NUTRIENT MANAGEMENT IN CASHEW NURSERY

By

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THESIS

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Faculty of Agriculture
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DECLARATION

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

Vellanikkara
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CERTIFICATE

Certified that this thesis entitled **"Nutrient management in cashew nursery"** is a record of research work done independently by **Mr. Sinish,M.S** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Introduction

1. INTRODUCTION

Cashew (*Anacardium occidentale* L.) is one of the most important commercial crops of our country. Cashew, the dollar spinner of tropical climates was introduced to India by the Portuguese sailors in the sixteenth century and at present it is grown in an area of 7.2 lakh hectares with a production of 4.5 lakh tonnes. The present average productivity is between 0.7-0.9 t ha^{-1} which can be raised to 2-3 t ha^{-1} with high yielding varieties, quality planting materials and better management.

In cross pollinated crops like cashew, the seedling progeny does not result in true to type plants. Clonal plants are the only possibility for the availability of quality planting materials. It has already been confirmed that softwood grafts of high yielding varieties are the best planting materials in cashew (Dixit, 1999). So the production of successful grafts, irrespective of variety, mainly depends on the health, vigour and uniformity of rootstocks, besides good scion material and optimum growth conditions. Use of quality rootstock enhances the success percentage in grafting and reduces the cost of cultivation (Ramesh *et al., 1998).* This necessitates to evolve appropriate nutritional strategies for the vigorous rootstocks and ultimately better survival of cashew grafts.

The successful production of seedling for rootstock production is decided not only by the quality of seed nuts but also the constituent components provided in the potting medium and its nutritional status coupled with its physical and biological properties. Organic manures serve as a steady source of macro and micro nutrients, improve water holding capacity, aeration and provides a better condition for the seed nuts to germinate and grow. So far, only cowdung had been utilised along with soil and sand in the potting media. Since there is a tremendous awareness of increased usage of coirpith compost in agriculture and since it can be made available in plenty, it could be tested as a component in the preparation of potting mixture which has high nutrient content and water holding capacity.

Poultry manure contains more nutrients including Ca and S which is needed in better quantities by oil and protein rich crops. However it is reported to evolve more heat during the process of decomposition. Hence its suitability has to be assessed as an ingredient in the potting mixture and utilised especially under situations of surplus local availability.

Biofertilizers occupy a very prominent role in sustainable agriculture. They are environment friendly and provide low cost agricultural input and improve the rhizosphere of crops. The predominant soil type in Kerala is lateritic which has high P fixation capacity. Hence there is tremendous scope for introducing *Azospirillum*, Phosphorus Solubilizing Bacteria and Arbuscular Myccorhizal Fungi for maintaining continuous fertility in the potting mixture since a period of about one year is required from sowing seeds and planting of cashew grafts in the main field.

The grafts produced at present often show yellowing and poor growth even before it is sold. In order to sustain the vigour of grafts, different nutrient supplementation at various stages with different sources should be tried, which will definitely lead to a better acceptability in the market and ultimately good establishment in the main field. So a detailed investigation, integrating the use of organics, bio fertilizers and inorganic fertilizers, was taken up in the nursery stage of cashew with the major objectives as follows:

1. To select the best organic source of nutrients for the preparation of potting media of cashew
2. To study the influence of bio fertilizers on the rootstock production
3. To develop nutritional management technique to boost the growth and vigour of cashew grafts.

Review of literature

2. REVIEW OF LITERATURE

Cashew is mainly propagated by softwood grafting and for these vigorous rootstocks of appropriate growth at an early stage is required. Large scale production of grafts in the nurseries with assured quality can be possible only if suitable potting mixture is prepared with required levels of nutrients, preferably amended with biofertilizers for sustaining the grafts till it reaches planting stage. Even though works on this line is meagre, a serious effort is taken to review the available literature and is presented in this chapter.

The organic matter content of the tropical soil is comparatively low due to high temperature favouring intense microbial activity and enhanced rate of decomposition. It is well known that the soil without any supply of organic matter is impoverished and in course of time will lose its productivity. Organic manures can effectively act as slow release nutrient sources and some of the organic amendments bring about pest suppression (Gaur *et al.*, 1984). Addition of organic manures like cowdung, poultry manure, coirpith compost etc improve the physical, chemical and biological properties of soil and there by enhance the growth of the seedlings. Potting media with soil, sand and FYM in 1:1:1 proportion has been found to be ideal for raising seedlings of most of the crops. In this study potting media mixed with cowdung, poultry manure and coirpith compost with sand and soil were used, but information pertaining to these organic manures in potting mixture is lacking. Hence, available literatures on the effect of these manures on crop growth in the main field are also reviewed here.

2.1.1. FARMYARD MANURE

Singh *et al.* (1980) stated that the continuous application of FYM to soil appreciably reduced the p^H of soil and increased the organic carbon, total N, available N,P,K,Ca and Mg. Prasad *et al.* (1984) found that FYM application enhanced the availability of native and applied micro nutrient cations through the transformation of solid phase to soluble metal complexes

Considerable improvement in total N and N balance, available N and K status of soil was reported due to FYM application by Chellamuthu *et al.* (1988). Augmentation in organic carbon status by the incorporation of FYM and crop residues were reported (Sharma and Arora, 1988., Badanur *et al.*, 1990). Sharma and Saxena (1990) stated that the P availability in rhizosphere soil of maize was improved significantly by addition of FYM. Similar trend of increase by the addition of FYM was also reported by Badanur *et al.* (1990)

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

Beniwal and Dhawan (1991) observed minimum germination of seeds of *Anthocephalus chinensis* when grown in pure soil medium and better germination and growth in the medium containing FYM. Kumar *et al.* (1992) found that a combination of soil and FYM in 1:1:1 proportion increased seedling height and dry matter production of *Swietenia macrophylla* and *Dalbergia latifolia* seedlings. Jagadeeshkumar (2000) reported that among the three potting media compared, the best performance of cashew seedlings was observed with 1:1 soil: FYM mixture followed by 1:1:1 soil: sand: FYM mixture. Seedlings grown in 1:1 soil: sand mixture exhibited relatively poor height, girth, number of leaves and leaf area.

Application of farmyard manure resulted in higher vegetative mass, dry weight, plant height and rate of dry matter increment per unit leaf area of capsicum (Cerna, 1980; Freitas *et al.*, 1982; and Valsikova and Ivănic,1982). They also reported that application of chemical fertilizers in the absence of FYM retarded the formation of vegetative organs and subsequently the reproductive organs and had resulted in lower flower production.

Arunkumar (1997) reported that in amaranthus FYM application was found to be superior to vermicompost in inducing better plant height, root biomass production, leaf area index and yield

An experiment conducted by Ismail *et al.* (1998) indicated that application of FYM @ 20 and 30 Mg ha^{-1} significantly increased the groundnut dry kernel yield, haulm yield, oil content and nutrient uptake over control. Joseph (1998) observed that in snakegourd, growth characters viz., weight of the root $plant^{-1}$ and dry matter production ha^{-1} were highest in FYM treated plants as compared to poultry manure or vermicompost treated plants.

2.1.2. POULTRY MANURE

Increase in available Zn status was observed due to the addition of poultry manure (Singh *et al.,* 1979). Ravikumar and Krishnamoorthy (1986) reported that available N content of vertisol was improved by the application of poultry manure.

Sharma and Saxena (1990) stated that the P availability in rhizosphere soil of maize was improved significantly by the addition of poultry manure. According to Prasanna (1998) the yield attributes of brinjal like number of fruit, volume of fruits, yield per plant and yield per plot was maximum with highest level of poultry manure. The total uptake of N, P and K were also maximum for the plant applied with higher level of poultry manure.

Shelke *et al.* (1999) reported that the highest available NPK content and their uptake by the brinjal plant were due to the application of 40% N through urea and 60% N through poultry manure. Singh *et al.* (1973) reported that in potato, poultry manure application exhibited better response than FYM on yield and growth attributes.

Prezotti *et al.* (1989) found that the application of poultry manure appreciably increased the yield and augmented fruit size in tomato. Anitha (1997) reported that in chilli various growth attributes like plant height, number of branches and dry matter production were better with poultry manure application

Study conducted by Nandini (1998) revealed that plant height at first harvest was increased by poultry manure at highest dose (100kg Nha^{-1}). Net assimilation rate and yield per plant was maximum for poultry manure at 75 kg N ha^{-1}.

2.1.3. COIRPITH COMPOST

Improvement in total N and N balance due to coir pith were reported by Ramaswami (1984), Chellamuthu *et al.* (1988). Considerable improvement in available N status of soil due to application of coir dust/composted coir pith was also reported (Loganathan, 1990).

Ganapathi (1991) reported that composted coir pith with all fertilizers registered higher availability of plant nutrients, dry matter production and uptake of rice crop than the raw coir pith alone and row coir pith plus all fertilizer treatments. Composted coir pith has beneficial effect as an organic manure in increasing the yield of crops like turmeric (Selvakumari *et al.*, 1991).

When fertilizer N is integrated with composted coirpith/ coirpith+biofertilizer, there is a possibility of saving fertiliser. N in each of the cereal crops, in addition to yield advantage and improved soil fertility for sustainable crop production (Duraisamy, 1992).

The result on the field experiment conducted by Duraisamy and Mani (2001) under integrated N management in sorghum-maize-soybean sequence in a mixed black soil revealed that super imposing of coirpith/coirpith + biofertilizer exhibited positive residual effect on the organic carbon and also available N,P and K status.

The result of the experiment conducted by Mahendran and Muthuramalingam (2002) revealed that soil available nutrient and corresponding yield increase in mandarin orange was noted towards the application of varying sources of P and composted coirpith.

The result of the experiment conducted by Venkatakrishnan and Ravichandran (1996) on sesame revealed that the yield could be increased by 63% with the application of composted coir pith over farmers practice. Suharban *et al.* (1997) in a pot culture experiment with bhindi reported that plant height was significantly influenced by coirpith compost treatment.

Basker and Saravanan (1998) reported that incorporation of coirpith in the potting medium significantly increased the yield of tomato. The highest yield was obtained for the potting medium which consisted of 75% soil + 25% coirpith followed by 50% soil + 50% coirpith.

A study conducted by Rajalingam and Kumar (2001) on the effect of the digested coirpith compost and biofertilizers on three varieties of tea viz., Assam jat, China jat and ATK clone revealed that different varieties recorded higher green leaf yield in different treatment containing digested coirpith compost and biofertilizers either alone or in combination with full or reduced level of estate practice.

2.2. EFFECT OF ORGANIC MANURES ON PHYSICAL PROPERTIES OF SOIL

Organic manure application improves physical properties of soil like structure and water holding capacity. It improves the infiltration of water and reduces run off.

Bulk density of soil was found to be decreased by continuous application of FYM and green manures (Havanagi and Mann, 1970., Biswas *et al.,* 1971). A decrease in bulk density was noticed by the application of lime and FYM in combination with chemical fertilizers, where as continuous use of chemical fertilizers alone caused an increase in bulk density (Sinha *et al.*, 1980)

Loganathan and Lakshminarasimhan (1979) reported that addition of organic and inorganic amendments increased the porosity and water retentivity of porous and open textured red sandy loam soils.

In a field experiment conducted in a heavy black soil Mayalagu (1983) observed significant increase in the moisture content and water holding capacity of the soil treated with soil amendments like coirpith, FYM and pressmud.

Many beneficial effects on soil properties like increase in pore space (Ramaswamy and Sree Ramulu, 1983), infiltration rate, hydraulic conductivity and favourable bulk density (Durai and Rajagopal, 1983) upon the addition of coirpith were reported. Porosity was improved by combined application of FYM and chemical fertilizers (Mahimairaja *et al.*, 1986). Pagliai *et al.* (1987) reported that application of poultry manure increased the porosity of a sandy loam soil. Loganathan (1990) observed an improvement in total porosity by the application of organic amendments like coirdust, FYM and groundnut shell powder in red soil.

Ahmed (1993) reported that composted coconut coir dust 15-20 tha^{-1} improved that soil conditions including soil strength and moisture retention capacity compared to the application of FYM at 10 tha^{-1}. It was noticed that the application of coirpith significantly improved the bulk density, maximum water holding capacity, percentage pore space and moisture retention at different tensions (Venugopal, 1995)

2.3. EFFECT OF MINERAL SUPPLEMENTS ON THE GROWTH OF PLANTS

Lefebvre (1973) found that mineral fertilization was important for cashew growth. He observed that application of nitrogen and phosphorous resulted in an increase in plant growth. However, potassium failed to record any increase in growth.

Sharma *et al.* (1974) reported that in mango seedlings the maximum uptake percentage was recorded under urea where as minimum under ammonium sulphate treatment. Urea showed superiority effect in apparent recovery in all the levels of application as compared to calcium nitrate and ammonium sulphate respectively in both the years. Application of fertilizers in increasing doses increased the removal and uptake of nitrogen by mango seedlings.

According to Haag *et al.* (1975) in cashew seedlings grown in nutrient solution, 2.40 to 2,58 per cent leaf N was found to be in the sufficiency range and 0.98 to 1.38 per cent in deficiency whereas for K it was from 1.11 to 1.29 and 0.20 to 0.26 per cent respectively. From the results of a sand culture experiment Falade (1978) concluded that for maximum growth in cashew seedlings 1.24, 0.12 and 0.34 per cent of leaf N, P and K were required.

In cashew seedlings, the leaf N concentration varied from 1.20 per cent to 3.24 per cent, the leaf P varied from 0.12 per cent to 0.81 per cent and leaf K from 0.87 to 3.17 per cent (Falade, 1978 and Gopikumar *et al.,* 1978).

Investigating the nutritional requirement of forest trees, Hassan and Dey (1979) applied all combinations of N,P and K at 0, 250 and 500 mg $plant^{-1}$ monthly to six week old seedlings grown in sand culture. The best growth and the highest concentration of nutrients were observed in plants when N, P and K were applied at 250 mg $plant^{-1}$ at monthly interval.

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

Ahenkorah *et al.* (1987) studied the effect of foliar fertilization of NPK (1 per cent of urea, muriate of potash and superphosphate) on cocoa seedlings and observed increased vigour and growth of seedlings.

From the results of sand culture studies in cashew, Gopikumar and Aravindakshan (1988) concluded that cashew seedlings raised in Hoagland nutrient solution completely devoid of N,P,K were short by 7.2 cm, 8.63 cm, 7.03 cm respectively compared to seedlings grown in nutrient solution containing N,P,K. At the same time the leaf number decreased by 25 per cent, 27 per cent and 25 per cent in the absence of N,P,K respectively in the nutrient solution. Variation in leaf N concentration ranging from 1.2 to 3.24, P from 0.11 to 0.34, and K from 1.06 to 3.17 per cent in cashew seedlings was observed when raised in Hoagland nutrient solution.

Sumiati (1988) reported that brocoli seedlings grown in jiffy pot with 1:1 mixture of stable manure + soil supplemented with NPK + metal K have highest plant height, root length, leaf area index, net assimilation rate and relative growth rate.

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

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

The experiment conducted by Kaith *et al.* (1995) uniform grafts of starking delicious apple revealed that 78ppm of substrate k was the most ideal for maintaining the optimum growth and nutrient status. Total uptake (leaf+ shoot+ root) of N,P,K,Ca,Mg,Fe,Mn,Zn and Cu increased with the increase in the substrate K levels upto 78ppm followed by a decrease.

Philip and Punnoose (1996) reported that in rubber seedling nursery 1 per cent urea foliar spray registered numerical superiority over other treatments. Soil application of nutrients and foliar spray of 1 per cent urea were significantly better than 2 per cent urea spray and ammophos spray at all concentrations. Latha (1998) reported that N, P and K use efficiency of cashew seedlings grown under pot culture was 24.7, 8.02 and 12.17 per cent respectively. N, P and K absorption of a six month old cashew seedlings was in the order of 151.95, 21.58 mg per plant with a nutrient absorption ratio of 7:1:2 (approximately). The leaf K content of six month old cashew seedlings increased from 1.70 per cent in control to 3.10 per cent when K was applied at the rate of 200 kg ha^{-1}.

The potting media containing 1:1 soil: FYM mixture supplemented with 200g N, 100g P_2O_5, 200g K_2O, per 100kg was found to be the best in cashew seedlings (Jagadeesh kumar, 2000).

Lima *et al.* (2001) reported that the addition of mineral nutrients and organic fertilizers on cashew seedlings significantly affected the height, dry matter weight of aerial parts and the number of leaves.

Manjunatha and Melanta (2001) concluded that 150, 20 and 100 ppm of N, P and K supplied through irrigation water at weekly intervals (100ml/plant/application) was found to be good for the successful growth of cashew rootstocks and grafts.

2.4. EFFECT OF BIO FERTILIZER INOCULATION

Bio fertilizers have an important role to play in improving nutrient supplies and their crop availability. They are of particular significance in intensively cultivated irrigated areas where in wide demand-supply gap of plant nutrients exists. Bio fertilizer is an important ingredient of integrated plant nutrient supply system. The performance of different bio fertilizers under actual field conditions is reviewed here under.

2.4.1. *Azospirillum*

Azospirillum is an aerobic nitrogen fixing bacterium that occurs as associative symbiont in the rhizosphere of many crop plants in tropics.

Tarrand *et al.* (1978) reported that all wild types of *Azospirillum* strains fix atmospheric nitrogen efficiently either as free-living bacteria or in association with plants. One of the striking response of crop plants upon inoculation with *Azospirillum* is the increased root and shoot growth and biomass accumulation

(Smith *et al.*, 1978). Increase in dry weight and total nitrogen content in *Zea mays* and *Setaria italica* associated with nitrogen-fixing *Azospirillum* was reported by Cohen *et al.* (1980).

Kapulnik *et al.*(1981) reported that total shoot and root weights, total N content, plant height and leaf length of wheat, sorghum and panicum were significantly increased by *Azospirillum* inoculation. *Azospirillum* was found to increase the growth and yield of many plantation crops (Govindan and Purushothaman, 1985).

Azospirillum root association indicate that the root development and function are affected by inoculation with the proper inoculum concentration which results in increased mineral (N, P, K and possibly micro element) uptake and in improvement of water status of *Azospirillum* inoculated plants in the field (Okon and Kapulnik, 1986).

Bottini *et al.*(1989)identified Gibberellins A_1, A_3, and iso-A_3 from aseptic cultures of *Azospirillum lipoferum.* According to Santhi and Vijayakumar (1998) all the growth parameters namely plant height, number of leaves, leaf area index, leaf weight, inflorescence number, length, weight, fresh weight and dry matter production were appreciably higher in *Azospirillum* inoculated plant of palmarosa.

Nair and Chandra (2001) reported that nutmeg seedling growth response was more after treatment with *Azospirillum* especially with the native isolate of *A. brasilense*. Studies conducted by Usha (2001) on cashew seedlings revealed the effectiveness of *Azospirillum* in the nursery. Saritha *et al.* (2002) recorded the nitrate tolerance, nitrogen fixation and plant growth promotion by *Azospirillum.*

2.4.2. Phosphorus Solubilizing Bacteria

Phosphorus Solubilising Bacteria produce growth promoting substances which influence plant growth (Mizhustin and Naumova, 1962). Sharma and

Singh (1971) reported that the phosphobacteria culture enhanced the efficiency of phosphatic fertilizers and increase N and P_2O_5 uptake and grain yield in maize.

Rangaswamy and Morachan (1974) reported that application of phosphobacterin to sorghum increased the available phosphorus in soil, and phosphorus content in the crop was highly influenced at all stages of growth. Nair and Subba Rao (1977) reported the presence of phosphate dissolving microorganisms in the rhizosphere of plantation crops like cocoa, coconut, tea etc.

According to Thomas and Shantaram (1986) inoculation of soil with efficient phosphate-solubilizing bacteria after addition of farmyard manure and rock phosphate released more available P from insoluble P sources from the soils of coconut plantation. Kapoor *et al.* (1989) showed that the solubilization of inorganic phosphate depends upon the type of organic acids produced by phosphate solubilizing microorganisms, which chelate the phosphate ions. Tri and dicarboxylic acids were more effective compared to monocarboxylic and aromatic acids in chelation.

According to Shehana and Abraham (2001) the quantity of available P in soil was the maximum with the addition of mussorie rock phosphate+ farmyard manure+ P solubilising organism. This was closely followed by the treatment mussorie phosphate+ P solubilising organisms.

2.4.3. Arbuscular Mycorrhizal Fungi (AMF)

Yost and Fox (1979) reported that in phosphorus deficient situation, P uptake by mycorrhizal plant was 25 times greater than by plant without mycorrhizal associations. It was stated that the inoculation with VAM fungi or *Glomus mosseae* significantly improved growth and phosphorus uptake of cassava.

The AMF synthesized plant growth regulating substances atleast two gibberellin-like substances, one with RF corresponding in position to authentic gibberellic acid, and four substances with the properties of cytokinins (Barea and Azcon-Anjuilar, 1982).

AMF inoculation induces better growth and more stem thickness facilitating early production of acid lime seedlings (Chandrababu and Shanmugan, 1983). AMF can directly enhance the uptake of micronutrient viz., Zn, Cu and Fe (Gildon and Tinker, 1983; Tinker and Gildon, 1983; Pacovsky, 1986; Kucey and Janzen, 1987 and Rai, 1988).

A preliminary work conducted on the effect of different mycorrhizal isolates on cashew by Krishna *et al.*(1983) revealed the need for screening and selecting efficient inoculant mycorrhizal fungus for cashew. Geddeda *et al.* (1984) reported that mycorrhizal inoculation increased growth and phosphorus content of apple seedlings.

According to Bolan *et al.* (1984), AMF plants draw most of their P from the soluble pool although they are more effective than non mycorrhizal plants. The mycelial network of endomycorrhizal fungi enabled plants to remove phosphate from a larger volume of soil extending beyond the immediate vicinity of the root surface. The cocoa seedlings inoculated with AMF (*Gigaspora spp.*) gave the most vigorous growth and higher phosphorus in the leaf tissues in unsterile soil compared to plants grown in steamed soil. (Chulan and Ragu, 1986).

Shivashankar and Iyer (1988) reported that mycorrhizal plants showed significant increase in the tissue N, P and leaf nitrate reductase activity over the control and nitrate compensation point was lower in mycorrhizal plants.

Sridar *et al.* (1990)reported that applying 2g superphosphate and 25g VAM increased cashew stem girth which in turn helped in better graft union.

In Hevea, the growth responses of seedling root stocks to introduced AMF were observed at RRIM (Ikram, 1990). It was also found that AMF inoculation increased the seedling dry weight by 70%. The maximum colonisation of AMF occurred in plots receiving farmyard manure alone in capsicum (Nair and Peter, 1991). *Glomus fasciculatum* was found to be more effective in enhancing growth and P uptake of cashew plants (Sivaprasad *et al.*, 1993) than *G.etunicatum.*

An *et al.* (1993) studied the effect of AMF (*G.etunicatum and G.fasciculatum*) on the growth and mineral composition of shoots and roots of apple seedlings. The inoculated plants could achieve sufficient girth for grafting much earlier than the uninoculated. AMF inoculation increased seedling growth, phosphorus uptake and seedling survival after transplanting to the field and ultimately the yields in coffee (Siqueria *et al.*, 1993).

The effect of different levels of AMF on the growth of cashew rootstocks was studied by Kumar *et al.* (1998). Application of AMF @ 10g bag^{-1} at the time of sowing was found to be effective. According to Ramesh *et al.* (1998), there was significant increase in plant height, girth, number of leaves, leaf area, root length, number of roots and plant biomass in cashew rootstocks by the inoculation of AMF. Nine AMF were screened for their ability to enhance the growth and uptake of P in cashew rootstock under glass house condition. *Acaulospora* and *Glomus mosseae* significantly increased plant height, girth and total biomass of cashew rootstocks as compared to uninoculated plants. Percentage root colonisation and P uptake were also significantly higher (Laskshmipathy *et al.*, 2000). Usha (2001) reported that AMF inoculation enhanced the growth of cashew seedlings in the nursery and grafts when planted in the field.

2.4.4. Effect of Biofertilizer Combinations (*Azospirillum* + PSB + AMF)

Rosalindpadma (1988) observed that combined inoculation of VAM and *Azospirillum brasiliense*, VAM and phosphobacteria in papaya and tobacco considerably enhanced the plant height, leaf number, root length, shoot and root dry weights and N, P and chlorophyll contents of plants.

Swarupa (1996) reported that combined application of *Azospirillum brasiliense* + Phosphobacteria + VAM fungi enhanced the growth and vigour of coffee seedlings.

Studies undertaken at tea plantations in Nilgiri's by Rajagopal and Ramarethinam, (1997) revealed that use of biofertilizers like *Glomus fasciculatum*, *Azospirillum brasiliense*, phosphobacteria and digested organic supplement gave better results in terms of growth and nutrient uptake in combination of two or three inoculants rather than single inoculation.

Ravichandran and Balasubramanian (1997) recorded the best growth and nodulation in *Casuarina equisetifolia* with AMF + *Azospirillum* + Phosphobacteria. Kennedy and Chellapillai, (1998) reported that combined inoculation of AMF, *Azospirillum* and phosphobacteria resulted in the highest plant height, total dry weight, AMF colonization and total N and P uptake in all the four shola tree species tested.

Nirmala *et al.* (1999) reported that combined application of *Azospirillum*, phosphobacteria and VAM each 2kg/ha with farmyard manure 30t/ha as soil application was found to have earliness, closer sex ratio, increased fruit size, number of fruits and mean tender fruit yield of cucumber.

Experiments conducted to test the effect of *Azospirillum*, phosphobacteria and AMF on growth and nutrient content of black pepper (*Piper nigrum*) cuttings indicated that growth parameters were on par with control when these three biofertilizers were applied individually, but their combination enhanced plant height, leaf area, biomass and dry matter production and nutrient content significantly over uninoculated control. (Kandiannan, *et al.*, 2000).

A study conducted by Rajalingam and Kumar (2001) on the effect of the digested coirpith compost and biofertilizers *Azospirillum*, phosphobacteria and AMF on three varieties of tea viz., Assam jat, China jat and ATK clone revealed that different varieties recorded higher green leaf yield in different treatments containing digested coirpith compostand biofertilizers either alone or in combination with full or reduced level of estate practice.

Vijayakumari and Janardhanan (2003) indicated that combined inoculation of biofertilizers viz., *Azospirillum* + Phosphobacteria + AMF improved seed germination, seedling growth and biometric changes such as chlorophyll, total soluble carbohydrates, reducing sugars, total free aminoacids, buffer soluble proteins and phenolics of silk cotton.

Materials and Methods

3. MATERIALS AND METHODS

The investigation on the "Nutrient Management in Cashew Nursery" was conducted at Department of Agronomy, College of Horticulture,Kerala Agricultural University,Vellanikkara during 2002-2003. The study consisted of the following two experiments.

EXPT.I - MANAGEMENT PRACTICES FOR CASHEW ROOTSTOCK PRODUCTION and

EXPT.II - MANAGEMENT PRACTICES OF CASHEW GRAFTS

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

3.1 LOCATION

The experiments were conducted at the Cashew Research Station, Madakkathara, Kerala Agricultural University, Thrissur, located at 10°32'N latitude and 76°10'E longitudes with an altitude of 22.5 m.

3.2 CLIMATE

The location is a typical humid tropical climate and the weather conditions prevailed during the period of study are furnished in Appendix I and Fig. 1.

3.3 SOIL

The soil of the experimental site is lateritic belonging to the soil order oxisols. The mechanical composition and chemical properties of the soil are given in Table 1.

3.4 VARIETY

The high yielding variety Madakkathara-1 (BLA-39-4) which has an average yield of 13.8 kg/tree/year was used for the study.

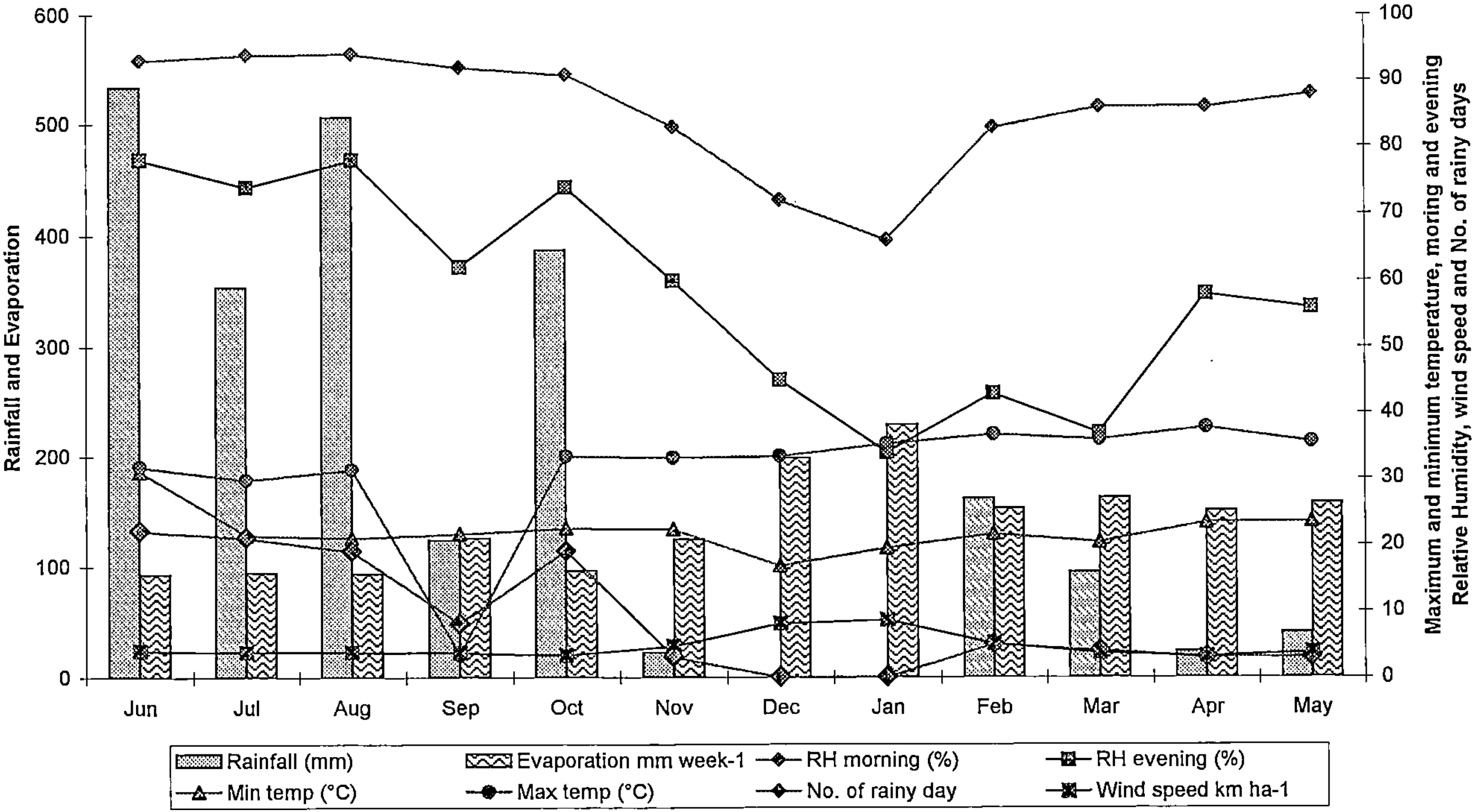


Fig.1. Monthly weather data during crop season (June 2002 - May 2003)

Table 1. Physico-chemical properties of soil

1. Mechanical composition

Coarse sand	: 28.9%
Fine sand	: 21.2%
Silt	: 15.6%
Clay	: 31.3%

2. Chemical properties

Particulars	Content	Procedure adopted
Organic carbon	0.7%	Walkley and Black method (Walkley and Black, 1934)
Available N	269.7 kg/ha	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P	5.7 kg/ha	Ascorbic acid reductant method (Watanabe and Olsen, 1958)
Available K	224 kg/ha	1N Neutral ammonium acetate extractant flame photometry (Jackson, 1958)
Exchangeable Ca	132 kg/ha	Neutral normal ammonium acetate extract titration with EDTA (Jackson, 1958)
Exchangeable Mg	44 kg/ha	Neutral normal ammonium acetate extract titration with EDTA (Jackson, 1958)
pH	5.6	1:2.5 soil suspension using pH meter (Jackson, 1973)
EC	0.1 dSm^{-1}	Supernatant of 1:2.5 soil suspension using EC bridge (Jackson, 1973)
CEC	4.0 centimoles kg^{-1}	Ammonium acetate method (Jackson, 1973)

3.5 TECHNICAL PROGRAMME

3.5.1 Exp.I. Management Practices for Cashew Rootstock Production

The technical programme consisted of treatment combinations involving three potting media containing sand,soil and cowdung/poultry manure/coirpith compost and three biofertilizer supplements as indicated below. The nutrient content of organic manures are given in this Table 2

Organic manures	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
cowdung	0.66	0.42	0.57	0.60	0.12
Poultry manure	1.50	1.39	1.06	2.67	0.44
coirpith compost	1.02	0.05	0.79	0.40	0.33

Treatments

1 Soil:Sand:Cowdung in 1:1:1 proportion (by volume)
2. Soil:Sand:Poultry manure in 1:1:1 proportion (by volume)
3. Soil:Sand:Coirpith compost in 1:1:1 proportion (by volume)
4. T_1 + *Azospirillum*
5. T_1 + Phosphorus Solubilizing Bacteria (PSB)
6. T_1 + Arbuscular Mycorrhizal Fungi (AMF)
7. T_1 + *Azospirillum* + PSB + AMF
8. T_2 + *Azospirillum*
9. T_2 + PSB
10. T_2 + AMF
11. T_2 + *Azospirillum* + PSB + AMF
12. T_3 + *Azospirillum*
13. T_3 + PSB
14. T_3 + AMF
15. T_3 + *Azospirillum* + PSB + AMF
16. Sand:Soil in 1:1 proportion

The experiment was laid out in Completely Randomised Design (CRD) with 16 treatments and 10 replications. The biofertilizers viz., *Azospirillum* sp, Phosphorus Solubilizing Bacteria (PSB) and Arbuscular Mycorrhizal Fungi (AMF) were obtained from TNAU, Coimbatore. As per the treatments, biofertilizer inoculum @ 10 g polybag^{-1} were added to the potting media and mixed thoroughly and filled in polythene bags (22 x 15 cm). The uniform sized seeds of variety Madakkathara-1 were selected and soaked for 24 hours in water prior to sowing. The polythene bags were irrigated with microsprinklers and weeding was done as and when they appeared.

3.5.1.1 Observations

1) Days to Germination and Germination Percentage

The number of days taken for germination was counted and the germination percentage was calculated.

2) Plant Height

Height of plants from the ground level to the terminal bud was recorded at fortnightly intervals.

3) Girth

Girth of the plants at collar region was observed at fortnightly intervals.

4) Number of Leaves

The total number of leaves of plants under each treatment was counted at fortnightly intervals.

5) Root Weight at the stage of grafting

The plants for distructive sampling were drawn randomnly from each treatment. After removing the polybag the root portion was thoroughly washed in a sieve to remove the soil. The root and shoot portions were separated and the root portion was dried in shade and later dried in a hot air oven to constant weight and expressed in g plant^{-1}.

6) Shoot Weight at the stage of grafting

The shoot portion of plants was first air dried and later dried in a hot air oven to a constant weight and expressed in g plant^{-1}.

7) Root:shoot ratio

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

8) Nutrient content

The N, P, K, Ca and Mg contents in the potting mixtures were analysed in the beginning and at the grafting stage. The leaves were also analysed at the grafting stage

9) Physical properties of the potting mixture

Bulk density, particle density, porosity and water holding capacity were estimated adopting Keen-Rhaezkowski box method.

3.5.2 Experiment II. Management Practices of Cashew Grafts

3.5.2.1 ***Soil Application of Nutrients (1 month after grafting)***

Treatments

1. Control (T_7 in experiment-I i.e., T_1 + *Azospirillum* + PSB + AMF) –No fertilizer application
2. Urea (40 g/10 l water) –100 ml graft^{-1}
3. Ammonium sulphate (80 g/10 l water) –100 ml graft^{-1}

4. Ammonium phosphate sulphate (80 g/10 l water) –100 ml graft $^{-1}$
5. Ammonium phosphate sulphate (80 g/10 l water) + MOP (25 g/10 l water) -- 100 ml graft $^{-1}$
6. 17:17:17 (100 g/10 l water) –100 ml graft $^{-1}$
7. Decanted extract of 1 kg groundnut cake + 17:17:17 (100 g/10 l water) –100 ml graft $^{-1}$

The experiment was laid out in CRD with 7 treatments and 10 replications. The cashew rootstocks grown in the potting mixture containing soil:sand:cowdung in 1:1:1 proportion inoculated with *Azospirillum* + PSB + AMF were used in this experiment. These plants were grafted at two months after sowing with the pre cured scions of Madakkathara-1 and one month after grafting the prepared nutrient solutions as per the treatments mentioned above were applied at 100 ml to each graft.

3.5.2.2 *Foliar Fertilization (3 months after grafting)*

Treatments

1. Control
2. 2% Urea spray
3. 2% Ammonium phosphate sulphate spray
4. 2% 17:17:17 spray

The experiment was laid out in 7 x 4 Factorial experiment in CRD with 28 treatments and 10 replications. Foliar application of the various nutrient sources were done at three months after grafting as per the treatments.

3.5.2.3 Observations of Experiment II

1) Number of Leaves

The total number of leaves of plants under each treatment was counted at monthly intervals.

2) Plant Height

Height of the plant from ground level to the terminal bud was recorded at 1, 3 and 6 months after grafting(MAG). Increase in plant height was taken as the height of the graft was decided by the length of rootstock and scion taken at the time of grafting.

3) Leaf Area

Constants were worked out for large, medium and small leaves of the plants relating the maximum length, breadth and area of leaves. The average of the constant calculated was 0.71 (K = leaf area / length x breadth). The maximum length and breadth of the leaves were taken and multiplied with the constant to get the leaf area and expressed in cm^2.

4) Root Weight

The root portion of each grafts were collected after six months as stated in section 3.5.1.1.5. The root and shoot portions were separated and the root portion was dried in shade and later dried in a hot air oven to constant weight and expressed in g $plant^{-1}$.

5) Shoot weight

The shoot portion of the uprooted plants at six months after grafting was first air dried and then oven dried to constant weight and expressed in g $plant^{-1}$.

6) Root:shoot ratio

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

7) Chlorophyll Content of Leaves

The top most fully matured leaf was taken as the index leaf (Mathew, 1990) for the estimation of chlorophyll. It was estimated by Dimethyl sulfoxide (DMSO) method (Shoaf and Lium, 1976).

8) Nutrient content

N, P, K, Ca and Mg contents of the potting mixtures and leaves were estimated at two months after soil application of nutrients (which was given at 1 month after grafting) and three months after foliar application of fertilizers (which was given at 3 months after grafting).

3.5.2.4 Estimation of Infection by Microbial Inoculants

3.5.2.4.1 Azospirillum

Enumeration of *Azospirillum* in the rhizosphere was estimated by Most Probable Number(MPN) technique(Cochran,1950). Soil samples from the rhizosphere of different treatments were taken and sieved in 2 mm mesh. 10 gram of the soil was suspended in 90 ml of sterilised water and 10 fold dilutions of the suspension were prepared by further dilutions. 1 ml aliquots of 10^{-3}, 10^{-4} and 10^{-5} were transferred to test tubes containing Okon's medium. The test tubes were incubated in a BOD incubator for three to four days at 37°C. The positive tubes were recorded and its population was calculated using MPN technique.

3.5.2.4.2 Phosphorus Solubilising Bacteria

For the growth of phosphate solubilizing microrganisms, Pickovskaya's solid medium containing tri calcium phosphate was prepared and enumerated by the method described by Rao and Sinha (1963). One gram of soil was suspended in 10 ml of sterilised water and serial dilutions were prepared. One ml aliquot of 10^{-6} dilution was plated on solid media in petridish and incubated for 4-5 days at 28 ± 2°C. Transparent zones indicates the presence of phosphate solubilizing micro organisms which were counted and expressed in cfu g^{-1} of soil.

3.5.2.4.3 AM Fungi Root Colonization

The thin feeder roots of the plants taken from different treatments were washed and cut into bits of about 1 cm. They were transferred into test tubes and fixed in FAA (Formalin, Acetic acid and Ethanol) @ 1:1:18 ml overnight. The root bits were hydrolysed in 10 per cent KOH at 90°C for 1 hour. Decanted the 10 per cent KOH and washed with water. Then alkaline H_2O_2 was added. After washing with water, it was neutralised with two per cent HCl and then stained with 0.05 per cent trypan blue. It was heated at 120° C for 10 minutes and decanted the stain as well as two per cent HCl. Then washed with lacto phenol solution. The roots were observed under the microscope for AMF colonisation (Philips and Hayman, 1970). The per cent infection was worked out as given below:

$$\text{Per cent infection} = \frac{\text{Total no. of positive root segments}}{\text{Total no. of root segments observed}} \times 100$$

3.5.2.4.4 AMF Spore Count

The AMF spores were isolated from the rhizosphere soil by wet sieving and decanting method (Gerdemann and Nicolson, 1963). About 10 g rhizosphere soil was suspended in 100 ml water and stirred well. After settling of the heavier particles, the supernatant was filtered through a set of sieves of size 425, 250, 106 and 45 microns. Finally the soil suspension present in 106 and 45 micron sieves were transferred to 100 ml beakers separately by gentle washing. The spore suspension was filtered through Whatmann No.1 filter paper. The filter paper containing spores were placed in a petridish and observed under stereomicroscope. The number of spores was counted separately and the total spore count was worked out by adding these two.

3.5.2.5 Chemical analysis

Table 3 Details of methods followed in soil chemical analysis

Nutrient analysed	Method	Reference
Available Nitrogen	Alkaline permanganate distillation method	Subbiah and Asija, 1956
Available phosphorus	Bray-1 extractant - Ascorbic acid reductant method	Watanabe and Olsen, 1965
Exchangeable potassium	Neutral normal ammonium acetate extractant using flame photometer	Jackson, 1958
Exchangeable calcium and Exchangeable Magnesium	Neutral normal ammonium acetate extract titration with EDTA	Jackson, 1958

Table 4 Details of methods followed in the analysis of plant samples

Nutrient analysed	Method	Reference
Nitrogen	Microkjeldhal's method	Jackson, 1958
Phosphorus	Diacid extract estimated colourimetrically in spectrophotometer	Jackson, 1958
Potassium	Diacid extract method using flame photometer	Jackson, 1958
Calcium and Magnesium	Alternate versenate method	Page, 1982

3.5.2.6 Statistical analysis

The statistical analysis was done using the methods suggested by Panse and Sukhatme (1967). MSTATC and MS-EXCEL Softwares were used for computation and analysis. Comparisons among treatment means were done using Duncan's Multiple Range Test (DMRT).

Results

4. RESULTS

The results of the experiment conducted on "Nutrient management in cashew nursery" are furnished below.

4.1 EXPT-I MANAGEMENT PRACTICES FOR CASHEW ROOTSTOCK PRODUCTION

The results of the study to identify the best organic source of nutrients among cowdung, poultry manure and coir pith compost used in the preparation of potting media and its influence with and without biofertilizers on the cashew rootstock production are presented below.

4.1.1 Nutrient Content in Potting Mixtures at the Beginning of the Experiment

The available nutrient content (N, P, K, Ca and Mg) in potting mixtures at the beginning is given in Table 5. At this stage available nitrogen (544.3 ppm) was the highest in the *Azospirillum* inoculated potting mixture containing poultry manure (T_8) followed by T_{11} (sand:soil:poultry manure + Azo + PSB + AMF) with 538.7 ppm N. The other potting mixtures containing poultry manure inoculated with biofertilizer, T_9 (PSB) and T_{10} (AMF) were on par with T_8 and the lowest N (127.7 ppm) was noticed in T_{16} (sand:soil potting mixture). The available phosphorus was found the maximum in the potting mixture containing poultry manure inoculated with Azo + PSB + AMF (T_{11}), AMF alone (T_{10}) and PSB alone (T_9) (146.3, 146.0, 146.0 ppm respectively) and the minimum P was found in T_{16} (3.0 ppm). All the treatments where poultry manure or cowdung was used in potting mixture were on par with T_{11}. The highest available potassium was also noticed in T_{11} i.e., Azo + PSB + AMF inoculated potting mixture of poultry manure (504.3 ppm) followed by T_{10} (453.7 ppm) and the lowest in T_{16} (86 ppm).

Table 5. Available nutrient content in potting mixtures at the beginning of experiment

Treatments	Nutrient content (ppm)				
	N	P	K	Ca	Mg
T_1 sand: soil: cowdung	154.7^{fg}	101.7^{a}	132.3^{fg}	139.4^{cde}	41.0 $(6.40)^{i}$
T_2 sand: soil: poultry manure	465.0^{b}	131.3^{a}	403.7^{b}	471.3^{b}	127.0 $(11.27)^{bcd}$
T_3 sand: soil: coirpith compost	179.3^{efg}	3.7^{b}	140.7^{efg}	91.0^{ef}	105.0 $(10.24)^{e}$
T_4 T_1+Azo	217.7^{cde}	104.7^{a}	164.3^{def}	145.3^{cde}	56.0 $(7.48)^{h}$
T_5 T_1+PSB	188.3^{ef}	125.7^{a}	170.3^{def}	169.0^{cd}	55.7 $(7.45)^{h}$
T_6 T_1+AMF	200.7^{def}	136.3^{a}	177.0^{cdef}	184.0^{c}	67.7 $(8.22)^{g}$
T_7 T_1+Azo+PSB+AMF	209.0^{def}	137.3^{a}	189.0^{cdef}	187.3^{c}	80.0 $(8.90)^{f}$
T_8 T_2+Azo	544.3^{a}	142.3^{a}	426.3^{b}	466.7^{b}	131.3 $(11.46)^{bc}$
T_9 T_2+PSB	492.0^{ab}	146.0^{a}	435.3^{b}	480.7^{ab}	138.7 $(11.78)^{ab}$
T_{10} T_2+AMF	491.7^{ab}	146.0^{a}	453.7^{ab}	493.3^{ab}	140.3 $(11.84)^{ab}$
T_{11} T_2+Azo+PSB+AMF	538.7^{a}	146.3^{a}	504.3^{a}	534.0^{a}	153.0 $(12.37)^{a}$
T_{12} T_3+Azo	270.7^{c}	5.0^{b}	184.3^{cdef}	102.7^{ef}	105.0 $(10.24)^{e}$
T_{13} T_3+PSB	238.0^{cde}	7.3^{b}	198.7^{cde}	115.3^{def}	114.0 $(10.67)^{de}$
T_{14} T_3+AMF	251.0^{cd}	6.7^{b}	219.7^{cd}	123.3^{de}	123.3 $(11.10)^{cd}$
T_{15} T_3+Azo+PSB+AMF	275.3^{c}	7.7^{b}	233.0^{c}	128.7^{cde}	131.7 $(11.47)^{bc}$
T_{16} sand: soil (1:1)	127.7^{g}	3.0^{b}	86.0^{g}	61.7^{f}	25.7 $(5.06)^{j}$

Data in the parenthesis are square root transformed values.

The exchangeable calcium (534 ppm) and exchangeable magnesium (153 ppm) were also found maximum in T_{11}. In the case of Ca ,T_{10} and T_9 were on par with T_{11}

4.1.2 Physical Properties of the Potting Mixtures

The physical properties of the four different kinds of potting mixtures viz., sand:soil:cowdung in 1:1:1 (T_1), sand:soil:poultry manure in 1:1:1 (T_2), sand:soil:coirpith compost in 1:1:1 (T_3) and sand:soil in 1:1 (T_{16}) were analysed(Table 6).

The bulk density was significantly higher in T_{16} (1.50 g/cc) and the lowest in T_3 (0.96 g/cc). T_2 and T_1 were on par with each other (1.21 and 1.18 g/cc respectively). The maximum particle density was found in T_{16} (2.5 g/cc) and T_2 (2.45 g/cc) was on par with it. The minimum was found in T_3 (2.06 g/cc). The pore space was found maximum in T_3 (59.90%) and the lowest in T_{16} (43.94%). T_1 and T_2 were on par (54.60 and 53.56% respectively). In the case of water holding capacity, the same pattern of result as that of pore space was found. It was highest in T_3 (48.84%) and lowest in T_{16}. (26.02%). T_2 (48.04%) and T_1 (35.12%) were on par.

4.1.3 Days to Germination and Germination Percentage

Days to germination and germination percentage are given in Table 7. sand:soil:coirpith compost + Azo + PSB + AMF (T_{15}) recorded the minimum days for germination (13 days). T_7 (sand:soil:cowdung + Azo + PSB + AMF) and biofertilizer inoculated potting mixture containing coirpith compost were on par with T_{15}. The maximum days for germination was noticed with T_3 (sand:soil:poultry manure) ie.,17.23 days. Poultry manure applied treatments took more days for germination.

Table 6. Physical properties of the potting mixtures

Potting mixture	Bulk density (g/cc)	Particle density (g/cc)	Pore space (%)	Water holding capacity (%)
sand: soil: cowdung (1:1:1)	1.18^{b}	2.29^{bc}	54.60^{b}	35.12^{b}
sand: soil: poultry manure (1:1:1)	1.21^{b}	2.45^{ab}	53.56^{b}	38.10^{b}
sand: soil: coirpith compost (1:1:1)	0.96^{c}	2.06^{c}	59.90^{a}	48.84^{a}
sand: soil (1:1)	1.50^{a}	2.59^{a}	43.94^{c}	26.02^{c}

Table 7. Days to germination and germination percentage of cashew nuts

Treatments	Days to germination	Germination percentage
T_1 sand: soil: cowdung	14.27^{cd}	88.80
T_2 sand: soil: poultry manure	17.23^{a}	68.40
T_3 sand: soil: coirpith compost	13.53^{cd}	83.30
T_4 T_1+Azo	14.00^{cd}	93.80
T_5 T_1+PSB	13.41^{cd}	93.75
T_6 T_1+AMF	13.81^{cd}	100.00
T_7 T_1+Azo+PSB+AMF	13.19^{d}	100.00
T_8 T_2+Azo	17.00^{ab}	68.40
T_9 T_2+PSB	16.38^{ab}	72.20
T_{10} T_2+AMF	16.77^{ab}	76.50
T_{11} T_2+Azo+PSB+AMF	15.85^{b}	81.30
T_{12} T_3+Azo	13.33^{d}	88.00
T_{13} T_3+PSB	13.19^{d}	88.00
T_{14} T_3+AMF	13.07^{d}	94.00
T_{15} T_3+Azo+PSB+AMF	13.00^{d}	100.00
T_{16} sand: soil (1:1)	14.62^{c}	76.50

Germination percentage ranged from 68.4 to 100 per cent in different treatments. All the seeds germinated in AMF (T_6) and Azo + PSB + AMF (T_7 and T_{15}) inoculated treatments of cowdung and coirpith compost. The minimum percentage (68.4) was found in poultry manure applied potting mixtures (T_2 and T_8). Compared to other treatments, poultry manure applied potting mixture had minimum germination percentage.

4.1.4 Microbial Population

Data regarding population dynamics of microflora in potting mixture at the time of germination of nuts are given in Table 8.

Total population of *Azospirillum* was the highest (2.00 x 10^4 cell g^{-1}) in the potting mixture containing sand:soil:cowdung + Azo + PSB + AMF (T_7). It was 93 per cent more than the absolute control [sand:soil (1:1)].

Population of phosphorus solubilizing bacteria was found to be the maximum (37.67 x 10^6 cfu g^{-1}) in T_7 and it was 77.9 per cent more than in absolute control T_{16} (8.33 x 10^6 cfu g^{-1}).

The number of spores of Arbuscular Mycorrhizal Fungi was found to be highest in T_7 (31.50) and the minimum in T_{16} (3.50). T_7 had 88.9 per cent more spores than T_{16}.

4.1.5 Height

Height of the plants was observed from 15 days after germination at fortnightly intervals (Table 9). T_7 (sand:soil:cowdung + Azo + PSB + AMF) showed the maximum height (9.37 cm) at 15 days after germination (DAGN) but its effect was on par with all cowdung and coirpith compost applied treatments. Minimum height (6.19 cm) was observed in absolute control T_{16} (sand:soil in 1:1).

Table 8. Total microbial population (*Azospirillum*, PSB, AMF) in the potting mixtures at the time of germination of nuts

Treatments	*Azospirillum* (× 10^4 Cellg^{-1} potting mixture)	PSB (× 10^6 Cfug^{-1} potting mixture)	AMF Spore population (10g^{-1} potting mixture)
T_1 sand:soil:cowdung	0.28 (3.44^{cde})	15.33 (7.18^{ef})	8.50 (0.92^{efg})
T_2 sand:soil:poultry manure	0.19 (3.26^{de})	9.00 (6.95^{h})	4.00 (0.59^{h})
T_3 sand:soil:coirpith compost	0.29 (3.26^{de})	10.67 (7.03^{gh})	5.50 (0.72^{gh})
T_4 T_1+ Azo	0.25 (3.88^{b})	16.33 (7.21^{e})	10.00 (0.99^{ef})
T_5 T_1+ PSB	0.31 (3.48^{cde})	30.06 (7.48^{ab})	12.50 (1.09^{def})
T_6 T_1+ AMF	0.28 (3.44^{cde})	17.00 (7.23^{de})	25.50 (1.41^{ab})
T_7 T_1+Azo+ PSB+ AMF	2.00 (4.30^{a})	37.67 (7.58^{a})	31.50 (1.50^{a})
T_8 T_2+ Azo	0.39 (3.59^{bcd})	10.67 (7.02^{gh})	5.50 (0.74^{gh})
T_9 T_2+ PSB	0.24 (3.38^{cde})	21.67 (7.34^{cd})	8.00 (0.90^{fg})
T_{10} T_2+ AMF	0.32 (3.49^{cde})	12.33 (7.09^{fg})	13.50 (1.13^{cde})
T_{11} T_2+ Azo+ PSB+ AMF	0.47 (3.66^{bc})	23.67 (7.37^{bc})	17.00 (1.23^{bcd})
T_{12} T_3+ Azo	0.39 (3.59^{bcd})	13.33 (7.12^{efg})	8.50 (0.92^{efg})
T_{13} T_3+ PSB	0.26 (3.41^{cde})	26.00 (7.41^{bc})	10.00 (0.99^{ef})
T_{14} T_3+ AMF	0.28 (3.44^{cde})	14.33 (7.15^{ef})	16.50 (1.22^{bcd})
T_{15} T_3+ Azo+ PSB+ AMF	0.50 (3.69^{bc})	28.33 (7.45^{bc})	21.00 (1.32^{abc})
T_{16} sand: soil	0.14 (3.15^{e})	8.33 (6.92^{h})	3.50 (0.54^{h})

Data in parenthesis are logarithmically transformed values

At 30 days after germination, the T_7 recorded the maximum height (15.07 cm) which was on par with all cowdung applied treatments and combined biofertilizers inoculated treatments (Azo + PSB + AMF) of coirpith compost and poultry manure. Minimum height (8.95 cm) was found in T_{16}.

At 45 days after germination, T_7 recorded the maximum height (18.88 cm) and all the cowdung applied treatments were on par with it. T_{16} recorded the lowest height (12.08 cm).

At 60 days after germination also T_7 gave the maximum height (23.4 cm). Here the AMF and PSB inoculated treatments of cowdung and Azo + PSB + AMF and AMF alone applied treatments of poultry manure were on par with T_7. The lowest height was found in T_{16} (14.88 cm).

The results showed that T_7 recorded the maximum height and T_{16} showed the minimum height throughout the period of study (upto 60 DAGN).

4.1.6 Girth

Data on the girth of plants recorded from 15 days after germination at fortnightly intervals are given in Table 9. Girth was found the maximum with T_7 (1.76, 2.19, 2.58 and 3.12 cm respectively) at 15, 30, 45 and 60 days after germination. At all the stages of observation T_{16} gave the minimum girth. At 15 DAGN all the treatments were on par with T_7. At 30 DAGN all the biofertilizer inoculated treatments of cowdung, combined inoculation of Azo + PSB + AMF treated plants of poultry manure and coirpith compost and PSB inoculated treatment of coirpith compost were on par with T_7. At 45 DAGN all the biofertilizer inoculated treatments of cowdung were on par and at 60 DAGN, the AMF applied treatment of cowdung was on par with T_7.

Table 9.Effect of potting mixtures and biofertilizer inoculation on the height, girth and number of leaves, at fortnightly intervals from day of germination(DAGN)

Treatments	Height (cm)				Girth (cm)				No. of leaves			
	15 DAGN	30 DAGN	45 DAGN	60 DAGN	15 DAGN	30 DAGN	45 DAGN	60 DAGN	15 DAGN	30 DAGN	45 DAGN	60 DAGN
T_1 sand: soil: cowdung	8.82^{abc}	13.78^{s}	17.37^{ab}	20.22^{bcd}	1.64^{a}	2.07^{bcd}	2.26^{fg}	2.52^{f}	7.15^{ab}	9.39^{cde}	10.92^{ef}	13.08^{ef}
T_2 sand: soil: poultry manure	6.57^{ef}	11.72^{d}	15.42^{bc}	19.51^{d}	1.58^{a}	1.92^{e}	2.19^{g}	2.45^{fg}	6.23^{d}	9.00^{e}	10.31^{fg}	12.92^{f}
T_3 sand: soil: coirpith compost	8.29^{abcd}	11.99^{cd}	14.04^{c}	17.12^{e}	1.62^{a}	1.99^{de}	2.28^{efg}	2.39^{g}	7.08^{abc}	9.31^{de}	10.31^{fg}	12.69^{fg}
T_4 T_1+Azo	9.11^{a}	14.28^{ab}	17.55^{ab}	21.24^{bcd}	1.68^{a}	2.12^{ab}	2.52^{ab}	2.77^{de}	7.23^{a}	10.15^{abcd}	12.23^{fg}	15.00^{cd}
T_5 T_1+PSB	9.29^{a}	14.45^{ab}	17.68^{ab}	21.38^{abcd}	1.70^{a}	2.15^{ab}	2.57^{a}	2.97^{bc}	7.31^{a}	10.31^{abc}	12.54^{bcd}	15.23^{bcd}
T_6 T_1+AMF	9.26^{a}	14.35^{ab}	17.71^{ab}	22.06^{ab}	1.72^{a}	2.11^{abc}	2.52^{ab}	3.02^{ab}	7.39^{a}	10.38^{ab}	12.92^{abc}	15.38^{abcd}
T_7 T_1+Azo+PSB+AMF	9.37^{a}	15.07^{a}	18.88^{a}	23.40^{a}	1.76^{a}	2.19^{a}	2.58^{a}	3.12^{a}	7.46^{a}	10.77^{a}	13.23^{abc}	16.31^{a}
T_8 T_2+Azo	6.60^{ef}	11.91^{cd}	15.62^{bc}	19.71^{d}	1.63^{a}	2.00^{cde}	2.36^{cdef}	2.82^{de}	6.39^{cd}	9.69^{bcde}	12.38^{a}	14.85^{d}
T_9 T_2+PSB	7.66^{cde}	12.24^{cd}	15.77^{bc}	21.18^{bcd}	1.65^{a}	2.00^{cde}	2.30^{defg}	2.70^{e}	6.39^{cd}	9.39^{cde}	12.00^{abc}	15.00^{cd}
T_{10} T_2+AMF	7.33^{def}	12.14^{cd}	16.12^{bc}	21.37^{abcd}	1.67^{a}	2.04^{bcd}	2.41^{bcd}	2.81^{de}	6.46^{bcd}	9.85^{abcde}	12.69^{cd}	15.69^{abcd}
$T_{11}$$T_2$+Azo+PSB+AMF	7.54^{bcde}	13.20^{abcd}	16.65^{b}	21.99^{abc}	1.71^{a}	2.09^{abcd}	2.45^{bc}	2.89^{cd}	6.77^{abcd}	10.31^{abc}	12.92^{abc}	16.00^{ab}
T_{12} T_3+Azo	8.71^{abc}	12.27^{cd}	15.80^{bc}	19.82^{cd}	1.65^{a}	1.99^{cde}	2.36^{cdef}	2.77^{de}	6.92^{abcd}	9.08^{e}	11.38^{de}	13.92^{e}
T_{13} T_3+PSB	8.54^{abc}	12.80^{bcd}	16.20^{bc}	20.39^{bcd}	1.68^{a}	2.09^{abcd}	2.41^{bcd}	2.80^{de}	7.15^{ab}	10.00^{abcd}	12.38^{abc}	14.92^{d}
T_{14} T_3+AMF	8.94^{ab}	12.89^{bcd}	16.49^{b}	20.81^{bcd}	1.69^{a}	2.06^{bcd}	2.39^{bcde}	2.82^{de}	7.31^{a}	10.15^{abcd}	12.92^{abc}	15.54^{abcd}
T_{15} T_3+Azo+PSB+AMF	9.28^{a}	13.28^{abcd}	16.38^{b}	20.95^{bcd}	1.71^{a}	2.09^{abcd}	2.40^{bcd}	2.85^{d}	7.54^{a}	10.23^{abcd}	13.08^{ab}	15.92^{abc}
T_{16} sand: soil	6.19^{f}	8.95^{e}	12.08^{d}	14.88^{f}	1.58^{a}	1.66^{f}	2.03^{h}	2.23^{h}	6.23^{d}	8.00^{f}	10.00^{g}	12.00^{g}

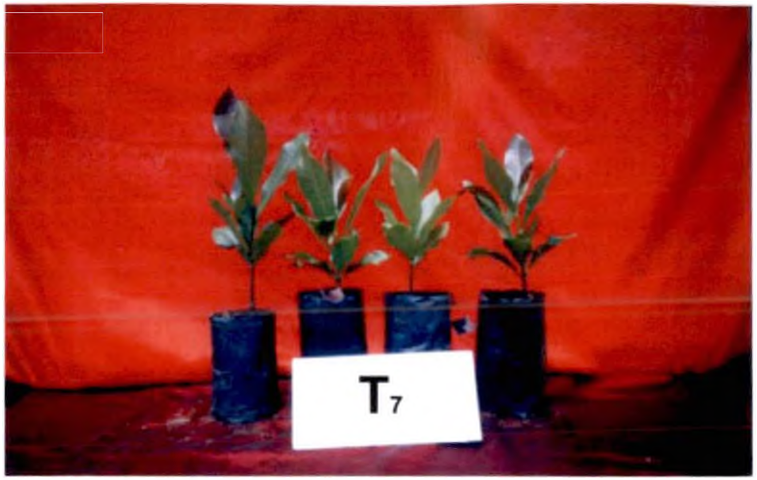


Plate1. Seedlings in potting mixture containing cowdung + *Azospirillum* +PSB +AMF

Plate 2. Seedlings in potting mixture containing coirpith compost +*Azospirillum* +PSB +AMF

Plate3. Seedlings in potting mixture containing poultry manure + *Azospirillum* +PSB +AMF

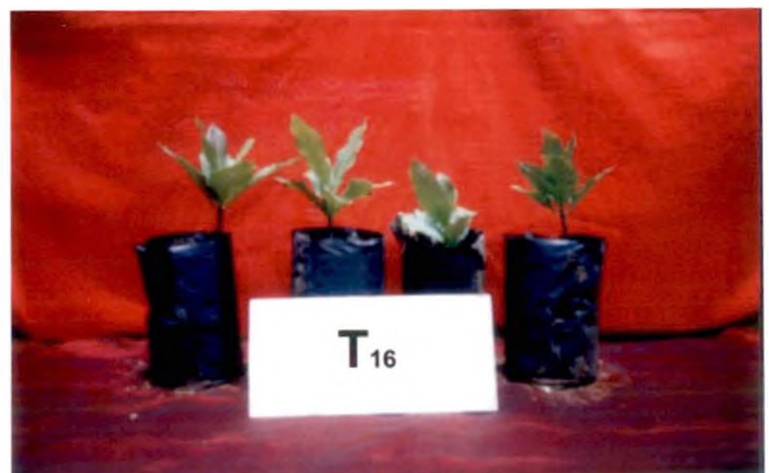


Plate 4. Seedlings in potting mixture containing only sand and soil

4.1.7 Number of Leaves

The number of leaves were recorded from 15 days after germination at fortnightly intervals(Table 9). At 15 days after germination, the maximum number of leaves (7.54 and 7.46) was recorded in combined biofertilizer (Azo + PSB + AMF) inoculated treatments of coirpith compost (T_{15}) and cowdung (T_7). At 30 days after germination T_7 was found to be superior (10.77 leaves). Biofertilizer inoculated treatments of cowdung, Azo + PSB + AMF and AMF alone inoculated treatments of poultry manure (T_{11} and T_{10} respectively) and coirpith compost (T_{15}, T_{13}, T_{14}) were on par with T_7. At 45 days after germination, the maximum number of leaves (13.23) was recorded with T_7. At 60 days after germination also the maximum number of leaves (16.31) was found in T_7 and T_{11}, T_{15}, T_{10}, T_{14} and T_6 were on par with it. At all the stages of observation T_{16} (sand:soil in 1:1) was inferior to other treatments.

4.1.8 Root Dry Weight

The root dry weight was found at the stage of grafting (Table 10). It was significantly higher in T_7 i.e., sand:soil:cowdung + Azo + PSB + AMF (1.48 g) and the lowest (0.77 g) in T_{16} (sand:soil in 1:1).

4.1.9 Shoot Dry Weight

The shoot dry weight was the highest (4.59 g) in T_7 and the lowest (3.02 g) in T_{16}(Table 10).

4.1.10 Root: shoot Ratio

The root:shoot ratio on dry basis at the time of grafting is given in Table 10. The maximum root:shoot (0.32) was noticed in T_7, where as the minimum

Table 10. Dry weight of root, shoot and root : shoot ratio at grafting stage of cashew

Treatments	Dry weight plant^{-1} (g)		
	Root	Shoot	Root: Shoot
T_1 sand: soil: cowdung	1.04^{defg}	4.03^{cde}	0.26^{ab}
T_2 sand: soil: poultry manure	1.00^{fg}	3.89^{ef}	0.25^{b}
T_3 sand: soil: coirpith compost	0.92^{g}	3.71^{f}	0.24^{b}
T_4 T_1+Azo	1.18^{bc}	4.27^{bcd}	0.28^{ab}
T_5 T_1+PSB	1.19^{bc}	4.29^{bc}	0.28^{ab}
T_6 T_1+AMF	1.30^{b}	4.40^{ab}	0.29^{ab}
T_7 T_1+Azo+PSB+AMF	1.48^{a}	4.59^{a}	0.32^{a}
T_8 T_2+Azo	1.03^{defg}	3.96^{def}	0.26^{ab}
T_9 T_2+PSB	1.10^{cdef}	4.10^{bcde}	0.27^{ab}
T_{10} T_2+AMF	1.16^{cde}	4.15^{bcde}	0.28^{ab}
T_{11} T_2+Azo+PSB+AMF	1.21^{bc}	4.31^{abc}	0.28^{ab}
T_{12} T_3+Azo	1.02^{efg}	4.01^{cdef}	0.25^{b}
T_{13} T_3+PSB	1.11^{cdef}	4.15^{bcde}	0.27^{ab}
T_{14} T_3+AMF	1.14^{cde}	4.22^{bcd}	0.27^{ab}
T_{15} T_3+Azo+PSB+AMF	1.17^{cd}	4.24^{bcd}	0.27^{ab}
T_{16} sand: soil (1:1)	0.77^{h}	3.02^{g}	0.25^{b}

(0.24) in T_3 followed by T_{16}, T_2 and T_{12} (0.25). All the other treatments were on par with T_7.

4.1.11 Nutrient Content in Leaves

The nutrient content (N, P, K, Ca, Mg) of leaves were analysed at the stage of grafting (Table 11). The nitrogen content was significantly higher (1.53%) in T_8 (sand:soil:poultry manure + Azo) followed by T_{11} (1.47%) and the lowest (0.91%) in T_{16}. The phosphorus content was the highest (0.20%) in T_{11} and T_9 (sand:soil:poultry manure + PSB). All the poultry manure containing treatments were on par with it and the lowest P (0.03%) was found in T_{16}. The potassium content was found maximum in T_{11} (1.68%) and T_{10} (sand:soil:poultry manure + AMF) was on par with it. The lowest K was in T_{16} (0.62%). The maximum calcium content (0.21%) was noticed in T_{11} followed by T_{10} (0.19%) which was on par with cowdung containing potting mixtures inoculated with AMF and PSB either alone or in combination (Azo + PSB + AMF). The lowest Ca was found in T_{16} (0.05%). The magnesium content was also maximum in T_{11} (0.20%) and it was seen that Mg content was higher when poultry manure was used as an organic source in potting mixture. The minimum Mg content was observed in T_{16} like all the other nutrients.

4.1.12 Nutrient Content in Potting Mixtures at the Stage of Grafting

The available nutrient content (N, P, K, Ca, Mg) in potting mixture at grafting is given in Table 12. The maximum available nitrogen (225 ppm) was found in T_{11} (sand:soil:poultury manure + Azo + PSB + AMF) and biofertilizer inoculated treatments of cowdung and all the potting mixture containing poultry manure were on par with it. The lowest N (117.7 ppm) was noticed in T_{16} (sand:soil in 1:1). Available phosphorus was found to be the highest (77.3 ppm) in T_{11} followed by T_9 (sand:soil:poultry manure + PSB) 74.0 ppm. The treatments with biofertilizers inoculation irrespective of poultry manure or cowdung in

Table 11. Nutrient content in the leaves at grafting stage as influenced by the potting mixtures and biofertilizer inoculation

Treatments	Nutrient content (%)				
	N	P	K	Ca	Mg
T_1 sand: soil: cowdung	1.10^{fg}	0.08^{bcde}	0.85^{i}	0.10^{cdef}	0.09^{fgh}
T_2 sand: soil: poultry manure	1.19^{de}	0.17^{a}	1.28^{de}	0.16^{abc}	0.15^{abcde}
T_3 sand: soil: coirpith compost	0.99^{h}	0.04^{de}	0.87^{i}	0.06^{ef}	0.06^{gh}
T_4 T_1+Azo	1.41^{b}	0.07^{bcde}	1.05^{gh}	0.11^{cde}	0.11^{defgh}
T_5 T_1+PSB	1.17^{ef}	0.11^{b}	1.03^{gh}	0.13^{bcd}	0.10^{efgh}
T_6 T_1+AMF	1.32^{c}	0.09^{bcd}	1.13^{fg}	0.15^{abc}	0.14^{abcdef}
T_7 T_1+Azo+PSB+AMF	1.42^{b}	0.10^{bc}	1.18^{ef}	0.18^{ab}	0.16^{abcd}
T_8 T_2+Azo	1.47^{ab}	0.18^{a}	1.40^{cd}	0.15^{abc}	0.15^{abcde}
T_9 T_2+PSB	1.30^{c}	0.20^{a}	1.50^{bc}	0.16^{abc}	0.17^{abc}
T_{10} T_2+AMF	1.44^{b}	0.19^{a}	1.60^{ab}	0.19^{a}	0.18^{ab}
T_{11} T_2+Azo+PSB+AMF	1.53^{a}	0.20^{a}	1.68^{a}	0.21^{a}	0.20^{a}
T_{12} T_3+Azo	1.24^{cde}	0.05^{cde}	0.95^{hi}	0.05^{ef}	0.12^{cdefg}
T_{13} T_3+PSB	1.09^{g}	0.06^{bcde}	0.93^{hi}	0.08^{def}	0.10^{efgh}
T_{14} T_3+AMF	1.20^{de}	0.06^{bcde}	1.15^{fg}	0.10^{cdef}	0.13^{bcdef}
T_{15} T_3+Azo+PSB+AMF	1.25^{cd}	0.06^{bcde}	1.22^{ef}	0.13^{bcd}	0.13^{bcdef}
T_{16} sand: soil (1:1)	0.91^{i}	0.03^{e}	0.62^{j}	0.05^{f}	0.04^{h}

potting mixture were on par with T_{11}. Lowest content was noticed in T_{16} (1.7 ppm). the available potassium was the maximum (200 ppm) in T_{11} and all the biofertilizer inoculated treatments of poultry manure and cowdung containing potting mixture were on par with T_{11}. The lowest K was found in T_{16} (68 ppm). The exchangeable calcium and magnesium also showed a similar trend as that of K with a maximum of 193.3 ppm in T_{11} and minimum of 22 ppm in T_{16} in the case of Ca. In the case of Mg it was 87 and 12 ppm respectively.

4.1.13 Microbial Population at 2 MAS or at Grafting Stage

Population of *Azospirillum* sp , PSB, AMF spores and AMF percentage root infection are given in Table 13.

Result showed that population of *Azospirillum* was the highest (8.9 x 10^4 cell g^{-1}) in the potting mixture containing sand:soil:cowdung + Azo + PSB + AMF (T_7). It was 96.8 per cent more than absolute control T_{16} (0.28 x 10^4 cell g^{-1}).

The population of phosphorus solubilizing bacteria was found maximum (74 x 10^6 cfu g^{-1}) in T_7 and it had 75.2 per cent more population than in absolute control T_{16} (18.33 x 10^6 cfu g^{-1}).

Total Arbuscular Mycorrhizal Fungal spores was the maximum (38 spores per 10 g potting mixture) in T_7 and it had 80.3 per cent more spores than in absolute control T_{16} (7.50).

Arbuscular Mycorrhizal Fungi percentage root infection was found highest in T_7 (70.85%) and the lowest (8.33%) in T_2 (sand:soil:poultry manure). T_7 had 82.4 per cent more root infection than absolute control T_{16} (12.50%).

Table 12. Available nutrient content in potting mixtures at the time of grafting

Treatments	Nutrient content (ppm)				
	N	P	K	Ca	Mg
T_1 sand: soil: cowdung	161.7[bcdeg]	47.7[c]	112.7[def]	122.0[bc]	22.7[bc]
T_2 sand: soil: poultry manure	185.7[abcde]	55.0[bc]	128.7[bcde]	127.3[bc]	27.0[abc]
T_3 sand: soil: coirpith compost	127.0[ef]	2.7[d]	98.3[ef]	35.7[de]	19.3[bc]
T_4 T_1+Azo	215.3[ab]	54.7[bc]	142.7[abcde]	136.0[abc]	38.0[abc]
T_5 T_1+PSB	191.3[abcd]	70.0[ab]	159.7[abcde]	157.3[ab]	42.7[abc]
T_6 T_1+AMF	197.0[abc]	67.3[ab]	175.0[abc]	163.0[ab]	55.7[abc]
T_7 T_1+Azo+PSB+AMF	220.0[ab]	72.0[ab]	181.3[abc]	178.7[ab]	70.0[abc]
T_8 T_2+Azo	215.7[ab]	61.3[abc]	157.0[abcd]	148.7[ab]	53.7[abc]
T_9 T_2+PSB	194.7[abcd]	74.0[a]	174.0[abcd]	168.7[ab]	68.0[abc]
T_{10} T_2+AMF	203.3[abc]	67.0[ab]	189.7[ab]	180.3[ab]	78.7[ab]
T_{11} T_2+Azo+PSB+AMF	225.0[a]	77.3[a]	200.0[a]	193.3[a]	87.0[a]
T_{12} T_3+Azo	144.7[cdef]	3.3[d]	119.7[cdef]	42.3[de]	39.7[abc]
T_{13} T_3+PSB	136.3[def]	5.0[d]	121.7[cdef]	53.0[de]	35.3[abc]
T_{14} T_3+AMF	135.3[def]	4.7[d]	132.7[bcde]	65.3[de]	55.3[abc]
T_{15} T_3+Azo+PSB+AMF	150.0[cdef]	5.3[d]	138.0[bcde]	82.7[cd]	66.7[abc]
T_{16} sand: soil (1:1)	117.7[f]	1.7[d]	68.0[f]	22.0[e]	12.0[c]

Table 13. Total microbial population (*Azospirillum*, PSB, AMF) in the potting mixtures and AMF root infection at grafting

Treatments	*Azospirillum* (× 10^4 Cellg^{-1} potting mixture)	PSB (×10^6 Cfug^{-1} potting mixture)	AMF	
			Spore population (per 10g potting mixture)	Root infection (%)
T_1 sand: soil: cowdung	0.46 (3.66^{def})	25.00 (7.40^{fg})	13.50 (1.13^{defg})	16.67 (1.16^{def})
T_2 sand: soil: poultry manure	0.29 (3.47^{h})	18.67 (7.27^{hi})	9.50 (0.98^{fgh})	8.33 (0.92^{f})
T_3 sand: soil: coirpith compost	0.30 (3.48^{h})	21.67 (7.33^{ghi})	8.00 (0.90^{gh})	12.50 (1.07^{ef})
T_4 T_1+ Azo	1.17 (3.99^{b})	30.00 (7.48^{ef})	14.00 (1.14^{def})	20.83 (1.31^{cde})
T_5 T_1+ PSB	0.45 (3.65^{def})	62.33 (7.79^{a})	16.50 (1.21^{cdef})	29.15 (1.46^{bcd})
T_6 T_1+ AMF	0.50 (3.69^{cde})	31.33 (7.49^{def})	33.00 (1.52^{ab})	62.50 (1.79^{ab})
T_7 T_1+ Azo+ PSB+ AMF	8.9 (4.73^{a})	74.00 (7.87^{a})	38.00 (1.58^{a})	70.85 (1.85^{a})
T_8 T_2+ Azo	0.43 (3.61^{efg})	23.67 (7.37^{fgh})	18.00 (1.22^{cde})	12.50 (1.07^{ef})
T_9 T_2+ PSB	0.30 (3.48^{h})	36.33 (7.56^{cde})	11.50 (1.05^{efgh})	12.50 (1.07^{ef})
T_{10} T_2+ AMF	0.33 (3.51^{gh})	24.00 (7.38^{fgh})	22.00 (1.34^{bcd})	37.49 (1.57^{abc})
T_{11} T_2+ Azo+ PSB+ AMF	0.62 (3.79^{c})	40.00 (7.60^{bcd})	26.00 (1.42^{abc})	45.83 (1.66^{ab})
T_{12} T_3+ Azo	0.58 (3.76^{cd})	27.33 (7.43^{fg})	12.00 (1.07^{efgh})	16.67 (1.16^{def})
T_{13} T_3+ PSB	0.39 (3.58^{efgh})	41.67 (7.62^{bc})	13.00 (1.11^{defg})	20.83 (1.31^{cde})
T_{14} T_3+ AMF	0.35 (3.54^{fgh})	27.67 (7.44^{efg})	25.50 (1.41^{abc})	50.00 (1.70^{ab})
T_{15} T_3+ Azo+ PSB+ AMF	1.1 (4.02^{b})	47.67 (7.68^{b})	28.00 (1.45^{abc})	54.17 (1.73^{ab})
T_{16} sand: soil	0.28 (3.45^{h})	18.33 (7.25^{i})	7.50 (0.87^{h})	12.50 (1.07^{ef})

Data in parenthesis are logarithmically transformed values

4.2 EXPT-II MANAGEMENT PRACTICES OF CASHEW GRAFTS

Assuming that T_7 (sand:soil:cowdung + Azo + PSB + AMF) of experiment I will give better results, sufficient number of plants were maintained and used in the experiment II. These plants were grafted at 2 MAS with pre cured scions of Madakkathara-1.

4.2.1 Soil Application of Nutrients to the Grafts

Soil application of nutrients viz., urea, ammonium sulphate (AS), ammonium phosphate sulphate (APS), MOP, 17:17:17 mixture and local practice like decanted extract of groundnut cake (DEGN) was done at 1 month after grafting (MAG) and observations were taken at monthly intervals. The results are given below.

4.2.1.1 *Height*

Based on the height of rootstock at which sufficient girth is achieved for grafting and length of scion, usually 2-3 cm difference was noticed on rootstocks and or scions. So height at 1 MAG i.e., before nutrient application to the grafts and at 3 MAG were taken and only increase in height was recorded at monthly intervals.

At 1 MAG (Table 14) the maximum height (29.07 cm) was found in T_1 (control - sand:soil:cowdung + Azo + PSB + AMF) and the minimum (25.98 cm) in T_6 (soil application of 17:17:17) even though all the treatments were on par.

Increase in plant height was observed at monthly intervals (Table 15). At 1-2 MAG T_7 (DEGN + 17:17:17 mixture) was found superior (2.55 cm) and the lowest increase (1.15 cm) was noticed in T_1 (control). All the other treatments were on par with T_7. At 2-3 MAG also the same trend of result was observed with the maximum (2.90 cm) in T_7 and the minimum (1.45 cm) in T_1.

Increase in height from 1-3 MAG (Table 14) shows that the maximum vlaue (5.45 cm) was found in T_7 and the lowest (2.60 cm) in T_1. All the other treatments were on par with T_7. The observed height was 30.99 to 33.14 cm at 3 MAG.

4.2.1.2 *Number of Leaves*

The number of leaves were observed at monthly intervals (Table 15). At 2 MAG and 3 MAG there was no significant differences between treatments. Maximum number of leaves (9.4 and 10.8 respectively) was found in T_7 and the minimum (7.9 and 9.3 respectively) in T_1. So at 3 MAG the number of leaves varied from 9.3 to 10.8.

4.2.1.3 *Leaf Area*

Leaf area per plant was found out at monthly intervals (Table 15). T_7 recorded the maximum leaf area per plant (186.7 cm^2) at 2 MAG and T_6 (17:17:17 100 g/10 l water) was found on par with T_7. The minimum leaf area was found in T_1 (94.94 cm^2). At 3 MAG similar pattern of result was found with the maximum leaf area in T_7 (254.9 cm^2) and the minimum (123.1 cm^2) in T_1.

4.2.1.4 *Nutrient Content of Leaves*

The nutrient content of leaves were analysed at 3 MAG and the results are given in Table 16. The nitrogen content was maximum in T_7 (1.49%) which was significantly different from other treatments. The minimum N content was noticed in T_1 (1.21%). Phosphorus content was the highest (0.136%) in T_7 and the lowest (0.087%) in T_1 but the differences were not significant. In the case of potassium

Table 14. Effect of soil application of nutrients on height of grafts and increase in height from 1-3 MAG

Treatment	Height (cm)		Increase in height (cm)
	1MAG	3MAG	1-3 MAG
T_1 Control (sand: soil: cowdung+ Azo+PSB+AMF)	29.07[a]	31.67[a]	2.60[b]
T_2 Urea (40g/10 l water)	27.23[a]	32.05[a]	4.82[a]
T_3 Ammonium sulphate (80g/10 l water)	27.59[a]	31.95[a]	4.36[a]
T_4 Ammonium phosphate sulphate (80g/10 l water)	26.45[a]	31.21[a]	4.76[a]
T_5 Ammonium phosphate sulphate (80g/10 l water) + (25g/10 l water)	28.28[a]	33.14[a]	4.86[a]
T_6 17:17:17 (100g/10 l water)	25.98[as]	30.99[a]	5.01[a]
T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)	26.94[a]	32.39[a]	5.45[a]

Table 15. Increase in height, number of leaves and leaf area at monthly intervals as influenced by soil application of nutrients to grafts

Treatment	Increase in height (cm)		Number of leaves		Leaf area (cm^2 $plant^{-1}$)	
	1 to 2 MAG	2 to 3 MAG	2 MAG	3 MAG	2 MAG	3 MAG
T_1 Control (sand: soil: cowdung+ Azo+PSB+AMF)	1.15[b]	1.45[b]	7.9[a]	9.3[a]	94.9[d]	123.1[e]
T_2 Urea (40g/10 l water)	2.30[a]	2.52[a]	9.2[a]	10.6[a]	144.3[b]	197.3[cd]
T_3 Ammonium sulphate (80g/10 l water)	2.08[ab]	2.28[a]	9.2[a]	10.3[a]	124.8[c]	173.9[d]
T_4 Ammonium phosphate sulphate (80g/10 l water)	2.16[ab]	2.60[a]	9.2[a]	10.4[a]	123.6[c]	175.0[d]
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water)	2.31[a]	2.55[a]	9.3[a]	10.7[a]	153.1[b]	220.1[bc]
T_6 17:17:17 (100g/10 l water)	2.31[a]	2.70[a]	9.1[a]	10.5[a]	171.4[a]	235.3[ab]
T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)	2.55[a]	2.90[a]	9.4[a]	10.8[a]	186.7[a]	254.9[a]

also T_7 showed significantly higher (1.38%) and the minimum was found in T_1 (1.00%). The calcium content was also the highest in T_7 (0.26%) and the lowest content in T_1 (0.17%). All the other treatments were on par. Magnesium content was not significantly different between treatments. The maximum Mg content (0.19%) was in T_7 and the minimum (0.13%) in T_1. From the results it is found that the maximum content of all nutrients were in T_7 and minimum in T_1.

4.2.1.5 *Nutrient Content in Potting Mixtures*

The available nutrient content (N, P, K, Ca, Mg) in potting mixtures were analysed at 3 MAG (Table 17). The available nitrogen content was not significantly different between treatments but it was relatively higher (144.7 ppm) in T_7 (DEGN + 17:17:17) and in T_2 (Urea). The minimum N (115.7 ppm) was noticed in T_1 (control). In the case of phosphorus the maximum (59.7 ppm) was in T_7 followed by T_6 (17:17:17 mixture) and the minimum (36.3 ppm) was in T_1. The potassium content was also maximum (165.7 ppm) in T_7 followed by T_6 (165.3 ppm) and the minimum was noticed in T_1 (74.7 ppm). The highest calcium content (118 ppm) was found in T_7 and the lowest (52.0 ppm) in T_1. All the other treatments were on par with T_7. Magnesium content was relatively higher in T_7 (50.3 ppm) and the lowest (16.7 ppm) in T_1 but the differences were not significant. From the results it was clear that T_7 recorded the maximum contents of all nutrients and T_1 recorded the lowest content since no nutrient supplementation was given.

4.2.1.6 *Microbial Population*

In this experiment, all the treatments are having the same potting mixture (sand:soil:cowdung + Azo + PSB + AMF). So composite samples were taken and analysed for population dynamics of microflora (Table 18). *Azospirillum* population in the composite samples were 11.3 and 11.4 x 10^4 cell g^{-1} potting mixture. Phosphorus solubilising bacterial population was 92.3 and 90 x 10^6 cfu g^{-1}

Table 16. Nutrient content in leaves at 3 MAG as influenced by soil application of nutrients to grafts

Treatments	Nutrient content (%)				
	N	P	K	Ca	Mg
T_1 Control (sand: soil: cowdung+ Azo+ PSB+AMF)	1.21[c]	0.087[a]	1.00[d]	0.17[b]	0.13[a]
T_2 Urea (40g/10 l water)	1.42[b]	0.093[a]	1.07[d]	0.22[ab]	0.17[a]
T_3 Ammonium sulphate (80g/10 l water)	1.36[cd]	0.091[a]	1.02[d]	0.23[ab]	0.16[a]
T_4 Ammonium phosphate sulphate (80g/10 l water)	1.31[d]	0.111[a]	1.05[d]	0.20[ab]	0.15[a]
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water)	1.33[d]	0.112[a]	1.18[c]	0.21[ab]	0.15[a]
T_6 17:17:17 (100g/10 l water)	1.41[bc]	0.122[a]	1.27[b]	0.23[ab]	0.17[a]
T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)	1.49[a]	0.136[a]	1.38[a]	0.26[a]	0.19[a]

Table 17. Available nutrient content in potting mixtures at 3 MAG as influenced by soil application of nutrients to grafts

Treatments	Available nutrient content (ppm)				
	N	P	K	Ca	Mg
T_1 Control (sand: soil: cowdung+ Azo+PSB+AMF)	115.7[a]	36.3[a]	74.7[c]	52.0[b]	16.7[a]
T_2 Urea (40g/10 l water)	140.7[a]	40.0[a]	82.7[c]	81.7[ab]	33.0[a]
T_3 Ammonium sulphate (80g/10 l water)	130.7[a]	39.7[a]	86.7[bc]	72.0[ab]	21.0[a]
T_4 Ammonium phosphate sulphate (80g/10 l water)	131.0[a]	56.0[a]	114.7[abc]	63.7[ab]	24.0[a]
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water)	135.3[a]	55.3[a]	143.0[ab]	89.7[ab]	38.0[a]
T_6 17:17:17 (100g/10 l water)	134.3[a]	57.0[a]	165.3[a]	101.0[ab]	47.0[a]
T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)	144.7[a]	59.7[a]	165.7[a]	118.0[a]	50.3[a]

Table 18. Microbial population at 3 MAG as influenced by soil application of nutrients to grafts

Samples	Azospirillum ($\times 10^4$ Cellg^{-1} potting mixtures)	PSB ($\times 10^4$ cfu g^{-1} potting mixture)	AMF spore population (10 g^{-1} potting mixture)
sand:soil:cowdung+Azo+PSB+AMF (S_1)	11.4 (4.92)	92.3 (7.96)	48.0 (1.68)
S_1 +organic +inorganic nutrients	11.3 (4.89)	90.0 (7.95)	45.3 (1.65)

Data in parentheses are logarithmically transformed values potting mixture and Arbuscular Mycorrhizal Fungi spores were 48 and 47.3 per 10 g potting mixture.

4.2.2 Foliar Fertilization to the Grafts

Eventhough soil application of nutrients at 1 MAG was given, to sustain the growth of grafts foliar fertilization of 2 per cent urea/ammonium phosphate sulphate/17:17:17 mixture was tried at 3 MAG. In all the 7 soil nutrient application treatments a control was kept without foliar fertilization to the grafts. So altogether there were 28 treatments replicated ten times. The results of this experiment are furnished below.

4.2.2.1 *Height*

Increase in plant height were recorded at monthly intervals (Tables 19, 20, 21) and increase in height from 3 MAG to 6 MAG is given in Table 22. Height at 6 MAG is given in Table 23.

Increase in height at 3-4, 4-5 and 5-6 MAG showed that out of all treatment combinations the maximum increase (2.04, 2.46 and 2.35 cm respectively) was observed with 2 per cent 17:17:17 spray on T_7 (soil application of DEGN + 17:17:17 mixture). The minimum increase was noticed in control plants without nutrient supplementation. Among the different foliar sprays, 2 per cent 17:17:17 spray was found superior to ammonium phosphate sulphate while 2 per cent urea spray was on par with it.

Increase in plant height from 3-6 MAG also showed that along with soil application of DEGN + 17:17:17 mixture, foliar application of 2 per cent 17:17:17 spray recorded the highest value (6.85 cm) and the minimum (3.09 cm) in control of T_1 (T_1F_0). It is also evident that 17:17:17 mixture and urea were better than

Table 19. Increase in height (cm) from 3 MAG to 4 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	1.07^{E}	1.43^{BCDE}	1.19^{CDE}	1.540^{ABCDE}	1.318^{b}
T_2	1.21^{BCDE}	1.58^{ABCDE}	1.40^{BCDE}	1.66^{ABCDE}	1.46^{b}
T_3	1.09^{F}	1.52^{ABCDE}	1.41^{BCDE}	1.63^{ABCDE}	1.41^{b}
T_4	1.17^{CDE}	1.54^{ABCDE}	1.35^{BCDE}	1.68^{ABCDE}	1.43^{b}
T_5	1.15^{DE}	1.52^{ABCDE}	1.33^{BCDE}	1.68^{ABCD}	1.42^{b}
T_6	1.14^{DE}	1.57^{ABCDE}	1.40^{BCDE}	1.75^{ABC}	1.47^{b}
T_7	1.34^{BCDE}	1.79^{AB}	1.66^{ABCDE}	2.04^{A}	1.71^{a}
Mean	1.17^{c}	1.56^{ab}	1.39^{b}	1.71^{a}	

Table 20. Increase in height (cm) from 4 MAG to 5 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	1.04^{E}	1.59^{BCDE}	1.34^{CDE}	1.55^{BCDE}	1.38^{c}
T_2	1.34^{CDE}	1.59^{BCDE}	1.41^{CDE}	1.57^{BCDE}	1.48^{bc}
T_3	1.28^{DE}	1.54^{BCDE}	1.48^{BCDE}	1.69^{BCDE}	1.50^{bc}
T_4	1.10^{E}	1.56^{BCDE}	1.44^{CDE}	1.63^{BCDE}	1.43^{bc}
T_5	1.20^{DE}	1.59^{BCDE}	$1.4\ 5^{CDE}$	1.73^{ABCDE}	1.49^{bc}
T_6	1.46^{CDE}	2.00^{ABCD}	1.52^{BCDE}	2.14^{ABC}	1.78^{ab}
T_7	1.54^{BCDE}	2.27^{AB}	2.13^{ABC}	2.46^{A}	2.10^{a}
Mean	1.28^{c}	1.73^{ab}	1.54^{b}	1.82^{a}	

Table 21. Increase in height (cm) from 5 MAG to 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.95^{F}	1.41^{DEF}	1.30^{EF}	1.74^{ABCDE}	1.35^{c}
T_2	1.34^{DEF}	1.79^{ABCDE}	1.70^{ABCDE}	1.77^{ABCDE}	1.65^{b}
T_3	1.40^{DEF}	1.70^{ABCDE}	1.58^{BCDEF}	1.95^{ABCDE}	1.66^{b}
T_4	1.38^{DEF}	1.83^{ABCDE}	1.71^{ABCDE}	1.86^{ABCDE}	1.70^{b}
T_5	1.49^{CDEF}	1.85^{ABCDE}	1.56^{CDEF}	1.88^{ABCDE}	1.70^{b}
T_6	1.40^{DEF}	1.96^{ABCDE}	1.56^{CDEF}	2.17^{ABC}	1.77^{ab}
T_7	1.52^{CDEF}	2.26^{AB}	2.01^{ABCD}	2.35^{A}	2.04^{a}
Mean	1.35^{c}	1.83^{ab}	1.63^{b}	1.96^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

Table 22. Increase in height (cm) 3 to 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	3.09^{H}	4.43^{EFG}	3.83^{FGH}	4.83^{CDEFG}	4.05^{c}
T_2	3.89^{FGH}	4.97^{CDEFG}	4.51^{DEFG}	5.00^{CDEFG}	4.59^{bc}
T_3	3.75^{GH}	4.71^{DEFG}	4.37^{EFGH}	5.27^{BCDE}	4.53^{bc}
T_4	3.65^{GH}	4.93^{CDEFG}	4.50^{DEFG}	5.15^{CDEF}	4.56^{bc}
T_5	3.84^{FGH}	4.96^{CDEFG}	4.34^{EFGH}	5.29^{BCDE}	4.61^{bc}
T_6	3.90^{FGH}	5.53^{BCDE}	4.51^{DEFG}	6.06^{ABC}	5.00^{b}
T_7	4.40^{FGH}	6.45^{AB}	5.80^{ABCD}	6.85^{A}	5.88^{a}
Mean	3.79^{c}	5.14^{a}	4.55^{b}	5.49^{a}	

Table 23. Height (cm) at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	34.36^{FG}	36.33^{ABCDEF}	35.83^{CDEFG}	$36.05^{ABCDEFG}$	35.64^{b}
T_2	34.24^{FG}	$35.98^{ABCDEFG}$	35.70^{CDEFG}	36.37^{ABCDEF}	35.57^{b}
T_3	35.54^{CDEFG}	36.77^{ABCDE}	36.47^{ABCDEF}	36.53^{ABCDEF}	36.32^{ab}
T_4	33.81^{G}	35.55^{CDEFG}	35.88^{BCDEFG}	36.80^{ABCDE}	35.51^{b}
T_5	34.93^{DEFG}	$36.12^{ABCDEFG}$	35.79^{CDEFG}	37.73^{ABC}	36.14^{b}
T_6	34.82^{EFG}	36.37^{ABCDEF}	35.78^{CDEFG}	37.32^{ABCD}	36.07^{b}
T_7	35.86^{BCDEFG}	38.22^{AB}	36.77^{ABCDE}	38.26^{A}	37.28^{a}
Mean	34.79^{c}	36.48^{ab}	36.03^{b}	37.01^{a}	

T_1 Control (Sand: Soil: Cowdung+Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

ammonium phosphate sulphate. Plant height at 6 MAG was maximum with 2 per cent 17:17:17 spray on T_7 (38.26 cm).

4.2.2.2 *Number of Leaves*

Number of leaves were observed at monthly intervals (Tables 24, 25, 26). At 4 MAG, the maximum number of leaves (12.30) was observed with 2 per cent urea spray on T_2 (soil application of urea) but at 5 and 6 MAG, the maximum number (15.1 and 17 leaves, respectively) was found with 2 per cent 17:17:17 spray on T_7. At all the stages of observation minimum leaves were found with T_1F_0. While comparing the controls it was noted that T_7 was better and with respect to foliar sprays 2 per cent urea and 2 per cent 17:17:17 were on par.

4.2.2.3 *Leaf Area*

Leaf area per plant at monthly intervals are furnished in the Tables 27, 28, 29. It was found the maximum with 2 per cent 17:17:17 spray on T_7 (403.2, 464.2 and 637.6 cm^2 respectively at 4, 5 and 6 MAG). Minimum was found in the control of T_1 (187.6, 221.4 and 301.4 cm^2 respectively). Among the control treatments, T_7 control recorded maximum and 2 per cent 17:17:17 spray was found significantly superior over the other foliar sprays on all treatment. It was also noticed that foliar sprays on T_7 produced the maximum leaf area in general at all stages of observation.

4.2.2.4 *Root weight*

Root dry weight at 6 MAG is given in Table 30. It was the maximum with 2 per cent 17:17:17 spray on T_7 (9.066 g) which was on par with 2 per cent ammonium phosphate sulphate spray. The minimum (3.027 g) was found in control of T_1 (T_1F_0). Among the control treatments, T_7 control was found superior to other controls. Generally it was noticed that 2 per cent 17:17:17 spray was

Table 24. Number of leaves at 4 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	9.40^{G}	10.00^{FG}	9.80^{G}	10.30^{EFG}	9.88^{e}
T_2	10.10^{FG}	12.50^{A}	11.10^{CDEF}	12.10^{ABC}	11.45^{ab}
T_3	9.80^{G}	11.00^{CDEF}	10.50^{DEFG}	11.40^{ABCDE}	10.68^{cd}
T_4	9.70^{G}	11.30^{BCDE}	10.30^{EFG}	11.10^{CDEF}	10.60^{d}
T_5	9.90^{FG}	11.60^{ABCD}	11.00^{CDEF}	11.50^{ABCD}	11.00^{bcd}
T_6	10.00^{FG}	11.90^{ABC}	11.10^{CDEF}	11.70^{ABC}	11.18^{abc}
T_7	10.30^{EFG}	12.30^{AB}	11.80^{ABC}	12.10^{ABC}	11.63^{a}
Mean	9.89^{c}	11.51^{a}	10.80^{b}	11.46^{a}	

Table 25. Number of leaves at 5 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	10.60^{M}	11.30^{KLM}	11.10 l^{M}	11.40^{JKLM}	11.10^{d}
T_2	11.50^{JKLM}	14.10^{ABC}	12.80^{CDEFGHI}	13.90^{ABCDE}	13.07^{b}
T_3	11.00^{LM}	12.50^{FGHIJK}	11.70^{IJKLM}	12.70^{DEFGHIJ}	11.98^{c}
T_4	10.90^{LM}	12.90^{CDEFGHI}	12.00^{GHIJKL}	13.00^{CDEFGHI}	12.20^{c}
T_5	11.30^{KLM}	13.10^{CDEFGHI}	12.50^{FGHIJKL}	13.30^{BCDEFG}	12.55^{bc}
T_6	11.50^{JKLM}	14.00^{ABC}	12.60^{EFGHIJK}	13.80^{BCDEF}	12.98^{b}
T_7	11.80^{HIJKLM}	14.50^{AB}	13.20^{CDEFG}	15.10^{A}	13.65^{a}
Mean	11.23^{c}	13.20^{a}	12.27^{b}	13.31^{a}	

Table 26. Number of leaves at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	11.80^{K}	13.00^{GHIJK}	12.60^{IJK}	13.10^{FGHIJK}	12.63^{d}
T_2	13.10^{FGHIJK}	15.90^{AB}	14.20^{DEFGH}	16.10^{AB}	14.82^{b}
T_3	12.50^{IJK}	15.20^{BCD}	13.70^{EFGHIJ}	15.30^{BCD}	14.18^{c}
T_4	12.30^{JK}	14.30^{DEFG}	13.90^{DEFGHI}	14.50^{CDEF}	13.75^{c}
T_5	12.80^{HIJK}	15.00^{BCDE}	13.90^{DEFGHI}	15.00^{BCDE}	14.18^{c}
T_6	13.10^{FGHIJK}	16.10^{AB}	14.30^{DEFG}	16.40^{AB}	14.98^{b}
T_7	13.90^{DEFGHI}	16.70^{A}	15.80^{ABC}	17.00^{A}	15.85^{a}
Mean	12.79^{c}	15.17^{a}	14.06^{b}	15.34^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

Table 27. Leaf area plant^{-1} (cm^2) at 4 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	*Mean*
T_1	187.6^{P}	269.0^{LMN}	247.5^{NO}	300.3^{IJ}	251.1^{e}
T_2	256.9^{MN}	326.1^{FGH}	305.2^{HIJ}	358.6^{CDE}	311.7^{c}
T_3	229.8^{O}	314.2^{GHIJ}	293.1^{JK}	336.3^{EFG}	293.4^{d}
T_4	229.0^{O}	307.7^{HIJ}	291.6^{JKL}	333.4^{FG}	290.4^{d}
T_5	274.4^{KLM}	345.6^{DEF}	321.4^{FGHI}	387.6^{AB}	332.3^{b}
T_6	294.8^{JK}	363.4^{CD}	321.1^{FGHI}	389.3^{AB}	342.2^{b}
T_7	303.2^{HIJ}	377.2^{BC}	332.1^{FG}	403.2^{A}	353.9^{a}
Mean	253.7^{d}	329.0^{b}	301.7^{c}	358.4^{a}	

Table 28. Leaf area plant^{-1} (cm^2) at 5 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	221.4^{M}	294.1^{K}	267.8^{L}	313.2^{IJK}	274.1^{f}
T_2	302.6^{JK}	358.7^{FG}	341.1^{GHI}	396.0^{DE}	349.6^{c}
T_3	263.3^{L}	347.1^{FGH}	331.0^{HIJ}	374.4^{EF}	328.9^{d}
T_4	261.2^{L}	324.5^{HIJ}	307.5^{JK}	360.9^{FG}	313.5^{e}
T_5	309.7^{JK}	404.0^{D}	366.2^{FG}	443.3^{ABC}	380.8^{b}
T_6	315.8^{IJK}	421.8^{BCD}	398.1^{DE}	444.7^{AB}	395.1^{a}
T_7	322.8^{HIJK}	424.2^{BCD}	416.4^{CD}	464.2^{A}	406.9^{a}
Mean	285.3^{d}	367.8^{b}	346.9^{c}	399.5^{a}	

Table 29. Leaf area plant^{-1} (cm^2) at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	301.4^{O}	383.0^{KLM}	366.7^{LMN}	429.4^{HI}	370.1^{e}
T_2	392.0^{JKL}	467.7^{FG}	444.5^{GH}	515.4^{DE}	454.9^{c}
T_3	360.3^{MN}	442.5^{GH}	417.2^{HIJ}	483.9^{EF}	426.0^{d}
T_4	348.7^{N}	428.5^{HI}	418.2^{HIJ}	473.1^{FG}	417.1^{d}
T_5	398.4^{IJK}	510.4^{DE}	485.9^{EF}	571.5^{C}	491.5^{b}
T_6	404.2^{IJK}	519.8^{D}	485.9^{EF}	566.5^{C}	494.1^{b}
T_7	427.4^{HI}	607.8^{B}	562.8^{EF}	637.6^{A}	558.9^{a}
Mean	376.0^{d}	479.9^{b}	454.4^{c}	525.3^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

significantly superior over the other foliar treatments and T_7 recorded the maximum dry weight compared to other treatments irrespective of foliar sprays.

4.2.2.5 *Shoot Weight*

Shoot dry weight (Table 31) was found the highest (20.2 g) in T_7 with 2 per cent 17:17:17 spray which was on par with 2 per cent urea and ammonium phosphate sulphate sprays. The lowest dry weight (10.50 g) was noticed in T_1F_0. T_7 control (T_7F_0) recorded the maximum value with respect to other control treatments. Generally 2 per cent urea spray and 17:17:17 spray were on par on all treatments and T_7 was significantly superior over the other treatments irrespective of foliar sprays.

4.2.2.6 *Root:shoot Ratio*

Root:shoot ratio on dry basis was found at 6 MAG (Table 32). The maximum root:shoot (0.467) was noticed with 2 per cent ammonium phosphate sulphate spray on T_3 (soil application of ammonium sulphate) and the minimum (0.283) in T_1 control. With respect to the control treatments T_3 control (T_3F_0) had the maximum value. The foliar spray of 2 per cent ammonium phosphate sulphate and 17:17:17 were found on par generally on all treatments.

4.2.2.7 *Chlorophyll Content of Leaves*

Chlorophyll content of leaves was estimated at 6 MAG (Table 33, 34, 35). Results showed that chlorophyll 'a', chlorophyll 'b' and total chlorophyll were found superior with 2 per cent 17:17:17 spray on T_7 (0.377, 0.481 and 0.858 mg g^{-1} of leaves respectively). The lowest content was noted in T_1 control (0.253, 0.303 and 0.55 respectively).

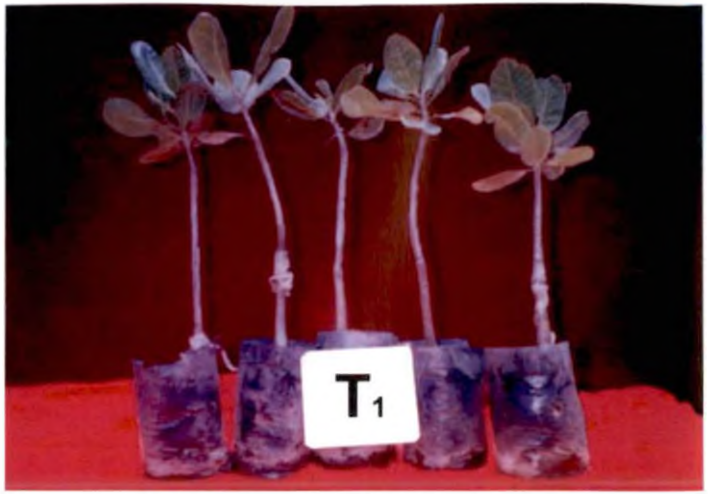


Plate 5. Control plants without nutrient application to grafts

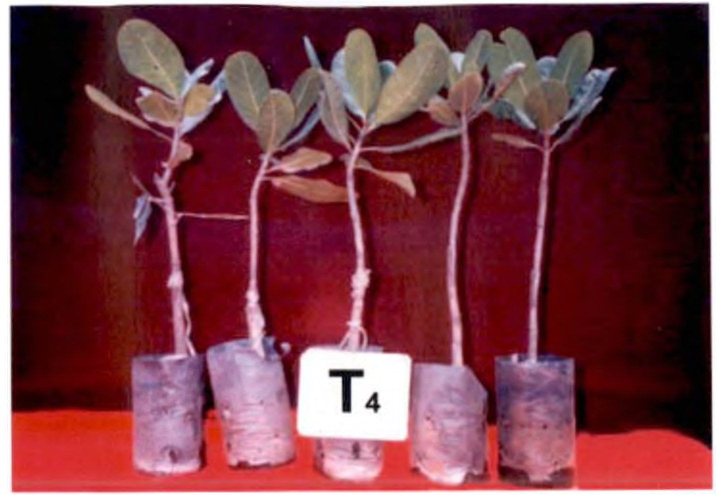
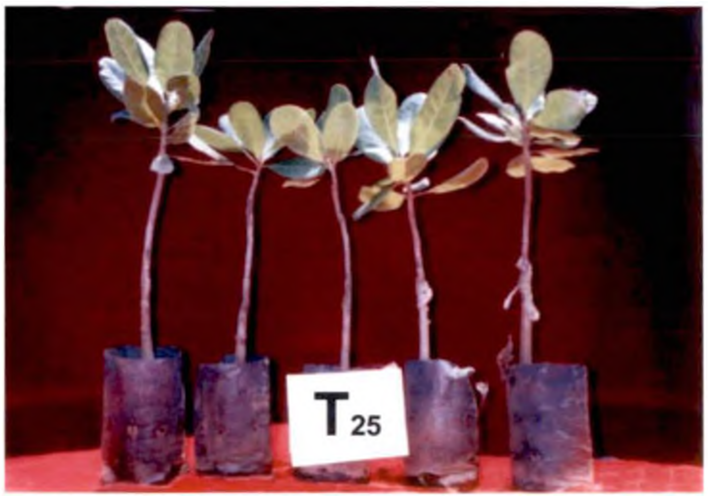
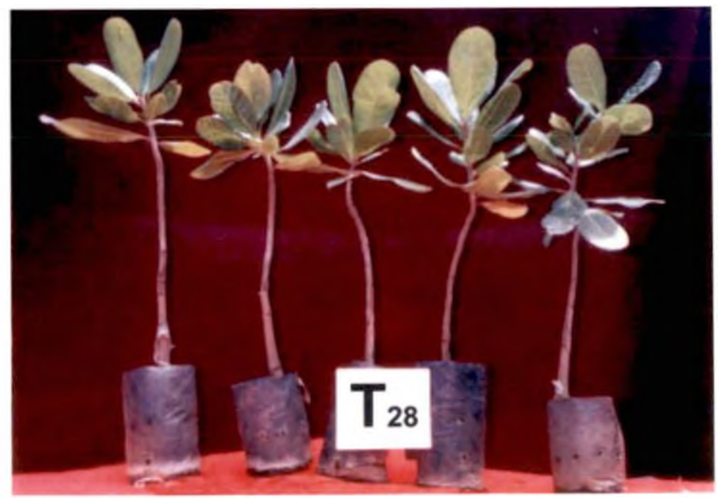


Plate 6. Foliar spray of 17:17:17 on control





Soil application of decanted extract of groundnut cake + 17:17:17

Plate 7. Without foliar application

Plate 8. With foliar application of 17:17:17

significantly superior over the other foliar treatments and T_7 recorded the maximum dry weight compared to other treatments irrespective of foliar sprays.

4.2.2.5 *Shoot Weight*

Shoot dry weight (Table 31) was found the highest (20.2 g) in T_7 with 2 per cent 17:17:17 spray which was on par with 2 per cent urea and ammonium phosphate sulphate sprays. The lowest dry weight (10.50 g) was noticed in T_1F_0. T_7 control (T_7F_0) recorded the maximum value with respect to other control treatments. Generally 2 per cent urea spray and 17:17:17 spray were on par on all treatments and T_7 was significantly superior over the other treatments irrespective of foliar sprays.

4.2.2.6 *Root:shoot Ratio*

Root:shoot ratio on dry basis was found at 6 MAG (Table 32). The maximum root:shoot (0.467) was noticed with 2 per cent ammonium phosphate sulphate spray on T_3 (soil application of ammonium sulphate) and the minimum (0.283) in T_1 control. With respect to the control treatments T_3 control (T_3F_0) had the maximum value. The foliar spray of 2 per cent ammonium phosphate sulphate and 17:17:17 were found on par generally on all treatments.

4.2.2.7 *Chlorophyll Content of Leaves*

Chlorophyll content of leaves was estimated at 6 MAG (Table 33, 34, 35). Results showed that chlorophyll 'a', chlorophyll 'b' and total chlorophyll were found superior with 2 per cent 17:17:17 spray on T_7 (0.377, 0.481 and 0.858 mg g^{-1} of leaves respectively). The lowest content was noted in T_1 control (0.253, 0.303 and 0.55 respectively).

Table 30. Root dry weight (g) at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	3.027^{L}	4.070^{K}	4.263^{K}	5.097^{J}	4.114^{E}
T_2	5.057^{J}	6.023^{HI}	6.220^{GH}	6.473^{FGH}	5.943^{D}
T_3	5.573^{IJ}	6.817^{EFG}	7.487^{BCD}	7.703^{BCD}	6.895^{C}
T_4	5.920^{HI}	7.057^{DEF}	7.290^{DE}	7.233^{DE}	6.875^{C}
T_5	6.190^{GH}	7.260^{DE}	7.340^{CDE}	7.450^{DE}	7.060^{C}
T_6	6.347^{GH}	7.707^{BCD}	7.967^{BC}	8.047^{B}	7.517^{B}
T_7	6.473^{FGH}	8.033^{B}	8.830^{A}	9.066^{A}	8.101^{A}
Mean	5.512^{d}	6.710^{c}	7.064^{b}	7.304^{a}	

Table 31. Shoot dry weight (g) at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	10.50^{L}	13.75^{JK}	12.53^{K}	14.45^{HIJ}	12.81^{E}
T_2	13.55^{JK}	17.66^{CDEF}	16.63^{EFG}	16.93^{DEFG}	16.19^{D}
T_3	14.20^{IJ}	17.59^{CDEF}	15.91^{FGH}	17.10^{DEFG}	16.20^{D}
T_4	15.64^{GHI}	18.35^{BCDE}	17.03^{DEFG}	18.02^{BCDE}	17.26^{C}
T_5	16.21^{FG}	19.05^{ABC}	16.98^{DEFG}	18.31^{BCDE}	17.64^{C}
T_6	16.62^{EFG}	19.74^{AB}	18.56^{ABCD}	18.70^{ABCD}	18.40^{B}
T_7	17.05^{DEFG}	20.17^{A}	20.07^{A}	20.20^{A}	19.37^{A}
Mean	14.82^{c}	18.044^{a}	16.82^{b}	17.67^{a}	

Table 32. Root : shoot ratio at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.283^{J}	0.297^{IJ}	0.340^{HI}	0.357^{GH}	0.319^{c}
T_2	0.370^{FGH}	0.340^{HI}	0.374^{EFGH}	0.383^{DEFGH}	0.367^{b}
T_3	0.393^{BCDEFGH}	0.387^{CDEFGH}	0.467^{A}	0.458^{AB}	0.424^{a}
T_4	0.380^{EFGH}	0.387^{CDEFGH}	0.427^{ABCDEF}	0.403^{BCDEFG}	0.399^{a}
T_5	0.380^{EFGH}	0.380^{EFGH}	0.433^{ABCDE}	0.407^{ABCDEFG}	0.400^{a}
T_6	0.380^{EFGH}	0.390^{BCDEFGH}	0.427^{ABCDEF}	0.430^{ABCDEF}	0.407^{a}
T_7	0.380^{EFGH}	0.397^{BCDEFGH}	0.443^{ABCD}	0.450^{ABC}	0.418^{a}
Mean	0.367^{b}	0.368^{b}	0.416^{a}	0.411^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

Table 33. Chlorophyll 'a' (mg g^{-1}) of leaves at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.253^{I}	0.294^{DEFGHI}	0.278^{EFGHI}	0.295^{CDEFGHI}	0.280^{d}
T_2	0.278^{FGHI}	0.332^{ABCDEFG}	0.309^{BCDEFGH}	0.341^{ABCDE}	0.315^{bc}
T_3	0.269^{HI}	0.319^{ABCDEFGH}	0.301^{BCDEFGHI}	0.323^{ABCDEFGH}	0.303^{cd}
T_4	0.274^{GHI}	0.328^{ABCDEFGH}	0.304^{BCDEFGHI}	0.336^{ABCDEFG}	0.310^{bc}
T_5	0.292^{DEFGHI}	0.339^{ABCDEF}	0.327^{ABCDEFGH}	0.350^{ABCD}	0.327^{abc}
T_6	0.303^{BCDEFGHI}	0.345^{ABCD}	0.339^{ABCDEF}	0.361^{AB}	0.337^{ab}
T_7	0.308^{BCDEFGHI}	0.358^{ABC}	0.350^{ABCD}	0.377^{A}	0.348^{a}
Mean	0.282^{c}	0.331^{ab}	0.316^{b}	0.340^{a}	

Table 34. Chlorophyll 'b' (mg g^{-1}) of leaves at 6 MAG as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.303^{J}	0.363^{EFGHI}	0.355^{FGHIJ}	0.386^{CDEFGHI}	0.351^{e}
T_2	0.344^{GHIJ}	0.405^{BCDEFG}	0.400^{BCDEFG}	0.421^{BCDE}	0.393^{bcd}
T_3	0.325^{IJ}	0.387^{CDEFGH}	0.389^{CDEFGH}	0.406^{BCDEF}	0.377^{de}
T_4	0.336^{HIJ}	0.396^{BCDEFGH}	0.392^{CDEFGH}	0.417^{BCDE}	0.385^{cd}
T_5	0.360^{EFGHIJ}	0.415^{BCDEF}	0.415^{BCDEF}	0.439^{ABC}	0.407^{abc}
T_6	0.373^{DEFGHI}	0.422^{BCDE}	0.420^{BCDE}	0.456^{AB}	0.418^{ab}
T_7	0.380^{CDEFGHI}	0.436^{ABCD}	0.431^{ABCD}	0.481^{A}	0.432^{a}
Mean	0.346^{c}	0.403^{b}	0.400^{b}	0.430^{a}	

Table 35. Total chlorophyll (mg g^{-1}) of leaves at 6 MAG as influenced by foliar fertilization

Treatments	F_1	F_2	F_3	F_4	Mean
T_1	0.555^{O}	0.657^{JKLM}	0.633^{KLMN}	0.681^{HIJK}	0.631^{e}
T_2	0.621^{LMN}	0.737^{CDEFGHI}	0.709^{FGHIJ}	0.762^{BCDEF}	0.707^{c}
T_3	0.594^{NO}	0.705^{FGHIJ}	0.689^{HIJK}	0.729^{DEFGHI}	0.679^{d}
T_4	0.611^{MN}	0.723^{EFGHI}	0.695^{GHIJ}	0.753^{CDEFG}	0.695^{cd}
T_5	0.652^{JKLM}	0.753^{CDEFG}	0.742^{CDEFGH}	0.789^{BCD}	0.734^{b}
T_6	0.676^{IJKL}	0.766^{BCDEF}	0.760^{BCDEF}	0.816^{AB}	0.754^{ab}
T_7	0.688^{HIJK}	0.793^{BC}	0.780^{BCDE}	0.858^{A}	0.780^{a}
Mean	0.628^{c}	0.733^{b}	0.715^{b}	0.770^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

4.2.2.8 *Nutrient Content of Leaves*

The nutrient content of leaves were analysed at 6 MAG. The results showed that leaf N (Table 36) was significantly higher 1.61%) with 2 per cent urea spray on T_7 and the lowest (1.07%) in control of T_1 (T_1F_0). Among the control treatments T_7 control (T_7F_0) showed the maximum value and with respect to the foliar sprays, 2 per cent urea was significantly higher in all treatments.

The leaf P content (Table 37) was found maximum (0.125%) with 2 per cent ammonium phosphate sulphate spray on T_7 followed by 2 per cent 17:17:17 spray on T_7 (0.124%) and the lowest content (0.065%) in T_1F_0. Among the control treatments T_7 control recorded maximum and 2 per cent ammonium phosphate sulphate and 17:17:17 sprays were on par generally in all treatments.

The potassium content (Table 38) was found significantly higher (1.39%) with 2 per cent 17:17:17 spray on T_7 and the lowest (0.81%) in T_1 control. Control of T_7 recorded maximum value with respect to other controls and among the different foliar sprays, 2 per cent 17:17:17 spray was statistically significant.

The leaf calcium and magnesium contents are given in Tables 39 and 40. Both of them followed a similar pattern of result as that of potassium. Maximum Ca and Mg was found in 2 per cent 17:17:17 spray on T_7 (0.227 and 0.144% respectively) and the minimum in T_1F_0 (0.073 and 0.6% respectively). It was found that T_7 recorded the maximum content of all leaf nutrients compared to other treatments irrespective of foliar sprays.

4.2.2.9 *Nutrient Content in Potting Mixture*

The content of available nutrients (N, P, K, Ca and Mg) in the potting mixtures was found out at 6 MAG. Table 41 shows that available nitrogen was more (128.7 ppm) in the potting mixture of T_2 (soil application of urea) with 2 per

Table 36. N content of leaves at 6 MAG (%) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	1.07^{S}	1.30^{JKL}	1.20^{Q}	1.17^{R}	1.18^{f}
T_2	1.25^{O}	1.55^{B}	1.44^{EF}	1.40^{G}	1.41^{b}
T_3	1.20^{Q}	1.45^{E}	1.33^{I}	1.32^{IJ}	1.33^{d}
T_4	1.15^{R}	1.41^{G}	1.31^{JK}	1.28^{MN}	1.29^{e}
T_5	1.16^{R}	1.43^{F}	1.30^{KLM}	1.29^{LM}	1.29^{e}
T_6	1.22^{P}	1.50^{C}	1.39^{G}	1.36^{H}	1.37^{c}
T_7	1.27^{N}	1.61^{A}	1.51^{C}	1.48^{D}	1.47^{a}
Mean	1.19^{d}	1.46^{a}	1.35^{b}	1.33^{c}	

Table 37. P content of leaves at 6 MAG (%)as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.065^{J}	0.068^{IJ}	0.081^{FGHIJ}	0.076^{GHIJ}	0.072^{d}
T_2	0.071^{HIJ}	0.074^{HIJ}	0.089^{EFGH}	0.084^{EFGHIJ}	0.079^{d}
T_3	0.068^{IJ}	0.071^{HIJ}	0.089^{EFGH}	0.084^{EFGHIJ}	0.078^{d}
T_4	0.079^{FGHIJ}	0.083^{EFGHIJ}	0.100^{BCDEF}	0.095^{CDEFG}	0.089^{c}
T_5	0.082^{EFGHIJ}	0.085^{EFGHI}	0.101^{BCDE}	0.096^{CDEFG}	0.091^{bc}
T_6	0.087^{EFGHI}	0.090^{DEFGH}	0.110^{ABC}	0.109^{ABCD}	0.099^{b}
T_7	0.109^{ABCD}	0.117^{AB}	0.125^{A}	0.124^{A}	0.119^{a}
Mean	0.080^{b}	0.084^{b}	0.099^{a}	0.095^{a}	

Table 38. K content of leaves at 6 MAG (%) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.81^{Q}	0.92^{N}	0.87^{P}	0.98^{L}	0.89^{g}
T_2	0.95^{M}	1.03^{JK}	0.99^{L}	1.20^{D}	1.04^{d}
T_3	0.89^{O}	0.98^{L}	0.95^{M}	1.12^{F}	0.99^{f}
T_4	0.91^{N}	1.02^{K}	0.98^{L}	1.15^{E}	1.02^{e}
T_5	1.05^{IJ}	1.10^{GH}	1.06^{I}	1.28^{C}	1.12^{c}
T_6	1.09^{H}	1.11^{FG}	1.11^{FG}	1.32^{B}	1.16^{b}
T_7	1.15^{E}	1.19^{D}	1.20^{D}	1.39^{A}	1.23^{a}
Mean	0.98^{d}	1.05^{b}	1.02^{c}	1.21^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

Table 39. Ca content of leaves at 6 MAG (%)as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.073^{R}	0.127^{JKL}	0.120^{KLM}	0.133^{IJK}	0.113^{f}
T_2	0.093^{OPQ}	0.167^{EF}	0.113^{LMN}	0.167^{EF}	0.135^{d}
T_3	0.080^{QR}	0.107^{MNO}	0.100^{NOP}	0.160^{FG}	0.112^{f}
T_4	0.87^{PQR}	0.153^{FGH}	0.127^{JKL}	0.140^{HIJ}	0.127^{e}
T_5	0.100^{NOP}	0.153^{FGH}	0.140^{HIJ}	0.193^{CD}	0.147^{c}
T_6	0.140^{HIJ}	0.193^{CD}	0.180^{DE}	0.220^{AB}	0.183^{b}
T_7	0.147^{GHI}	0.200^{C}	0.207^{BC}	0.227^{A}	0.195^{a}
Mean	0.103^{d}	0.157^{b}	0.141^{c}	0.177^{a}	

Table 40. Mg content of leaves at 6 MAG (%)as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	0.060^{K}	0.076^{JK}	0.080^{IJ}	0.100^{GH}	0.079^{e}
T_2	0.076^{JK}	0.108^{EFG}	0.104^{FG}	0.132^{ABC}	0.105^{bcd}
T_3	0.072^{JK}	0.104^{FG}	0.096^{GHI}	0.124^{BCDE}	0.099^{cd}
T_4	0.068^{JK}	0.104^{FG}	0.100^{GH}	0.120^{CDEF}	0.098^{d}
T_5	0.080^{IJ}	0.108^{EFG}	0.112^{DEFG}	0.128^{ABCD}	0.107^{bc}
T_6	0.084^{HIJ}	0.108^{EFG}	0.112^{DEFG}	0.136^{ABC}	0.110^{b}
T_7	0.096^{GHI}	0.140^{AB}	0.132^{ABC}	0.144^{A}	0.128^{a}
Mean	0.077^{c}	0.107^{b}	0.105^{b}	0.126^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

cent urea spray and the lowest (77.3 ppm) in control of T_1 (T_1F_0). Compared to other control treatments, available N was more in T_2F_0 and with respect to foliar sprays, 2 per cent urea had significantly higher N.

The available phosphorus (Table 42) was found maximum (45.3 ppm) with 2 per cent ammonium phosphate sulphate spray on T_5 (soil application of APS + MOP) followed by on T_7 (41.0 ppm) and the lowest (20.7 ppm) in T_1F_0. While comparing non foliar applied treatments T_5F_0 had maximum value but controls of T_7, T_6 and T_4 (in all these treatments P was given as soil application) were on par with it. Foliar sprays did not make significant difference in P content.

The available potassium (Table 43) was found superior with 2 per cent 17:17:17 spray on T_5 (162.7 ppm) followed by on T_7 (153.3 ppm) and the lowest in T_1 control (73.3 ppm). Among the control treatments, T_5 control was comparatively superior and with respect to different foliar sprays 17:17:17 spray was significantly superior in general. Comparing the soil applied nutrients it was found that T_5 was significantly superior over other treatments irrespective of foliar sprays.

Exchangeable calcium (Table 44) was found to be the highest (177.7 ppm) with 2 per cent 17:17:17 spray on T_7 and the lowest (27.7 ppm) in T_1 control. Among the control treatments T_7 control recorded maximum and foliar application of 2 per cent 17:17:17 spray was significantly superior to other foliar sprays. Treatment wise it was noticed that T_7 was significantly superior over the other treatments irrespective of the foliar sprays.

The exchangeable magnesium in the potting mixtures are given in the Table 45. It was found that the highest content (41.3 ppm) was in T_7 potting. mixture sprayed with 2 per cent 17:17:17 and the lowest (9.3 ppm) in T_1 control. Control treatment of T_7 recorded maximum content compared to other controls.

Table 41. Available N in the potting mixtures at 6 MAG (ppm) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	77.3^{I}	97.0^{CDEFGH}	89.7^{FGHI}	84.0^{HI}	87.0^{c}
T_2	94.3^{DEFGHI}	128.7^{A}	116.7^{ABC}	110.3^{ABCDE}	112.5^{a}
T_3	90.0^{FGHI}	117.3^{AB}	110.3^{ABCDE}	105.7^{BCDEFG}	105.8^{ab}
T_4	91.3^{EFGHI}	119.3^{AB}	112.0^{ABCD}	103.7^{BCDEFG}	106.6^{ab}
T_5	89.7^{FGHI}	120.7^{AB}	116.7^{ABC}	109.3^{ABCDE}	109.1^{ab}
T_6	87.0^{GHI}	115.0^{ABC}	107.3^{BCDEF}	102.7^{BCDEFGH}	103.0^{b}
T_7	88.7^{FGHI}	122.3^{AB}	111.3^{ABCD}	109.7^{ABCDE}	108.0^{ab}
Mean	88.3^{c}	117.2^{a}	109.1^{b}	103.6^{b}	

Table 42. Available P in the potting mixtures at 6 MAG (ppm) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	20.7^{C}	21.7^{BC}	24.3^{BC}	23.0^{BC}	22.4^{c}
T_2	22.0^{BC}	23.0^{BC}	26.0^{ABC}	23.7^{BC}	23.7^{c}
T_3	24.0^{BC}	24.3^{BC}	27.3^{ABC}	26.3^{ABC}	25.5^{bc}
T_4	26.7^{ABC}	28.0^{ABC}	32.0^{ABC}	30.0^{ABC}	29.2^{abc}
T_5	28.3^{ABC}	30.0^{ABC}	45.3^{A}	39.7^{ABC}	35.8^{a}
T_6	28.0^{ABC}	29.0^{ABC}	34.7^{ABC}	30.3^{ABC}	30.5^{abc}
T_7	28.0^{ABC}	30.7^{ABC}	41.0^{AB}	37.0^{ABC}	34.2^{ab}
Mean	25.4^{b}	26.7^{ab}	33.0^{a}	30.0^{ab}	

Table 43. Available K in the potting mixtures at 6 MAG (ppm) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	73.3^{L}	96.0^{IJK}	93.3^{JK}	104.0^{GHIJK}	91.7^{d}
T_2	90.7^{K}	102.7^{HIJK}	101.3^{IJK}	122.7^{DEFG}	104.3^{c}
T_3	90.3^{K}	108.7^{EFGHIJK}	108.0^{FGHIJK}	122.7^{DEFG}	107.4^{c}
T_4	97.3^{IJK}	113.3^{EFGHI}	112.0^{EFGHIJ}	125.3^{DEF}	112.0^{c}
T_5	121.3^{DEFGH}	133.3^{CD}	138.7^{BCD}	162.7^{A}	139.0^{a}
T_6	108.0^{FGHIJK}	121.3^{DEFGH}	124.0^{DEF}	146.7^{ABC}	125.0^{b}
T_7	113.3^{EFGHI}	125.3^{DEF}	128.0^{DE}	153.3^{AB}	130.0^{b}
Mean	99.2^{c}	114.4^{b}	115.0^{b}	133.9^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

Table 44. Exchangeable Ca in the potting mixtures at 6 MAG (ppm) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	27.7^{K}	36.7^{JK}	38.0^{JK}	43.3^{IJK}	36.4^{e}
T_2	42.7^{IJK}	55.0^{GHIJ}	56.0^{GHIJ}	58.0^{GHI}	52.9^{d}
T_3	37.0^{JK}	51.3^{HIJ}	48.7^{HIJ}	55.3^{GHIJ}	48.1^{d}
T_4	41.7^{IJK}	52.7^{HIJ}	51.3^{HIJ}	56.3^{GHIJ}	50.5^{d}
T_5	51.0^{HIJ}	65.0^{DEFGH}	60.0^{FGHI}	72.7^{CDEFG}	62.2^{c}
T_6	61.3^{EFGHI}	77.7^{CDEF}	79.0^{CDE}	86.3^{BC}	76.1^{b}
T_7	81.0^{BCD}	98.0^{AB}	97.3^{AB}	111.7^{A}	97.0^{a}
Mean	48.9^{c}	62.3^{b}	61.5^{b}	69.1^{a}	

Table 45. Exchangeable Mg in the potting mixtures at 6 MAG (ppm) as influenced by foliar fertilization

Treatments	F_0	F_1	F_2	F_3	Mean
T_1	9.3^{D}	10.3^{D}	12.0^{CD}	15.3^{CD}	11.8^{d}
T_2	13.3^{CD}	20.7^{BCD}	18.7^{BCD}	26.0^{ABCD}	19.7^{cd}
T_3	10.3^{D}	20.7^{BCD}	20.3^{BCD}	24.3^{ABCD}	18.9^{cd}
T_4	12.0^{CD}	17.7^{BCD}	16.0^{BCD}	21.7^{ABCD}	16.8^{d}
T_5	21.3^{BCD}	27.0^{ABCD}	26.7^{ABCD}	31.3^{ABC}	26.6^{bc}
T_6	24.0^{ABCD}	31.7^{ABC}	32.0^{ABC}	36.0^{AB}	30.9^{ab}
T_7	31.3^{ABC}	36.0^{AB}	36.0^{AB}	41.3^{A}	36.2^{a}
Mean	17.4^{b}	23.4^{ab}	23.1^{ab}	28.0^{a}	

T_1 Control (Sand: Soil: Cowdung+ Azo+PSB+AMF), T_2 Urea (40g/10 l water),
T_3 Ammonium sulphate (80g/10 l water), T_4 Ammonium phosphate sulphate (80g/10 l water),
T_5 Ammonium phosphate sulphate (80g/10 l water) + MOP (25g/10 l water),
T_6 17:17:17 (100g/10 l water), T_7 Decanted of 1kg groundnut cake + 17:17:17 (100g/10 l water)
F_0 Control, F_1 2% urea spray, F_2 2% Ammonium phosphate sulphate spray, F_3 2% 17:17:17 spray

Table 46. Microbial population at 6 MAG as influenced by foliar fertilization

Samples	Azospirillum (× 10^4 Cellg^{-1} potting mixtures)	PSB (× 10^4 cfu g^{-1} potting mixture)	AMF Spore population (per 10 g potting mixture)
sand:soil:cowdung+Azo+PSB+AMF+soil application of nutrients (S_1)	16 (5.20)	103 (8.01)	55.7 (1.74)
S_1+foliar fertilization	16 (5.20)	98.3 (7.99)	52.3 (1.72)

Data in parenthesis are logarithmically transformed values

Generally foliar sprays were on par and with respect to soil application treatments, T_7 and T_6 were on par.

4.2.2.10 *Microbial Population at 6 MAG*

The composite sample were taken and analysed for microbial population (Table 46). In the composite samples *Azospirillum* population was 16 x 10^4 cell g^{-1} of potting mixture. Phosphorus Solubilizing Bacterial population was 103 and 98.3 x 10^6 cfu g^{-1}. Arbuscular Mycorrhizal Fungal spores was 55.7 and 52.3 per 10 g potting mixture.

Plate 9. A view of plants before grafting

Plate 10. A view of plants after grafting

Discussion

5. DISCUSSION

The results of the experiment conducted to study the nutrient management in cashew nursery are discussed in this chapter. The experiment I consisted of management practices for cashew rootstock production and experiment II consisted of management practices of cashew grafts.

5.1. EXPT I MANAGEMENT PRACTICES FOR CASHEW ROOT STOCK PRODUCTION.

The results obtained from the experiment to study the effect of different potting media and biofertilizer supplements on the growth and vigour of cashew rootstocks are discussed here under.

5.1.1 Physical Properties of Potting Mixtures

The physical properties of the potting mixtures viz., sand: soil: cowdung (T_1), sand:soil:poultry manure (T_2), sand:soil:coirpith compost (T_3), and sand:soil (T_{16}) varied significantly. The bulk density and particle density were found to be decreased by the application of organic manures compared to T_{16}. This result was in accordance with the reports of Havanagi and Mann (1970) and Biswas *et al.* (1971). The highest bulk density and particle density were observed in T_{16} and the lowest in T_3 because when organic manure is applied the mass per unit volume of the soil decreases.

The pore space and water holding capacity were increased with the organic manures especially coirpith compost in potting mixtures. This result was in accordance with the findings of various workers (Loganathan and Lakshminarasimhan, 1979; Mayalagu, 1983, Pagliai *et al.*, 1987; Ahmed, 1993 and Venugopal, 1995).

5.1.2 Days to Germination and Germination Percentage

With respect to days to germination and germination percentage the cowdung and coirpith compost applied potting mixture were better compared to poultry manure. Biofertilizer inoculated treatments were superior to uninoculated controls. Among this combined biofertilizers (*Azospirillum*+PSB+AMF) inoculation decreased days taken for germination with better germination percentage (Fig.2). The use of biofertilizers achieved higher N fixation, N release and solubilisation of P resulting in better germination. In single biofertilizer inoculated treatments, more germination was noticed in AMF treated ones compared to *Azospirillum* and PSB irrespective of types of potting mixtures. The minimum germination percentage was observed in the potting mixtures involving poultry manure and it took 17.23 days to achieve 68.4 per cent germination, while 100 per cent germination was achieved by T_6, T_7 and T_{15} with in 13-14 days involving cowdung and coirpith compost. It is known fact that while poultry manure is applied it generates more heat in the soil during the decomposition and it might have affected the germination of nuts.

5.1.3 Growth Characters

The growth characters like height (Fig.3), girth, number of leaves, dry weight of root, shoot and root:shoot ratio were maximum in the potting mixture containing sand:soil:cowdung+ AZO+ PSB+ AMF compared to other two organic manure applied potting mixtures. In the case of potting mixtures containing poultry manure or coirpith compost also combined inoculation was found better than single biofertilizer inoculation. This positive influence of combine inoculation of *Azospirillum*, PSB,and AMF has also been reported by several workers (Rosalindpadma, 1988; Swarupa, 1996; Kandiannan *et al.,* 2000 and Vijayakumari and Janardhanan, 2003) in crops like papaya, tobacco, coffee seedlings, black pepper and silk cotton. Among the single biofertilizer inoculated treatments, AMF inoculation was comparatively better. This influence of AMF in

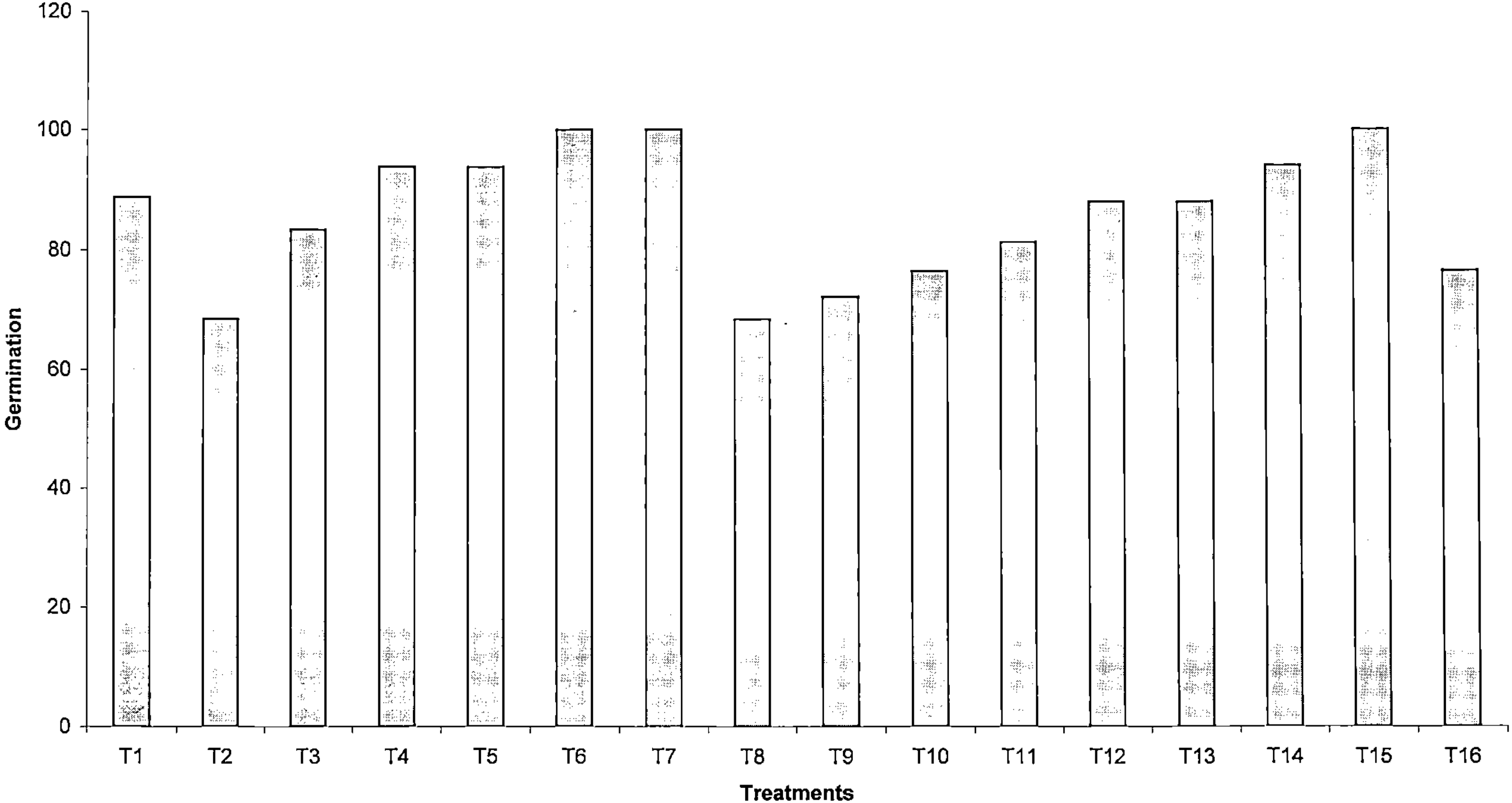


Fig.2. Germination percentage of cashew as influenced by different potting mixtures and biofertilizers

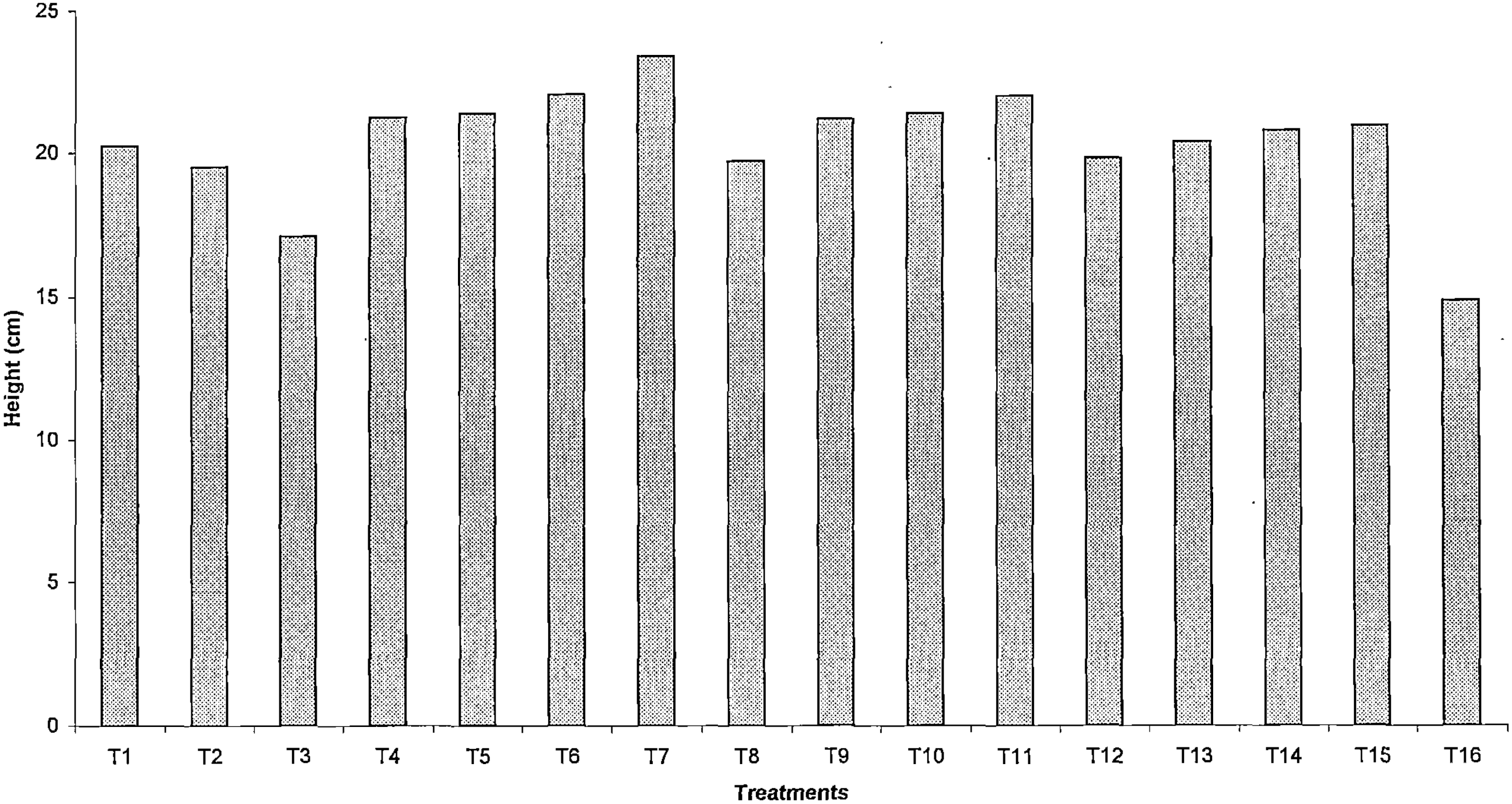


Fig.3. Height of seedlings at the time of grafting as influenced by different potting mixtures and biofertilizers

plant growth was in accordance with the studies of Kumar *et al.*, 1998, Ramesh *et al.* 1998, Lakshmipathy *et al.* 2000 and Usha, 2001 in cashew seedlings. Microbial inoculation improves the nutrient status of soil and facilitates a steady supply of nutrients during the growth of seedlings which is manifested in better growth characters.

Among the organic manures in the potting mixtures, cowdung was found to be the best in case of biometric characters. The positive influence of cowdung in stimulating growth of cashew seedlings was reported by Jagadeesh kumar (2000). In other crops like amaranthus and snake gourd, Arunkumar (1997) and Joseph (1998), reported that the performance was better with FYM application compared to vermicompost and poultry manure. It may be because of lowering of bulk density and particle density and improvement in water holding capacity, aeration and porosity of potting mixture in addition to a steady supply of nutrients by FYM application.

5.1.4 Nutrient Content in Leaves

The nutrient content in leaves (Table 11) showed that higher N,P,K(Fig.4), Ca and Mg(Fig.5) was found in the combined biofertilizer (Azo+PSB+AMF) inoculated treatment irrespective of type of the organic manure in the potting mixture. Among this, the highest content was noticed in poultry manure applied treatments followed by cowdung treated ones. The PSB solubilize phosphates in the potting mixture and it is reported that in mycorrhizal association, the fungal hyphae function just like root hair. This increases the surface area and available nutrient absorption and transportation, which ultimately result in the higher absorption and accumulation of nutrients by the plant. Production of plant growth hormones leading to better root development also favours nutrient uptake (Rizzardi, 1990; Sivaprasad *et al.*, 1992 and An *et al.*, 1993). Mycorrhizal plants increased the rates of respiration and photosynthesis, increased amplitude of sugars, aminoacids, RNA etc. and more chloroplasts, mitochondria and xylem

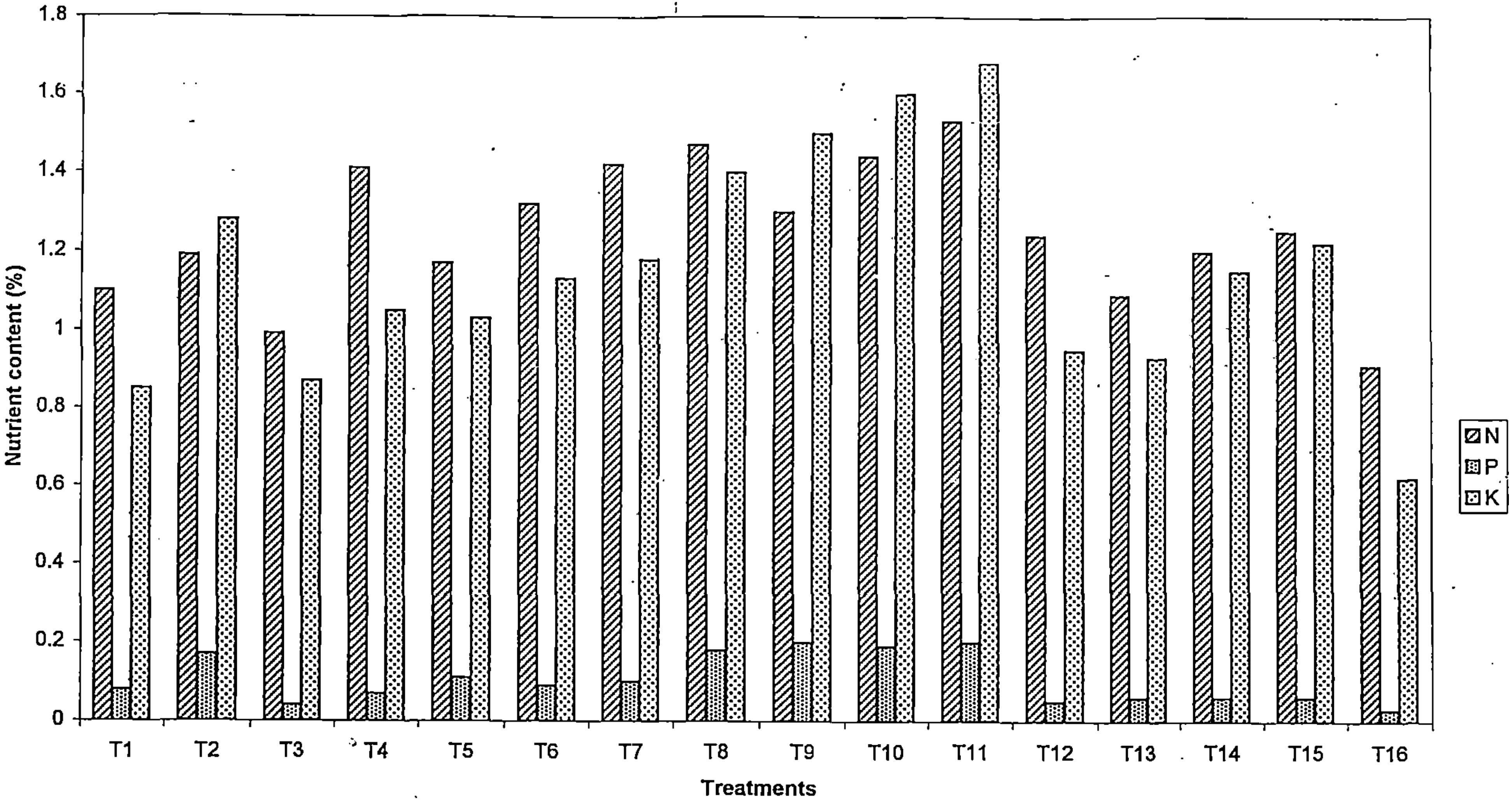


Fig.4. NPK content in leaves at grafting stage of cashew seedlings

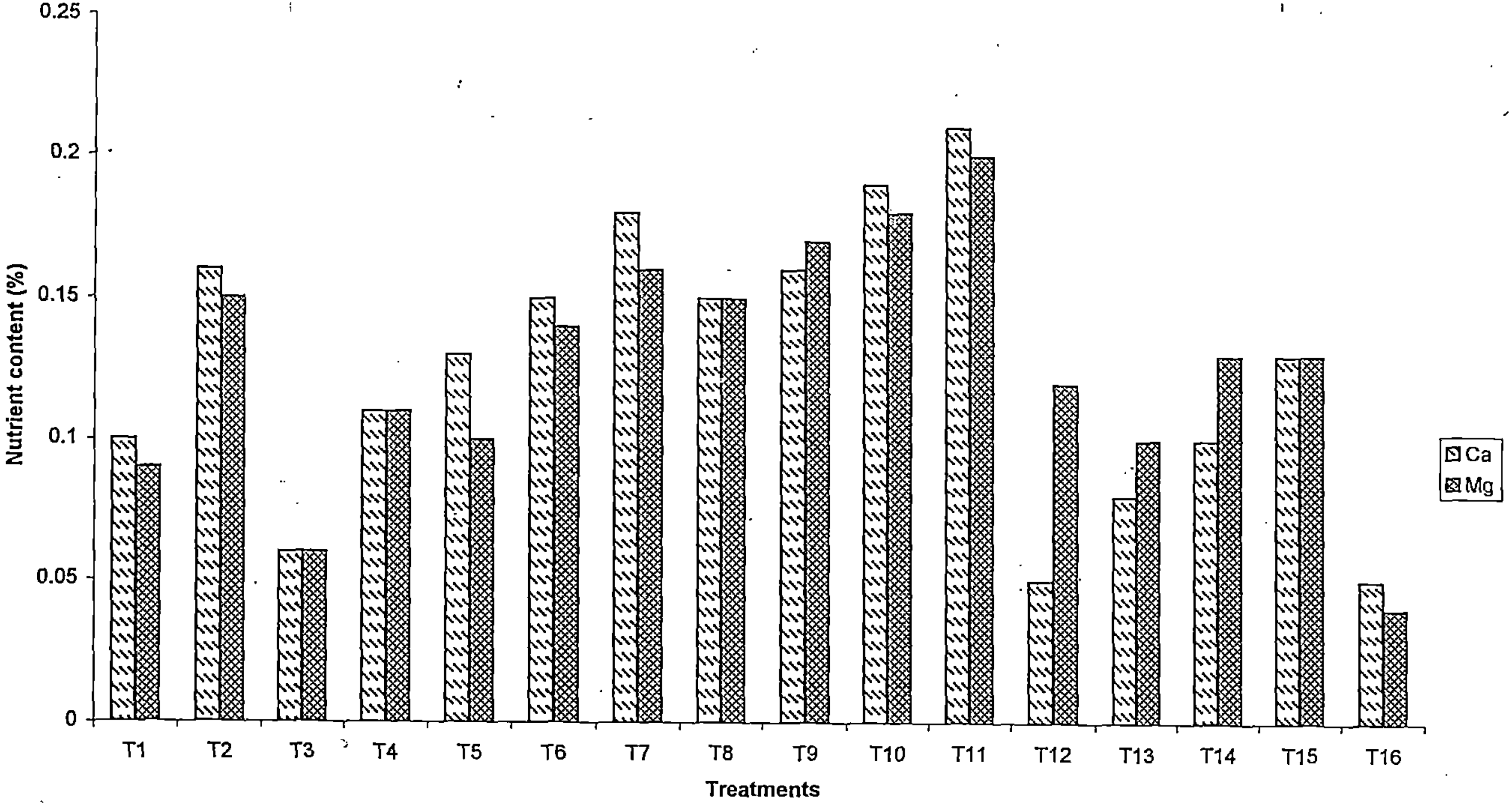


Fig.5. Ca and Mg content in leaves at grafting stage of cashew seedling

vessels (Krishna and Bagyaraj, 1982 and Hayman, 1982). Increase in nitrogen content may be due to enhanced uptake of NO_3, NH_4 consequent to nitrogen fixation by the *Azospirillum* sp inoculated plants (Jain and Patriquin, 1984 and Barton *et al.*, 1986).

5.1.5 Nutrient Content in Potting Mixtures

The available nutrient content in the potting mixture was found to be reduced from the beginning of the experiment to the grafting stage. Initially the available nutrients (N,P,K, Ca and Mg) were very high (Table 5) in the potting mixture containing poultry manure in general and in the Azo+PSB+AMF inoculated treatment in particular. This increased content in the poultry manure treatments may be due to the higher nutrient in this organic manure (Table 2). There after a steep decline in nutrient content was observed in poultry manure and coirpith compost applied potting mixtures compared to cowdung. At the stage of grafting the nutrient contents (Table 12) of potting mixture containing poultry manure and cowdung was almost equal. The loss of nutrients was higher in poultry manure and coirpith compost treated ones. In cowdung the loss was less which might be due to higher microbial activity. At grafting stage also the highest nutrients was found in T_{11} (sand:soil:poultry manure + Azo+PSB+AMF). In the other two organic manures applied potting mixtures also the nutrient content was higher in combined biofertilizer inoculated treatments.

The advantage of this combined inoculation might be due to the synergistic action of microbes. Fixation of atmospheric N by crop plants with the help of *Azospirillum* sp has been proved in many crops. All wild type of *Azospirillum* fix atmospheric N either as free living bacteria or in association with plants (Tarrand *et al.*, 1978). A saving of 33 per cent fertilizer nitrogen due to *Azospirillum* has been reported in ginger (Patil and Knode, 1988). A higher soil N level due to *Azospirillum* inoculation has been reported by Vasudevan *et al.* (1993).

Regarding available phosphorus, the higher values were obtained when PSB was inoculated. Phosphorus-solubilizing bacteria in acid soils (P^H 5-6.5) help in solubilizing the insoluble phosphates and make it available to the plants (AICRPS, 2000). The solubilization of phosphorus by these organisms is attributed to excretion of organic acids viz., citric, fumaric, glutamic, glyoxilic, lactic, maleic, oxalic, succinic and alpha ketoglutaric acids (Rao, 1983).

The improvement of available P can also be attributed to favourable effect of AMF. Better rhizosphere effect due to AMF association has been reported in several crops. PSB survived longer around mycorrhizal roots than non mycorrhizal roots of maize plants and sometimes even acted synergistically with mycorrhiza to increase the plant growth (Azcon *et al.*, 1976).

Enhanced potassium, calcium and magnesium availability may be attributed to the synergistic effect of different biofertilizers in the potting mixtures.

5.1.6 Microbial Population

Microbial population of *Azospirillum* sp, PSB and AMF in the potting mixture was estimated at the time of germination of nuts. The AMF root infection was also estimated at grafting. At these stages the microbial population was high in the combined inoculated (Azo+PSB+AMF) treatment irrespective of the potting mixture. Among this potting mixture containing sand:soil:cowdung + AZO+PSB+AMF recorded significantly higher population followed by coirpith compost and poultry manure applied treatments. The higher population in the combined inoculated treatments might be due to the synergistic effect of these microorganisms in combination. The results were in confirmation with the studies of AICRPS (2000) and Stephan (2002). The maximum colonisation of AMF in FYM applied plots was reported by Nair and Peter (1991). Dinesh *et al.* (1998)

reported that soils amended with FYM registered significantly greater microbial biomass.

The above discussion on the results of experiment I leads to the conclusion that for successful production of cashew rootstocks a potting mixture with sand:soil:cowdung was better and a further boosting was observed when potting mixture received microbial inoculation of *Azospirillum*, PSB and AMF. Eventhough, poultry manure had better nutrient content it was less suitable in the preparation of potting mixtures for cashew. Towards grafting stage it was seen that the performance of seedlings was better even in poultry manure applied treatments compared to coirpith compost applied treatments.

5.2. EXPT II MANAGEMENT PRACTICES OF CASHEW GRAFTS

In this experiment, all the treatments were having the same potting mixture, (sand:soil:cowdung+ *Azospirillum*+ PSB+ AMF) and the treatment differences were only with respect to the nutrient supplementation through various sources at 1 month after grafting(MAG) and 3 MAG through soil and foliar application, respectively.

5.2.1. Soil Application of Nutrient to the Grafts

100 ml of the nutrient solutions viz., urea 40g/10 l water (T_2), ammonium sulphate 80g/10 l water (T_3), ammonium phosphate sulphate 80g/10 l water + MOP 25g/10 l water (T_5), 17:17:17 100g/10 l water (T_6) and decanted extract of 1kg groundnut cake + 17:17:17 100g/10 l water (T_7) was given at 1 month after grafting as soil application with a control (T_1). The results obtained are discussed here under.

5.2.1.1 *Growth Characters*

The height of the grafts was noted at 1 MAG and 3 MAG (Table 14) however it can't be expected to give real effects of the treatments since the height of the plant was decided by the length of rootstock and scion taken at the time of grafting. Therefore increase in plant height(Table 15;Fig.6) was noted to find the treatment effect. Increase in height due to nutrient supplements showed significant difference from the control but it was on par between the nutrient supplemented treatments. The results indicated that nutrient supplementation was necessary to improve the height of grafts. A close perusal of the data indicated that increase in height was comparatively higher in T_7 (decanted extract of groundnut cake+ 17:17:17 mixture). Increase in plant height from 1-3 MAG also showed the similar result. With respect to number of leaves all the treatments were on par but leaf area per plant (Fig.7) was found higher in potassium applied treatments (T_5, T_6 and T_7). The results obtained on the biometric characters with nutrient supplements corroborate the findings of Lahav (1973) and Jagadeeshkumar (2000).

5.2.1.2 *Nutient Content in Leaves*

Nutrient content in leaves at 3 MAG (Table 16;Fig.8) reveals that nitrogen was significantly higher in T_7. There was no significant difference between treatments in the case of phosphorus, though highest content was in T_7. Potassium, and calcium contents were significantly higher in T_7 and magnesium was not differing significantly but higher concentration was observed in T_7.Nutrient content in leaf reflects the availability of nutrients in the rhizosphere. The non significant difference in the leaf nutrient contents among the inorganic treatments indicate a more or less equal availability, however an organic source like decanted extract of groundnut cake was introduced together with 17:17:17 mixture there was significant increase in all the nutrients. This suggests the possibility of availability of nutrients from both inorganic and organic sources.

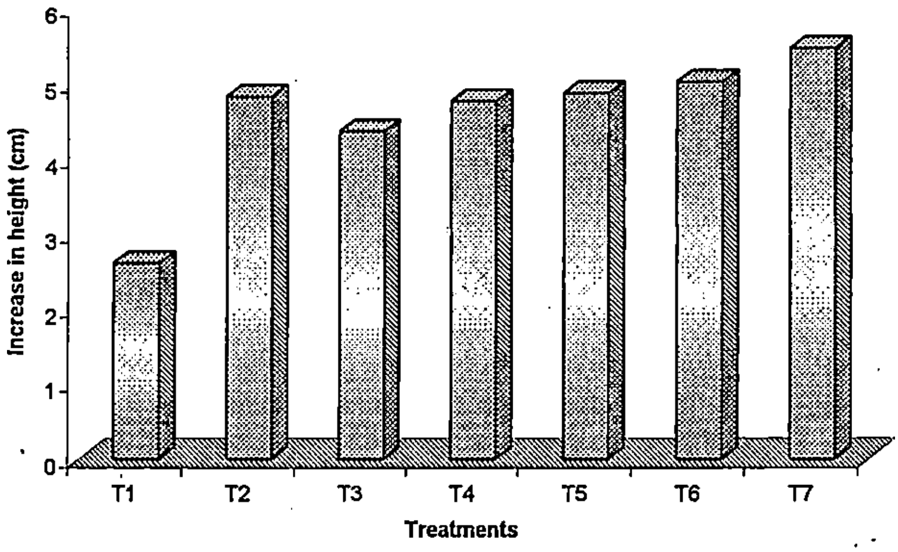


Fig.6. Increase in height from 1-3 MAG of cashew as influenced by soil application of nutrients

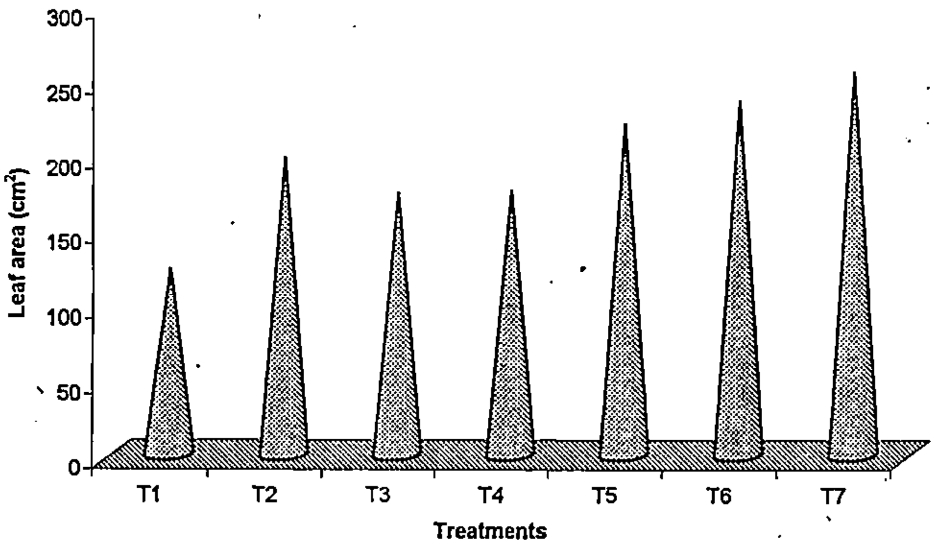


Fig.7. Leaf area plant^{-1} at 3 MAG of cashew as influenced by soil application of nutrients

Groundnut solution might have acted as a synergist to supply more soil nutrients possibly through enhanced mineralization and it enhanced the activity of soil micro organisms.

5.2.1.3 *Nutrient Content in Potting Mixtures*

The available nutrient content in the potting mixture at 3 MAG (Table 17) showed that N,P and Mg did not differ significantly between treatments but was comparatively more in T_7. Available potassium was significantly higher in T_7 and T_6 which were comparable with T_5. With respect to calcium all the nutrient supplemented treatments were significantly different from the control. The mineral nutrient supply has improved the nutrient supplying capacity of the media.

5.2.1.4 *Microbial Population at 3 MAG*

The population of *Azospirillum* sp, PSB and AMF showed an increasing trend from the beginning of the experiment till 3 MAG. The microbial population in the samples with nutrient supplementation and without nutrient supplementation samples did not showed much difference. This indicated the nutrient supplementation at this concentration has no effect on the population of micro organisms. These biofertilizers had pronounced effect on growth of the grafts by improving the nutrient availability and uptake by the plants. Bagyaraj (1990) reported that combined application of biofertilizers had significant effect on root colonization and sporulation, growth and yield due to the reason that micro organisms acted synergistically when added simultaneously.

So considering the overall results, it can be concluded that application of 100 ml of decanted extract of 1kg groundnut cake+ 17:17:17 (100g/10 l water) was better. The improved growth of plants in T_7 might be due to the addition of a combination of organic and inorganic source of nutrients (groundnut cake+

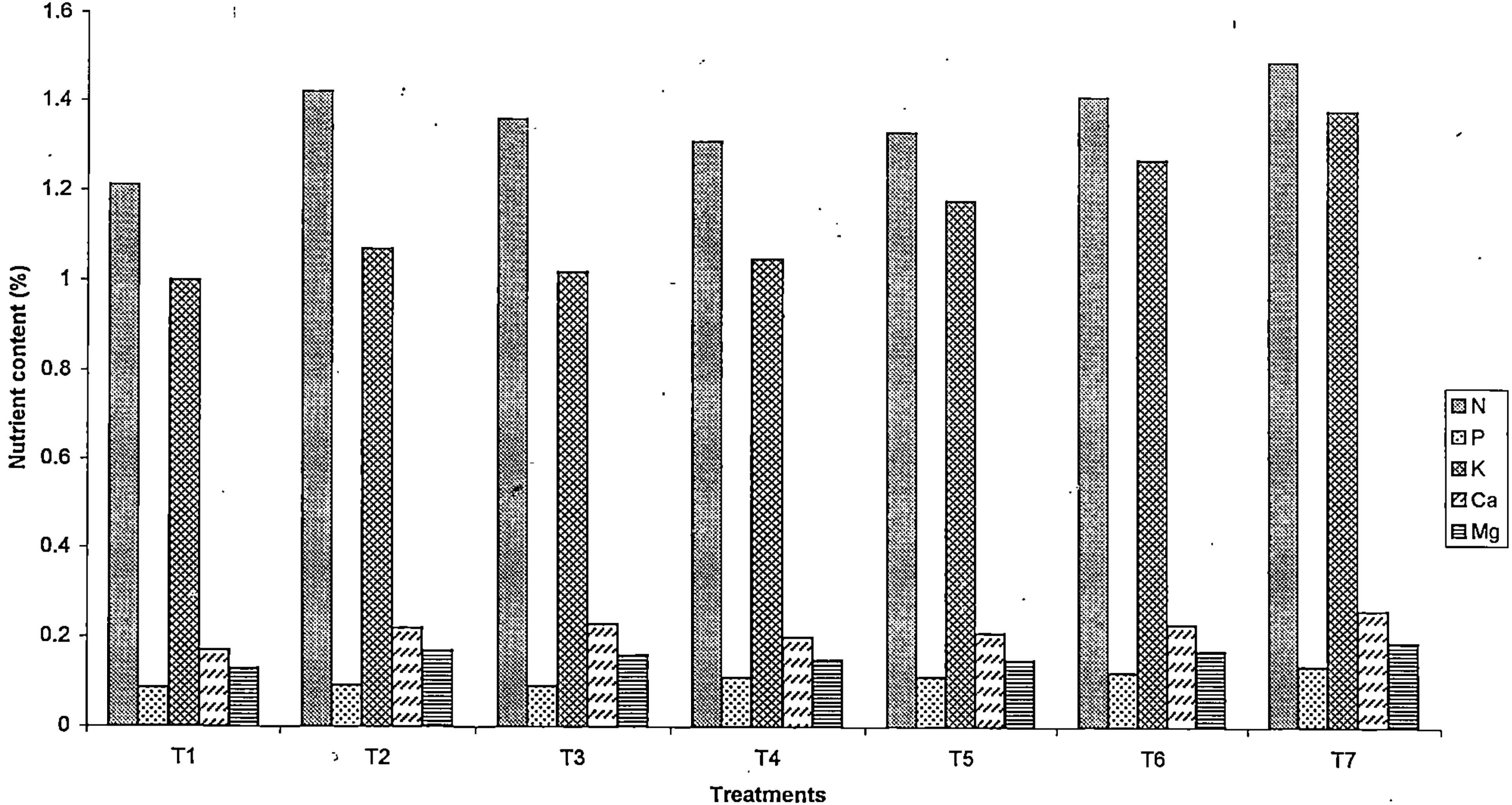


Fig.8. Nutrient content in leaves at 3 MAG of cashew as influenced by soil application of nutrients

17:17:17 mixture) along with the biofertilizers inoculation. These results showed the importance of integrated nutrient management even in nursery stage of cashew.

5.2.2. Foliar Fertilization to the Grafts

Three months after grafting foliar fertilization of 2% urea, ammonium phosphate sulphate, 17:17:17 mixture and a control without foliar fertilization was given to all the 7 soil application treatments to find the best foliar spray that will boost up the growth of the grafts. The results obtained are discussed below.

5.2.2.1 *Growth Characters*

From 3-6 MAG maximum increase in plant height(Fig.9) was found with T_7 (soil application of decanted extract of groundnut cake+ 17:17:17 mixture) sprayed with 2% 17:17:17 mixture. It was on par with 2% urea spray. The result of the foliar sprays on all the treatments revealed that 2% 17:17:17 spray was better than ammonium phosphate sulphate. It might be due to the reduction in nutrient status of the potting mixture while the grafts were growing and taking up more quantity of major nutrients and since 17:17:17 mixture adds all the major nutrients viz., N, P and K.

The number of leaves at 4 MAG was found the maximum with 2% urea spray on T_2 (soil application of urea) but at 5 and 6 MAG, the maximum number of leaves was observed in 2% 17:17:17 spray on T_7 followed by 2% urea. In general foliar application of 2% 17:17:17 and 2% urea were on par compared to ammonium phosphate sulphate spray.

From the above results it can be concluded that 2% 17:17:17 spray was found better than other foliar fertilizations. This is in accordance with the findings of Gopikumar and Aravindakhan (1988) and Panda and Saha (1988) who reported that cashew seedlings raised without N, P and K were shorter with thin stem and less number of leaves compared to plants provided with balanced quantity of N, Pand K.

Leaf area per plant at all stages of observation showed a significant difference with 2% 17:17:17 spray on T_7 compared to other foliar sprays which contained only N or P (Fig.10). In all the treatments leaf area was high with 17:17:17 spray. This increased leaf area might be due to the balanced availability of all the primary nutrients. The role of potassium on production of leaves and vegetative growth was well documented by Lahav (1973) who observed significant reduction in leaf size, longevity and leaf area with potassium starvation. There exists a positive relationship between leaf area and over all plant growth. As leaves are the photosynthesizing units of a plant, higher total leaf area through higher number of leaves or by increased area of individual leaves will result in improved benefit to the plant in the form of stored food materials.

Root dry weight at 6 MAG showed that it was maximum with 2% 17:17:17 spray on T_7 which was on par with ammonium phosphate sulphate spray. 2% 17:17:17 spray was found superior in all the treatments followed by 2% ammonium phosphate sulphate spray compared to urea. This effect might be due to the action of phosphorus together with N and K which helps in the better root development.

The result of the shoot dry weight at 6 MAG showed that, though it was found maximum with 2% 17:17:17 spray on T_7, 2% urea and ammonium phosphate sulphate were on par with it. Among the foliar sprays 2% urea and 17:17:17 mixture were on par generally in all the treatments.

Root: shoot ratio was found maximum with 2% ammonium phosphate sulphate spray on T_3 (soil application of ammonium sulphate) followed by 17:17:17 spray on T_3. This increased root: shoot ratio on T_3 was due to the lower shoot dry weight with this treatment. Hence a satisfactory result in this case was obtained with 2% 17:17:17 and 2% ammonium phosphate sulphate on T_7 because root and shoot dry weight was comparatively maximum in these treatments with a R:S ratio of 0.450 and 0.443 respectively.

5.2.2.2 *Chlorophyll Content*

Chlorophyll content of leaves at 6 MAG showed that chlorophyll 'a', chlorophyll 'b' and total chlorophyll(Fig.11) were the highest with 17:17:17 spray on T_7. On all the treatments 17:17:17 mixture was found superior to the other sprays. This might be due to the balanced fertilization and the role of K in chlorophyll development. Increase in chlorophyll content in the leaves due to K application was observed by Roy and Choudhari (1980). Potassium checks the chlorophyll degradation and promotes the synthesis of both chlorophyll 'a' and 'b' (Mengel *et al.*, 1981).

5.2.2.3 *Nutrient Content in Leaves*

Nutrient content in the leaves at 6 MAG revealed that nitrogen was significantly higher with 2% urea spray on T_7(Fig.12) and urea spray showed significant increase in all the treatments compared to other foliar sprays. This result was in accordance with the findings of Ankiah and Rao (1983) who reported that foliar application of urea up to four per cent concentration significantly increased the leaf N content of cashew, beyond which there was nominal increase only.The leaf phosphorus content showed that it was the highest with 2% ammonium phosphate sulphate spray followed by 17:17:17 spray on T_7. The foliar sprays of ammonium phosphate sulphate and 17:17:17 mixture were on par in all treatments in general. The effect of P in increasing the height and flushes in cashew in laterite soils has already been reported (Nambiar, 1983 and Latha, 1992). The potassium content in leaves was significantly higher with 2% 17:17:17 spray on T_7(Fig.12) and it was observed that on all the treatments 2%

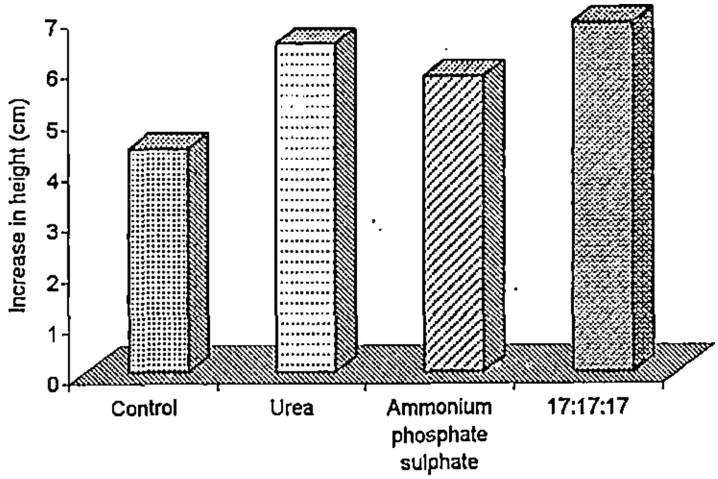


Fig.9. Increase in height from 3-6 MAG of cashew as influenced by foliar fertilization

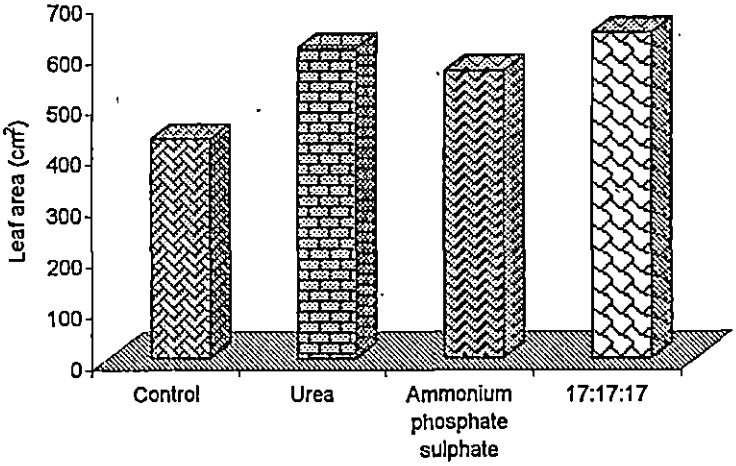


Fig.10. Leaf area plant^{-1} at 6 MAG of cashew as influenced by foliar fertilization

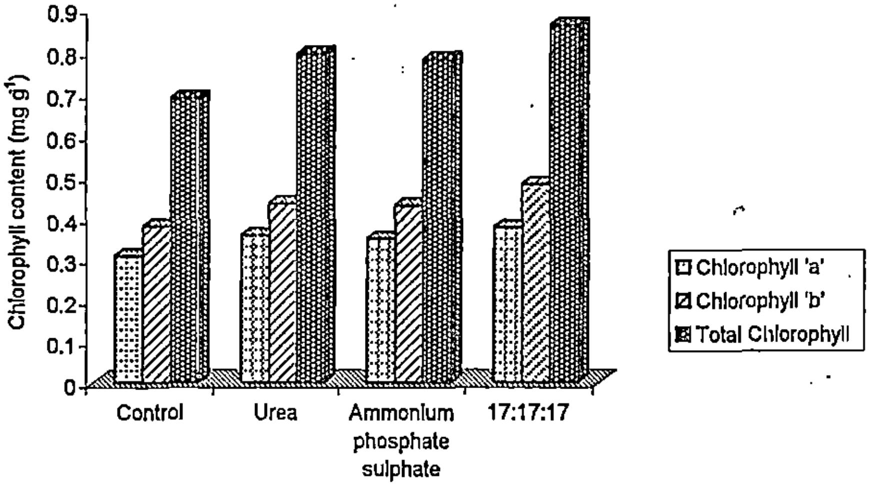


Fig.11. Chlorophyll content of leaves at 6 MAG of cashew as influenced by foliar fertilization

17:17:17 spray was significantly superior compared to other foliar sprays. The role of K in plants is attributed mainly to the improvement of internal nutritional environment i.e. the translocation of other nutrients. Higher K application in laterite soil was found to decrease the toxic levels of Fe and Mn in plant tissues (Bridgit, 1999). Leaf calcium was significantly higher in 2% 17:17:17 spray on T_7 (Fig.12) and 17:17:17 spray differ significantly on all the treatments. Magnesium content in the leaves was comparatively higher in T_7 sprayed with 2% 17:17:17 mixture(Fig.12). Among the foliar sprays, 17:17:17 spray was significantly superior on all the treatments.

5.2.2.4 *Nutrient Content in Potting Mixtures*

The nutrient status in the potting mixture at 6 MAG showed that the available nitrogen (Table 41) was the highest when soil and foliar application of urea was given. It is because of the higher content of N in urea. The available phosphorus (Table 42) was found to be the maximum with 2% ammonium phosphate sulphate spray on T_5 (Soil application of ammonium phosphate sulphate+ MOP), though the foliar sprays did not differ significantly. The higher P content in T_5 may be due to the microbial inoculation of PSB and AMF in the potting mixture at the beginning of the experiment and the supply of P through the fertilizer ammonium phosphate sulphate. The available potassium (Table 43) was higher in the treatments were foliar spray with 2% 17:17:17 was given and the maximum was observed in T_5 followed by T_7. The exchangeable calcium (Table 44) was the maximum with 17:17:17 spray on T_7 which was on par with urea and ammonium phosphate sulphate spray. The exchangeable magnesium (Table 45) was relatively higher in 17:17:17 spray on T_7, though all the foliar sprays were on par. The N, P, K, Ca and Mg contents in T_7 as influenced by foliar fertilisation is shown in Fig. 13. This higher nutrient contents noticed in the potting mixtures, might be due to the beneficial effects of micro organisms and interaction of the nutrients present in the fertilisers utilized (Dhillon and Ampornpan, 1992). T_7

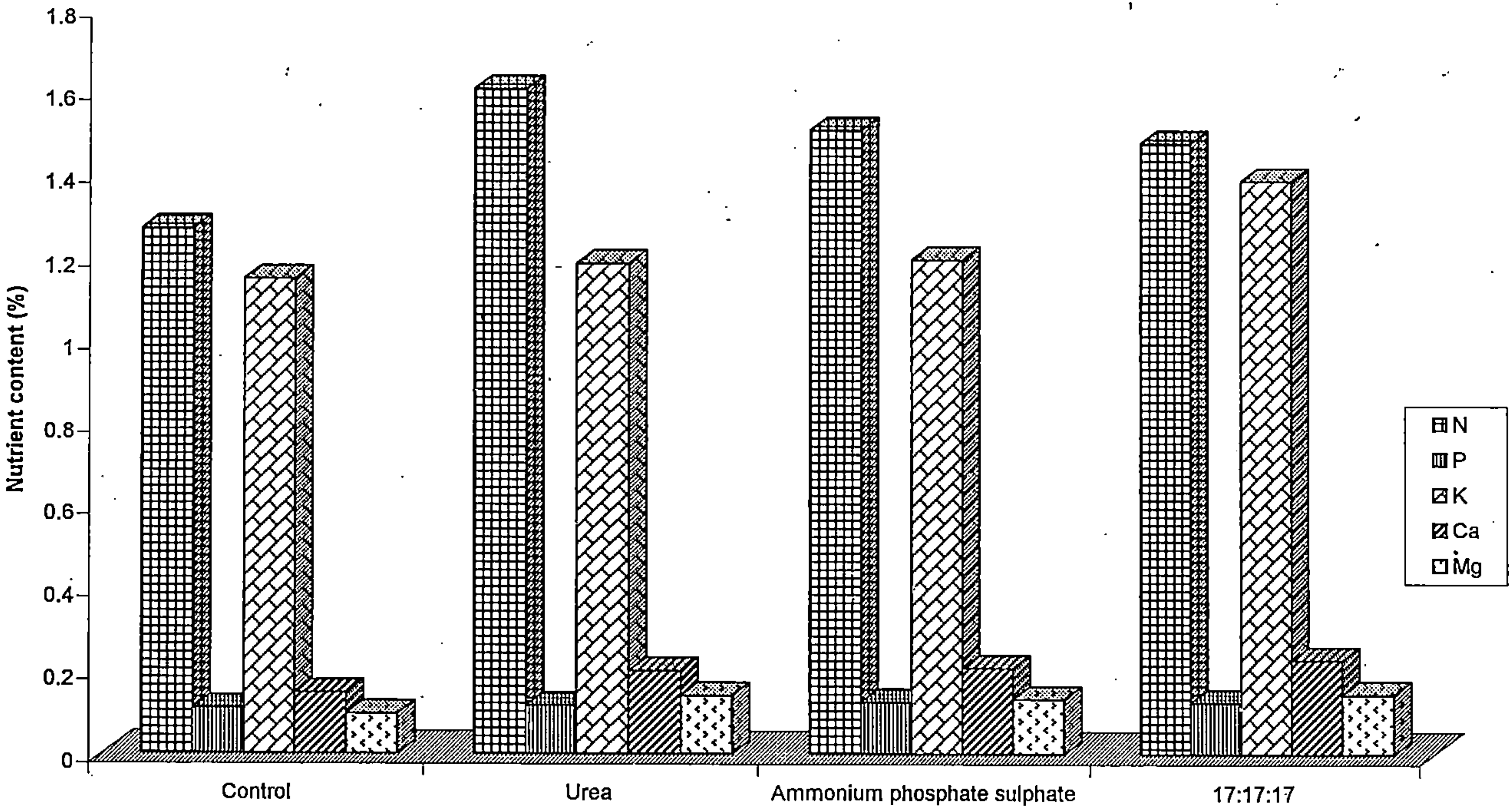


Fig.12. N, P, K, Ca and Mg content of leaves at 6 MAG of cashew as influenced by foliar fertilization

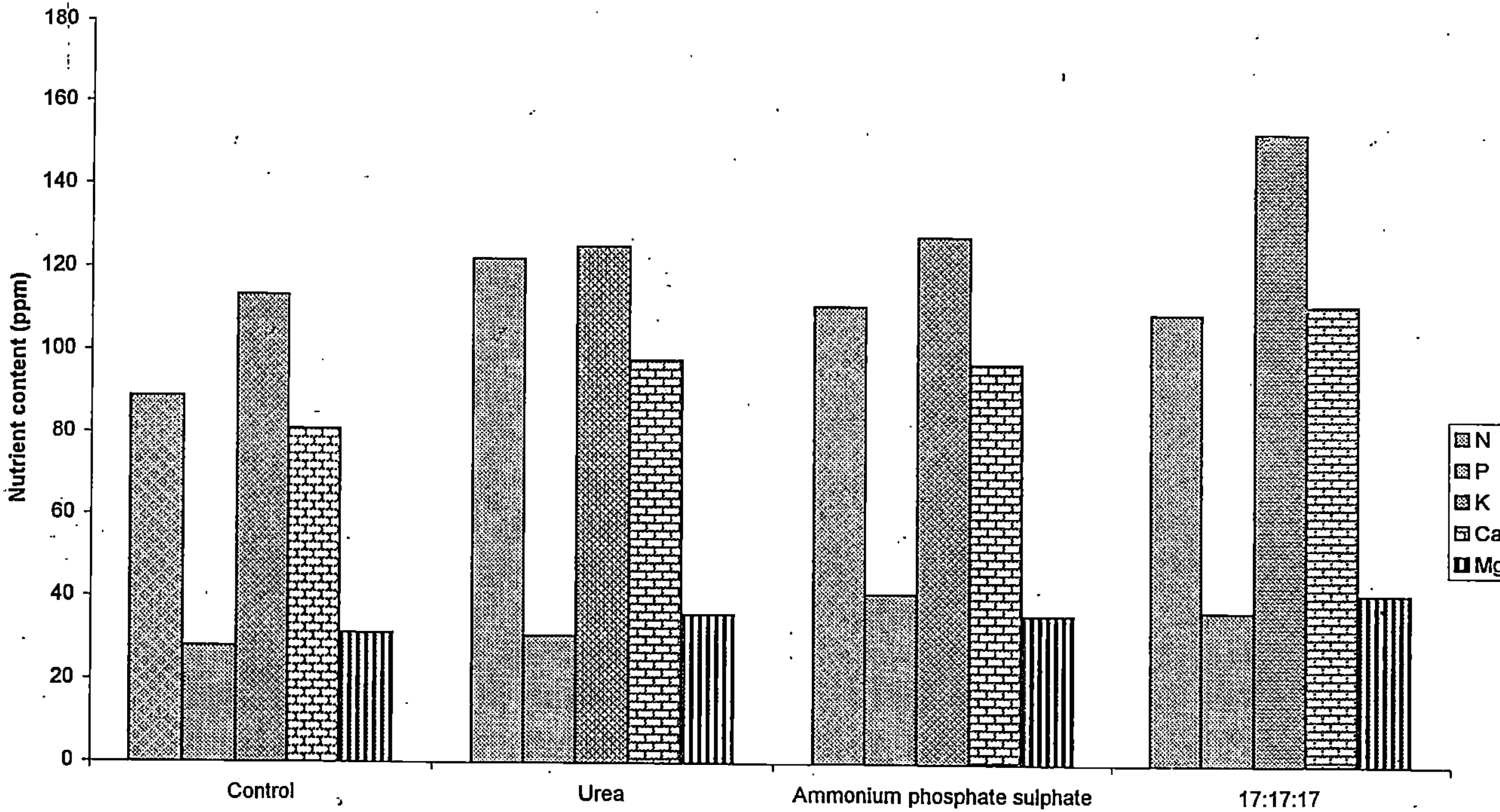


Fig.13. N,P,K,Ca and Mg content in potting mixtures at 6 MAG of cashew as influenced by foliar fertilization

received a combination of microbial inoculation along with organic and inorganic supply of nutrients.

5.2.2.5 *Microbial population at 6 MAG*

All the potting mixtures are having the same composition and microbial inoculation, so population of *Azospirillum* sp,+PSB+AMF in the composite samples revealed that it showed an increasing pattern from 3 MAG till 6 MAG. The microbial population was almost the same where soil application of nutrients was done irrespective of foliar fertilization. This revealed that the foliar fertilization did not affect the microbial population. The improved performance of grafts might be due to the interaction of biofertilizers, inorganic NPK and cowdung. This result was in accordance with the finding of Muthuramalingam, (1996). Velmurugan, (1998) reported that triple inoculation of *Azospirillum*, PSB and AMF with inorganic fertilizers significantly increased the growth, nutrient uptake and AMF colonization dual inoculation.

From the above findings, it can be concluded that foliar fertilization with 2% 17:17:17 spray was highly essential in improving the growth of grafts at a later stage eventhough soil application of nutrients was given one month after grafting. It was clear from the result that if only soil application was given, the growth of grafts in terms of biometric observation and nutrient status decreased. This result was in conformity with the study of Devarajan *et al.* (1991) that foliar nutrition of N, P and K as a supplement to soil application increased the performance of seedlings. Ahenkorah *et al.* (1987) also reported that foliar fertilization of NPK (1%) on cocoa seedlings increased the vigour and growth of seedling. The overall results of the experiment II revealed that soil application of 100 ml of decanted extract of groundnut cake+ 17:17:17 mixture at 1 MAG followed by foliar fertilization with 2% 17:17:17 mixture at 3 MAG coupled with biofertilizer inoculation improved the growth and vigour of cashew grafts.

Summary

6. SUMMARY

The experiment on Nutrient management in cashew nursery was conducted at Department of Agronomy, College of Horticulture, Vellanikkara, Thrissur during 2002-2003. It consisted of the studies on the management practices for cashew root stock production and management practices of cashew grafts.

EXPT 1. MANAGEMENT PRACTICES FOR CASHEW ROOT STOCK PRODUCTION

The experiment consisted of three different types of potting mixtures containing sand, soil and cowdung/ poultry manure/ coirpith compost supplemented with biofertilizers *Azospirillum* (Azo), Phosphorus Solubilizing Bacteria (PSB) and Arbuscular Mycorrhizal Fungi (AMF) either alone or in a combination of these three. An absolute control with the potting mixture containing sand and soil in 1:1 proportion was also maintained.

The available nutrient content in the potting mixtures at the beginning of the experiment showed that N was the highest in *Azospirillum* sp inoculated potting mixture containing poultry manure (T_8) followed by T_{11} (sand:soil:poultry manure+ Azo+PSB+AMF).The content of P, K, Ca and Mg registered the maximum in T_{11}.

The physical properties of the potting mixtures viz., sand:soil:cowdung (T_1), sand:soil:poultry manure (T_2), sand:soil:coirpith compost (T_3) and sand:soil:cowdung (T_{16}), showed that the bulk density and particle density were the highest in T_{16} and the lowest in T_3. The maximum pore space and water holding capacity were found in T_3 and the minimum in T_{16}.

The days to germination was minimised with an increased germination percentage in cowdung and coirpith compost applied potting mixtures compared to poultry manure. Among the biofertilizer inoculated treatments, combined inoculation (Azo+PSB+AMF) took only less days for germination. The minimum days for germination was found in T_{15} (sand: soil: coirpith compost+ *Azospirillum*+ PSB+ AMF). All the nuts germinated in the T_6 (sand: soil: cowdung+ AMF), T_7 (sand: soil: cowdung+ Azo+ PSB+ AMF)and T_{15}. The growth characters like height, girth, number of leaves dry weights of root, shoot and root:shoot ratio were maximum in T_7.

Among the nutrient content in leaves, N was significantly higher in T_{11} (sand:soil:poultry manure+ Azo+ PSB+ AMF) followed by T_8 (sand:soil:poultry manure+ Azo). P content was more in poultry manure applied treatments and it was significantly higher than other treatments. Higher quantity of K was recorded in T_{11} followed by T_{10} (sand:soil:poultry manure+ AMF). Ca and Mg contents registered the highest value in T_{11} followed by T_{10}.

Available nutrient contents (N, P, K, Ca and Mg) in the potting mixtures at grafting showed that it was the maximum in T_{11}.

The treatments which received the combined biofertilizers registered higher population of *Azospirillum*, PSB, AMF spores and AMF root infection in all the organic manure containing potting mixtures, with the highest values recorded in T_7.

EXPT II. MANAGEMENT PRACTICES OF CASHEW GRAFTS

In this experiment all the treatments were having the same potting mixture (sand:soil:cowdung+*Azospirillum*+ PSB+ AMF) with nutrient supplementation as soil application at 1 MAG and foliar application at 3 MAG.

Soil Application of Nutrients to the Grafts

Increase in height of the grafts was obtained due to soil application of nutrients up to 3 MAG compared to control. Even though various sources were used such as urea, ammonium sulphate, ammonium phosphate sulphate, MOP, 17:17:17 mixture and groundnut cake, the differences were not significant in height as well as leaf number. Leaf area per plant was significantly superior in T_7 (groundnut extract +17:17:17) followed by T_6 (only 17:17:17).

The nutrient content in leaves at 3 MAG showed that N and K were significantly higher in T_7. P did not differ significantly between treatments. With respect to Ca the highest content was noticed in T_7 and all the other nutrient supplemented treatment were on par. No substantial difference was noticed in Mg content between treatments.

Foliar Fertilization to the Grafts

Among the different foliar sprays, the maximum increase in plant height from 3-6 MAG was observed with 2% 17:17:17 spray followed by 2% urea spray on T_7 (soil application of decanted extract of groundnut cake + 17:17:17 mixture).

The maximum number of leaves at the end of the experiment was found with 2% 17: 17:17 spray followed by urea spray on T_7.

Leaf area per plant was found higher with 2% 17: 17:17 spray on all treatments and the maximum in T_7 at all stages of observation.

Root dry weight at 6 MAG was the maximum with 2% 17: 17:17 spray. followed by 2% ammonium phosphate sulphate spray on T_7. The highest shoot dry weight was also found with 2% 17:17:17 spray on T_7 but the other two foliar sprays were on par with it. The root: shoot ratio of T_7 with 2% 17:17:17 spray was also comparatively better.

Chlorophyll 'a', chlorophyll 'b' and total chlorophyll were found to be the maximum with 2% 17:17:17 spray on T_7.

Nutrient contents in leaves at 6 MAG revealed that N, P, K, Ca and Mg were significantly higher in T_7. All the nutrients except N and P were the highest with 17:17:17 spray. In the case of N it was with 2% urea and in the case of P it was with 2% ammonium phosphate sulphate spray.

Regarding the available nutrients in the potting mixtures at 6 MAG, the maximum N was recorded with 2% urea spray on T_2 (soil application of urea). P was found the highest in 2% ammonium phosphate sulphate spray on T_5 (soil application of ammonium phosphate sulphate+ MOP). The maximum K was observed with 2% 17:17:17 spray on T_5. Ca and Mg were the highest in 2% 17:17:17 spray on T_7.

Microbial population of *Azospirillum* sp, PSB, AMF spores were on the increasing trend from the beginning of the experiment till 6 MAG.

The experiment I showed that for the successful production of cashew root stocks, a potting mixture with sand:soil: cowdung was better and a further boosting was observed when the potting mixture received microbial inoculation of *Azospirillum,* PSB and AMF in combination

From the experiment II it was revealed that the growth and vigour of cashew grafts was improved with the soil application of 100 ml of decanted extract of groundnut cake +17:17:17 mixture at 1MAG followed by foliar fertilization with 2 per cent 17:17:17 mixture at 3MAG coupled with biofertilizer inoculation.

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* Originals not seen

Appendices

Appendix – I
Monthly weather data during crop season (June 2002 – May 2003)

Sl. No.	Month	Temperature (°C)			Relative humidity (%)		Sunshine hrs day^{-1}	Evaporation mm	Rainfall mm	No. of rainy days	Wind speed km hr^{-1}
		Maximum	Minimum	Mean	Morning	Evening					
1	June	31.8	31.0	31.4	93	78	2.7	92.5	533.5	22	4.0
2	July	29.8	21.4	25.6	94	74	3.4	94.6	354.2	21	3.8
3	August	31.4	21	26.2	94	78	3.1	93.4	506.6	19	3.8
4	September	33.3	21.6	27.3	92	62	7.8	125.5	124.0	8	3.7
5	October	33.4	22.5	27.8	91	74	4.4	96.2	387.7	19	3.3
6	November	33.2	22.3	27.8	83	60	6.3	124.9	22.1	3	4.7
7	December	33.4	16.8	25.1	72	45	8.7	198.8	0	0	8.1
8	January	35.3	19.5	27.4	66	34	9.4	229.1	0	0	8.6
9	February	36.8	21.6	29.2	83	43	9.2	152.9	162.1	5	5.1
10	March	36.0	20.4	28.2	86	37	8.5	162.5	94.8	4	3.7
11	April	37.8	23.4	30.6	86	58	7.5	150.7	23.8	3	3.2
12	May	35.6	23.5	29.5	88	56	6.3	158.1	40.3	3	3.8

Appendix II

Composition of Okon's medium

a)	KH_2PO_4	-	4.0 g
	K_2HPO_4	-	6.0 g
	Distilled water	-	500 ml
b)	$MgSO_4.7H_2O$	-	0.2 g
	NaCl	-	0.1 g
	$CaCl_2$	-	0.02 g
	NH_4Cl	-	1.0 g
	Malic acid	-	5.0 g
	NaOH	-	3.0 g
	Yeast extract	-	0.05 g
	$Na_2\ M_0\ O_4$	-	0.001 g
	H_3BO_3	-	0.0014 g
	$Cu_4\ (NO_3)_2$	-	0.0004 g
	$ZnSO_4$	-	0.0021 g
	$FeCl_3$	-	0.002 g
	Agar	-	2 g
	Distilled water	-	500 ml
c)	Bromothymol blue	-	2.0 ml
	0.5% alcoholic solution		
	pH	-	7

Appendix III

Composition of Pikovskaya's medium

Glucose	-	10.0 g
$Ca_3(PO_4)_2$	-	5.0 g
$(NH_4)_2\ SO_4$	-	0.5 g
KCl	-	0.2 g
$MgSO_4.7H_2O$	-	0.1 g
$MnSO_4$	-	Trace
$FeSO_3$	-	Trace
Yeast extract	-	0.5 g
Distilled water	-	1000 ml
Agar	-	18 g

NUTRIENT MANAGEMENT IN CASHEW NURSERY

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The experiment on "Nutrient management in cashew nursery" was taken up during 2002-2003 at College of Horticulture, Vellanikkara, Thrissur. The experimental site was Cashew Research Station, Madakkathara, Kerala Agricultural University. It consisted of two parts viz., management practices for cashew root stock production and the management practices of cashew grafts.

The experiment on the management practices for cashew root stock production was conducted to select the best organic sources (cowdung, poultry manure, coirpith compost) of nutrients in the potting media and to find the effect of *Azospirillum*, Phosphorus Solubilizing Bacteria and Arbuscular Mycorrhizal Fungi inoculation on the growth of root stocks.

The bulk density and particle density were found to be decreased and by the application of organic manure in the potting mixtures and the lowest was found with coirpith compost. The pore space and water holding capacity were increased by the organic manures in the potting mixtures and the maximum was observed with coirpith compost.

In all the organic manure containing potting mixtures combined inoculation of *Azospirillum*, PSB and AMF decreased the days taken for germination, compared to single inoculation and the minimum was observed in coirpith compost applied treatment. The maximum germination percentage was found with AMF inoculation in cowdung containing potting mixture and *Azospirillum*+ PSB+ AMF inoculated potting mixtures of cowdung and coirpith compost. Among the different potting mixtures, a higher growth rate of seedlings were observed in the potting mixture containing sand:soil:cowdung+ *Azospirillum*+ PSB+ AMF.

The care and management of grafts in the nursery involved soil and foliar application of nutrients in the second part of the experiment. Here all the

treatments were having the same potting mixture (sand:soil:cowdung+ *Azospirillum*+PSB+AMF) and nutrient supplementation through various sources were given at 1 MAG and 3 MAG through soil and foliar application respectively. The performance of the grafts were found better with the soil application of 100 ml of decanted extract of groundnut cake + 100 ml of 17:17:17 mixture (prepared by 100g 17:17:17 mixture added in 10 l water) at 1 MAG followed by 2% 17:17:17 spray at 3 MAG.