf phosphorus. Haag et al.(1975) reported that 0.16 to 0.20 per cent cashew of leaf P was under adequate range and 0.11 to 0.14 per cent was under deficient range. Falade (1978) recorded maximum growth of cashew in relation to leaf phosphorus concentration of 0.118 per cent in a sand culture experiment. Kumar (1982) reported that cashew leaf contains about 22.76 per cent of total phosphate in the plant system.

Reese and Koo (1977) studying the effect of irrigation and fertility on tomple orange trees reported that increased level of phosphorus application increased leaf phosphorus.

2.8.3 Potassium

Calton et al. (1961) reported that leaf potassium content varied from 1.69 per cent in thrifty trees grown on unfavourable physical conditions of soil wetness. Lefebvre (1973) investigating the cashew deficiency symptoms in Madagascar observed that in general, cashew contained 0.88 per cent of leaf potassium. Haag, et al.

(1975) reported adequate range for leaf potassium to be 1.11 to 1.29 per cent and deficient range to be 0.20 to 0.26 and also confirmed that leaf potassium content was concomitant variable with age of the tree. Working with cashew seedlings in sand culture to study the effect of macro and micro nutrients on growth, Falade (1978) reported maximum growth at 0.342 per cent potassium concentration in leaf.

In the tree crops like citrus, Koo and Reese (1973, 1977) recorded increased level of leaf potassium in citrus leaves due to increased potassium application. In the study on the effect of irrigation and fertility on temple orange trees, Reese and Koo (1977) reported that increased levels of potassium application increased leaf potassium content but lowered leaf magnesium content. Potassium content of leaf was very well correlated with the fruit production, fruit size in citrus plantations and leaf analysis to be the reliable analysis for assessing the yield of citrus as reported by Coetzee (1980).

The foregoing review thus indicates that leaf potassium could be increased by higher amounts of potassic fertilisers and that leaf potassium could be a reliable index for assessing the yield of tree crops.

2.8.4 Calcium

Calton et al. (1961) gave a range for leaf calcium content from 0.09 per cent in thrifty trees to 0.16 per cent in unthrifty trees. From Madagascar, Lefebvre (1973) reported that cashew trees contained nearly 0.284 per cent calcium in their leaves. Haag, et al. (1975) reported that 0.24-0.75 per cent leaf calcium to be adequate and 0.05 to 0.11 per cent to be deficient in cashew. Falade (1978) reported that the cashew seedlings growing vigorously contained 0.176 per cent calcium.

Kelly et al. (1972) working on valencia oranges reported an increase in leaf calcium content with an increase in the levels of nitrogen application whereas increased levels of potassium application reduced leaf calcium.

2.8.5 Leaf magnesium

Calton et al. (1961) recorded 0.2 per cent leaf magnesium in thrifty and 0.17 per cent in unthrifty cashew trees growing in unfavourable physical conditions of soil wetness. Lefebvre (1973) reported 0.163 per cent leaf magnesium in cashew under Madagascar conditions. Haag et al. (1975) reported that 0.23-0.31 per cent magnesium as adequate range in cashew. They also indicated that leaf magnesium was independent of age of the tree. In a sand culture experiment, Falade (1978) reported

maximum growth of cashew seedling at 0.088 per cent magnesium.

2.8.6 Zinc content

Zinc is an important metal ion in cashew nutrition. Lefebvre (1973) reported that the best response of NPK fertilisers were masked due to zinc deficiency in the experimental plots. He observed that 20 ppm of zinc on oven dry weight basis to be optimum level in cashew. Haag, et al. (1975) described zinc deficiency symptoms in cashew and reported 12 ppm is optimum level in leaf. Ohler (1979) reported from his sand culture studies that zinc deficiency developed early but was not lethal to crop.

2.8.7 Nutrient removal by cashew

It will be difficult to generalise the nutrient removal by cashew as the absorption pattern depends upon the genotype, soil fertility and other agroecological factors. However, Mohapatra, et al. (1973) studied the nutrient removal from a 15-year old nondescriptive stray cashew tree and reported that vegetative parts remove 1.721 kg N, 0.406 kg P_2O_5 and 0.8 kg K_2O, apples (155 kg) remove 0.370 kg N, 0.117 kg P_2O_5 and 0.282 kg K_2O and nuts (24 kg) remove 0.756 kg N, 0.229 kg P_2O_5 and 0.183 kg K_2O thus accounting for a cumulative removal of 2.847 kg N, 0.752 kg P_2O_5 and 1.265 kg K_2O/tree/ year. However, this study suffers from the lack of data

on the nutrient accumulation in the trunk, as trunk is one of the richest store houses for phosphorus and calcium as described by Kumar (1982).

2.9 Cation exchange capacity of roots

Mattson and Larsson (1948) developed a theory relating to CEC of plant roots and differential uptake of mono and divalent cations for different plant species on the basis of Donnon equilibria. According to this concept, plant roots of high CEC would absorb relatively more divalent cations than those of monovalent cations and vice versa.

Blanchard (1955) opined that higher CEC increases the release of calcium from insoluble $CaCO_3$ by virtue of the increased surface area per unit weight and fibrous nature of the roots.

Drake and Stockel (1945) reported that higher solubility of phosphorus from rock phosphate should increase with the increase of CEC of plant root which should act as a chelating agent and dissolve out the rock phosphate crystals.

McLean et al. (1951) showed that the CEC of plant roots could be increased for some plant species by increasing the nitrogen level between deficiency and very high ranges. They also reported 10-40% increase in CEC as well as in nitrogen percentage in

the roots and leaves of oats, corn, wheat and cotton. Smith and Wallace (1956) also confirmed the above theory.

Huffaker and Wallace (1958) established possible relations to hold good between CEC and cation uptake of citrus, maize and soybean. They also reported a variation in root CEC within plant species. They recorded a range of 25.0 to 41.8 m eq/100g root of soybean. Crooke et al. (1960) reported that nitrogen content of leak root segments was directly related to root CEC. They failed to establish whether the decrease in root CEC was due to development of cell wall or concentration of pectin. Crooke and Knight (1962) evaluating the published data on the mineral composition of plants in the light of CEC and observed that CEC value of roots is independent of soil type.

Drake (1961) suggested that higher level of N may increase CEC possibly by increasing cell division and decreasing the non-pectic carbohydrates in cell walls of the roots. He opined that CEC in some plant species was affected by fertility levels specially of N. This increase might be due to increased number of exchange spots due to increased root hairs and root tip development and also partly from pectin amino group.

Heintze (1961) established a satisfactory relationship between the CEC of the legume roots and

the roots and leaves of oats, corn, wheat and cotton. Smith and Wallace (1956) also confirmed the above theory.

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Heintze (1961) established a satisfactory relationship between the CEC of the legume roots and

their uptake of mono-divalent ions.

Paliwal and Subramaniam (1964) could not bring about any change in CEC of roots of wheat, tobacco, maize and mung when grown under varying levels of Ca/K ratio (1.5-3.9) in sand culture and also at different levels of P. Dhawan and Mahajan (1968) reported that the plant roots of high yielding varieties gave higher values of CEC and consequently were capable of withstanding higher dose of fertiliser application. Paliwal (1969) reported that at higher levels of Ca or K, luxury consumption and ion antagonism influence the relative uptake of cations. The other source of error may be due to the complex nature of the internal part of the root which partially contributes to CEC. It is not also known whether all the apparent CEC of the roots take part in absorption and subsequent absorption of cations or only a fraction of it. The integrated effect seems responsible for a poor and limitted applicability of the relation between CEC and cation uptake.

Mehrotra and Saksena (1970) studied the crop yields at different levels of soil fertility. The CEC of plant roots showed a positive correlation with the yield of crops with the maximum in treatments with NPK at the highest levels.

Determination of CEC of the roots is an indirect approach to establish the nutrient absorption and in turn its relation to crop productivity. Evidences are that CEC is highly influenced by native soil fertility and also by applied nutrients to crop plants. Though some observations have been reported in plantation crops like arecanut and coconut, on high degree of CEC association with higher yields by Mohapatra et al. (1972), a definite evidence is not available on the influence of applied fertiliser in increasing the root CEC and its relation to cashew productivity.

2.10 Economics analysis of fertiliser application

With low response varieties coupled with non-remunerative prices, application of fertilisers to cashew did not attract much attention of the growers in the past. With the identification of fertiliser responsive varieties and highly remunerative prices for raw cashew nuts, now the crop is attaining a profile of importance in waste land agriculture.

Earlier experiments on fertiliser usage in cashew suffered from bringing about potential economic returns because of non-descriptive and low responsive types used for experimentation with limited number of treatments.

The experiments conducted at Vengurla from 1972-1976 showed a marginal net return of Rs.2.00 per tree

per year due to fertiliser application (Anonymous,1976). In another experiment conducted from 1970 to 1976 wherein 666g N, 266g P_2O_5 and 533g K_2O was applied, the net profit per tree was reported to be Rs.7.40 per year after six years of experimentation (Anonymous, 1976). From another experiment conducted at Vridhachalam, farm yard manure (25 kg) and 600g N gave the maximum net return of Rs.7.50 per tree per year (Anonymous, 1976).

Cashew yields are thus seen to be influenced by fertiliser application and the magnitude of net profit depends upon the price structure for raw cashew nut.

Materials and Methods

III. MATERIALS AND METHODS

Investigations on the "Effect of N.P.K. on seed progeny and air layers in Cashew" were carried out at Cashew Seed Farm (CPCRI), Shantigodu under Central Plantation Crops Research Institute, Regional Station, Vittal 574 243, Dakshina Kannada District of Karnataka, India.

This project was started in 1979 and the trees started yielding from 1981 onwards. The experiment was utilised for the conduct of the Ph.D. programme. Detailed observations on growth, yield and yield attributes which are required for interpretation of results are taken from this experiment and the observations covered a period of two years, 1982-1983.

3.1 Location

Shantigodu is situated about 55 km East of Mangalore at 12°.57' North latitude and 75°.25' East longitude. The mean elevation of the farm is 200 m above mean sea level (MSL).

3.2 Climate

The data on rainfall, maximum temperature, minimum temperature and sunshine hours are given in Table 3.1 to 3.4. The data show that there is not much deviation

Table 3.1 Rain fall (mm)

Month	Average 1969-81	1982		1983		1984	
		During the year	Deviation	During the year	Deviation	During the year	Deviation
January	0.0	0.0	0.0	0.0	0.0	0.56	+0.56
February	0.0	0.0	0.0	0.0	0.0	0.00	0.00
March	1.45	0.0	-1.45	0.0	-1.45	3.12	+1.67
April	40.80	8.70	-32.10	0.0	-40.80	43.30	+2.50
May	92.67	171.20	+78.53	32.30	-60.37		
June	1076.07	930.00	-146.07	477.30	-598.77		
July	1276.82	937.10	-339.77	1407.00	+130.18		
August	797.00	1618.40	+821.40	1176.70	+379.70		
September	310.27	101.30	-208.97	673.50	+363.23		
October	193.27	135.50	-57.77	111.40	-81.87		
November	111.12	46.40	-64.72	46.60	-64.52		
December	13.42	0.00	-13.42	6.60	-6.82		
Total	3913.0	3951.6	+38.60	3931.40	+18.40		

Table 3.2 Maximum temperature (°C)

Month	Average 1969-81	1982		1983		1984	
		During the year	Deviation	During the year	Deviation	During the year	Deviation
January	33.10	33.2	+0.10	33.9	+0.80	33.4	+0.30
February	34.25	33.6	-0.65	34.0	-0.25	35.3	+0.78
March	35.47	35.2	-0.27	35.1	-0.37	34.7	-0.77
April	35.35	35.7	+0.35	35.9	+0.55	34.8	-0.55
May	34.67	35.2	+0.53	35.3	+0.63		
June	29.50	28.8	-0.70	32.7	+3.18		
July	28.30	28.9	-0.60	29.0	+0.70		
August	28.32	28.3	-0.02	28.5	+0.18		
September	30.02	30.4	+0.38	30.7	+0.68		
October	31.95	32.5	+0.55	32.3	+0.35		
November	32.15	33.1	+0.95	33.3	+0.85		
December	33.30	33.3	0.00	33.0	-0.30		

Table 3.3 Minimum temperature (°C)

Month	Average 1969-81	1982		1983		1984	
		During the year	Deviation	During the year	Deviation	During the year	Deviation
January	18.97	18.7	-0.27	17.3	-1.67	2.10	+2.03
February	20.87	21.0	+0.13	18.8	-2.07	22.4	+15.3
March	22.87	22.1	-0.77	21.5	-1.37	23.3	+0.43
April	21.20	21.2	-0.00	20.0	-1.20	21.2	0.00
May	24.27	24.5	+0.23	24.8	+0.53		
June	22.97	22.8	-0.17	24.4	+1.43		
July	22.70	22.8	+0.10	23.1	+0.40		
August	22.70	22.7	0.00	23.4	+0.70		
September	22.70	22.6	-0.12	23.4	+0.68		
October	22.82	22.9	+0.08	22.9	+0.08		
November	21.82	22.2	+0.38	20.4	-1.42		
December	19.92	19.5	-0.42	21.8	+1.88		

Table 3.4 Sunshine (h/day)

Month	Average 1969-81	1982		1983		1984	
		During the year	Deviation	During the year	Deviation	During the year	Deviation
January	9.97	9.7	-0.27	9.3	-0.67	8.4	-1.57
February	10.90	9.3	-1.60	9.1	-1.70	9.3	-1.60
March	9.76	9.7	-0.06	9.5	-0.26	8.3	-1.46
April	9.09	9.5	+0.41	8.6	-0.51	8.3	-0.79
May	8.33	8.1	-0.23	8.7	+0.33		
June	8.38	8.1	-0.28	9.1	+0.73		
July	8.71	8.1	-0.61	8.6	-0.11		
August	8.71	7.9	-1.81	6.8	-1.91		
September	5.48	6.0	+0.52	3.4	-2.08		
October	7.88	7.6	-0.28	7.6	-0.28		
November	7.92	7.9	-0.02	9.2	+1.28		
December	8.77	9.0	+0.23	6.7	-2.77		

from the normal pattern.

3.3 Soil pedigree

The jungle land was cleared and the experiment was laid out in 1979.

3.4 Soil chemical properties

The data on soil chemical properties are given in Table 3.5.

3.5 Variety and planting material

Cashew seedlings and air layers were collected from a single mother tree No.47 belonging to accession VTH-17;. The original mother tree belonged to H 4-7 (Anakkayam), a high yielding variety from Kerala. The mother tree No.47 gave about 20.2 kg dry cashew nuts at the 10th year of orchard life.

3.6 Experimental details

3.6.1 Treatments

The treatments consisted of NPK at three levels each (150, 300, 450g N, 50,100,150g P_2O_5 and 50,100, 150g K_2O/tree/year). The total treatment combinations were 27 in each group of planting material.

3.6.2 Design and layout

The plan of layout is shown in Fig.1 and the general view of the plantation in Plate 2.

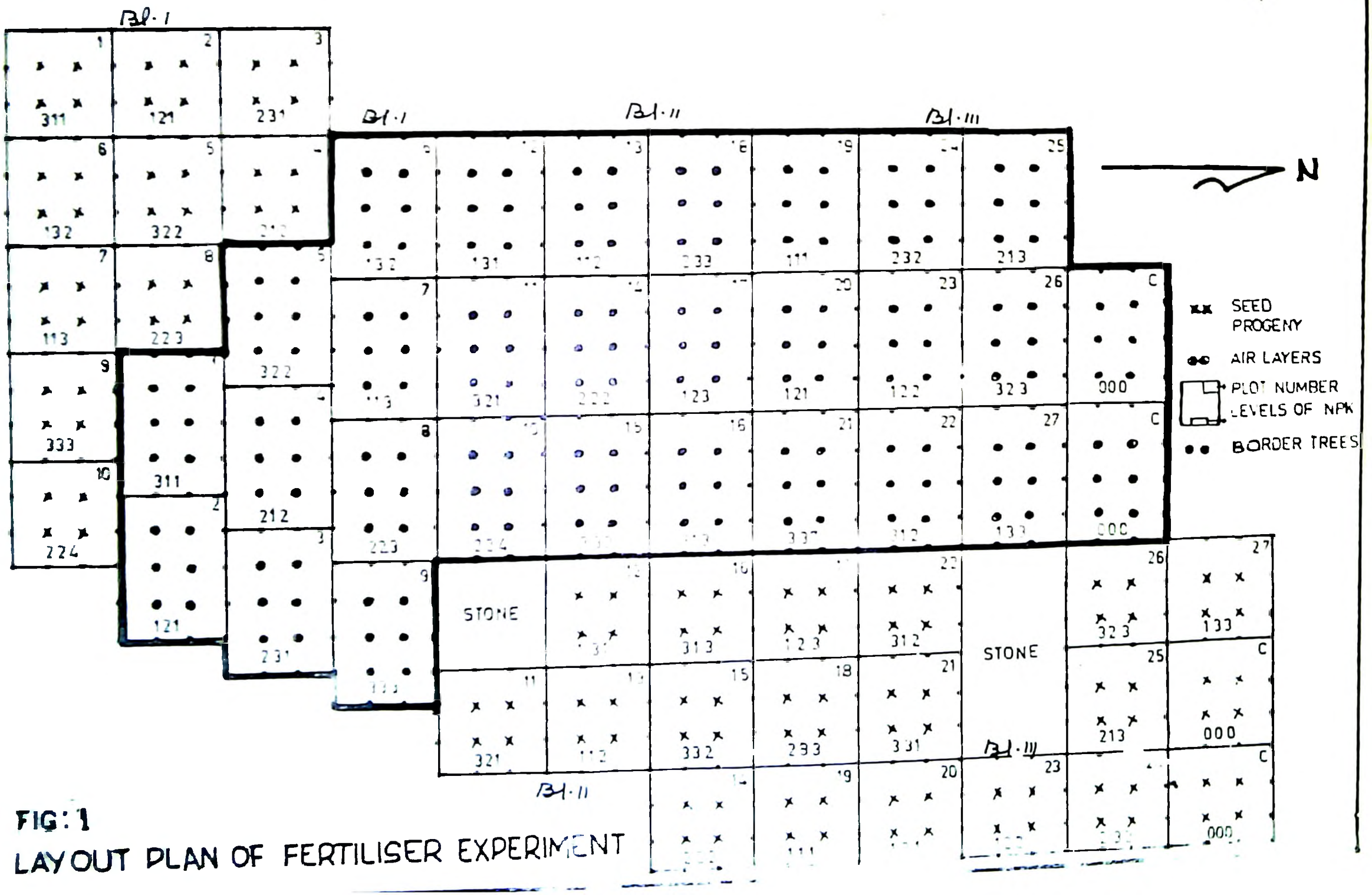


FIG: 1

LAYOUT PLAN OF FERTILISER EXPERIMENT

Table 3.5 Fertility status of the soil in the experimental field

Nutrient (%)	
Av. nitrogen	0.017
Av. phosphorus	0.0015
Av. potassium	0.0058
Calcium	0.0003
Magnesium	0.0006
Zinc (ppm)	0.98

The experiment was laid out in a 3^3 confounding design during 1979 with 27 treatments in a single replication. Layers plot consisted of six test layers in each treatment surrounded by a border of trees. Seedling plot consisted of four test seedlings surrounded by a border of trees.

3.7 Details of cultivation

3.7.1 Planting method

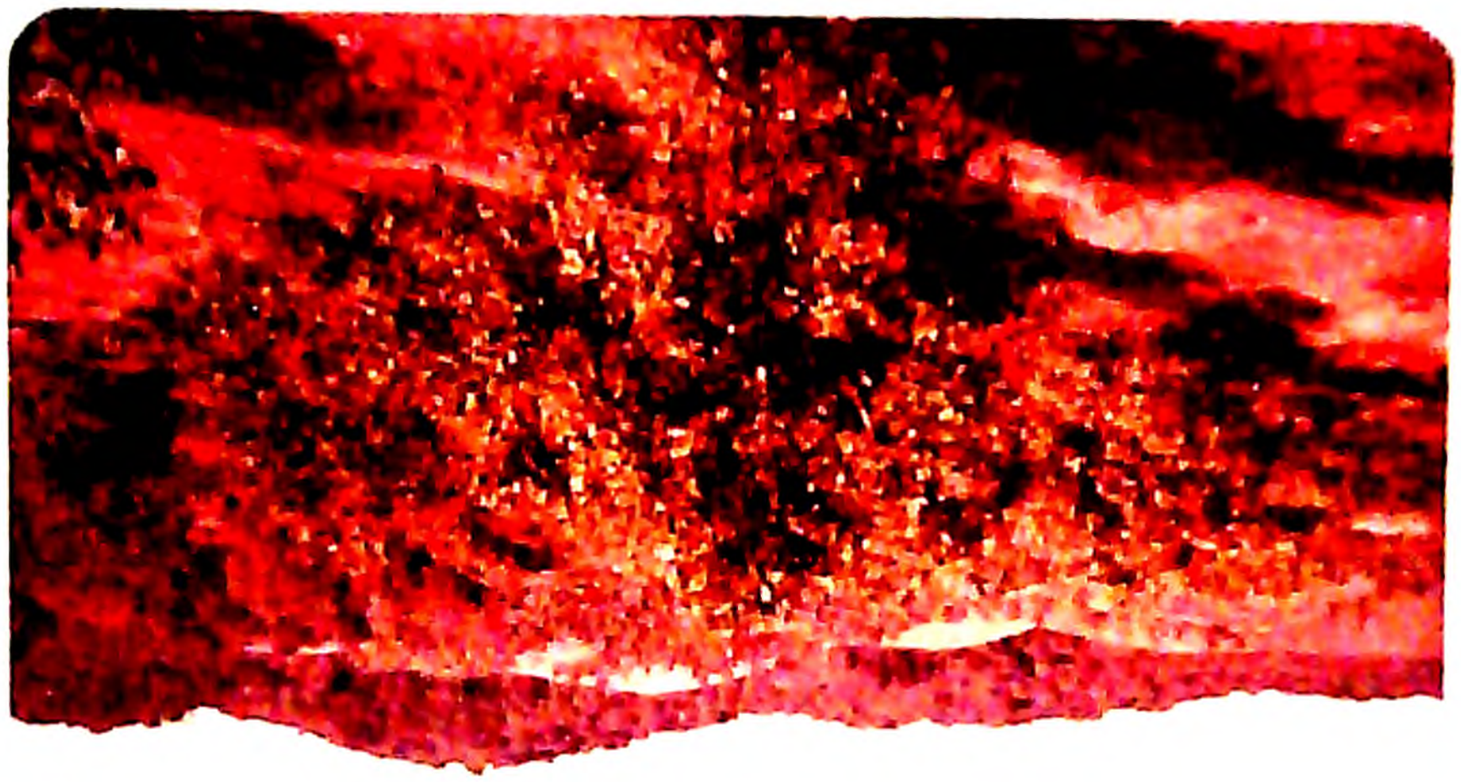
Pits size of 90 cm^3 were dug and filled up to the surface level with the top soil. Seedlings and layers of the same nursery age were pre-cured and planted exactly in the middle of the pit adopting 8 x 8m square system of planting as per the treatments.

3.7.2 Establishment and care

All the seedlings and layers were established in the field without any casualty. A two metre radius circular basins were made and all the weed growth was removed as and when needed.

All the experimental trees were being fertilised at full dose of P and half dose each of N and K during August-September and the remaining half dose each of N and K during May-June in pre dug circular trenches of size of 30 cm width and 20 cm depth. Nitrogen was applied as urea, phosphorus as single super phosphate and potassium as potassium chloride.

Plate 2. General view of the plantation



Three rounds of Endosulfan 0.05% was sprayed at 30 day intervals starting from the date of flush emergence. Periodical check up was done to detect any root and/or stem borer. However, no casualty due to borer was recorded.

3.7.3 Harvest

Normally the picking starts in the month of January-February and lasts upto April-May. All the nuts were detached from the well ripe peduncle, cleaned, sun-dried for 1 week and the weights were recorded at fortnightly intervals.

3.8 Growth parameters

3.8.1 Height

Plant height was measured from the ground level in centimetres to the point where the maximum growth was observed.

3.8.2 Canopy radius

Four readings comprising of two maximum and two minimum lateral spreads were recorded in centimeters and the average was taken.

3.8.3 Canopy surface area

Surface area of each tree was estimated by the formula given by Mohapatra et al. (1973). The cashew

trees are normally spherical in shape, their canopies were assumed as an upper half of ellipsoid of the type:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1 \qquad \ldots\ldots 1$$

where a, b and c are the semi-principal axes.

For all practical purposes, this can be assumed as a=b≠c. The plane of the vertical cross section of the canopy was considered as an ellipse of the type:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \qquad \ldots\ldots 2$$

where a and b are the semi-major and semi-minor axes. Surface area is obtained by rotating the ellipse around minor or major axes using two formulae as given under:

$$\text{Surface area} = \tfrac{1}{2}\left(2\pi a^2 + \frac{b^2}{e}\log_e\frac{1+e}{1-e}\right) \ldots 3$$

$$\text{Surface area} = \tfrac{1}{2}\left(2\pi b^2 + 2\frac{ab}{e}\sin^{-1}e\right) \ldots 4$$

where a = semi-major axis
b = semi-minor axis

$$\text{Eccentricity } e = \sqrt{1 - \frac{b^2}{a^2}}$$

$\sin^{-1}e$ = angle in radians corresponding to e.

3.8.4 No. of leader branches and lateral shoots

Leader branches and lateral shoots that emerged on leader shoots (plate 3) were counted by using $0.5m^2$ quadrant from four sides of the canopy of each tree and computed per tree.

Plate 3. A ladder with laterals

3.8.5 Leaf area index

Leaf area index was computed by multiplying the number of leaves with average leaf area and by dividing the product by 64. Individual leaf area was calculated from the following regression equation specially derived for this purpose.

$$\hat{y} = 1.8721 + 0.6824\ x$$

where y = estimated leaf area

x = product of maximum length and maximum breadth of leaf

3.8.6 Canopy compactness

Total leaf area per tree was divided by total surface area of each tree to obtain an estimate of leaf area per unit area of the canopy. It was expressed as leaf area in square metres per square metre canopy surface area.

3.9. Light infiltration

Light incidence was measured under each crop canopy at three different heights at 12.00 noon during February using quantum meter and the incidence of light is expressed as μ E /m^2/sec.

3.10 Leaf characteristics

For all practical purposes, leaf characters were studied only in air-layers to get comprehensive idea.

3.10.1 Chlorophyll pigments

Fully matured and well exposed leaves were collected and total chlorophyll and chlorophyll a and b were estimated by using 80 per cent Acetone as described in A.O.A.C. (1970) and expressed as mg/g of leaf.

3.10.2 Total sugars

Total sugars in leaf was estimated by Phenol-sulphuric acid method described by Dubois et al.(1951) and expressed as mg/100g leaf.

3.10.3 Cuticular resistance

Cuticular resistance was measured during 1982-83 only in terms of rate constant of moisture loss expressed in $g.H_2O/h$ as described by Mee (1961).

3.10.4 Leaf water content

Fully matured leaves were collected early in the morning at flower initiation stage and dried in an oven after the initial weight was recorded. The loss in weight on drying was expressed as per centage of water in leaf.

3.10.5 Specific leaf weight

Fully matured leaves were collected during flower initiation stage and discs of known area were cut, dried and weighed. Specific leaf weight was expressed as mg. dry matter per square centimeter of leaf area.

3.11 Fruit characters

Fruit and nut characters are worked out only in air layers as the fruit and nut characters exhibited high degree of segregation in seed progeny with reference to size, shape and colour of the fruit (Plates 5 and 6).

3.11.1 Volume

Twenty uniformly matured fruits were collected at random from each tree and the volume was determined by water displacement technique. The volume was expressed as ml/fruit.

3.11.2 Weight

The weight of the same fruits was recorded and expressed in grams per fruit.

3.11.3 Juice

The same 20 fruits gathered at random for studying the weight and volume were dried in the draft air oven at 80°C till constant weight was achieved and the dry matter of the fruit was recorded. The loss in weight was reported as per cent juice in the fruit on fresh weight basis.

3.11.4 Total soluble solids (T.S.S) in juice

Fruit juice was extracted from 20 randomly selected matured fruits and T.S.S. was recorded immediately using refractometer (Erma, Optical Instruments,

Plate 5. Small sized fruits and nuts in HDPE treatment in air layers

Plate 6. Small red fruits with bold nuts in seed progeny

Tokyo, Japan) and expressed as percentage.

3.11.5 Sugar per cent

The juice was clarified using lead acetate and sugar per cent was estimated by using Abbe's refractometer and expressed as percentage.

3.11.6 Juice reaction

Juice reaction was estimated directly by employing single electrode Elico pH meter.

3.11.7 Ascorbic acid content

Ascorbic acid content of the fruit was estimated by macerating the fruit pulp thoroughly by employing 0.4% oxalic acid and titrating it against 2,6-Dichlorophenol Indophenol dye by visual titration method as described by Roe (1961) and expressed as mg of ascorbic acid/100g fruit.

3.12 Nut characteristics

3.12.1 Nut volume

One hundred nuts were picked up randomly for determining volume by water displacement technique and expressed as millilitres per nut.

3.12.2 Nut weight

One hundred nuts were randomly picked and their weight was recorded and presented as weight per nut in grams.

3.12.3 Nut density

Average density of the nut was computed from the total weight divided by volume.

3.12.4 Shelling per cent

One kg of nuts were dried properly and shelled. The kernel weight thus obtained was recorded as per cent over total weight of nuts.

3.12.5 Test weight of kernel

Test weight of kernel was computed from the weight of the kernel obtained for working out shelling per cent.

3.12.6 Protein content of kernels

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

3.13 Yield attributes

3.13.1 Precocity of flowering

The exact dates of flush and flower emergence were recorded and the time taken for flowering from the date of flushing was calculated.

3.13.2 Number of determinate shoots

During maximum flowering stage, determinate shoots (panicle bearing shoots) were counted by using 0.5 m^2 quadrant from four sides of the canopy of each tree and computed per tree basis.

3.13.3 Ratio of determinate to total shoots

The ratio was worked out by dividing the determinate shoots by total shoots present on the tree.

3.13.4 Number of nuts

Number of nuts was computed by dividing the total yield by individual nut weight in each treatment.

3.14 Yield

Cashew nuts were separated from the ripe fruit and dried for 1 week. The dried nuts were weighed and expressed in kg/tree.

3.15 Leaf sampling and analysis

Fully matured leaves from October-November flush were collected all around the tree as described by Kumar (1962) dried to a constant weight, powdered and used for chemical analysis. Leaf N, P, K, Ca, Mg and Zn were estimated by standard procedures (Jackson, 1973).

3.16 Critical concentration of NPK in leaf

Critical concentrations of N and P in leaf were worked out by fitting a quadratic function between leaf nutrient concentration and yield. The critical concentration for K was not worked out in view of the linearity of the response curves (Donovan, et al. 1973).

3.17 Root cation exchange capacity

Feeder roots were collected randomly allround the tree from 0-50 cm depth of soil, cleaned, dried and powdered. Root CEC was measured by the procedure as described by Crooke(1961).

3.18 Soil sampling and analysis

Soil sampling was done during May 1984 from each treatment in air layers plot. Three core samples were drawn all round the tree from 0-100 cm depth. Soil N,P,K and pH were determined as per the standard procedures outlined by Jackson (1973).

3.19 Production functions and optimum dose of yields

Production functions, optimum doses and expected yields were calculated as per the procedures explained by Andre Guinard (1982).

3.20 Economics of cultivation

Economics of cultivation was worked out taking into account, the cost of all the cultural operations, fertiliser application, plant protection and harvest. The input costs and sale price of cashewnuts are presented in Table 3.6.

Table 3.6 Cost of inputs for cashew cultivation and sale price of cashewnuts

Nature of input	Expenditure (Rs.)
Urea	2.10 / kg
Single super phosphate	0.86 / kg
Muriate of potash	1.12 / kg
Ring weeding (3 times)	1.25 / tree
Trenching and fertiliser application	0.75 / tree
Labour for spraying	0.50 / tree
Endosulfan	0.1[illegible] / tree
Nut collection charges	0.50 / kg
Sale price of cashew	10.00 / kg

3.21 Statistical analysis

The data for the years 1982-83 and 1983-84 were pooled and subjected to statistical analysis. Conclusions were drawn based on the pooled analysis data only. The level of significance used in 'F' test was 0.05 probability (Fisher and Yates, 1957).

IV. RESULTS

The results of the investigation "Effect of NPK on seed progeny and air layers in Cashew" are presented here.

4.1 Growth parameters

4.1.1 Height

The data on plant height as influenced by various fertilisers in seed progeny and air layers are presented in Tables 4.1 and 4.2.

It is seen from the tables that the main effects of all the fertilisers were significant with respect to plant height both in seed progeny and air layers. Tallest plants were recorded at N_3 level of nitrogen application in seed progeny, whereas in air layers, plant height increased significantly up to N_2 level and thereafter increasing level of nitrogen did not increase plant height. Increasing levels of phosphorus application significantly increased plant height in both the plant materials. Tallest plants were recorded at P_3 level. Similar was the trend with potassium application wherein the tallest plants were produced by K_3 level of application in both the plant materials.

Among various interactions only P,K combinations were found significant in seed progeny. Tallest plants

Table 4.1 Effect of NPK on plant height (cm) in seed progeny

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	289	326	350	322	297	322	347	P1	262	309	332
N2	304	338	348	330	307	335	348	P2	322	332	355
N3	310	345	367	341	316	342	365	P3	336	357	373
Mean	301	336	355	-	307	333	353				

General mean = 331

CD (P=0.05) for comparing main effects = 6.0

CD (P=0.05) for comparing interaction effects= 10.4

CV(%) = 1.57

Table 4.2 Effect of NPK on plant height (cm) in air layers

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	293	312	326	310	290	315	326	P_1	283	295	309
N_2	308	326	346	330	318	327	345	P_2	300	314	331
N_3	286	297	311	309	292	308	328	P_3	316	341	358
Mean	296	315	338	-	300	316	333				

General mean =316

CD ($P=0.05$) for comparing main effects =9.7

CD ($P=0.01$) for comparing interaction effects =16.9

CV(%) =2.67

were recorded under P_3 K_3 combination of fertilisers and were significantly superior to the shortest plants produced under P_1 K_1. It may also be seen that the application of P_1 and K_1 levels gave higher height than P1K1 combination. In air layer, only NP combinations were found significant. Tallest plants were recorded under N_3P_3 combination compared to N1P1 combinations. Eventhough, PK interaction was not significant, P_3K_3 level has given the tallest plants and P_1K_1 gave the shortest plants and it has followed the same trend as that of seed progeny.

4.1.2 Canopy radius

The data pertaining to the canopy radius as influenced by various fertilisers in seed progeny and air layers are given in Tables 4.3 and 4.4.

From the tables it is seen that the seed progeny canopy radius was not significantly influenced by different levels of nitrogen. However, in layers canopy radius increased significantly upto N_2 level (Plate 10) and thereafter the increase had no significance. Increasing levels of phosphorus and potassium increased canopy radius significantly with a maximum radius at the highest levels both in seed progeny and air layers.

Among interactions only NP interactions were found significant in air layers. Maximum canopy radius was recorded at N_3P_3 level of combination and was significantly superior to N_1P_1.

4.1.3 Surface area

The data on the canopy surface area development in seed progeny and air layers as influenced by the main effects are presented in Fig. 2 and their interactions in Tables 4.5 and 4.6.

In seed progeny, maximum surface area was recorded at N_3 level of application, whereas in air layers, the same was recorded by N_2 level of fertilizer application beyond which there was a decrease. Phosphorus and potassium applications at P_3 and K_3 levels significantly recorded maximum surface area both in seed progeny and air layers. Among the interactions only NP combinations were found significant in air layers. Increasing levels of phosphorus increased surface area development. N_2P_3 and N_3P_3 have given maximum surface area and are on par.

4.1.4 Number of leader branches

The data on the leader branches produced in seed progeny and air layers as influenced by different

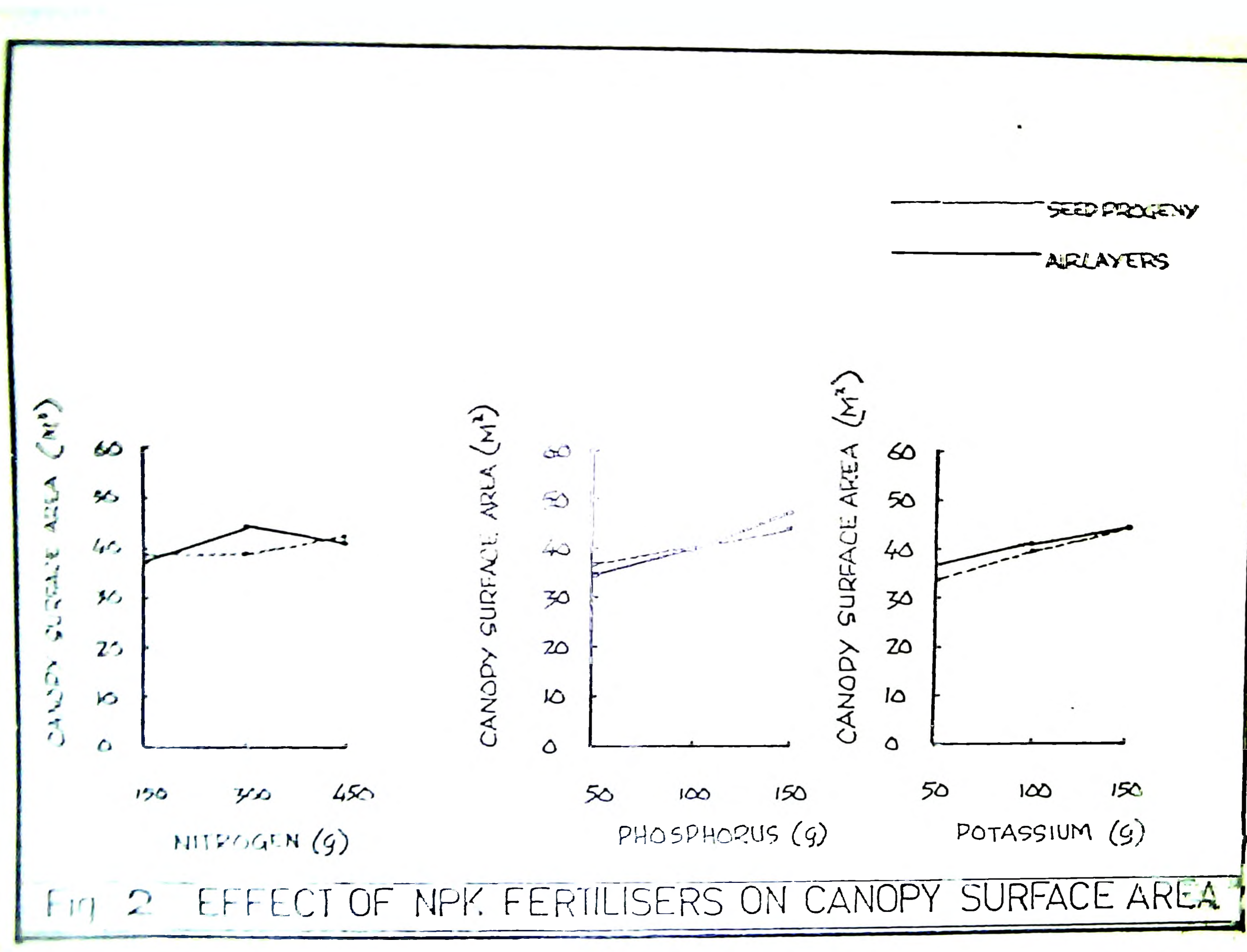


Fig 2 EFFECT OF NPK FERTILISERS ON CANOPY SURFACE AREA

Table 4.3 Effect of NPK on canopy radius (cm) in seed progeny

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	147.33	161.33	166.33	158.33	144.67	160.33	170.00	P_1	138.00	147.67	162.33
N2	149.67	162.67	167.00	159.78	144.67	156.67	173.00	P2	149.67	161.00	177.33
N3	151.00	164.00	178.33	164.44	149.67	165.33	178.67	P3	156.33	173.67	182.00
Mean	149.33	162.67	170.67	-	147.00	160.78	173.89				

General mean =160.89
CD (P=0.01) for comparing main effects =5.304
CD (P=0.05) for comparing interaction effects =NS
CV(%) =2.85

Table 4.4 Effect of NPK on canopy radius (cm) in air layers

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	150.33	171.00	196.00	172.44	160.67	171.00	185.67	P1	158.00	172.00	189.67
N2	184.00	189.00	216.33	196.44	180.67	196.33	206.33	P2	170.00	186.33	196.00
N3	185.33	192.33	215.33	197.67	185.00	198.33	209.67	P3	198.33	207.33	216.00
Mean	173.22	184.11	207.22	-	175.44	188.56	200.56				

General mean =188.19
CD (P=0.05) for comparing main effects =3.654
CD (P=0.05) for comparing interaction effects =6.329
CV (%) =1.683

Table 4.5 Effect of NPK on surface area (m^2) of the canopy in seed progeny

Nutrient levels	P_1	P_2	P_3	K_1	K_2	K_3		K_1	K_2	K_3
N_1	31.37	38.11	42.63	32.21	37.61	42.57	P_1	27.16	34.68	39.16
N_2	34.19	40.39	42.51	34.15	39.35	43.62	P_2	36.07	39.16	45.56
N_3	35.13	41.39	48.03	35.63	42.20	47.63	P_3	38.78	45.31	49.10

General mean =39.11
CD (P=0.05) for comparing main effects =1.873
CD (P=0.05) for comparing interaction effects=NS
CV(%) =4.117

Table 4.6 Effect of NPK on surface area (m^2) of the canopy in air layers

Nutrient levels	P_1	P_2	P_3	K_1	K_2	K_3		K_1	K_2	K_3
N_1	30.09	37.32	43.72	33.33	37.99	39.81	P_1	32.04	35.06	37.63
N_2	39.13	41.99	49.35	40.60	41.26	48.61	P_2	35.80	40.29	44.38
N_3	35.51	38.16	49.95	36.35	41.22	46.03	P_3	42.45	48.11	52.46

General mean = 40.91
CD (P=0.05) for comparing main effects = 1.342
CD (P=0.01) for comparing interaction effects = 2.326
CV (%) = 2.81

levels of fertilizers are presented in Tables 4.7 and 4.8.

Nitrogen levels did not bring any significant variation in the number of leader branches produced in seed progeny. In air layers the effect of N could be seen upto N_2 level beyond which there was no increase in leader production.

In seed progeny, phosphorus application at P_3 level significantly recorded higher number of leader branches and was superior to P1 level, whereas in air layers, leader branches increased significantly with every increment in phosphorus upto P_3 level.

Though potassium at K_1 level recorded the maximum number of leader shoots in seed progeny, the difference in leader production due to K_2 and K_3 levels was not significant. However, in air layers leader shoot production increased significantly with the increase in the level of potassium application.

None of the interactions effects was found significant with respect to leader branches production in seed progeny. However, NP and PK interactions were found to influence significantly in air layers. Increasing levels of phosphorus application in presence of nitrogen increased leader branch production. Maximum number of leader branches was recorded under

Table 4.7 Effect of N:K on number of leaders in seed progeny

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	886	1008	1228	1041	953	1162	1107	P1	721	934	1021
N2	833	1065	1164	1023	792	919	1278	P2	828	1112	1281
N3	956	1119	1356	1144	937	1170	1395	P3	1083	1207	1478
Mean	892	1074	1256	-	877	1084	1260				

General mean = 1074
CD (P=0.05) for comparing main effects = 185.0
CD (P=0.05) for comparing interaction effects = NS
CV(%) = 14.93

Table 4.8 Effect of NPK on number of leaders in air layers

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	715	1102	1216	1021	852	1027	1184	P_1	739	850	987
N_2	900	1551	1[illegible]23	12[illegible]	[illegible]6[illegible]	1382	1132	P_2	920	1254	1569
N_3	962	1094	1[illegible]06	1221	972	12[illegible]	1[illegible]15	P_3	1124	1550	1507
Mean	859	1250	1[illegible]95	-	9[illegible]	1220	1351				

General mean = 1168
CD(P=0.05) for comparing main effects = 110.8
CD(P=0.05) for comparing interaction effects = 192.0
CV(%) = 8.23

N_3P_3 level compared to N1P1 level. Among PK interactions, increasing levels of phosphorus in the presence of potassium increased leader branches. Maximum number of leader branches was recorded under P_2K_3 and was on par with P_3K_2 and P_3K_3 levels. Though NP and PK interactions were not significant in seed progeny, increasing phosphorus level in the presence of nitrogen or potassium substantially increased leader branch production. Maximum number of leader branches was recorded under N_3P_3 level.

4.1.5 Number of lateral shoots

The data on the number of lateral shoots as influenced by the main effects of fertilisers in seed progeny and air layers are presented in Fig. 3 and their interactions in Tables 4.9 and 4.10.

In seed progeny, nitrogen at the level of application alone significantly recorded maximum number of lateral shoots whereas in air layers, maximum number of lateral shoots was recorded at N2 level beyond which there was no significant increase.

In seed progeny and air layers, every increment in phosphorus and potassium levels significantly increased lateral shoot production.

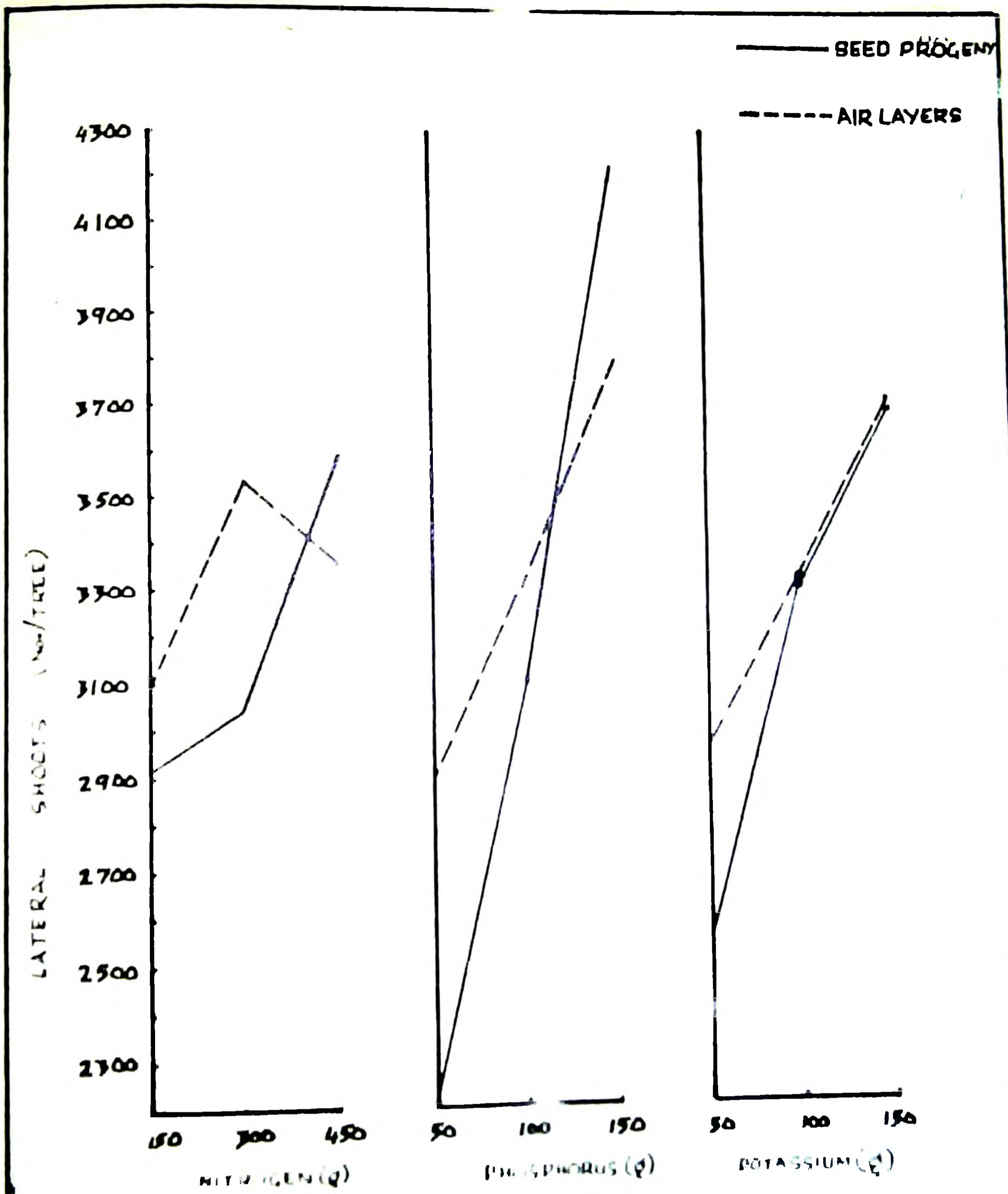


FIG: 3
EFFECT OF FERTILISERS ON LATERAL SHOOT PRODUCTION.

Table 4.9 Effect of NPK on number of laterals in seed progeny

Nutrient levels	P1	P2	P3	K1	K2	K3		K1	K2	K3
N1	1909	3031	3799	2290	3052	3396	P1	1644	2437	2562
N2	1952	2961	4230	2596	2973	3575	P2	2291	3201	3834
N3	2782	3331	4640	2781	3881	4094	P3	3733	4268	4669

General mean = 3182
CD(P=0.05) for comparing main effects = 269.6
CD(P=0.05) for comparing interaction effects=NS
CV(%) = 7.34

Table 4.10 Effect of NPK on number of laterals in air layers

Nutrient levels	P1	P2	P3	K1	K2	K3		K1	K2	K3
N1	2675	2992	3419	2815	3080	3390	P1	2597	2917	3111
N2	3036	3771	3800	3079	3537	3992	P2	2962	3311	3673
N3	2914	3183	3968	2973	3315	3776	P3	3308	3705	4374

General mean = 3329
CD(P=0.05) for comparing main effects = 147.2
CD(P=0.05) for comparing interaction effects = 254.9
CV(%) = 3.83

None of the interactions was found significant in seed progeny. In air layers, only NP combinations were found significant. Increasing levels of phosphorus in the presence of nitrogen increased lateral shoot production.

4.1.6 Leaf area index

The data on leaf area index as influenced by various levels of fertilisers in air layers are presented in Table 4.11.

The maximum leaf area index was recorded at N2 level of nitrogen application, beyond which, there was no significant increase. Increasing levels of phosphorus and potassium application upto the highest levels significantly increased the leaf area index. None of the interaction effects was found to influence LAI.

4.1.7 Canopy compactness

The data on the canopy compactness of seed progeny and air layers as influenced by fertilisation are presented in Tables 4.12 and 4.13.

Nitrogen application at N3 level recorded the maximum canopy compactness in seed progeny (Plate 4). Nitrogen levels did not bring any significant influence on the canopy compactness in air layers.

Plate 4. .. compact tree in seed progeny

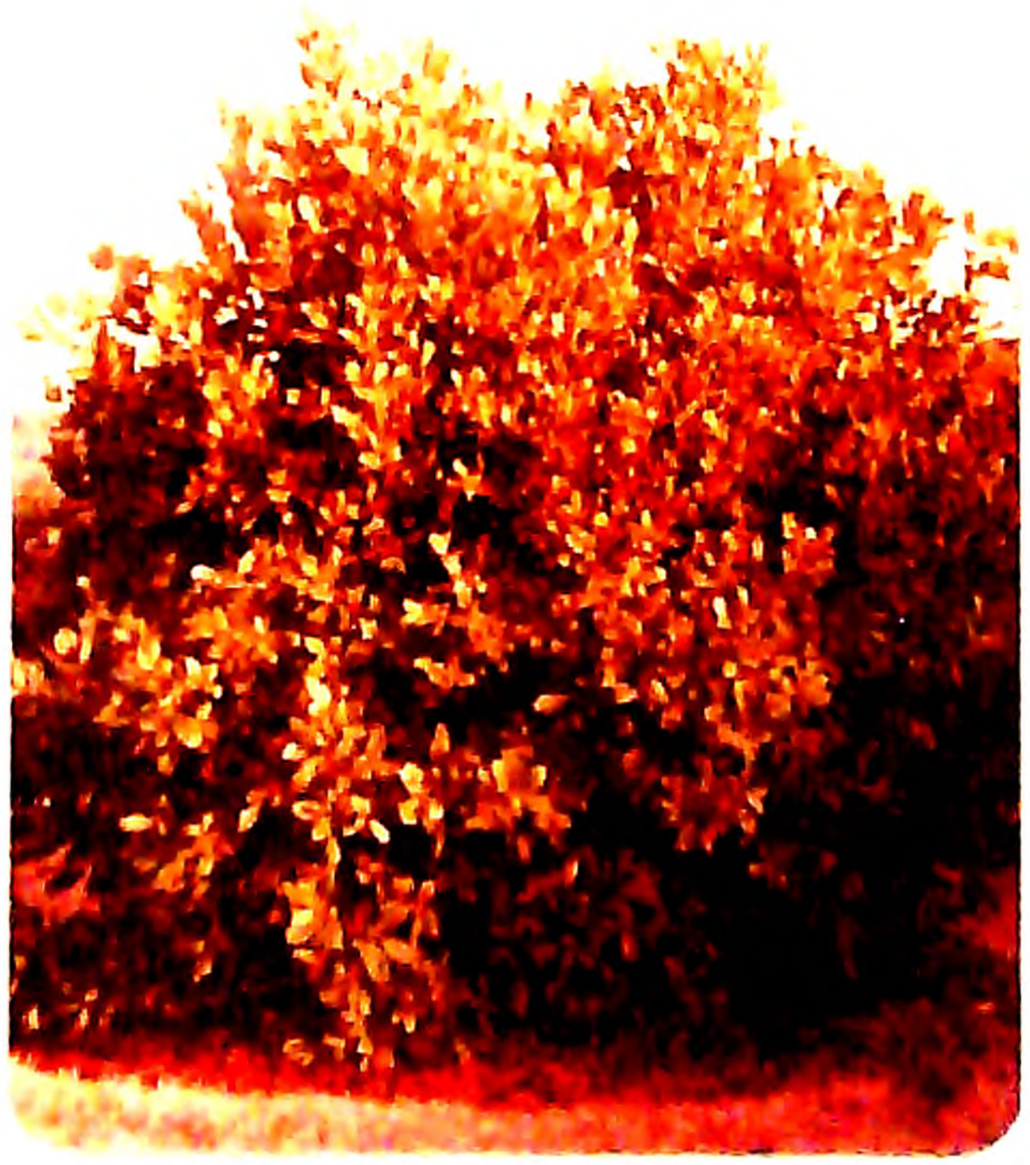


Plate 7. A lanky layer with sparse foliage in absolute control plots

Table 4.11 Effect of NPK on leaf area index in air layers

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1.98	2.61	2.96	2.59	2.19	2.78	2.79	P_1	1.85	2.26	2.60
N_2	2.34	3.30	4.01	3.22	2.35	2.98	3.51	P_2	2.49	2.98	3.38
N_3	2.39	2.95	3.67	2.97	2.61	2.93	3.18	P_3	3.25	3.71	3.89
Mean	2.24	2.95	3.62	-	2.38	2.90	3.29				

General mean = 2.93
CD(P=0.05) for comparing main effects = 0.199
CD(P=0.05) for comparing interaction effects = NS
CV( ) = 5.89

Table 4.12 Effect of NPK on canopy compactness in seed progeny (leaf area m^2/ unit surface area m^2)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	4.20	5.03	5.44	5.82	5.59	6.05	5.84	P_1	5.04	5.70	5.18
N_2	5.04	6.19	7.00	6.08	5.60	6.45	6.17	P_2	5.65	7.36	7.03
N_3	6.67	7.02	6.58	6.7[illegible]	6.41	7.24	6.67	P_3	6.91	6.69	6.42
Mean	5.30	6.68	6.67	-	5.87	6.58	6.21				

General mean = 6.22
CD(P=0.05) for comparing main effects = 0.701
CD(P=0.05) for comparing interaction effects = 1.215
CV(%) = 9.78

Table 4.13 Effect of NPK on canopy compactness in air layers (Leaf area m^2/ unit surface area m^2)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N_1	4.63	4.69	5.30	4.94	5.17	5.06	4.59	P1	4.50	4.44	4.36
N_2	4.15	5.34	5.77	5.09	5.13	5.15	4.96	P2	5.08	5.18	5.13
N_3	4.51	5.36	5.14	5.00	4.86	4.92	5.21	P3	5.60	5.55	5.26
Mean	4.43	5.13	5.47	-	5.06	5.06	4.92				

General mean = 5.011
CD(P=0.05) for comparing main effects = 0.355
CD(P=0.05) for comparing interaction effects = 0.616
CV(%) = 6.15

Phosphorus at P2 level of application significantly recorded maximum canopy compactness and was on par with P_3 level in seed progeny. In air layers maximum compactness was recorded under P3 level of fertilisation and was on par with P2 level.

Potassium levels did not show any significant effect on canopy compactness in air layers, whereas in seed progeny, K_2 recorded maximum compactness and was on par with K_3.

Among the interactions, only NP combinations were found significant in seed progeny as well as in air layers.

4.2 Light intensity

The data on light intensity under the cashew canopy are presented in Table 4.14.

Increasing levels of nitrogen, phosphorus and potassium significantly reduced light infiltration.

Among the interactions only NP combinations were significant. Least light infiltration was recorded under N_3P_3 level.

4.3 Leaf characteristics

4.3.1 Chlorophyll-a

The data on the chlorophyll-a content as influenced by different fertilisers are presented in

Plate 3. A lanky tree with sparse foliage in absolute control plots

Table 4.14. Effects of NPK on light interception in air layers ($\mu \Sigma cm^{-2}$ sec^{-1})

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1100.33	1027.00	956.67	1028.00	1041.33	1029.67	1010.00	P_1	934.00	911.67	890.33
N_2	909.33	853.33	787.00	849.78	862.33	847.00	820.33	P_2	877.33	859.00	836.67
N_3	726.33	692.67	673.33	640.78	668.67	639.67	614.00	P_3	764.00	745.67	717.33
Mean	912.00	857.67	742.33	-	858.11	838.78	814.78				

General mean = 837.33
CD(P=0.05) for comparing main effects = 15.000
CD(P=0.05) for comparing interaction effects = 25.982
CV(%) = 1.553

Table 4.15.

Nitrogen application significantly increased chlorophyll-a with every increment in the level of application.

Phosphorus at P_3 level alone recorded significantly higher chlorophyll-a.

Every increment in the level of potassium brought about a significant increase in chlorophyll-a content of leaves.

Among the interactions only NK combinations were found significant. Maximum chlorophyll-a was recorded at N_3K_3 level and was on par with N_3K_2, N_2K_3 and N_1K_3 levels.

4.3.2 Chlorophyll-b

The data on the chlorophyll-b content as influenced by various fertilizers are presented in Table 4.16.

Maximum chlorophyll-b content was recorded at N_3 level and it was on par with N_2. Chlorophyll-b content increased significantly with every increment of phosphorus and potassium levels.

Among the interactions, NK combinations alone were found significant. The highest level of chlorophyll-b was recorded under N_3K_3 level closely followed by N_3K_2, N_2K_3 and N_1K_3.

Table 4.15 Effect of NPK on chlorophyll-a (mg/g) content of leaves

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	4.33	4.92	5.91	5.05	3.71	4.73	6.73	P_1	4.30	5.17	6.20
N_2	5.47	5.89	6.59	5.98	5.38	5.98	6.60	P_2	4.95	5.56	6.65
N_3	5.86	6.35	6.80	6.34	5.73	6.15	6.73	P_3	5.62	6.43	7.25
Mean	5.22	5.72	6.43	-	4.96	5.72	6.70				

General mean = 5.79

CD(P=0.05) for comparing main effects = 0.343
CD(P=0.05) for comparing interaction effects = 0.594
CV(%) = 5.13

Table 4.16 Effect of NPK on chlorophyll-b (mg/g) content of leaves

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	2.18	2.56	2.77	2.50	1.88	2.39	3.25	P_1	2.32	2.43	3.05
N_2	2.60	2.97	3.27	2.95	2.71	2.85	3.23	P_2	2.41	2.84	3.29
N_3	3.01	3.04	3.30	3.12	2.89	3.19	3.28	P_3	2.76	3.15	3.43
Mean	2.60	2.86	3.11	-	2.51	2.81	3.26				

General mean = 2.86
CD (P=0.05) for comparing main effects = 0.223
CD (P=0.05) for comparing interaction effects = 0.387
CV (%) = 6.785

4.3.3 Total chlorophyll

The data on total chlorophyll content as influenced by various fertilisers are given in Table 4.17.

Total chlorophyll increased significantly with every increment in the level of nitrogen, phosphorus and potassium application.

Among the interactions, NK combinations were found significant. Maximum chlorophyll was recorded at N1K3 level and it was on par with N3K2 and N3K3.

4.3.4 Total sugars

The data on the total sugars in leaf at flush emergence and flower emergence stages as influenced by the main effects are presented in Fig.4 and their interactions in Tables 4.18 and 4.19.

Total sugar was increased both at flushing and flowering stage with every increment of nitrogen,phosphorus and potassium levels significantly.

In general, total sugars increased from flushing stage to flower emergence stage in all the treatments.

4.3.5 Cuticular resistance

The data on cuticular resistance as influenced by the main effects of fertilisers are presented in Fig.5

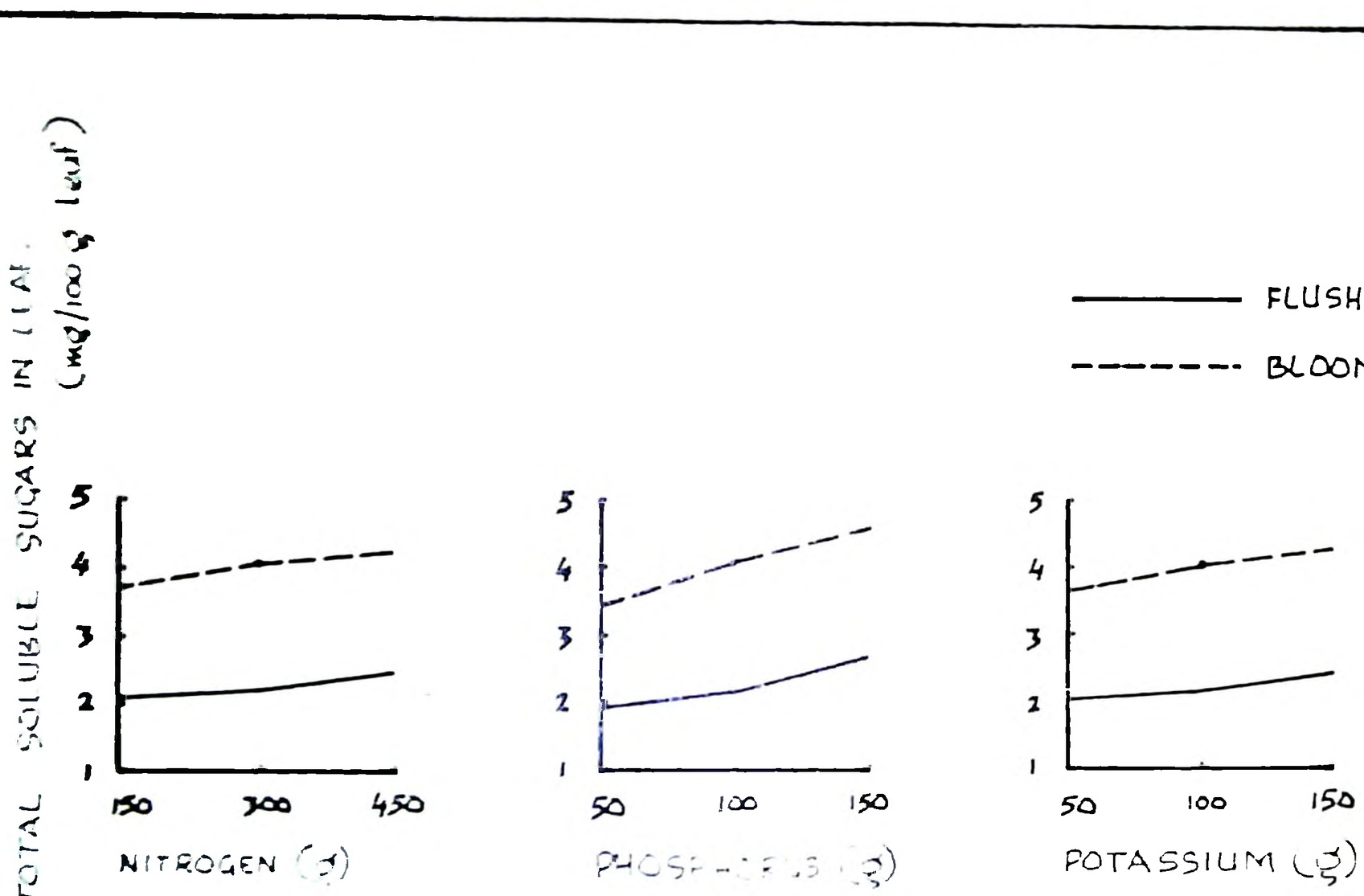


FIG: 4.

EFFECT OF FERTILISERS ON TOTAL SOLUBLE SUGARS IN LEAF.

Table 4.17 Effect of NPK on total chlorophyll (mg/g) content of leaves

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	6.50	7.40	8.67	7.52	5.57	7.03	9.97	P1	6.60	7.59	9.24
N2	9.07	8.86	9.35	9.43	8.13	8.83	9.83	P2	7.39	8.32	9.95
N3	8.37	9.40	9.89	9.39	8.67	9.53	9.86	P3	8.37	9.58	10.47
Mean	7.31	8.55	9.47	-	7.45	8.50	9.89				

General mean = 8.61
CD(P=0.05) for comparing main effects = 0.435
CD(P=0.05) for comparing interaction effects = 0.754
CV(%) = 4.38

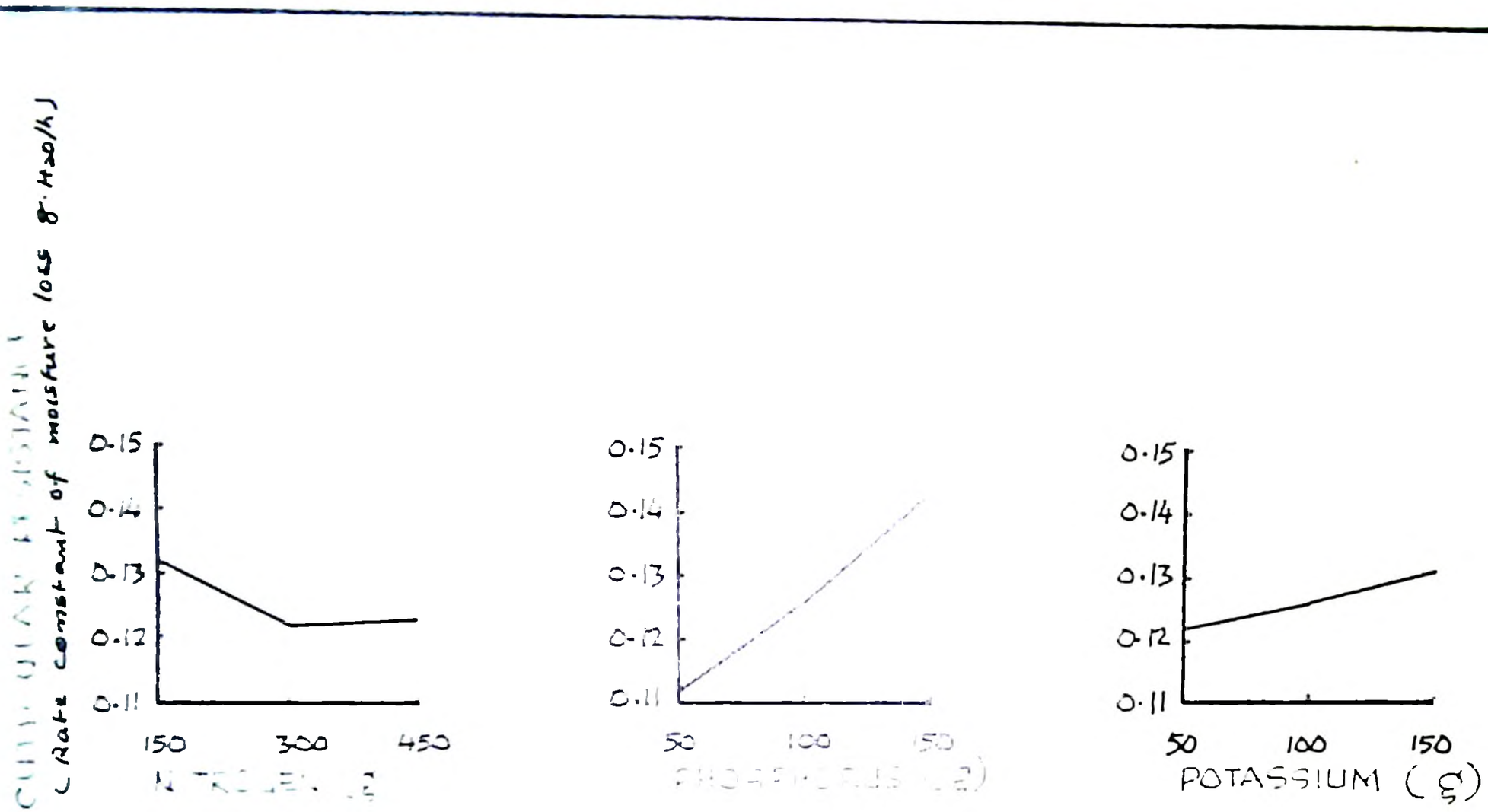


FIG: 5

EFFECT OF FERTILISERS ON LEAF CUTICULAR RESISTANCE.

Table 4.18 Effect of NPK on total sugars (mg/100g leaf) in leaf at flush emergence in air layers

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1.77	1.93	2.47	2.05	1.90	2.00	2.27	P_1	1.67	1.80	2.13
N_2	1.80	2.03	2.68	2.17	2.03	2.10	2.37	P_2	1.80	2.03	2.43
N_3	2.03	2.37	2.83	2.41	2.13	2.30	2.70	P_3	2.53	2.67	2.77
Mean	1.87	2.11	2.66		2.02	2.17	2.45				

General mean = 2.21
CD(P=0.05) for comparing main effects = 0.106
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 4.17

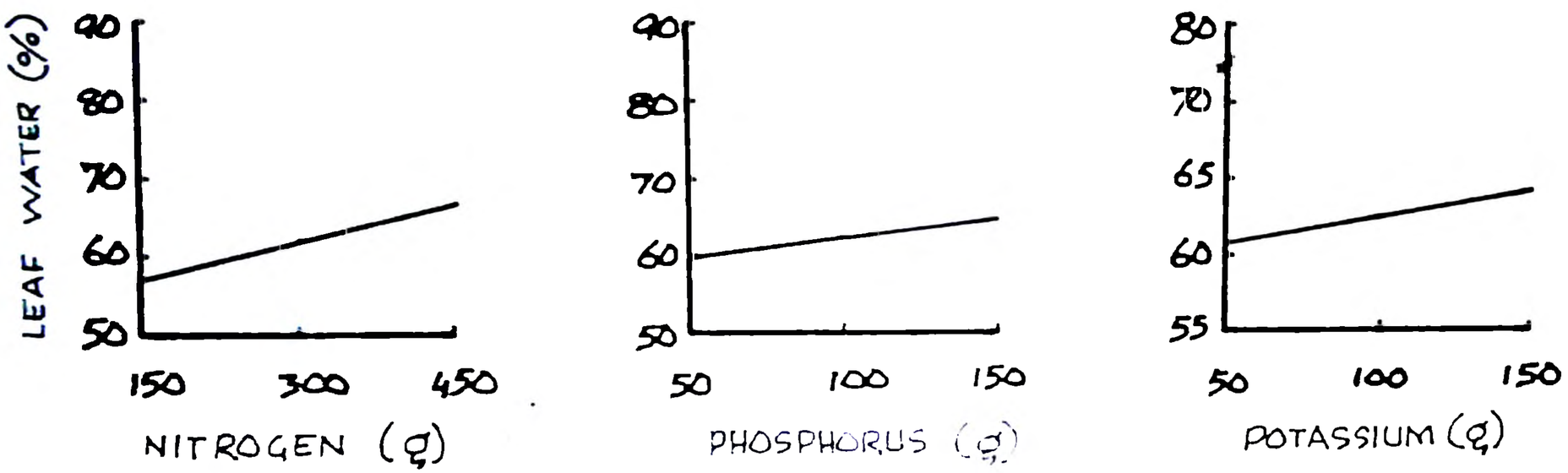


FIG: 6

LEAF WATER (%) AS INFLUENCED BY DIFFERENT FERTILISERS.

Table 4.20 Effect of NPK on cuticular resistance (rate constant of moisture loss, g.H_2O/h)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.1166	0.1358	0.1409	0.1331	.1315	0.1233	0.1446	P_1	0.1105	0.1044	0.1204
N_2	0.1127	0.1196	0.1357	0.1226	.1242	0.1290	0.1148	P_2	0.1186	0.1302	0.1277
N_3	0.1059	0.1311	0.1515	0.1295	.1110	0.1281	0.1330	P_3	0.1377	0.1458	0.1443
mean	0.1117	0.1255	0.1426		0.1222	0.1265	0.1308				

General mean = 0.1266
CD (P=0.05) for comparing main effects = 0.0080
CD (P=0.05) for comparing interaction effects = 0.0139
CV (%) = 5.8

Table 4.21 Effect of NPK on leaf water content (%)

Nutrient levels	P1	P2	P3	mean	K1	K2	K3		K1	K2	K3
N1	56.16	57.57	59.02	57.58	56.20	57.64	58.90	P1	57.93	59.87	61.58
N2	58.98	61.95	64.50	61.77	59.76	61.52	64.06	P2	60.56	62.36	64.43
N3	64.21	67.32	70.96	67.70	65.71	67.37	70.01	P3	63.22	64.29	66.96
Mean	59.79	62.46	64.82	-	60.56	62.17	64.32				

General mean = 62.36
CD(P=0.05) for comparing main effects = 0.733
CD(P=0.05) for comparing interaction effects = 1.269
CV(%) = 1.019

Table 4.22 Effect of NPK on specific leaf weight (mg/cm^2)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	9.61	10.79	11.01	10.47	10.02	10.52	10.86	P_1	9.23	9.82	10.43
N_2	9.66	10.77	11.21	10.56	10.22	10.59	10.86	P_2	10.50	11.12	11.58
N_3	10.20	11.65	12.07	11.31	10.29	11.21	12.39	P_3	10.80	11.41	12.11
Mean	9.82	11.07	11.44	-	10.18	10.78	11.37				

General mean = 10.78
CD(P=0.05) for comparing main effects = 0.282
CD(P=0.05) for comparing interaction effects = 0.489
CV(%) = 2.27

Increasing nitrogen levels increased SLW. However, significantly maximum SLW was recorded at N_3 level alone. All the levels of phosphorus and potassium have significantly increased SLW.

Among the interactions, only NK combinations were significant. Maximum SLW was recorded at N_3K_3 level and was significantly superior to all other combinations.

4.4 Fruit characteristics

4.4.1 Fruit volume

The data on fruit volume are presented in Table 4.23.

Fruit volume decreased significantly with every increment in the level of nitrogen and phosphorus. However, potassium application significantly increased fruit volume by every increment in the level of application.

Among the interactions only NP combination was significant. Smallest fruit has been recorded at N_3P_3 and N_2P_3 level of application.

4.4.2 Fruit weight:

The data of the fruit weight are presented in Table 4.24.

Table 4.23 Effect of NPK on fruit volume (ml/fruit)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	78	65	61	69	65	69	73	P_1	65	69	76
N_2	71	62	52	62	59	61	66	P_2	58	61	65
N_3	61	56	52	56	53	55	61	P_3	53	56	59
Mean	70	61	56	--	58	62	67				

General mean = 62
CD(P=0.05) for comparing main effects = 2.6
CD(P=0.05) for comparing interaction effects = 4.6
CV(%) = 3.7

Nitrogen and phosphorus application did not bring about any significant variation in fruit weight. However, fruit weight decreased from 2nd level of nitrogen and phosphorus application. Fruit weight increased significantly at K_3 level of application. None of the interactions was found significant.

4.4.3 Juice

The data on juice per cent in apples are presented in Table 4.25.

Nitrogen at N_3 level had recorded significantly the highest juice per cent in apples. Phosphorus application was also influenced the same to a significant extent. P_2 and P_3 levels were on par. Every level of potassium application significantly increased juice per cent.

Among the interactions only NK combination was significant. Maximum juice per cent was recorded at N_3K_3 level of application.

4.4.4 Total soluble solids (TSS)

The data on total soluble solids in cashew apple juice are presented in Table 4.26.

Maximum per cent of total soluble solids were recorded at N_3 level of application and was on par with N_2. Phosphorus application reduced TSS of fruit juice upto P_2 level significantly. However, least TSS was

Table 4.25 Effect of NPK on juice percentage in apple

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	91.77	93.03	93.63	92.81	91.37	92.97	94.10	P1	91.93	92.17	93.37
N2	92.73	93.37	93.93	93.83	92.60	93.10	93.80	P2	92.17	93.67	93.80
N3	93.27	94.03	94.10	93.90	93.67	93.23	94.80	P3	93.23	93.17	94.53
Mean	92.59	93.81	93.61	-	92.54	93.10	93.90				

General mean = 93.18
CD(P=0.05) for comparing main effects = 0.524
CD(P=0.05) for comparing interaction effects = 0.909
CV(%) = 0.488

Table 4.26 Effect of NPK on total soluble solids (%) in fruit juice

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	14.67	14.00	13.67	14.11	14.67	14.33	13.33	P_1	15.67	15.67	15.67
N_2	16.00	15.00	14.33	15.11	15.33	15.33	14.67	P_2	15.67	14.67	14.33
N_3	16.33	15.67	14.67	15.56	16.00	15.33	15.33	P_3	14.67	14.67	13.33
Mean	15.67	14.89	14.22	-	15.33	15.00	14.44				

General mean = 14.93
CD(P=0.05) for comparing main effects = 0.830
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 4.82

Table 4.27 Effect of NPK on sugar content (%) in fruits

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	12.47	12.47	13.36	13.10	12.70	11.91	12.58	P_1	11.03	13.80	13.46
N_2	14.39	13.19	12.91	13.61	13.08	13.96	13.79	P_2	13.31	12.51	13.21
N_3	11.43	13.06	11.96	13.15	13.69	12.73	13.03	P_3	12.13	12.30	12.73
Mean	13.76	13.01	12.39	-	13.16	12.87	13.13				

General mean = 13.05
CD(P=0.05) for comparing main effects = 0.848
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 5.63

recorded at P3 level. Potassium did not bring any significant variation. None of the interaction effects was found significant.

4.4.5 Fruit sugars

The data on fruit sugar content are given in Table 4.27.

Nitrogen at N2 level significantly increased fruit sugars, beyond which there was no significance. Phosphorus beyond P1 level significantly brought down fruit sugars. Potassium levels did not show any significant variation. None of the interaction effects was found significant.

4.4.6 Juice reaction (pH)

The data on fruit juice reaction (pH) are presented in Table 4.28.

Nitrogen application has reduced the pH even though not to a significant extent. Phosphorus at P2 level alone produced significant reduction in juice reaction. Every increment in the level of potassium application increased juice acidity significantly. None of the interaction effects was significant.

4.4.7 Ascorbic acid

The data on ascorbic acid content of the fruit are presented in Table 4.29.

Table 4.28 Effect of NPK on juice reaction (pH)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	1.31	1.37	1.30	1.33	1.28	1.33	1.30	P1	1.15	1.31	1.17
N2	1.35	1.32	1.11	1.26	1.10	1.28	1.09	P2	1.50	1.36	1.16
N3	1.28	1.33	1.26	1.29	1.50	1.37	1.09	P3	1.13	1.18	1.05
Mean	1.32	1.34	1.21	-	1.29	1.33	1.13				

General mean = 1.29
CD(P=0.05) for comparing main effects = 0.060
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 1.22

Table 4.29 Effect of NPK on ascorbic acid content (mg/100g fresh fruit)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	188	193	[illegible]	195	17[illegible]	198	21[illegible]	P1	195	213	227
N2	223	21[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	P2	191	217	223
N3	22[illegible]	221	[illegible]	[illegible]	21[illegible]	[illegible]	[illegible]	P3	21[illegible]	228	243
Mean	212	[illegible]	[illegible]	--	[illegible]	[illegible]	231				

General mean = 217
CD (P=[illegible]) for comparing main effects = 10.2
CD (P=[illegible]) for comparing interaction effects = NS
[illegible] = 4.10

Table 4.30 Correlation coefficients between leaf nutrients and fruit quality

	LEAF NUTRIENTS					FRUIT QUALITY CHARACTERS				
	N	P	K	Ca	Mg	Sugar	Acidity	Juice	Ascorbic acid	TSS
	1	2	3	4	5	6	7	8	9	10
1	1.000	0.1860	0.1609*	-0.1104*	-0.1986**	-0.1118	-0.1809*	0.6070**	0.5810**	-0.1728
2		1.0000	0.8135**	-0.7178**	-0.2201	-0.3810*	-0.4724*	0.4112*	0.2640	-0.6769**
3			1.0000	-0.8169**	-0.2064	-0.1651*	-0.5360**	0.1959**	0.2508	-0.7125**
4				1.0000	0.0350	0.5639**	0.1152*	-0.3920*	-0.1894	0.7159**
5						-0.0922	0.6872**	-0.4264*	-0.6912**	0.0649
6							0.0252	-0.1939	0.1796	0.4670*
7								-0.3578*	-0.6929**	0.4119*
8									0.4832*	-0.2801
9										-0.0004

Nitrogen at N2 level significantly recorded maximum ascorbic acid content beyond which there was no significance. Phosphorus at P3 level alone recorded the highest level of ascorbic acid. Every increment in the level of potassium application, significantly increased ascorbic acid content. None of the interactions was found significant.

4.5 Nut characteristics

4.5.1 Nut volume

The data on nut volume are given in Table 4.31.

Nitrogen at N3 level alone significantly produced the smallest nuts. Nut volume significantly decreased with every increment in the level of phosphorus and potassium. Among interactions only NP and NK effects were significant. Smallest nuts were recorded at N3P3 and N3K3 levels of application.

4.5.2 Nut weight

The data on per nut weight are presented in Table 4.32.

Application of nitrogen and phosphorus significantly brought down the weight with every increment in the levels of application. However, potassium levels did not show any significant reduction. None of the interaction effects was found significant.

Table 4.31 Effect of NPK on nut volume (ml/nut)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	7.30	6.73	[illegible]	[illegible]	7.23	6.77	6.13	P1	7.23	7.03	6.87
N2	7.23	6.80	[illegible]	[illegible]	7.03	6.93	6.70	P2	7.03	6.60	6.10
N3	6.60	6.50	[illegible]	[illegible]	6.60	6.37	6.30	P3	6.50	6.43	6.17
Mean	7.04	6.68	6.10	--	6.95	6.69	6.38				

General Mean = 6.707
CD(P=0.05) for comparing main effects = 0.102
CD(P=0.05) for comparing interaction effects = 0.176
CV(%) = 1.315

Table 4.31 Effect of NPK on nut volume (ml/nut)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	7.30	6.73	6.10	6.81	7.23	6.77	6.13	P1	7.23	7.03	6.87
N2	7.23	6.80	6.23	6.50	7.03	6.93	6.70	P2	7.03	6.60	6.10
N3	6.60	6.50	6.17	6.42	6.60	6.37	6.30	P3	6.50	6.43	6.17
Mean	7.04	6.68	6.17	--	6.95	6.69	6.38				

General mean = 6.707
CD(P=0.05) for comparing main effects = 0.102
CD(P=0.05) for comparing interaction effects = 0.176
CV(%) = 1.315

Table 1.32 Effect of NPK on nut weight (g/nut)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	7.37	7.10	6.83	7.17	7.27	7.10	6.93	P_1	7.13	7.17	7.33
N_2	7.73	7.17	7.13	7.34	7.33	7.[illegible]0	7.30	P_2	7.20	6.93	6.97
N_3	7.13	6.83	6.47	6.81	6.90	6.80	6.73	P_3	6.87	6.90	6.67
Mean	7.41	7.03	6.81	-	7.17	7.10	6.99				

General mean = 7.09
CD(P=0.05) for comparing main effects = 0.118
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 1.82

4.5.3 Nut density

The data on nut density are presented in Table 4.33.

Nitrogen and phosphorus application did not bring any significant variation. Potassium application at K2 levels alone significantly increased the nut density. None of the interactions was found significant.

4.5.4 Shelling percentage

The data on shelling percentage are presented in Table 4.34.

Shelling per cent increased significantly with every increment in the level of application of nitrogen, phosphorus and potassium. Among the interactions, PK combinations alone were significant. Maximum shelling per cent was recorded at P3K3 level followed by P2K3 level.

4.5.5 Test weight of kernel

The data on test weight are presented in Table 4.35.

Test weight of kernels was increased upto P2 level significantly, beyond which there was no significance. The trend on phosphorus application seemed to be erratic. Every increment in the level of potassium application significantly increased the test weight. None of the interaction effects was significant.

Table 1.33 Effect of NPK on nut density (g/ml)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1.02	1.06	1.07	1.05	1.01	1.06	1.08	P_1	1.01	1.07	1.07
N_2	1.08	1.06	1.08	1.07	1.05	1.07	1.09	P_2	1.03	1.05	1.09
N_3	1.09	1.06	1.05	1.07	1.05	1.07	1.07	P_3	1.01	1.07	1.09
Mean	1.06	1.06	1.07	--	1.01	1.07	1.08				

General mean =1.06
CD(P=0.05) for comparing main effects =0.030
CD(P=0.05) for comparing interaction effects =NS
C.V(%) =2.50

Table 4.34 Effect of NPK on shelling percentage

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	25.39	25.91	27.20	26.17	25.28	25.98	27.24	P_1	24.61	26.23	26.83
N_2	25.86	26.49	27.76	26.70	25.29	26.94	27.87	P_2	25.15	26.18	28.00
N_3	26.43	27.21	29.00	27.55	26.62	27.71	28.33	P_3	27.43	27.91	28.60
Mean	25.89	26.51	27.98	-	25.73	26.88	27.81				

General mean = 26.81
CD(P=0.05) for comparing main effects = 0.386
CD(P=0.05) for comparing interaction effects = 0.669
CV(%) = 1.24

Table 1.35 Effect of NPK on test weight of kernels (g/1000 kernels)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1869	1811	1867	1849	1826	1815	1907	P_1	1839	1967	1900
N_2	2022	1913	1939	1958	1973	2009	2015	P_2	1809	1810	1961
N_3	1891	1861	1941	1898	1833	1890	1912	P_3	1858	1929	1923
Mean	1929	1873	1916	-	1878	1915	1955				

General mean = 1905
CD(P=0.05) for comparing main effects = 33.9
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 1.5

4.5.6 Kernel protein

The data on kernel protein are given in Table 4.36.

Nitrogen, phosphorus and potassium significantly increased kernel protein with every increment in the level of application.

Among interactions only NK combination was significant. Significantly maximum protein content was recorded at N3K3 level of application followed by N2K3.

4.6 Yield attributes

4.6.1 Precocity of flowering

The data on the number of days taken from flushing to flowering (precocity) as influenced by the main effects of fertilisers are presented in Fig.7 and their interaction effects in Table 4.37.

Nitrogen at N3 level alone significantly the number of days taken from flushing to flowering. Every increment in the level of phosphorus application also significantly brought down the number of days from flushing to flowering. Potassium at K2 level alone could bring down the same significantly. None of the interactions was found significant.

4.6.2 Determinate shoots

The data on the number of determinate shoots are produced in Table 4.38.

Table 1.36 Effect of NPK on kernel protein content (%)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N1	19.81	21.69	24.34	22.28	20.41	24.45	26.12	P1	21.06	22.47	23.25
N2	22.55	24.93	27.89	25.12	22.91	25.80	27.73	P2	23.77	25.53	26.63
N3	24.44	28.32	31.75	28.17	23.17	25.62	30.66	P3	26.15	27.97	29.86
Mean	22.27	25.31	27.99	--	22.17	25.29	28.17		23.67	25.32	26.58

General mean = 25.19
CD(P=0.05) for comparing main effects = 0.812
CD(P=0.05) for comparing interaction effects = 1.124
CV(%) = 2.82

Table 4.37 Effect of NPK on precocity (days) of flowering

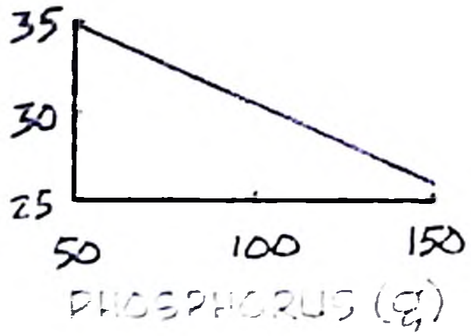
Nutrient levels	P_1	P_2	P_3	Means	K_1	K_2	K_3		K_1	K_2	K_3
N_1	37.67	33.33	23.33	33.44	38.00	35.00	26.33	P_1	37.67	35.67	31.67
N_2	37.67	31.00	21.00	30.89	31.67	31.33	29.67	P_2	33.67	30.33	27.33
N_3	29.67	27.00	21.33	26.00	29.33	25.00	23.67	P_3	27.67	25.33	20.67
Means	35.00	30.44	24.55	-	33.00	30.44	26.55				

General mean = 30.00
CD(P=0.05) for comparing main effects = 3.255
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 9.10

Table 4.38 Effect of NPK on number of determinate shoots

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	851	1061	1251	1058	814	1159	1200	P_1	781	984	1152
N_2	1033	1447	1604	1362	1007	1397	1681	P_2	994	1396	1637
N_3	1033	1519	2131	1562	1222	1592	1872	P_3	1268	1768	1964
Mean	972	1342	1666	--	1014	1383	1584				

General mean = 1327
CD(P=0.05) for comparing main effects = 74.6
CD(P=0.05) for comparing interaction effects = 129.3
CV(%) = 4.87



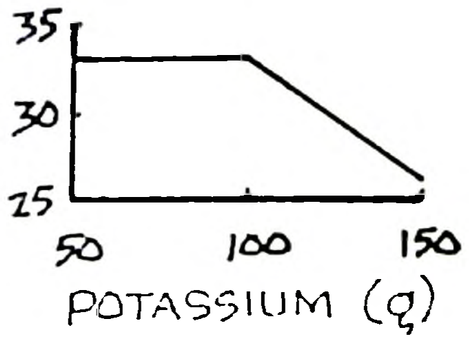


FIG: 7

EFFECT OF FERTILISERS ON PRECOCITY OF FLOWERING

Panicles were increased significantly with every increment in the level of nitrogen, phosphorus and potassium. All the interaction effects were found significant. Maximum number of productive laterals were recorded at N_3P_3, N_3K_3 and P_3K_3 level of fertilisers application.

4.6.3 Determinate to total shoot ratio

The data on determinate to total shoot ratio is presented in Table 1.39.

Nitrogen application showed a gradual increase in this ratio. Phosphorus application did not show any increase beyond P_2 level. Maximum ratio of determinate to total shoots was observed at K_2 level followed by K_3 level of potassium application.

4.6.4 Number of nuts

The data on the number of nuts are presented in Table 4.40. The data were not statistically analysed.

The data indicated that the number of nuts was increased substantially with N and P application compared to potassium. Maximum number of nuts was recorded at N_3P_3 level of combination.

Table 4.39 Effect of NPK on determinate to total shoot ratio

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.272	0.265	0.247	0.260	0.237	0.291	0.260	P_1	0.251	0.285	0.308
N_2	0.272	0.282	0.294	0.280	0.264	0.297	0.289	P_2	0.253	0.298	0.304
N_3	0.294	0.313	0.327	0.310	0.291	0.311	0.332	P_3	0.281	0.315	0.265
Mean	0.280	0.285	0.286	--	0.262	0.299	0.291				

General mean = 0.283

Table 4.40 Effect of NPK on number of nuts (per tree)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	280	511	151	109	363	125	150	P_1	415	435	467
N_2	486	587	613	560	570	546	561	P_2	533	592	613
N_3	551	638	700	627	560	618	689	P_3	568	565	627
Mean	139	579	586	--	502	508	567				

General mean = 532

4.7 Yield

The data on nut yields of seed progeny and layers as influenced by the main effects of fertilisers are presented in Fig.8 and their interactions in Tables 4.41 and 4.42.

The results presented in Table 4.41 showed that the main effects of treatments were significant. Nitrogen had given a progressive increase in the yield of cashew. The yield increase from N2 to N3 is substantial and significant.

Phosphorus levels also had influenced the production. The maximum and significant yield increase was obtained by P3 level. Potassium application has resulted in registering significant increase at every level. The highest yield was recorded in the application over when compared to P3 or N3. The interaction effects were not significant. As far as layers are concerned, the difference between the N2 and N3 levels was not significant even though N2 and N3 levels were significantly superior to N1 and they were on par. In other words, there was a substantial yield increase from N1 to N2 beyond which it was marginal. In the case of P also, the quantum jump was more from P1 to P2 and from P2 to P3 there was no difference. Potash application had also responded at K3 level registering the highest yield and this was significantly superior to K1 even

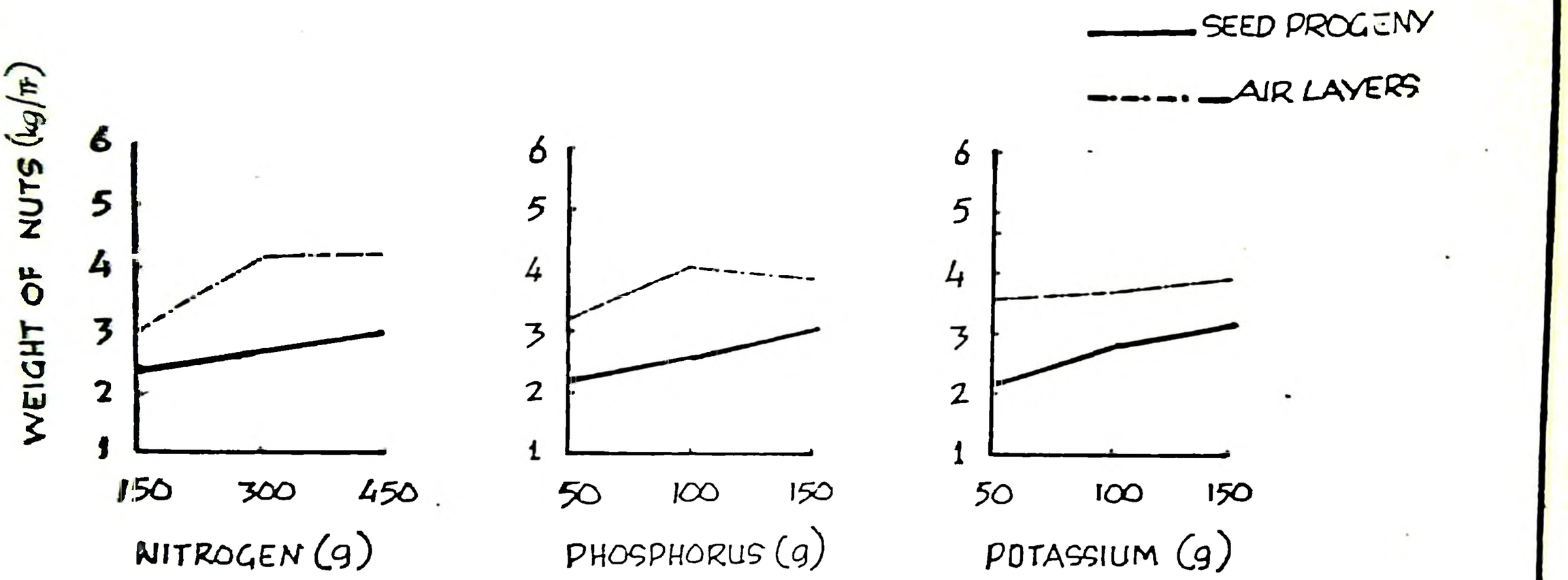


FIG : 8

EFFECT OF FERTILISERS ON NUT PRODUCTION IN AIR LAYERS AND SEED PROGENY

Table 4.41 Effect of NPK on weight (kg/tree) of cashewnuts in seed progeny

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1.20	1.54	1.78	1.50	.06	1.47	1.98	P_1	1.02	1.35	2.11
N_2	1.61	1.46	1.81	1.62	..27	1.68	1.9[illegible]	P_2	1.20	1.85	1.96
N_3	1.67	2.01	2.40	2.02	..47	2.05	2.56	P_3	1.58	1.99	2.42
Mean	1.49	1.67	2.00		1.27	1.73	2.16				

General mean = 1.72
CD(P=0.05) for comparing main effects = 0.289
CD(P=0.05) for comparing interaction effects= NS
CV(%) = 31.805

Table 4.42 Effect of NPK on weight (kg/tree) of cashewnuts in air layers

Nutrient levels	P1	P2	P3	mean	K1	K2	K3		K1	K2	K3
N1	2.06	3.63	3.08	2.92	.64	3.02	3.12	P1	3.08	3.25	3.42
N2	3.76	4.21	4.37	4.11	4.18	4.04	4.12	P2	3.84	4.10	4.27
N3	3.93	4.35	4.53	4.27	.00	4.20	4.63	P3	3.90	3.90	4.18
Mean	3.25	4.07	3.99		3.62	3.75	3.96				

General mean = 3.77
CD(P=0.05) for comparing main effects = 0.232
CD(P=0.05) for comparing interaction effects = 0.402
CV(%) = 5.34

though on par with K2. Maximum yield was obtained by K3 level in air layers as against K3 level in seed progeny.

Interaction NP was significant with N3P3 combination recording maximum yield.

4.8 Leaf analysis

4.8.1 Leaf nitrogen

The data on leaf nitrogen are presented in Table 4.43.

Significantly maximum leaf nitrogen was recorded at N3 level of application. Leaf nitrogen was increased significantly with every level of phosphorus and potassium application. Among the interactions, NK combinations were significant with respect to leaf nitrogen. Maximum leaf nitrogen was recorded at N3K3 level of application followed by N3K2 level.

4.8.2 Leaf phosphorus

The data on leaf phosphorus are presented in Table 4.44.

Leaf phosphorus was decreased significantly with every increment in the level of nitrogen application, whereas application of phosphorus and potassium significantly increased leaf phosphorus upto second level, beyond which there was no significance. Among the

Table 4.43 Effect of NPK on leaf nitrogen (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1.77	2.10	2.24	2.04	1.83	2.10	2.18	P_1	1.84	2.00	2.05
N_2	1.86	2.06	2.32	2.08	2.05	2.07	2.13	P_2	2.08	2.25	2.32
N_3	2.26	2.49	2.61	2.53	2.34	2.53	2.61	P_3	2.30	2.50	2.50
Mean	1.99	2.22	2.47	-	2.07	2.25	2.32				

General mean = 2.22
CD(P=0.05) for comparing main effects = 0.062
CD(P=0.05) for comparing interaction effects = 0.108
CV(%) = 2.45

Table 4.44 Effect of NPK on leaf phosphorus (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.15	0.17	0.18	0.17	0.14	0.18	0.18	P_1	0.13	0.15	0.15
N_2	0.15	0.15	0.17	0.15	0.15	0.15	0.16	P_2	0.14	0.16	0.17
N_3	0.14	0.14	0.15	0.14	0.13	0.14	0.15	P_3	0.15	0.17	0.17
Mean	0.14	0.16	0.16	--	0.14	0.16	0.16				

General mean = 0.15
CD(P=0.05) for comparing main effects = 0.004
CD(P=0.05) for comparing interaction effects = 0.008
CV(%) = 3.73

interactions, NP and NK combinations were significant with respect to leaf phosphorus.

4.8.3 Leaf potassium

The data on leaf potassium are presented in Table 4.45.

Leaf potassium was decreased upto N2 level of application beyond which there was no significance, while the same was increased significantly with every increment of P application. Potassium content of leaf was increased by K application. K2 and K3 were on par in leaf potassium. Among the interactions only NP combination was significant with respect to leaf potassium.

4.8.4 Leaf calcium

The data on leaf calcium is presented in Table 4.46.

Increasing levels of nitrogen application significantly increased leaf calcium. Phosphorus and potassium levels significantly decreased leaf calcium. Among the interactions only PK combination was significant. P3K3 level had recorded the lowest leaf calcium.

4.8.5 Leaf magnesium

The data on leaf magnesium are presented in Table 4.47.

Table 4.45 Effect of NPK on leaf potassium (%)

Nutrient levels	P1	P2	P3	Mean	K1	K2	K3		K1	K2	K3
N_1	0.83	1.02	1.13	0.99	0.89	1.01	1.08	P1	0.74	0.85	0.91
N_2	0.82	0.88	0.98	0.89	0.85	0.91	0.92	P2	0.83	0.95	0.99
N_3	0.85	0.88	0.87	0.90	0.81	0.91	0.95	P3	0.97	1.05	1.05
Mean	0.83	0.92	1.02	--	0.85	0.95	0.98				

General mean = 0.93
CD(P=0.05) for comparing main effects = 0.041
CD(P=0.05) for comparing interaction effects = 0.072
CV(%) = 3.91

Table 4.46 Effect of NPK on leaf calcium (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.18	0.12	0.09	0.13	0.16	0.13	0.12	P_1	0.26	0.21	0.18
N_2	0.21	0.15	0.12	0.16	0.19	0.15	0.14	P_2	0.16	0.14	0.12
N_3	0.24	0.14	0.14	0.17	0.20	0.18	0.15	P_3	0.13	0.11	0.10
Mean	0.21	0.14	0.12	--	0.18	0.15	0.13				

General mean = 0.16
CD(P=0.05) for comparing main effects = 0.013
CD(P=0.05) for comparing interaction effects = 0.023
CV(%) = 7.55

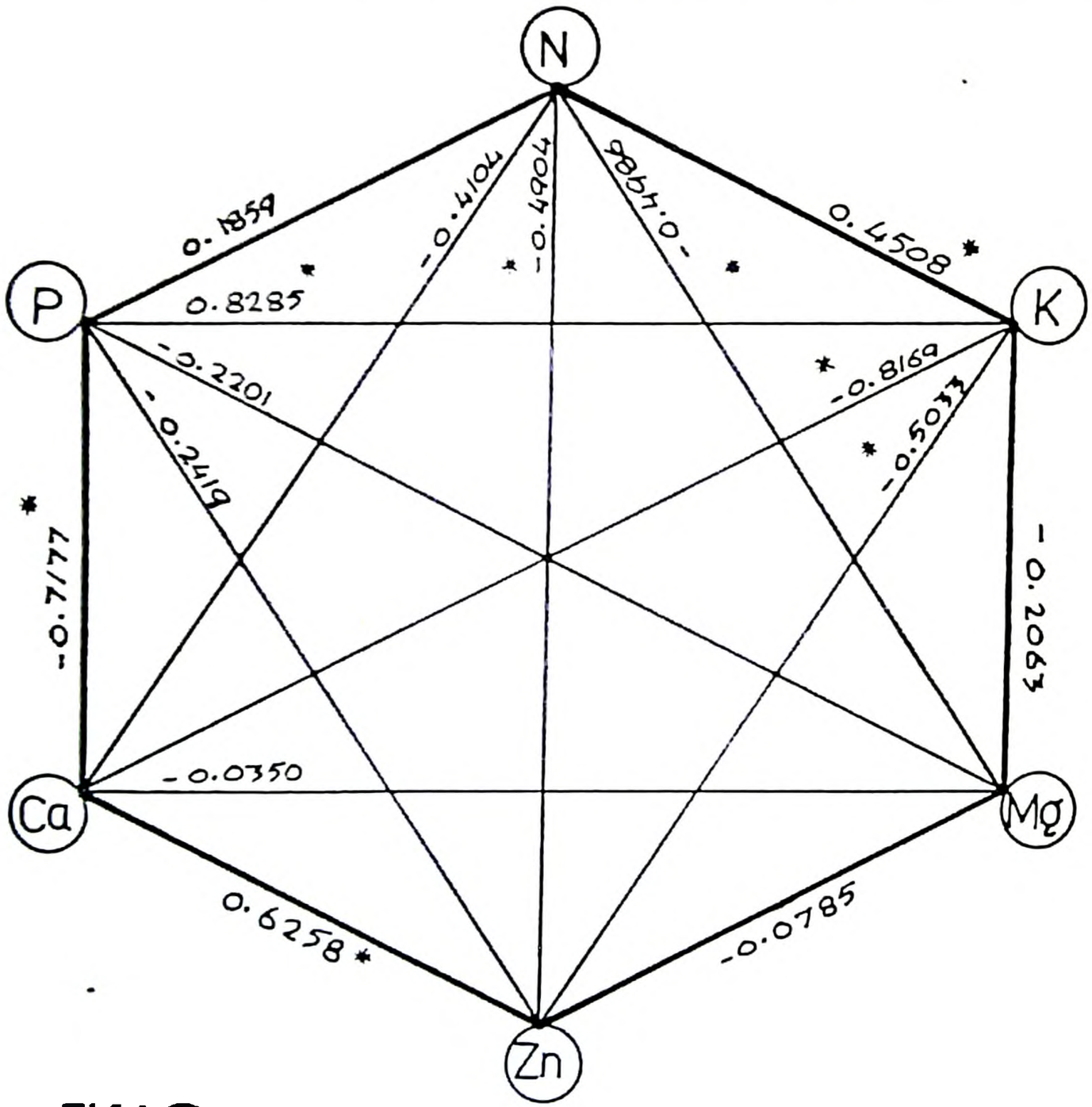


FIG: 9

INTER CORRELATIONS AMONG LEAF NUTRIENTS.

Table 4.47 Effect of NPK on leaf magnesium (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.17	0.18	0.18	0.17	0.19	0.17	0.16	P_1	0.18	0.16	0.16
N_2	0.17	0.17	0.17	0.17	0.18	0.17	0.16	P_2	0.18	0.17	0.16
N_3	0.16	0.17	0.16	0.16	0.17	0.16	0.15	P_3	0.16	0.18	0.17
Mean	0.17	0.17	0.17	--	0.18	0.17	0.16				

General mean = 0.17
CD(P=0.05) for comparing main effects = 0.0047
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 0.24

Leaf magenesium was decreased at N3 level of nitrogen application. Phosphorus levels did not show any effect, whereas increasing levels of potassium decreased leaf magnesium. None of the interaction effects was found significant.

4.3.6 Leaf zinc

The data on leaf zinc are given in Table 4.48.

Nitrogen at N2 level had significantly increased leaf zinc beyond which there was a decrease. At the same time phosphorus levels progressively decreased leaf zinc. Potassium levels did not significantly influence the same.

4.9 Critical concentrations of N and P in leaf

The critical concentration levels for N and P were 2.09% and 0.14% respectively (Fig.10 and 11). In view of the linear response to K application, the critical concentration for K was not worked out. The quadratic functions were fitted for N

$$\hat{y} = 2.02 + 1.693\ x - 0.3498\ x^2$$

$$R^2 = 0.187$$

For P

$$\hat{y} = 0.8788 + 23.97\ x - 108.6\ x^2$$

$$R^2 = 0.037$$

where x is the leaf nutrient concentration and y is the estimated yield.

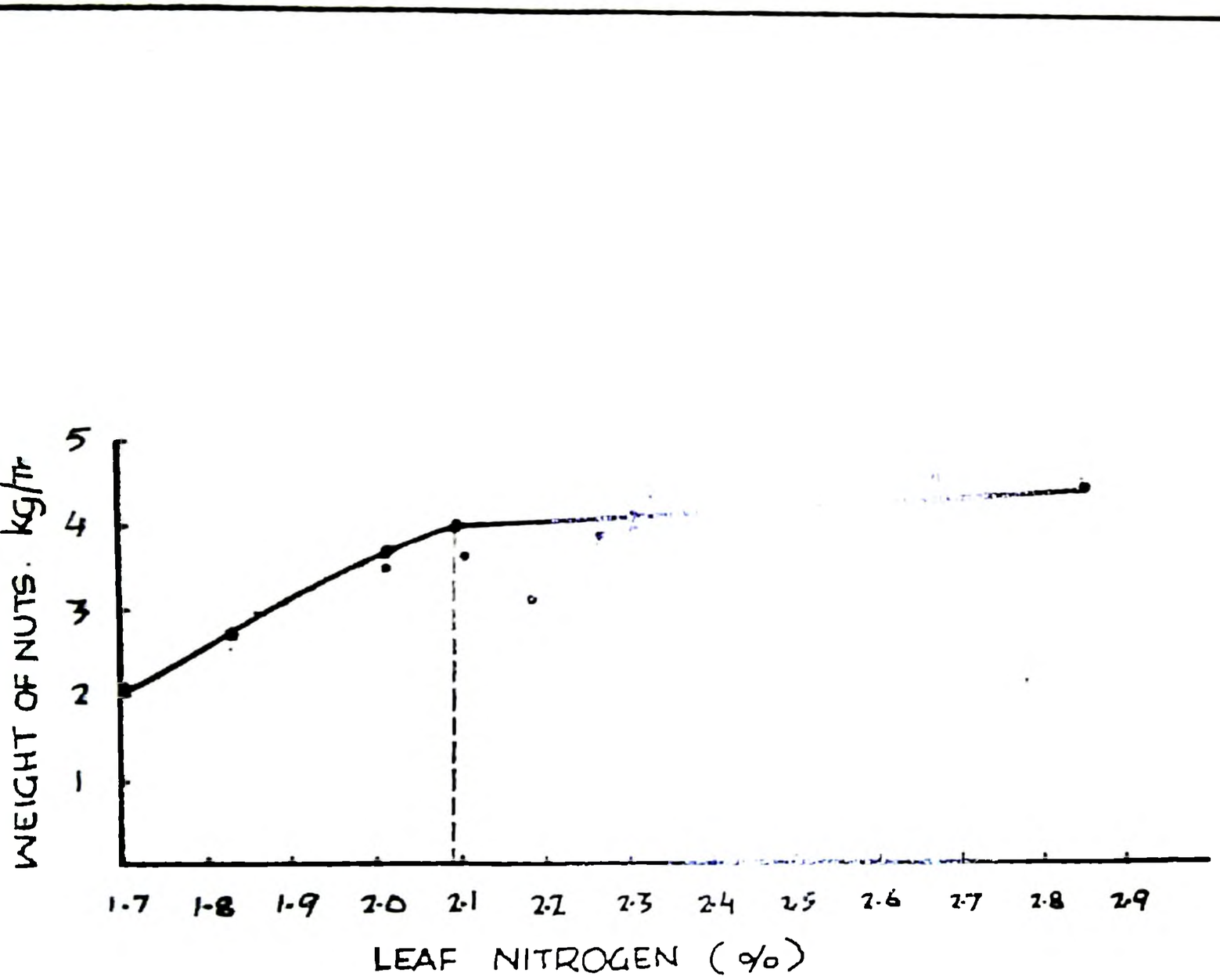


FIG: 10 LEAF NITROGEN INRELATION TO YIELD

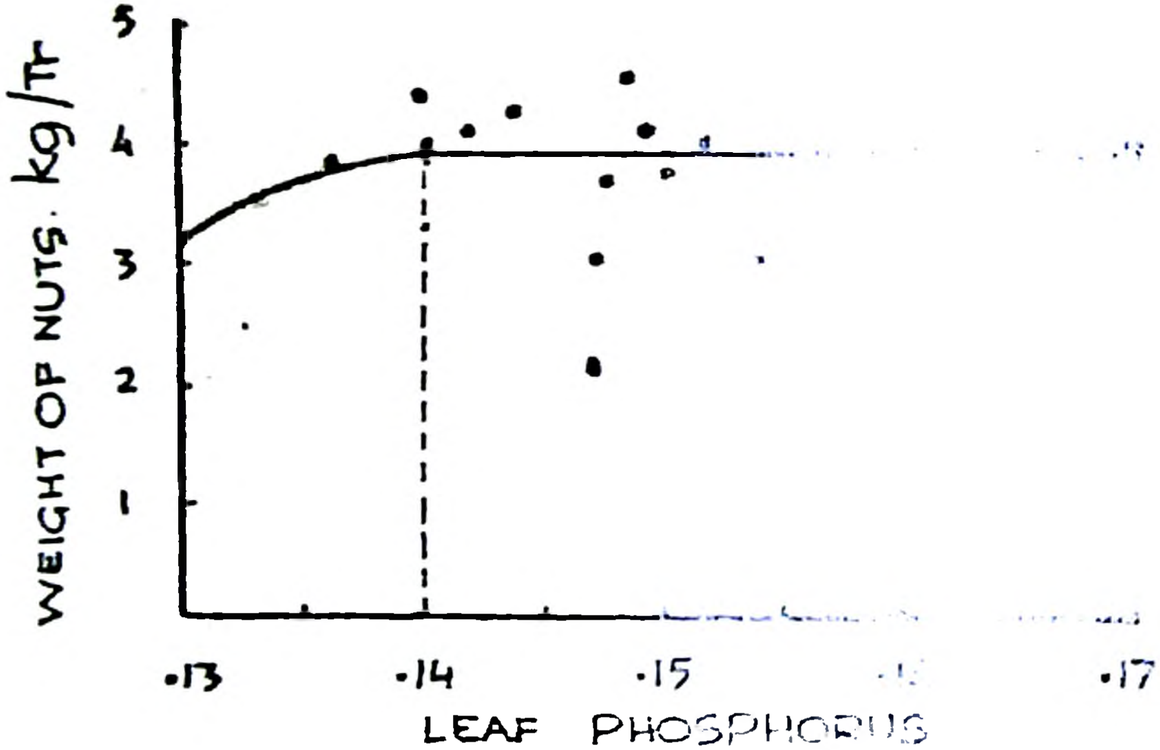


FIG : 11. LEAF PHOSPHORUS INRELATION TO YIELD.

Table 4.48 Effect of NPK on leaf zinc (ppm)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	41.00	35.67	29.33	35.33	30.00	35.00	41.00	P_1	48.00	45.00	47.33
N_2	57.33	40.33	27.33	41.67	45.00	38.00	42.00	P_2	38.67	35.00	38.67
N_3	42.00	36.33	30.33	36.22	41.00	37.33	30.33	P_3	29.33	30.33	27.33
Mean	46.78	37.44	29.00	--	38.67	36.78	37.78				

General mean = 37.74
CD(P=0.05) for comparing main effects = 5.211
CD(P=0.05) for comparing interaction effects = 9.025
CV(%) = 11.96

Table 4.49 Correlation coefficients between yield and growth parameters

Characters	1	2	3	4	5	6	7
1. Yield	1.000	0.6555*	0.5846*	0.5491*	0.6615*	0.6309*	0.2959
2. Surface area		1.000	0.3666*	0.9506*	0.8745*	0.9341*	0.4818*
3. Leader branches			1.000	0.8592*	0.8484*	0.8386*	0.4830*
4. Lateral shoots				1.000	0.8775*	0.9120*	0.4856*
5. Determinate shoots					1.000	0.8425*	0.4407*
6. LAI						1.000	0.6927*
7. Canopy compactness							1.000

Table 4.50 Correlation coefficients between yield, growth parameters and leaf characteristics

Characters	6	7	8	9	10	11	12	13
1. Yield	0.6497*	0.6552*	0.5613*	0.6774*	0.7008*	0.0219	0.1360	0.6467*
2. Surface area	0.7501*	0.7097*	0.8112*	0.8766*	0.6594*	0.4575*	0.5575*	0.7644*
3. Leader branches	0.7230*	0.6557*	0.7010*	0.8531*	0.5306*	0.3728	0.5363*	0.7237*
4. Determinate shoots	0.8674*	0.7173*	0.8135*	0.8491*	0.8336*	0.2614	0.4328*	0.8895*
5. LAI	0.7907*	0.7175*	0.8100*	0.9123*	0.6629*	0.4838*	0.5890*	0.7850*
6. SLW	1.000	0.6673*	0.8657*	0.8493*	0.3611*	0.3583	0.5923*	0.7883*
7. Total chlorophyll		1.000	0.7505*	0.7618*	0.7232*	0.3807	0.4500*	0.7432*
8. Sugars at flushing			1.000	0.8303*	0.8460*	0.3692*	0.6138*	0.7814*
9. Sugars at flowering				1.000	0.8206*	0.4363*	0.6752*	0.8265*
10. Leaf N					1.000	0.1859	0.4508*	0.7809*
11. Leaf P						1.000	0.8285*	0.1892
12. Leaf K							1.000	0.3903*
13. Root CEC								1.0000

Both the above functions were not found significant.

4.10 Root cation exchange capacity

The data on the root cation exchange capacity as influenced by the main effects of fertilisers are presented in Fig.12 and the interaction effects in Table 4.51.

Increasing levels of nitrogen and phosphorus significantly increased root CEC. Potassium application at K2 level was significantly superior to K1 and was on par with K3.

Among the interactions only NK combination was significant. N3K3 recorded maximum root CEC.

4.11 Soil analysis

4.11.1 Organic carbon

The data on soil organic carbon are presented in Table 4.52.

Nitrogen application at N2 level and beyond significantly reduced organic carbon content. Phosphorus and potassium levels did not show any significant variation.

NK variation was significant. N3K3 level of application recorded the lowest organic carbon content.

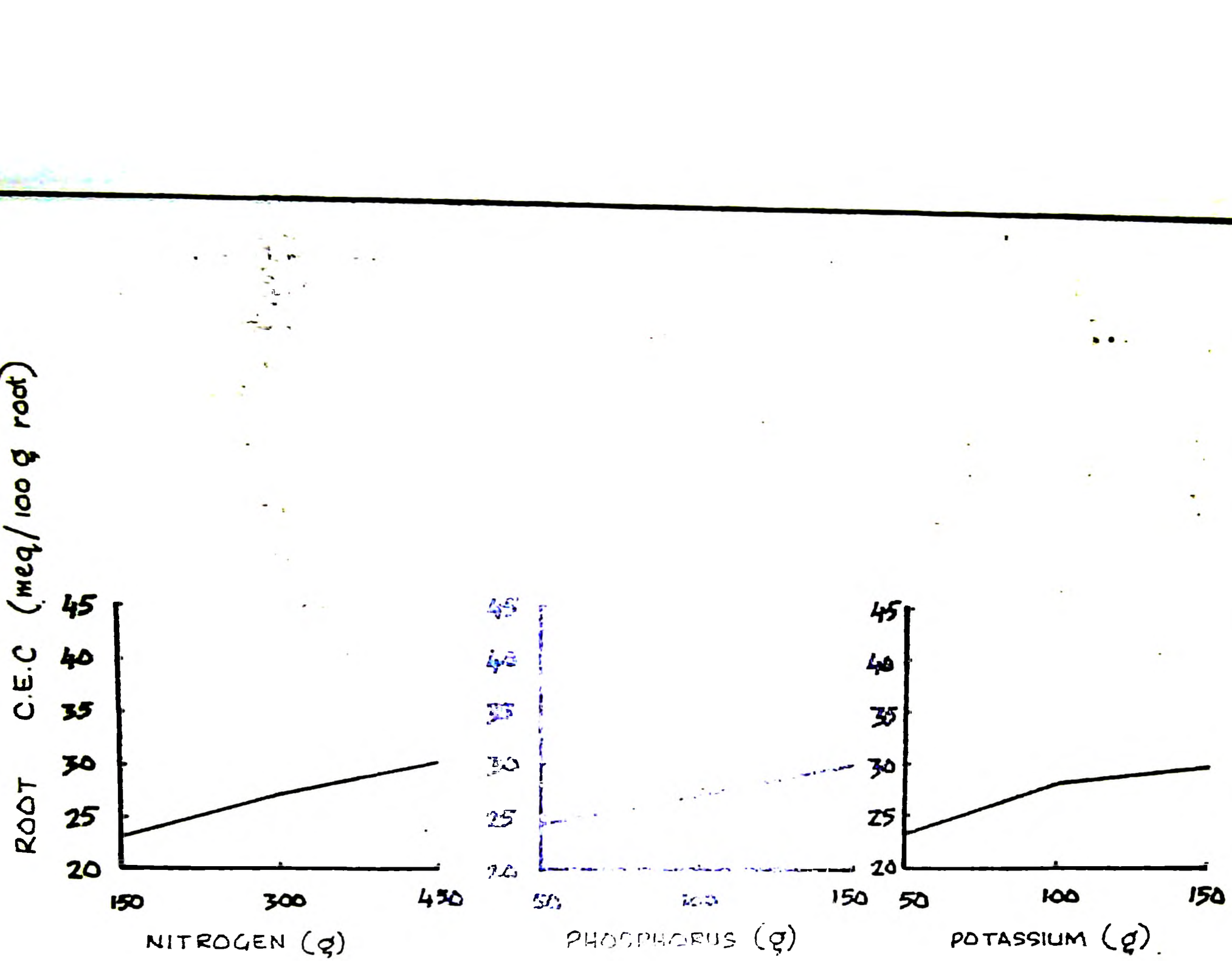


FIG:12

EFFECT OF FERTILISERS ON ROOT CATION EXCHANGE CAPACITY

Table 4.51 Effect of NPK on root CEC (meq/100g root)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	21.67	23.33	26.00	23.67	21.67	24.33	25.00	P_1	20.00	25.67	27.00
N_2	23.67	27.00	31.00	27.22	21.33	29.33	31.00	P_2	23.00	28.67	28.67
N_3	27.33	30.00	32.67	30.00	26.00	31.33	32.67	P_3	26.00	30.67	33.00
Mean	24.22	26.77	29.89		23.00	28.33	29.55				

General mean = 26.96
CD(P=0.05) for comparing main effects = 1.172
CD(P=0.05) for comparing interaction effects = 2.550
CV(%) = 4.73

Table 4.52 Effect of NPK on residual soil organic carbon (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1.56	1.55	1.71	1.61	1.44	1.62	1.76	P_1	1.27	1.25	1.24
N_2	1.19	1.28	1.01	1.16	1.19	1.16	1.14	P_2	1.30	1.23	1.25
N_3	1.01	0.94	0.96	0.97	1.22	0.90	0.78	P_3	1.29	1.19	1.20
Mean	1.25	1.26	1.23	--	1.29	1.22	1.23				

General mean = 1.25
CD(P=0.05) for comparing main effects = 0.155
CD(P=0.05) for comparing interaction effects = 0.268
CV(%) = 10.7

4.11.2 Total nitrogen

The data on total nitrogen are presented in Table 4.53.

Nitrogen, phosphorus and potassium levels significantly increased soil nitrogen content by every increment in the level of application. None of the interactions was found significant.

4.11.3 Phosphorus

The data on available phosphorus are presented in Table 4.54.

Nitrogen application significantly decreased the available phosphorus content. Phosphorus level did not show any significant variation. Potassium application decreased the available phosphorus at K_2 level beyond which there was no significance. Among the interactions, only NK combinations were found significant.

4.11.4 Potassium

The data on the soil potassium are presented in Table 4.55.

Nitrogen application upto N_2 level significantly increased soil potassium beyond which there was a decrease. Phosphorus at P_3 level had significantly increased soil potassium. Increasing levels of potassium increased soil potassium at all levels. Among the interactions, only NK combirations were found significant.

Table 4.53 Effect of NPK on residual soil total nitrogen (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.12	0.13	0.14	0.13	0.11	0.13	0.15	P_1	0.12	0.14	0.16
N_2	0.14	0.14	0.16	0.15	0.12	0.15	0.17	P_2	0.13	0.15	0.17
N_3	0.16	0.18	0.19	0.17	0.15	0.18	0.19	P_3	0.14	0.17	0.18
Mean	0.14	0.15	0.16	--	0.13	0.15	0.17				

General mean = 0.15
CD(P=0.05) for comparing main effects = 0.007
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 3.90

Table 4.54 Effect of NPK on residual soil phosphorus (%)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	0.10	0.07	0.15	0.11	0.18	0.08	0.06	P_1	0.13	0.06	0.04
N_2	0.05	0.03	0.03	0.04	0.04	0.04	0.03	P_2	0.08	0.04	0.04
N_3	0.09	0.06	0.08	0.07	0.09	0.07	0.07	P_3	0.10	0.09	0.07
Mean	0.08	0.05	0.08	--	0.10	0.06	0.05				

General mean = 0.07
CD(P=0.05) for comparing main effects = 0.029
CD(P=0.05) for comparing interaction effects = 0.051
CV(%) = 35.91

Table 4.55 Effect of NPK on residual soil potassium (ppm) in air layers plot

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	230	253	263	248	143	240	363	P_1	137	237	317
N_2	280	270	320	290	170	250	450	P_2	130	227	370
N_3	210	203	263	226	120	253	303	P_3	167	280	400
Mean	240	242	282	--	144	248	372				

General mean = 255
CD(P=0.05) for comparing main effects = 20.5
CD(P=0.05) for comparing interaction effects = 35.6
CV(%) = 7.00

Table 4.56 Effect of NPK on residual soil pH

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	5.40	5.40	5.60	5.47	5.41	5.48	5.50	P_1	5.50	5.55	5.68
N_2	5.59	5.50	5.75	5.61	5.42	5.62	5.79	P_2	5.26	5.49	5.64
N_3	5.74	5.49	5.47	5.57	5.10	5.63	5.68	P_3	5.43	5.69	5.65
Mean	5.58	5.46	5.61	--	5.31	5.58	5.66				

General mean = 5.55
CD(P=0.05) for comparing main effects = 0.076
CD(P=0.05) for comparing interaction effects = 0.132
CV(%) = 1.19

4.11.5 Soil pH

The data on soil pH are presented in Table 4.56.

N application at N2 level has significantly increased soil pH beyond which there was a decrease. P apolication seemed to be erratic. K application had significantly increased the soil pH. K3 and K2 were on par.

4.12 Production functions

The production functions for nitrogen, phosphorus and potassium are worked out and presented in Table 4.57.

From the table, it is seen that nitrogen and phosphorus exhibited a curvulinear type of response with respect to yield. Potassium alone had shown a linear response.

Table 4.57. Production functions for N, P and K in air layers

N	$y = 123 + 462\ x - 87\ x^2$.	$R^2 = 0.4580$
P_2O_5	$y = 251 + 368.5\ x - 70.5x^2$.	$R^2 = 0.805$
K_2O	$y = 580 + 1.60\ x$.	$R^2 = 0.206$

Where y = estimated yield (kg/ha)
x = level of nutrients (kg/ha)

NP $y = 17.74+0.0081\ x - 0.0000197\ x^2 + 0.6552\ z - 0.000206\ z^2 - 0.000014\ xz$

Where y = estimated yield
x = quantity of N
z = quantity of P

4.13 Economic optimum doses of N and P fertilisers and expected yield

The optimum doses of N and P fertilisers and the expected yield are presented in Table 4.58.

The optimum doses for nitrogen was worked out to be 430.00g/tree/year and for phosphorus,130.00g/tree/year. The optimum dose for K was not worked out in view of the linear response to K application. The optimum doses for NP interaction was not worked out since the equation was not significant.

Table 4.58. Economic optimum doses of N&P fertilisers and expected yield in air layers

Nutrient	Doses (g/tree)	Expected yield (kg/tree)
Nitrogen	130.00	4.71
Phosphorus	130	1.50

The expected yields at optimum doses of N and P are 4.71 and 1.50 kg/tree/year respectively.

4.14 Economics of fertiliser application

The data on the economic analysis of fertiliser application to seed progeny and layers are presented in Table 4.59 and 4.60.

In seed progeny nitrogen application at N1 level alone significantly increased the net income, while in air layers, the same was recorded at N2 level only.

Table 4.59 Effect of NPK on net income from seed progeny (Rs./ha)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	1113	1600	1688	1477	910	1333	2189	P_1	609	1281	2403
N_2	1524	1578	1829	1644	1135	1685	2110	P_2	1203	1940	2081
N_3	1626	2045	2575	2082	1262	2130	2854	P_3	1495	1927	2669
Mean	1431	1741	2031	--	1102	1716	2384				

General mean = 1734
CD(P=0.05) for comparing main effects = 383.13
CD(P=0.05) for comparing interaction effects = NS
CV(%) = 19.15

Table 4.60 Effect of NPK on the net income from air layers (Rs./ha)

Nutrient levels	P_1	P_2	P_3	Mean	K_1	K_2	K_3		K_1	K_2	K_3
N_1	2429	4710	3813	3661	3256	3799	3926	P_2	3830	4087	4344
N_2	4874	5393	5624	5297	5110	5241	5539	P_2	4907	5333	5409
N_3	4958	5546	5740	5415	5013	5308	5918	P_3	4948	4926	5330
Mean	4087	5216	5059	--	4552	4783	5028				

General mean = 4791
CD(P=0.05) for comparing main effects = 403.4
CD(P=0.05) for comparing interaction effects = 698.7
CV(%) = 7.3

In seed progeny, the difference in the net income realised due to P1 and P2 or P2 and P3 was not significant. However, maximum net income was recorded under P_3 level. In air layers, phosphorus at P2 level alone recorded the maximum net income. Potassium application at K_3 level significantly recorded maximum net income in seed progeny, while in air layers, different levels of this element did not influence the net income significantly even though maximum profit was obtained at K_3 level.

The NP interaction was significant in air layers. Maximum net income was realised by N_3P_3 combination.

V. DISCUSSION

The salient features of the results involving the effects of NPK on seed progeny and air layers in cashew are discussed below with reference to the various objectives of the study.

5.1 Growth parameters

5.1.1 Height

N had exerted profound influence on plant height both in seed progeny and air layers. Increasing levels of N significantly increased plant height in seed progeny up to N3 level, whereas, in air layers, maximum height was recorded up to N2 level beyond which there was no increase. This is in conformity with the observations made by Lefebvre (1973) who emphasized that mineral fertilisation was important for cashew growth. Nambiar (1983) reported that application of 1000g N increased plant height in seed progeny on sandy loam soils of Bapatla.

The role of nitrogen in plant metabolism was well documented by many workers. It is known for the synthesis and translocation of phytohormones mainly of auxins. These harmones would have played a major role in elongation of the trees. However, the synthesis of such hormones seems to vary with the physiological maturity of

of the trees as already established by Ohler (1979). Perhaps, this is the first work on NPK nutrition on air layers. The observation is that beyond a certain level, N had no influence on plant height is substantiated by the physiological maturity of layers (Loc. cit, 1979) which will almost be completed by 4-5 years of orchard life as against seed progeny which continues to grow beyond this period (Plates 9 and 10).

Phosphorus at the highest level of application gave the tallest plants in both the plant material. These results are in agreement with Lefebvre (1973), Haag, et al. (1975) and Nambiar (1983) who recorded an increase in plant height due to adequate phosphate application. Generally, P has no role to play in increasing the vegetative growth specially plant height. However, the response to P application observed in this study is likely by the increased utilisation of nitrogen and consequent increase in plant height. This can be further confirmed from the tables on nitrogen content of leaf (Table 4.43) where in it was noticed that application of phosphorus increased nitrogen content of leaf tissue.

K application to cashew trees showed an increase in plant height in both the plant materials up to K1

Plate 9. .. tall growing tree in seed progeny under N3P3K3 treatment

level. However, Lefebvre (1973) in Madagascar and Nambiar (1983) in sandy soils of Bapatla did not record any increase in plant height due to potassium application. The fertilisers are applied in single dose before the onset of heavy rains. It is likely that the potassium fertilisers applied must have lost by leachings. This points at the necessity of split application for cashew which may be further investigated upon.

The PK interaction is significant in the case of seed progeny and NP interaction in air layers. It may be noted that in seed progeny which are deep rooted and in soils almost deficient in P and not fairly supplied with K, the application of these two nutrients at higher levels had an added significance. In air layers also, the same trend was noticed, even though not significant. With regard to NP interaction on layers, it may be noted that this effect is mainly due to the effect of phosphorus and the combination of N,P has given the maximum additive effect.

5.1.2 Canopy radius

The canopy radius was also influenced by N application in air layers at the middle level only. The differential behaviour is attributed to the morphological differences between the two propagules. Air layers generally do not attain much height and their tendency is

Plate 10. A prostrating layer under NaNO3 treatment

to spread laterally which is influenced only to a certain extent by nitrogen application (Plate 10). Where as in seed progeny this is not true.

In the case of P and K, the highest levels positively influenced this characters. The effect of phosphorus is attributed to its influence on the production of lateral buds (Mengel and Kirkby, 1983) which would have ultimately increased lateral branches resulting in a longer canopy radius. K might have influenced this character indirectly through the increased P uptake as is evidenced from Table 4.44.

5.1.3 Canopy surface area

The results presented in Tables 4.5 and 4.6 showed that nitrogen had significantly influenced the surface area in seed progeny, while in air layers nitrogen beyond 300g/tree/year did not increase surface area.

A perusal of the data on the height of the seedlings given in Table 4.1 showed that, this character was considerably influenced by N. Since height of the plant is an important character for increasing surface area, the response to nitrogen can be attributed to the same. However, in air layers beyond N2, there was a decrease. In air layers height is not increased beyond a certain level of N application.

In the case of P, there was a progressive increase in the surface area in both seed progeny and air layers along with the levels of phosphorus. The effect of P in increasing lateral spread as shown in Table 4.2, would have resulted in more surface area by P application.

With reference to K there was an increase in surface area which is attributed to the effect of K nutrition discussed earlier in plant height and canopy radius.

The significance of NP interactions noticed in this table has been attributed to the combined effect of height on nitrogen and lateral spread by phosphorus. It is interesting to note that nitrogen beyond 300g/tree, there was no significant increase by phosphorus application. Nitrogen at 300g, and phosphorus at 150g seemed to be the best combination for this character.

On perusal of the data (Table 4.3), it is clear that the degree of relation with lateral shoots was much higher compared to leader shoot production. It clearly indicated that the number of lateral shoot production was pivotal in increasing the surface area of the canopy.

5.1.4 Number of leader branches

N application did not have much effect on the production of leaders in seed progeny while in air layers

there was some effect only upto 300g N. With regard to phosphorus, P_3 level of application was beneficial both in seed progeny and air layers, whereas in potassium, K_2 level was sufficient in seedlings and K_3 level was required in air layers for maximum leader production. It may be stated that in seed progeny there was lot of heterogenity and the number of leaders was mainly influenced by genetic differences. In air layers, some influence on this vegetative character by nutrient application is seen. This is probably the reason for getting response at the highest level in air layers. Ensuring the availability of sufficient carbohydrate (staple) by mineral fertilisation (Table 4.18) would have helped to promote the production of more number of leader branches in fertilised plants (Hanson, 1971).

Leader branches (Table 4.19) established a positive and significant relation with laterals and soluble sugars at flushing. The number of leaders helped to increase the lateral shoot production through increased synthesis o carbohydrates in the presence of adequate leaf NPK.

5.1.5 Number of Lateral shoots

N application at the highest level in seed progeny and at middle level in air layers has given the maximum number of lateral shoots. P and K at the highest levels recorded maximum number of laterals in both the plant

materials. The lateral shoots are formed from the lateral buds present in the leader branches of the previous growth (Plate 3). Thus lateral shoot initiation is essentially a consequence of the lateral bud formation. The differential performance of seed progeny and air layers with reference to N nutrition is related to the progeny variations. In air layers, the production of laterals is not seen much influenced by N as against seed progeny. With the result, in air layers N beyond certain level has no influence on lateral production.

Increasing the level of N increases the synthesis and translocation of phytohormones like auxins and cytokinins. (Wagner and Michael, 1971). These hormones help to break the dominancy of buds and to keep the plant in more vegetative stage and hence, application of nitrogen increased lateral bud production in seed progeny. The role of P in bud formation and bud opening was well explained by Mengel and Kirkby (1980). Since, P needs in opening of the buds and growing of the new shoots, consequently higher levels of P application resulted in more number of lateral shoot production.

Plant organs, preferentially supplied with phloem sap such as developing buds contain high levels of K (Cassagnes, et al. 1969). Thus K helps in reducing the

transpiration rates (Brag, 1972) and keeps the growing buds alive which in turn develop into lateral shoots. Hence, an increase in the level of K application, increased the lateral shoot production.

In this connection, it may be pointed out that the plants which received high levels of NPK showed significantly higher contents of these nutrients in their plant parts (4.43, 4.44 and 4.45).

On perusal of the data (Table 4.49), it is seen that the laterals bear a positive and significant relation with panicles, LAI, compactness and total soluble sugars at flushing and flower forming stage. Increased number of lateral shoots increased leaf number, thereby increasing the leaf area index. Thus the total photosynthetic apparatus was triggered resulting in higher production of carbohydrates which enabled to increase the number of panicles and final yield.

5.1.6 Leaf area index

Since the lateral shoots bear the fresh leaves, any increase in the number of shoots increase the total production of leaves.

Consequently the LAI is indirectly determined by the total number of lateral shoots. In the present

investigation, N at 300g level only has influenced LAI while P and K application resulted in increasing this character up to the highest level. It may be recalled in this instance that the data on leaders and laterals (4.7 to 4.10) showed that these characters were influenced up to 300g N. As such the number of leaves would have been maximum at this level resulting in highest LAI. The relationship of nitrogen and LAI is very well established in many crops. In this study also, this relationship is seen existing is evidenced by the present investigation (Table 4.59).

The production of more leaders, and laterals consequent to P and K application would have naturally enhanced the total leaves and thereby resulted in higher LAI at higher levels of P and K nutrients.

[illegible] index had established the highest relationship with [illegible] at flushing and flowering followed by SLW, total chlorophyll, leaf nitrogen potassium and phosphorus. The [illegible] association of leaf area index (Table 4.49) with yield might be through leaf NPK in the presence of chlorophyll which led to increased dry matter production.

5.1.7 Canopy compactness

N nutrition had influenced the canopy compactness only in seed progeny mainly due to an increase in leaf area.

P application had influenced canopy compactness in both cases. The leaf area index was also seen influenced by P application and the increase in compactness may be attributed to this phenomenon.

K had some influence in increasing compactness in seedlings. In air layers their effect is not seen. The lack of influence of this nutrient on the compactness in air layers is attributed to its overall growth improvement.

5.2 Light infiltration

Light infiltration measured as incident light energy on ground has been negatively influenced by N and K application. The increase in compactness and LAI due to these nutrients has already been explained. This has naturally reduced the light infiltration. K even though has not increased compactness, significantly reduced leaf area index and thereby increasing the light intensity recorded on the ground.

5. [illegible]

5.3.1 Chlorophyll [illegible]

N application has resulted in higher total chlorophyll as well as chl b components.

N is one of the main inorganic consituents of chlorophyll molecule and hence, any increment in N

nutrition would help to maintain the chlorophyll content of leaf tissue at higher level. Schimizu and Torikata (1972) studied the chlorophyll content of Satsuma orange leaves and reported that leaf chlorophyll content was correlated with leaf N and both chlorophyll and leaf N increased by N fertilisation. Similar results were also recorded in this experiment. P has also influenced the chlorophyll content of leaves, just like in the case of nitrogen. P application has also resulted in high P content of leaves (Table 4.44). Increasing leaf P might be responsible for increased chlorophyll synthesis.

K levels showed a marked increase in chlorophyll pigments in cashew in the present investigation. Pissarek (1973) stressed the need of K in chloroplast development. Under nutrition of K results in chloroplasts and mitochondrial collapse (Kursanov and Vyskrebentzeva, 1966). In this study, K would have helped to maintain the chlorophyll pigments that were generated by N application.

The interaction of N and K is significant. The combinations involving highest level of K (150g) have recorded maximum total chlorophyll as well as a and b components. This shows the importance of K fertilisation in preventing the collapse of chloroplasts already formed by the influence of N. Increasing chloroplasts

content by higher levels of N fertilisation and protecting them without collapse by adequate potassium nutrition is to be investigated in greater detail in cashew. This will probably help in achieving greater production in cashew which is at present very low level in India.

An examination of correlation table 4.50 revealed that chlorophyll content was positively correlated with leaf sugars at flushing, flowering and leaf nitrogen. The leaf N in turn was increased by N fertilisation as revealed in Table 4.43. The leaf nitrogen had increased chlorophyll content which in turn might have led to a higher production of leaf sugars at flushing as well as at flowering.

5.3.2 Total sugars

Total sugars in leaf were increased with every increment in nitrogen, phosphorus and potassium. The increased metabolism by way of increased photosynthetic activity results in higher production of carbohydrates. Higher levels of nitrogen increased the total sugars both at flush emergence stage and flower forming stage. The rate of synthesis of total sugars was increased from flush emergence stage to flower forming stage. It clearly indicates that at flower forming, the metabolism of carbohydrates was enhanced to meet the growing demand of flowering and fruit formation. These results

are in acceptance of the results explained by Suryanarayana and Rao (1976 and 1978) who recorded an increase in glucose and fructose contents of mango leaves at the time of inflorescence development when compared to flower bud formation stage.

Increasing levels of nitrogen increased total sugars suggesting that under proper nutrition of nitrogen, the metabolism increases resulting into higher production of carbohydrates. Increased leaf nitrogen showed a positive relation with total soluble sugars at flushing ($r = 0.8460$) and at flower forming stage ($r = 0.8206$). The increased levels of total soluble sugars in plant system contribute to faster filling up of the grains as observed by Johnson and Tanner (1972). It appears that from the results that the current photosynthates contribute to the yield increase. Aulakh and Rao (1983) had also opined that, cashew yields are more dependent on the current photosynthates rather than by mobilisation of reserve foods. Similar results were also reported in apples by Hanson (1971). Kacharava (1975) studying the metabolism of N-containing compounds in satsuma orange leaves in relation to N application observed that high yielders to contain 3-5 times more sugars in leaves compared to poor yielders. He had also reported that

young mandarin trees accumulated more leaf carbohydrates due to an increase in the nitrogen fertilisers.

Increased chloroplasts increase the incorporation of inorganic phosphate besides CO_2, NH_3 and HNO_2 and exports triosphosphate and amino acids. Inorganic phosphate also had a considerable influence on starch synthesis in the chloroplast. ADP-glucose pyrophosphorylase is a key enzyme in starch synthesis and is allosterically regulated by inorganic phosphate and PGA (Preiss and Levi,1979). According to Heldt, et al.(1977) highest rates of starch synthesis were obtained with a PGA and Pi ratio of about 1:7. Increased levels of inorganic phosphate in the chloroplast triggers the triosphosphate production which is a precursor of sucrose synthesis.

Potassium is known to have a beneficial effect on ATP synthesis (Latzko and Kelly, 1979; Hart, 1972; Pfluger and Mengel, 1972). As ATP is required for numerous synthetic reactions, potassium may indirectly promote the synthesis of various organic compounds, such as proteins, sugars, and polysaccharides. Potassium levels gradually increased leaf sugars from 50g to 150g levels of application both at flush emergence and flower forming stages. Application of potassium also increased leaf potassium and was correlated with leaf

sugars (r=0.6752) at flower formation stage and (r=0.5138) at flush emergence stage indicating the essentiality of K in synthesis of sugars.

Total sugars in leaf at flushing and flower emergence stage established a positive relation with yield (Table 4.50), leaf nitrogen, phosphorus, potassium and root CEC. The increased root CEC would have helped in increased absorption of these elements thus helping in the synthesis of carbohydrates which ultimately reflected on yield production.

5.4.3 Cuticular resistance

N application has significantly increased cuticular resistance of the leaves. A perusal of the data on leaf moisture content (Table 4.21) showed that N application had significantly increased the same. It is generally accepted that under full turgour and nutrient availability, the metabolic activities increase leading to development of plant organs. Since, N is actively involved in the metabolic processes of the plants, the thick epidermis development might be the resultant of such metabolic processes. The development of thick epidermal layer offers resistance to transpiration. Association of higher cuticular resistance with increased productivity were reported by Brag (1972) Szarek and Ting (1974) and Yoshida and Coronel (1976) in other crops.

P application on the other hand gave decreased resistance at every level of application. The possible increase in cellular respiration and its effect on increased transpiration might have resulted into high rate of water loss with the increase in the level of P. K application from 50g to 150g did not bring any appreciable change in cuticular resistance. The highest level of K in this study failed to increase the cuticular resistance in cashew leaf. Probably suggesting that the highest level of application in this study is far below the requirement of the crop.

Dela Cadrdia and Benlloch (1980) emphasized the essential role of K for turgour. The high loss of water in plants not supplied with adequate level of potassium may also be due to a possible increase in transpiration rate both by stomatal and cuticular. The decreased cuticular resistance to water loss due to inadequate level of potassium application possible be the indirect effect on the development of their cuticle in leaves (Hagiraith, 1979).

The interaction NK is significant. Maximum resistance was recorded in N1K3 combination followed by N3K3, N2K2 and N1K1. In a treatment which received equal amounts of N and K, maximum loss of moisture was recorded. When N level was increased, under constant K level, resistance was found to increase. However, the

reverse was not true. This had indicated that cuticular resistance was mainly controlled by nitrogen levels compared to potassium levels in this experiment. This further strengthens the previous results. Since, cashew is a crop grown under rainfed conditions on marginal lands, the importance of application of higher doses of potassium for inducing drought resistance is stressed and to be further investigated employing higher levels of potassium.

5.3.4 Leaf water content

The leaf water content is an important factor for cashew as it helps the palisade parenchyma to keep in more succulent conditions. The nutrition has been found to play a definite role in keeping the moisture content of leaves at a certain level. From the present study, it is noted that N had a significant role in maintaining the moisture content at satisfactory level. P and K also had increased leaf moisture content. The role of N in increasing the succulence of the tissue and thereby resulting in high moisture content was very well established (Ruttey, 1968). P would have acted indirectly through the beneficial influence of N by leaf water content by increasing the N uptake (Table 4.43). Leaf water content showed a significant and positive relation with precocity of flowering (r=0.7501) and nut yield (r=0.7523).

5.3.5 Specific leaf weight

Specific leaf weight was increased with an increase in the levels of nitrogen, phosphorus and potassium. Increased chlorophyll pigments with an increase in photosynthetic activity increases the dry matter production under unlimited nutrient supply. This hypothesis was tested by Murata (1961) working on rice who recorded higher leaf area per unit leaf weight associating with low photosynthetic ratio and low productivity. Pearce et al. (1969) recommended SLW as a selection criterion for increasing yield in alfalfa since they could correlate the photosynthetic capability with SLW. Nitrogen application brought a significant increase in SLW in cashew and correlated well with yield (r=0.6497). Similar results were reported by Yoshida and Coronel (1976) who established a positive relation between nitrogen content, SLW and N. In fruit tree crops like apples, Tarini and Tukey (1961) suggested that SLW to be a reliable index of the previous environment of leaf and could establish a positive relation between leaf Pn and SLW. In this study also a positive correlation was observed between SLW and total soluble sugars.

SLW or in other words leaf dry matter was increased by P application probably through an increase through leaf sugars by this nutrient is already explained.

Higher levels of potassium helped to increase the specific leaf weight in cashew probably through increased level of chlorophyll pigments, enzyme synthesis and sugar production. SLW was increased with the increase in the level of potassium in the presence of nitrogen. The efficiency of potassium utilisation is enhanced in the presence of higher level of nitrogen with respect to drymatter production. Such types of results were reported by Gartner (1969) and Heathcote (1972).

SLW showed a positive relation with yield (Table 4.50). It had also a positive reaction with total chlorophyll, soluble sugars, leaf nitrogen, phosphorus and potassium. The increase in yield through SLW might be through higher production of photosynthates by increased photosynthetic rate in the presence of high chlorophylls, leaf nitrogen, phosphorus and potassium due to NPK application.

5.4 Fruit characteristics

The fruits of H1-7 variety are long yellow with bold nuts as seen in the mother tree.

5.4.1 Volume and weight

N and P fertilisation had a decreasing effect on fruit volume as well as on weight. Increasing levels of N and P decreased fruit volume substantially. Though,

not much literature is available on the effect of fertilisers on fruit volume of cashew, a good deal of reports were published in other crops. These results are in agreement with Koo and Reese (1975) who recorded smaller orange fruits in Hamlin, Pineapple and Valencia oranges due to an increase in nutrition. It is postulated that the photosynthetic activity before flower formation decides upon the sink strength and hence forth, under high level of nutrition a greater sink strength will be formed. In this investigation also, the number of panicles were substantially increased by nitrogen and phosphorus application (Table 4.38). Due to increased sink strength, the photosynthates are evenly distributed among the developing sinks. Eventhough, an increase in source has taken place due to nitrogen application (Table 4.11) it is presumed that the increase in sink is to a higher extent than that of the source, thereby the photosynthates available per sink is reduced. However, K application had a profound positive effect on fruit volume as well as weight. Largest and heaviest fruits were recorded under 150 g K2O application. These results are in agreement with Koo and Reese (1972 and 1977) who recorded larger fruits of citrus cultivars with increased K application. The role of K in translocating sugars into the developing fruit might

have helped in increasing the fruit volume and weight (Hall and Barker,1972 and Kiely,et al.1972).

5.4.2 Juice

All the nutrients had a positive effect in increasing the juice per cent of apples. Even though, volume of fruit was decreased by N and P application, the percentage of juice was seen increased by the same. The number of panicles were decided early and after meeting panicle initiation requirements of N and P by the first levels, the subsequent levels had probably helped to increase the percentage of juice. Eventhough weight was not showing any increase with regard to potassium, both volume and percentage of juice were seen increasing. This probably signifies the added importance of potassium in this crop. Koo and Reese (1977) also reported an increase in fruit juice due to K application to temple orange trees.

Juice percentage was increased significantly with the increase in leaf nitrogen, phosphorus and potassium (Table 4.30), while an increase in leaf calcium and magnesium decreased the same in cashew apples. Increasing the quantum of juice increased ascorbic acid content and decreased total soluble solids.

5.4.3 Total soluble solids and sugars

N fertilisation had given a positive influence on the TSS and sugar of fruits. However, P application gave a negative trend in this character. K had no effect at all. The role of N in increasing the source and photosynthetic mechanism is well established. This has naturally resulted in an increased carbohydrate conversion into sugars with consequent increase in TSS of fruits. However, P is seen to reduce these characters. It may be mentioned in this connection the sums total of the sugars available per sink is partitioned between fruit and developing nuts. It is reported that about 8.7 per cent (Ohler, 1979) of sugar is present in the nut. This obviously has to come through the fruit. Since the effect of P in carbohydrate synthesis is less than that of N, the available sugar will have to be rather divided between fruit and nut or in other words the partners (Plate 15) in the sink are acting in competitive manner. (Embleton, et al. 1980). The lack of significant result with regard to K is explained due to an increase in the fruit volume as well as juice percentage, with the result that the sugar content had almost remained same.

From the Table 4.30 it is seen that fruit sugar content established a significant and negative relation

with leaf phosphorus and potassium while leaf calcium had a positive and significant relation. Fruit sugars had a positive and significant relation only with total soluble solids. Leaf phosphorus and potassium had a negative and significant relation with total soluble solids, while leaf calcium showed a significantly positive relation (Table 4.30).

5.1.4. Juice reaction and ascorbic acid contents

Application of all the three nutrients had registered an increase in the ascorbic acid content (Table 4.29) with a consequent reduction in juice reaction (Table 4.28). Similar increase in juice reaction and ascorbic acid contents have been reported in other fruit crops. These results are in conformity with Reitz and Koo (1960), Azzony et al. (1970) who established a positive relation with leaf nitrogen and juice acidity. Moss (1972) reported the association of high leaf P with low acidity, whereas Koo and Reece (1975) and Embleton et al. (1980) confirmed that an increase in leaf K increases fruit acidity in various citrus varieties.

Fruit acidity had a negative relation (Table 4.30) with leaf nitrogen, phosphorus and potassium while leaf calcium and magnesium had a positive relation. Juice acidity had also a negative and significant relation with juice percentage and vitamin C content where as it has a positive relation with total soluble solids. Only

leaf nitrogen had a positive and significant relation with ascorbic acid content of fruits (Table 4.30), whereas leaf magnesium exhibited a significant and negative relation with ascorbic acid content.

5.5 Nut characteristics

5.5.1 Volume weight and density

Nut volume was decreased by N,P and K application. The nut weight was also seen decreased significantly only by N and P application. However, N and P nutrition did not have any effect in increasing the nut density, eventhough K application specifically increased the same.

The decrease in nut weight and volume by different levels of N and P applied in the investigation is attributed to increased number of panicles (Table 4.38) and number of nuts (Table 4.40) consequent to their application. As the number of sinks is more, naturally the size per nut will have to be lesser due to dilution effect (Plate 9, 10, and 11). This has also reflected in nut density, where in no effect is noticed due to N,P application probably because there was a corresponding decrease in both the volume as well as weight of nuts. However, in case of potassium, volume was decreased significantly and the nut weight remained almost same, where as there was an increase in nut density by different

levels of K. This shows that even though the nut volume was decreased, the nut weight was not decreased with the result there was an increase in nut density.

N application also decreased nut weight while recording an increase in leaf N (Table 4.43) and a reduction in leaf K (Table 4.45). The reduction in dry matter accumulation due to insufficiency of K in the presence of high levels of N was well established by Gartner (1969) and Northcote (1972).

Similarly P application had also decreased nut weight. P application at higher levels would have reduced zinc absorption by forming zinc complexes (Table 4.48). This is substantiated by negative correlation between leaf P and zinc (Fig.9). The decreased uptake would have naturally reduced IAA synthesis which is essential for plant metabolism. Another probable reason is that P application reduces CEC of roots as seen From the correlation tables, thus reducing much of the cation uptake. All these factors would have led to a reduction in nut weight (Cogliati and Dalla Rosa, 1980). Referring to the production functions (Table 4.57), it was seen that a linear response was functioning with K application. This suggests that the applied K is not sufficient. This may be another reason for reduced K content of leaf (Table 4.45). Similar reports were

given by Mengel and Haeder (1974) who observed a reduction in the rate of grain filling under high level of N and at sub-optimum levels of K.

Lefebvre (1973) also opined that the best results of NPK application were masked due to induced Zn deficiency and its effect on nutrient translocation to cashewnut.

5.5.2 Shelling percentage and test weight

These both characters were seen influenced by N and K. However, P had only produced effect on shelling percentage. The increase in the shelling percentage and test weight due to N and P might be explained on the beneficial effect of these nutrients as already explained. In this connection, it may be noted that there was a decrease in the volume and weight of nuts by N and P application. The lesser the volume, and the weight of the nut, the more the shelling percentage and test weight. As already explained the present level of fertilisation is just adequate for increasing the number of nuts. This has even though produced a small but significant effect in increasing the test weight especially in the case of P and K where in the linear trend is noticed. Further levels of P and K are required to obtain higher test weight.

5.5.3 Protein content

The NPK nutrition has definitely improved the quality of kernel. The beneficial effect of N is attributed due to the shifting of balance between carbohydrate and protein in favour of the later. Similarly P application had also influenced protein, through nitrogen. K would have helped in mobilising the precursors of proteins and translocating it to kernels (Watanabe and Yoshida, 1970; Hartt, 1972; Pfluger and Mengel,1972).

5.6 Yield attributes

5.6.1 Precocity of flowering

Flower bud initiation starts only after complete cessation of monsoon under west-coast of India. After flushing any amount of rain considerably prolong the gap between flushing and flower formation. Genotypic variability is found to exist. However, in a particular genotype, especially in air layers, application of fertilisers normally advances flushing and flowering compared to plants grown without proper nutrition. Highest levels of nitrogen application has significantly decreased the gap from flushing to flowering to 26 days. Rao and Hussain (1975) reported a minimum of 32 days for all the panicles to come out. Ohler (1979) also observed

30 days gap between flushing and flowering under Jamaica conditions.

Phosphorus showed a conspicuous reduction in the time taken from flushing to flower formation stages. Earlyness in flowering by P application is well established fact and needs no further explanation.

Potassium application at 150g level narrowed the gap between flushing and flower formation stages. May be, increased levels of potassium increased leaf potassium content and helped in transportation of the reserved pools to the growing points, thereby enhancing the growth rate and reducing the period between flush and flower initiation stages.

5.6.2 Number of determinate shoots

A greater amount of leaf area with elevated photosynthetic activity of new flushes demand a wider sink. This helps in elevating the growth and development of sinks (Plate 11) and hence, higher level of nitrogen helped to increase the flower panicles. Maximum number of productive laterals were produced at 150g level of phosphorus application. Increased level of phosphorus application increased leaf phosphorus content there by triggering the photosynthetic apparatus and phytohormone metabolism resulting in an increase in total determinate

shoot production. Potassium application increased the number of panicles. The role of potassium in enhancing the nitrogen metabolism and its effect on synthesis and translocation of carbohydrates was well documented earlier. Increased general nutritional status of the plants must have helped to increase the number of panicles.

The interaction NP, NK and PK are significant. The maximum values were obtained at the highest level of combinations. As expected, this is due to the balanced nutritional effect on this vital yield attributing factor.

The data on correlation coefficients (Table 4.50) indicate that the number of panicles was associated with LAI, sugars at flower formation stage, LAI, leaf nitrogen and total chlorophyll. Under favourable conditions, increased LAI and total chlorophyll would have helped to increase the total soluble sugars and thereby increasing the substrate for determining the sink strength. Thus increased sink strength helped to improve the relation with yield production.

5.6.3 Determinate to total shoots

Increased N and K nutrition substantially increased the ratio indicating that the production of

Plate 11. Cashew trees in full bloom under
irrigation treatment

N.P.K.
AIR LAYER

panicles was increased. However, P application had no effect on this ratio. It may be seen from the table 4.38 that the number of panicles were significantly increased by N,P and K nutrition. It is inferred that in the case of N and K vegetative shoots must have not been increased in the same model as that of reproductive shoots. With the result that there was a beneficial effect noticed in the ratio. However, in case of phosphorus, there was a progressive increase in the vegetative shoots as well with the result that the ratio was not significantly influenced. Added to this, the effect of phosphorus in inducing more lateral buds was already discussed, might be another possible reason for increasing the number of panicles.

5.6.4 Number of nuts:

Application of N and P fertilisers had substantially increased the nut number. However, similar rate of increase was not recorded with K levels.

N and P application increased the number of determinate shoots (Table 4.38) and total soluble sugars both at flush emergence and flower forming stages (Fig. 4). This indicated that both at flush and flower emergence stages, substrate synthesis was increased to meet the growing demand for carbohydrates for the

Plate 12. Abortive panicles in under nutrition plants

development of sinks. Since, the sink strength was decided much earlier and proper supply of substrate was ensured at the early development of sinks, it would have helped to retain the sink number at higher degree. Pillai and Pillai (1975) recorded a reduction in the number of sinks after pollination due to heavy shedding at various growth phases. They opined that the shedding might be due to a reduction in the carbohydrate supply to the growing sinks in cashew.

3.7 Nut yield

Fertilisation in cashew had a marked effect on growth and yield. Cashew trees under improper management and nutrition came to bearing very late (Ohler, 1979) and the yields were inconsistent. Such type of trees look lanky with sparse foliage hardly to meet the metabolic needs (Plates 7 and 8) irrespective of the progeny. On the contrary, plants supplied with balanced nutrition produce thick foliage with well developed panicles and nuts at an early stage (Plate 11).

In this investigation also, cashew yield was influenced by the number of productive panicles, surface area, LAI, number of leaders and laterals in that order.

In this connection, it may be noted that [illegible] ness is not at all [illegible] probably this is a [illegible] breeders. Certain [illegible] chlorophyll, [illegible] tion stages have [illegible] order. How the [illegible]

[illegible] application [illegible] higher yield [illegible] In the case of air layer [illegible] The comparative yield figure [illegible] of [illegible] 1.111 kg/tree in layers [illegible] is increasing [illegible]

Plate 13. Small nuts in N3P3K3 treatment

of panicles had increased by N application which had increased the nut number. N application had also increased leaf nitrogen which also would have helped to enhance LAI. The correlation studies conducted showed that the yield was positively correlated with surface area, productive panicles LAI and total chlorophyll.

Phosphorus has manifested its role in increasing the yield. P$_3$ level of phosphorus application had recorded the highest yield. Yield increase in cashew due to phosphorus application was reported by Lefebvre (1973), Pajari (1977) and Jambiar (1983).

Scrutiny of the correlation table reveals that surface area, LAI and leaf sugars at flushing and flowering stages were significantly correlated. The increase in surface area and LAI due to phosphate application was an indirect effect of nitrogen absorption as already explained. Phosphorus was directly influencing the sugar metabolism at flushing and flowering stages. The increase in leaf sugars in turn had increased productive panicles, which had a strong correlation with the former.

K had also influenced production in both the plant materials through its influence on surface area,

Plat. 1:. Bold nuts in N1P1K1 treatment

leader, laterals, productive panicles, LAI, total chlorophyll, leaf sugars at flushing and flowering leaf nitrogen and leaf phosphorus (Table 4.50).

K being a catalytic element, had influenced the uptake of other elements considerably. Its effect on the synthesis and translocation of sugar was already explained. The relationship with chlorophyll, LAI and surface area was through the indirect effect of nitrogen absorption.

On a comparison of the two tables 4.41 and 4.42 of the respective progenies it was found that the layers were more productive than the seed progeny during this period. Layers also resulted in more response to the applied fertilisers.

5.8 Leaf nutrient composition

Leaf nutrient contents of trees largely depend upon the location, age, genotype, type of the soil used and management practices in many of the deep rooted perennial trees. Literature available in cashew in these aspects mainly suffers from lack of descriptive analysis of the genotype.

5.8.1 Leaf nitrogen

N application had increased leaf N significantly during the course of study. Increasing levels of N

application to soil would have helped in direct absorption of this element by cashew trees. Similar results were observed by many workers in other crops. Reese and Koo (1975a) observed an increase in leaf nitrogen due to increased N fertiliser application to Hamlin, Pineapple and Valencia oranges. Milella and Deidda (1976), Reese and Koo (1977) and Hernandez (1979) also recorded increased levels of leaf nitrogen due to higher amounts of nitrogen application to different varieties of citrus trees. Reddy et al. (1983) recorded that increasing nitrogen application at 1500g per tree/year increased leaf nitrogen when compared to control.

The data indicated that (Table 1.50) leaf nitrogen had a positive and significant relation with [illegible] and root CEC. The role of root CEC in [illegible] and [illegible] was discussed earlier. Thus the increase in leaf nitrogen was mediated through various physiological process, ultimately establishing a positive and significant relation with yield.

5.9.2 Phosphorus

Phosphorus application enhanced leaf nitrogen in cashew. Increasing levels of phosphorus increased leaf nitrogen from 50g P_2O_5 to 150g P_2O_5 application. Since phosphate and nitrogen are required for the

metabolism in plants, an increase in phosphate in plant systems normally is associated by a concomitant increase in nitrogen supply by the soil.

Leaf phosphorus content progressively decreased with the increase in the level of nitrogen application. These results are in conformity with many workers who reported that decrease in leaf phosphorus, with increased N application in Valencia oranges. Kazak and Khalidy (1976) in Eureka lime, Khalidy and Nayyal (1976) in Avana mandarins, Millecia and Deidda (1976) in mandarins and Reddy et al. (1983) in cashew. Leaf nitrogen established a poor relation with leaf phosphorus.

Phosphorus and potash application increased P content of leaf. The reasons for increase in P content by P application had already discussed earlier.

5.3.4 Potassium

Application of potassium application increased leaf nitrogen by the addition of successive doses. The role of potassium in maintaining the turgidity and its effect on photosynthesis was well drawn in earlier paragraphs as described by Pfluger and Wiedemann (1977). Probably an increment in the potassium levels resulted with a concomitant increase in nitrogen absorption to meet the demand for the synthesis of protein and carbohydrates. Leaf nitrogen established a positive and

significant correlation (Fig. 9) with leaf potassium, indicating the simultaneous increase in leaf nitrogen and potassium.

Potassium application showed a significant increase in leaf phosphorus. The role of K in increased efficiency of phosphate was well detailed in many other crops. Pfluger and Wiedemann (1977) detailed the association of P and K and reported that the low molecular weight compounds such as amino acids and sugars may accumulate in plants poorly supplied with potassium was probably not a direct consequence of impaired enzyme activity but due to answer to an inadequate energy (ATP) supply. Thus creating energy shortage that induce a delay in protein synthesis which in turn may indirectly effect enzyme activity because a lack of enzyme proteins. An increase in leaf phosphorus showed a significant increase in leaf potassium as evidenced by positive and significant correlation (Fig. 9) supporting the mutual relation in photosynthetic process as described by Mitsui and Yoshida (1970).

Leaf potassium also declined with the increase in the levels of nitrogen just like in the case of leaf phosphorus. It may be due to the antagonistic effect of nitrogen with soil potassium that led to reduced

absorption by cashew trees. The synergistic role of potassium in the presence of nitrogen in loading the photosynthates was well established by Mengel and Haeder (1974).

Leaf potassium increased by the application of phosphorus. High amounts of super phosphate application indirectly adds more of calcium to the soil. Thus the increased level of soil calcium enhances absorption of potassium, as a result, the plants will be in a position to maintain higher levels of potassium. Similar results were reported by Vaisel (1962) who recorded enhanced uptake of monovalent cations like potassium under high level of calcium in root medium of barley plants.

Potash application showed an increase in leaf potassium. Increased potassium availability would have [illegible] the soil solution by the ion exchange mechanism. Leaf phosphorus and leaf potassium established a positive and significant relation (Fig. 9).

5.3.3 Calcium

Leaf calcium showed an increasing trend with the increase in the level of nitrogen application. Since, nitrogen has an antagonistic effect, higher

Plate 15. Development of competitive sinks (fruit and nut)

levels of nitrogen must have replaced calcium in the soil and thus calcium concentration was increased. These results are in conformity with Khalidy and Nayyal (1976) who observed a positive increase in leaf calcium due to increasing level of nitrogen to Eureka lemon.

Phosphorus application at 150g level substantially brought down leaf calcium to 0.12% when compared to 0.21% at 50g level of application. Under low pH of the soil, phosphate might have formed into insoluble complexes leading to reduced calcium availability to plants. Increasing leaf P established a negative and significant correlation with leaf calcium (Fig.9).

Calcium absorption was reduced by K fertilisers in cashew plants as evidenced by reduced calcium levels in leaf. Similar results were reported by many workers. Bonnemann and Snowball (1960) demonstrated that calcium content of plants was to a large extent genetically controlled and was little affected by the calcium supply provided that Ca supply was adequate in root medium for normal growth. But under limited supply, the uptake of Ca can also be competitively depressed by the presence of other cations, such as K and NH_4 which are rapidly taken by roots due to higher cation exchange capacity of roots (McLean, et al. 1956; Smith and

Wallace, 1956 and Drake (1964).

5.8.5 Magnesium

Nitrogen and potassium application to cashew showed a reduction in leaf magnesium. Leaf nitrogen established a negative relation (Fig.9) with leaf magnesium. The competitive effect of NH_4 and K on Mg uptake was observed by Mulder (1954).

Magnesium levels came down in leaf tissue due to increased levels of potassium application as revealed from correlation tables. This might be the probable reason for decreased Mg due to K application which is explained by the antagonism between Mg and K (Mulder, 1950). These results are in agreement with Hall (1971), Prine, et al. (1974) and Leggett and Gilbert (1969). Leaf potassium established a negative correlation with leaf Mg (r=0.20 s) indicating the competitive effect of potassium with magnesium absorption.

5.8.6 Zinc

Leaf zinc content was increased up to N_2 level. Zinc is closely involved in the N-metabolism of plants. Price et al. (1972) cited a number of references where In protein synthesis was hindered at zinc deficient levels. Increased nitrogen levels increases growth rate Indirectly by way of increasing tryphtophane, a

precursor to IAA synthesis (Tsui, 1948).

Phosphate application significantly brought down leaf zinc in cashew. The interaction of zinc with phosphorus was studied by many workers and high level of phosphorus was well known to induce zinc deficiency. A negative correlation was recorded between leaf P and leaf Zn justifying the above reasoning.

5.9 Critical concentration of N and K in leaf

Plant yields are normally limited by one or the other plant nutrients. The limited plant nutrients may exert adverse effects in terms of growth and yield. Normally in tree crops the initial symptoms or hidden hunger may not cause a visual set back to plants but as soon as the concentration drops beyond hidden hunger levels, there used to be a reduction in yield. Hence, it would be better to identify the nutritional status of the plant as a whole before any effective fertilisation programme.

Haq et al. (1975) recorded maximum growth at 2.4% - 2.8% and poor growth at 0.98% - 1.38% leaf N whereas Faluade (1978) reported maximum growth at 1.2% leaf N. The maximum response ranged from 2.09% to 2.84%. Though the maximum per cent nitrogen as

reported by Haag et al. (1975) is near to these maximum levels, the results reported by Falade (1978) are far below.

Haag et al. (1975) gave 0.16% - 0.20% leaf phosphorus to be adequate and 0.11% - 0.14% to be deficient ranges in relation to growth whereas Falade (1978) reported 0.118% leaf P to be optimum for maximum growth in cashew. In this study, the maximum response varied from 0.11% to 0.17% leaf P. The critical concentration worked out for phosphorus in this study is almost in agreement with the results of Haag et al. (1975). The non significance of the quadratic functions fitted might be due to a very large variation in yield under a particular nutrient concentration in leaf.

Since, trace crops show a reduction in certain elemental concentrations with ageing (Smith, 1962), it would be better to fit certain range for nutrients for higher yields rather pin-pointing to a particular value. The possible reason for variation in critical concentrations of N and P in this study with Haag et al.(1975) and Falade (1978) is that the critical concentrations were fixed in seedlings with reference to growth.

5.10 Root cation exchange capacity

Determination of cation exchange capacity of the root is an indirect approach to establish the nutrient absorption and in turn its relation to crop productivity. Evidences are that CEC is highly influenced by native soil fertility and also by applied nutrients.

N application increased root CEC of cashew. Increasing level of N application increased root CEC in oats, corn, wheat is reported by McLean et al.(1956). Later these results were conformed by Smith and Wallace (19). Drake (1964) postulated that higher level of nitrogen increases root CEC possibly by increasing cell division and by decreasing the non-pectic carbohydrates in cell walls of the roots. He felt that the increase might be due to increased number of exchange sites. Increased root CEC also increased nitrogen absorption as evidenced by high leaf nitrogen (Table 4.49). Root CEC had a positive and significant correlation with leaf nitrogen (Table 4.50).

Root cation exchange capacity was increased by the application of P fertilizers at 100g and 150g level compared to 50g. The increase in CEC due to P application may not be the direct effect of phosphate, being an anion, but by the increased calcium that is

present in single super phosphate. P application might have also increased the root growth and also absorption sites and hence, the increase in root CEC. This is clearly evident by the poor relation between CEC of roots and leaf phosphorus (Table 4.50). These results are in agreement with Paliwal and Subramanian (1969, who could not bring about any change due to phosphate application in root CEC.

K at 100g and 150g increased root CEC over 50g level of application. Increasing levels of potassium have also increased root CEC by way of increased root growth. Shiwin and Mahajan (1968) reported that the plant roots of high yielding varieties gave higher values of CEC and consequently were capable of withstanding higher dose of fertiliser application. Mattson and Koutler (1943) developed a theory relating to CEC of plant roots and differential uptake of mono and divalent cations for different plant species on the basis of Donnan's equilibria. According to this concept, plant roots of high CEC would absorb relatively more divalent cations than those of monovalent cations and vice-versa.

In this study, the plant root might have also absorbed cations according to the Donnon equilibria but their proportionate absorption into the leaves might

have not taken place due to translocation of ions into different parts of the plant. In this context, it is appropriate to mention that a major portion of Ca absorbed by cashew would be stored in bark (Kumar,1982) without translocating to the leaf. This indicated that though calcium was absorbed by cashew roots, it need not necessarily be reflected in leaf concentration since, bark is the store house for Ca. In such cases the relation becomes erratic as explained by Palival (1969).

5.11 Soil analysis

Soil organic carbon was reduced due to application of nitrogen. In general, soil phosphorus content was increased with the application of N (Table 4.54). Leaf Ca was also increased due to N application (Table 4.16). Leaf phosphorus was also more in the N applied plots when compared to P or K applied plots. In other words, N application would have increased P and Ca contents of soil, which would have helped to mineralise organic matter thereby resulting in the reduction of organic carbon. N application has however helped to increase N content of soil. Residual P content was seen decreased by N application at higher levels. N application had not given a definite trend in residual K content of soil.

P application had not significantly influenced organic carbon. There was a small increase in the residual N content of soil. More of phosphorus application increases mineralisation leading to a higher content of N in the soil. P helped to increase soil K. A perusal of the data on CEC, showed that P increased the above factor thus leading to high K content.

K does not have any significant effect on organic carbon content. K was found to reduce P content but a marked increase in soil K was recorded.

N application had generally increased soil pH. In the case of P also a similar trend was noticed. K had definitely helped to increase pH, The table 4.51 on CEC shows that this character was increased by the application of NPK. This would have had some influence on pH. It is also interesting to note that original pH was only 4.9 and there was a general increase in pH due to the crop management for 5 years.

5.12 Production function

The production functions for N and P showed curvilinear fashion and potassium showed a linear response. As discussed earlier, the sink strength is

determined much earlier and the nut filling takes place only at a later stage. On perusal of the data on individual nut weight (Table 4.32), there was a decrease as level of N and P increased. This had resulted due to an increase in the number of nuts. This indicated that the number of sinks were enhanced but at the same time there was no significant increase in total nut weight from second to third level of application.

In contrast to N and P, potassium showed a linear response. Individual nut weight did not decrease significantly even under K3 level of application indicating that K3 level itself is far below to enhance the number of sinks substantially even in early stages.

These results indicated that N and P between second and third level are sufficient. K level needs to be enhanced to push up the total sink strength (number as well as weight of nuts) far beyond the maximum doses tested in this trial.

5.13 Economic optimum doses of N and P fertilisers and expected yield

Under the above explained situations, the optimum doses for N (Table 4.38), fall between second and third levels of application, i.e. for N 430.00g/tree/

year and for P, between the second and third level, 130.000g/tree/year with an expected yield of 4.71 kg and 4.50 kg/tree/year respectively.

In case of K the optimum dose was not worked out in view of the linear response to applied K. In this investigation, the maximum dose given was 150g K/tree/year and an overall increase in production will be possible by higher levels of potassium on account of the linear trend obtained in this case.

In the present investigations, a ratio of 3:1 NK is followed. This is mainly due to the reason that the present package practice of recommendation for cashew is 250:125:125 NPK/tree/year (Bavappa, 1982). However, based on the present investigation, it is almost clear that K level has to be improved for getting the higher yield. It is also to be mentioned in this connection for many of the crops like coconut, arecanut, banana and sugarcane, more or less 1:1 NK ratio is being followed.

5.14 Economics of fertilisers application

Application of P and K fertilisers at their third level recorded the maximum net income in seed progeny as well as in air layers, while P at 150g level in seed progeny and 100g level in air layers recorded the

maximum net income. On perusal of the data, it is seen that the income realised from air layers was almost double when compared to seed progeny. The advantage of planting vegetatively propagated plant material is not only to get uniform yield but also to realise more income at an early orchard life.

Summary

VI. SUMMARY

Studies were made to assess the effect of NPK fertilisers on growth and yield of seed progeny and air layers of cashew at Central Plantation Crops Research Institute, Cashew Seed Farm, Shantigodu during 1982-83 and 1983-84.

The findings of the investigation are summarised as follows:-

Seed progeny and layers recorded maximum height at 450g N and 300g N levels respectively. Phosphorus and potassium each at 150g levels recorded the tallest plants in both the plant materials.

Canopy radius was not influenced by nitrogen levels in seed progeny, whereas in air layers, 300g N level of application recorded the maximum. Phosphorus and potassium at their highest levels of application recorded maximum canopy radius both in seed progeny and air layers.

Maximum surface area of seed progeny was recorded at 450g N level where as the same was observed at 300g N level in air layers. Phosphorus and potassium at their highest levels recorded maximum surface area in both the plant materials.

Nitrogen levels did not bring any effect on the number of leaders of seed progeny while 300g N in air layers recorded maximum leaders. Phosphorus and potassium at their highest levels increased the leader production in both the plant materials.

Nitrogen increased lateral shoot production up to the highest level in seed progeny and up to 300g N level in air layers. Highest levels of P and K recorded maximum lateral production in seed progeny as well as in air layers.

Nitrogen application at 450g level significantly recorded maximum canopy compactness in seed progeny while it had no effect on air layers. For maximum compactness, 100g P_2O_5 level was sufficient in seed progeny and 150g P_2O_5 level for air layers.

All the levels of NPK fertilisers decreased significantly the incident radiation on the ground in air layers by increasing the canopy growth.

Nitrogen at 300g level, phosphorus and potassium at the highest levels increased leaf area index significantly in air layers.

Total chlorophyll in air layers was significantly increased by every level of nitrogen, phosphorus and potassium application.

Increasing levels of NPK fertilisers significantly increased total sugars both at flush and flower emergence stages. Leaf cuticular resistance was influenced considerably by N application. Leaf water content was increased significantly with every increment in the level of nitrogen, phosphorus and potassium. Specific leaf weight was increased markedly by NPK fertilisers.

Nitrogen at the highest level induced early flowering. Every increment in the levels of P and K also induced earliness in flowering. Panicle production was increased significantly by NPK fertilisation. Highest ratio of determinate to total shoot production was recorded at 450g N level of application, while the same was recorded at 100g level each of P and K.

Fruit volume was decreased by N and P fertilisation, while potassium increased the same. Nitrogen and potassium favoured juice percentage in fruits. Ascorbic acid content was generally increased by NPK fertilisation.

In seed nursery, maximum yield was obtained by NPK at their highest levels. NPK had influenced the total production of nuts in the layers and maximum production was obtained at 450g N, 100g P_2O_5 and 150g K_2O.

Nut density was increased by K application alone. Shelling percentage was increased by NPK application. Only N and K had influenced test weight of kernels. NPK fertilisation had positive effect on kernel protein content.

Leaf N was increased by NPK application. Leaf phosphorus was increased by P and K application while N has reduced it. Leaf potassium was decreased due to nitrogen application while it was increased by P and K application. Nitrogen application resulted in an increase in leaf calcium where as phosphorus and potassium levels have significantly reduced the same. N and K reduced leaf mg while P had no effect. Leaf zinc was increased by N but decreased by P. K had no effect.

The critical levels for N and P in leaf are fixed at 2.03% and 0.14% respectively. The maximum levels of leaf N and P for maximum response are fixed at 2.84% and 0.17% respectively in this study.

Root CEC was increased by NPK fertilisation. N application reduced organic carbon and P, while it increased soil OC and pH. Phosphorus application increased soil N,K and pH. Potassium application increased soil N,K and pH where as it reduced soil P.

Nitrogen and phosphorus responses were curvulinear and potassium response was linear. The optimum doses worked out for N and P are 430 and 130g/tree/year respectively. The expected yield at optimum doses of N and P are 4.71 and 4.50 kg nuts/tree/year respectively.

Maximum income was realised at the highest levels of N and K and P at middle level in air layers, while in seed progeny, the highest levels recorded the maximum profits. Air layers give more income than seed progeny consequent to fertilisation.

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EFFECT OF NPK ON SEED PROGENY AND AIR LAYERS IN CASHEW
(*ANACARDIUM OCCIDENTALE L.*)

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ABSTRACT OF A THESIS
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ABSTRACT

An experiment was conducted to assess the effect of NPK fertilisers on seed progeny and air layers in cashew at Cashew Seed Farm, Shantigodu under Central Plantation Crops Research Institute, Regional Station, Vittal 574 243, during 1982-84. The treatments consisted of testing three levels each of N, P and K on seed progeny and air layers in cashew.

The study revealed that different growth parameters viz., height, canopy radius, surface area, leaf area index, number of leaders, laterals and canopy compactness were influenced by increasing levels of NPK fertilisers.

Total chlorophyll, total sugars, leaf water content, and specific leaf weight were influenced by NPK fertilisation while nitrogen alone increased cuticular resistance. Earliness in flowering, number of panicles and ratio of panicles to total shoots were increased by fertilisation.

Fruit juice percent and ascorbic acid content were favoured by NPK application.

Nut volume and weight were decreased due to N and P application while K application favoured nut density and test weight of kernels.

Leaf N was increased by NPK. Leaf P was increased by P and K application while it was reduced by N application. Leaf K was reduced by N application while it was increased by P and K application. N application resulted in an increase in leaf Ca, where as P and K reduced it. N and K reduced leaf Mg while P had no effect. N increased leaf Zn while P reduced the same. K had no effect.

Critical levels in leaf for N and P are fixed at 2.09% and 0.14% respectively. Root CEC was increased by NPK fertilisation. N application reduced organic carbon and P while it increased soil N, K and pH. P application increased soil N, K and pH. K application increased soil N,K and pH where as it reduced soil P.

N and P responses were curvulinear while potassium response was linear. The optimum doses of N and P were 440 and 120g/tree/year respectively. Maximum income was realised in the types.