NUTRITIONAL MANAGEMENT OF YELLOWING IN ARECANUT

By

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THESIS

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DECLARATION

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

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Certified that this thesis entitled **"Nutritional management of yellowing in arecanut"** is a record of research work done independently by Shri. Jacob D., 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

In India, arecanut (*Areca catechu* L.) popularly known as 'betelnut' or 'supari' is the most popular narcotic among masticants used by the rich and the poor alike. It also figures as an important socio-religious object. Apart from these, arecanut has industrial and medicinal uses. Polyphenols present in the betel nut have astringent, antimicrobial and antihelminthic properties. The alkaloid 'arecolin' in arecanut reduces blood pressure. Arecanut can counteract, to some extent, the carcinogenic effect of tobacco while chewing. Arecanut husk can be used for making hard board and wrapping paper.

India ranked first in both area (3.81 lakh ha) and production (4.83 lakh t) of arecanut during 2005-06. It is estimated that more than four million farmers in our country are depending on arecanut cultivation for their livelihood. In India even though commercial cultivation of the crop is confined to the states of Kerala, Karnataka, Maharastra, Assam, West Bengal, Orissa and Tamilnadu, the lions share of the production is from the first two states.

Arecanut is traditionally grown in the valleys. Arecanut fits well in high density multispecies cropping system along with banana, cocoa, pepper, betelvine, elephant foot yam and tapioca (Balasimha *et al*., 2004). Attracted by high market value of the produce, many farmers had switched over to arecanut cultivation and indiscriminately area expansion occurred, irrespective of the suitability of the crop to a particular region, both in traditional and non-traditional areas ranging from paddy fields to terraced uplands.

In 1961-62, the area under Arecanut in Kerala was 0.57 lakh ha. It increased to 1.09 lakh ha in 2005-06 with a production of 1.19 lakh nuts. Malappuram district (18 percent) ranks first in the area under arecanut cultivation. Kasargod (16 percent) and Kannur (13 percent) districts occupy the second and third respectively. Highest contribution in the case of arecanut production is 27 percent from Kasargod district. Kannur comes in the second place (14 percent). Kasargod district records the highest productivity (1856 kg ha^{-1}) (State Planning Board, 2006).

The entire arecanut growing tracts in Kerala and southern Karnataka are under the severe threat of a havoc called ‘yellowing in arecanut’. The first visible symptom is yellowing at tips of leaflets in two or three leaves of the outermost whorl. Reduction in yield up to 50 percent and a leaf fall up to 4 percent were recorded in affected palms over a short span of three years following the incidence of yellowing. Suspecting the association of plant pathogens with this problem, scientists have earlier called it as ‘yellow leaf disease’. Since no definite causative factors could be singled out till recently, it was decided to term the yellow leaf problem as ‘yellow leaf syndrome’. (Krishnamurthy and Vajranabhaiah, 2000). Stray incidences of the disaster have also been reported from northern Karnataka and parts of Maharastra, indicating that the malady is spreading towards north along the west cost of India. A survey conducted in 1976 revealed that 36 percent of areca growing tracts in Kerala and 24 percent in Karnataka were affected by yellowing (Saraswathy and Bhat, 2001).

The area under arecanut in Kerala exhibited an increasing trend up to the year 1974-75. But in the year 1975-76, a decline of about 6 percent in area was observed in Kerala alone compared to the previous year and this declining trend prevailed for a period of ten years. This decline in area is due to the serious occurrence of yellowing. Annual growth rate of consumption of arecanut is around 3 percent. At this rate, the requirement of arecanut by 2020 will be 0.62 Mt. Without area expansion, India needs to double the productivity to meet the increased demand (Rethinam and Sivaraman, 2001).

Among the various factors associated with yellowing of arecanut, soil health and balanced nutrition are profoundly important as they influence the incidence of yellowing either directly or indirectly. As yellowing in arecanut is not amenable to any chemical control method, the only way out to get good yield is to resort to better management of the garden (Saraswathy and Bhat, 2001). With this background, an investigation was undertaken to characterise the nature and intensity of yellowing in arecanut as well as the associated predisposing nutritional factors and to develop a management strategy to contain the yellowing in different toposequences.

The specific objectives intended to be studied in this context can be summarised as:

i. Development of a scoring system to assess the intensity of yellowing.

ii. Comparison of incidence of yellowing among converted paddy fields, garden lands and terraced uplands.

iii. Development of management strategies to contain yellowing of arecanut in various toposequences.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 HISTORY AND SPREAD OF YELLOWING IN ARECANUT

Yellowing is the most serious malady presently affecting arecanut palm. The yellowing was first reported in 1914 from Muvattupuzha, Meenachil and Chalakkudi areas of central Kerala succeeding a heavy flood (Nambiar, 1949). A preliminary survey conducted during 1959-60 showed that yellowing had spread to all parts of Kerala with a maximum incidence of 90 percent in Kollam district (CPCRI, 1960). Later, occurrence of yellowing was also noticed from central regions of Mumbai, parts of Karnataka and Tamilnadu (Menon, 1963).

Thorough and systematic observations were made from 1961 onwards with respect to the pattern of occurrence of yellowing. Seedlings planted in 1961 in virgin forest soil took up symptoms in 1968. The pattern of spread of yellowing from the primary focus was not in a definite manner and it was totally erratic. By 1971, with in a period of four years from the appearance of the first symptoms, about 80 per cent of the palms in the gardens showed symptoms of yellowing. This indicated the rapidity in further spread of yellowing (Rawther and Abraham, 1972).

Nair (1976) concluded that yellow leaf of arecanut was the most serious problem facing arecanut growers and was spreading steadily. Observations recorded over a period of eleven years from 1961 to 1972 in Kerala revealed rapid and indiscriminate spread of yellowing without any definite pattern (Rawther, 1982). Yellowing affects palms of all age groups. Yellowing was found to become epidemic following heavy winds. The incidence of yellowing appeared to be more in low lying plots where water table was high during rainy season. Usually seedlings planted in affected soil exhibited symptoms of yellowing after three years of planting (Rawther, 2000).

A comprehensive survey undertaken in 1976 in arecanut growing areas of Kerala revealed that yellowing was prevalent in all districts of Kerala. The study showed that the incidence of yellowing was very severe (more than 75percent) in Thiruvananthapuram, Kollam, Kottayam and Idukki (maximum incidence of 97 percent) districts and very low in Kannur and Malappuram districts (less than 20 percent). Ten to sixty per cent reduction in yield on account of yellowing was recorded. On an average, 36 percent of areca palms in Kerala were found to be affected with yellowing. (George *et al*.,1980).

A garden to garden survey in Karnataka during 1989 and 1990 revealed that yellowing was prevalent in all arecanut growing districts namely Dakshina Kannada, Uduppi, Kodagu, Chickmangalur, Shimoga and Uttara Kannada resulting in an yield loss of 508 tonnes of *chali* (Rawther, 2000). Yellowing had been reported from heavy rainfall hilly tracts (Sringeri, Tirthahalli and Sagar belt), coastal zones (Sampaje belt) of Karnataka and parts of Kerala (Kumaraswamy, 2000). In Karnataka, 40 per cent of areca gardens are having this problem (George *et al*., 1984; Krishnamurthy and Vajranabhaiah, 2000).

Apart from taking a heavy toll of the palms every year, the yellowing rendered arecanut cultivation uneconomical to the farmers due to reduced yield. Hence it is necessary to identify fresh incidence of yellowing as soon as it appears and manage the affected fields (Rawther, 2000).

2.2 SYMPTOMS OF YELLOWING IN ARECANUT

Field survey of 200 arecanut gardens at Koothattukulam and Punalur in Kerala and Jayapura in Karnataka showed that about 62 percent of the palms showing the symptoms of yellowing were in the age group of 5-25 years and about 25 percent were in the prebearing age. The oldest leaf was invariably the first to turn yellow. Later, yellowing gradually spread to upper leaves. In about 80 percent of the gardens, the appearance of the yellowing was reported to be sporadic. The leaf size was reduced in about 60 percent of the cases with 70 percent trees showing yellowing in more than three leaves. In 50 percent of the cases, foliar yellowing followed by necrosis and fall of tissues were confined to tip of leaves while in 37 percent, severe yellowing was noticed. The kernel was discoloured in 43 percent of the cases and nuts fell prematurely in 60 percent of the palms (Nagaraj *et al*., 1976).

2.2.1 Symptoms on leaves

An important observation in affected leaves was the occurrence of tyloses in varying numbers (up to 9) in cross section of xylem vessels. In early stages of yellowing, these appeared as tiny protrusions jutting into xylem vessels. Tyloses were formed by the investigation of the protoplast of the neighbouring parenchyma cells into xylem lumen through pits. They undergo secondary thickening as evidenced by reticulate surface patterns. As the yellowing advances, they increase in number and size resulting in partial to complete blocking of the lumen of xylem vessels (Nair, 1976). As yellowing advances, the whole crown size gets reduced. The leaves become stiff and pointed closely bunched and abnormally puckered. The leaf tips become necrotic and dry up during summer (Nair and Seliskar, 1978)

Nair (1994) observed that yellowing appears only at the tips of the leaflets from two or three leaves of the outermost whorl. This yellowing gradually extend to the middle lamella. During dry periods, the tips of the chlorotic leaflets become reduced in size, stiff, pointed, closely bunched and abnormally puckered. When the crown is yellowed, the folded spindle become necrotic and collapse. Eventually the crown topples from the trunk. The final phase occurs 12-18 months after pronounced yellowing of the crown. During the advancement of the yellowing, the spindle become brittle at the base, necrotic at the tip and fails to open. Spindle leaves break during winds and appear drooping from the crown.

Later, normal leaves emerge from the same crown. The leaf size is considerably reduced. As yellowing advances, the girth of the crown gradually tapers.

Typical symptoms are characterised by yellowing at the tips and spreading to the middle, along distinct boundaries on the leaflets. The entire leaf turns yellow with long green patch in the centre of the leaf. In advanced stage, the new leaf become shorter, closely bunched, abnormally paled and sometimes wilt and shred. There will be gradual tapering of the stem with reduction in girth at the plant top. The distance between nodes gets highly reduced, leading to 'stag head'. The plant crown breaks and falls off (Krishnamurthy and Vajranabhaiah, 2000).

The decrease of fluorescence indices in the leaves of affected palms corresponded with a reduction in chlorophyll and carotenoid pigments. These changes result in reduction of carboxylation efficiency (Chowdappa and Balasimha, 1992). Srinivasan (1982) recorded association of a deranged chlorophyllase-chlorophyll system with yellow leaf affected arecanut palms. In the affected palms, activity of chlorophyllase was enhanced and concomitantly the pigment chlorophyll declined. Chlorophyll destruction had primary relation with the degree of expression of yellow leaf syndromes. Consequently, pigment changes were apparently related to the diagnostic symptoms of yellowing in arecanut (Srinivasan, 1982). Thus, the phenomenon of foliar yellowing is due to loss of chlorophylls and carotenoids (Chowdappa *et al*., 2002)

The foliar yellowing due to yellow leaf disease (caused by phytoplasma) could be distinguished from physiological yellowing of palm owing to drought, lack of drainage or water logging, lime induced or nutritional disorders like nitrogen deficiency, mite and root grub infestation as the foliar yellowing in yellow leaf disease is characterised by abrupt demarcation between green and yellow region. There will be a clear band of green tissues adjacent to the midrib areas of the leaf as well as the leaflets (Menon, 1962; Rawther, 1976; Nair, 1994). One or two leaflets in any part of the foliage could be affected by yellowing (Nair, 1994). Yellow leaf disease is a slow decline disease distinct from all other yellowing due to pathological, entomological and nutritional reasons (Saraswathy and Bhat, 2001).

But the leaves of arecanut often turn yellow when sufficient nitrogen is not given or attack of pests like mite or root grub is present. While a general diffused yellowing is confined to the leaves attacked by pests, nitrogen starved plants also show similar diffused yellow colour in the leaves. The yellowing symptoms do not show distinct margins in all these cases. The characteristic symptoms generally differ slightly from garden to garden (Krishnamurthy and Vajranabhaiah, 2000).

2.2.2 Symptoms on nuts

Kernel discolouration is a common symptom associated with yellowing. The endosperms of the mature and immature nuts show a blackish discolouration mostly towards the calycular region. On drying the *chali* is shrivelled and of poor quality rendering them unsuitable for consumption. Thus the yellowing causes qualitative and quantitative loss of the crop. Shedding fruits in large numbers is also recorded during the course of yellowing (Nair, 1994; Pillai, 2000). Nair and Seliskar (1978) reported non production of inflorescence in affected palms. The yield of the affected palms is reduced to the extent of 50 percent over a period of three years. This is mainly due to the reduction in the inflorescence production as well as less nuts in the inflorescences (Nair, 1994). Yield in the affected palms gets reduced by about 30-40 percent per year and within 3-4 years the entire garden becomes most uneconomical when left without proper management (Vijayakumar *et al*., 1991; Krishnamurthy and Vajranabhaiah, 2000).

Rawther (1976, 1982); Nair and Rawther (2000) opined that the kernel discolouration is not an essential symptom of yellowing since palms with normal green foliage standing in the vicinity of affected palms also showed kernel discolouration. Further all the nuts produced in bunches of affected palms may not show endosperm blackening. Even palms exhibiting foliar yellowing sometimes produce normal nuts.

2.2.3 Symptoms on stem

The important characteristics of affected stems is the degeneration of the phloem bundles, presence of a discoloured mass blocking vascular bundles, discharge of unusual exudates from cut regions, discolouration of cut ends, disorganisation of ground tissues and presence of the parenchymatous cells (Nair, 1976). Reduction in internodal length and tapering of stem occurs in affected palms. Ultimately the palms may die or crown falls off leaving a bare trunk (Nair and Seliskar, 1978).

2.2.4 Symptoms on roots

Roots become discoloured, growth restricted, suberised affecting absorption of nutrients and new roots are either not produced or restricted (Krishnamurthy and Vajranabhaiah, 2000., Pillai, 2000). The lateral roots are not produced as profusely as in healthy palms. Tips and absorbing regions of young roots turn dark and gradually rot (Nair, 1976; Nair and Rawther, 2000). Outer cortex becomes discoloured and degenerated. Tyloses occur in the xylem vessels of about 60 percent of old roots. Proliferation of phloem was also noticed (Nair, 1976). In older roots, these projections were seen completely blocking the lumen of the xylem vessels (Chowdappa *et al*., 2002)

Rawther (1976) observed that 71 percent of the roots decayed in affected palms. Average number of branch roots per main root was 23 in healthy palms as against only 4 noticed in affected palms. Thus roots of affected palms show various stages of decay. The difference in the condition of roots between healthy and affected palms in the initial stages of infection was not significant. But as the yellowing progresses, the extent of root decay is also enhanced. Rotting of root system of palms in the advanced stage of yellowing is very high.

However no correlation could be made between root rot and foliar yellowing during different seasons (Rawther, 1976). This root rot is aggravated in water logged plantations and the disease incidence is more in gardens with higher water table (Chandramohan and Nair, 1985). Nair (1994) concluded that there is no significant correlation between root rot and yellowing in arecanut palms during different seasons.

2.2.5 Anatomical changes in yellowing affected palms

The yellow leaf disease affected palms show anatomical changes like plugging of vascular elements, degeneration and disorganization of various cells of the leaves, inflorescence, nut, stem and root. Nair (1968) observed multinucleate cells, deranged tissue differentiation, blocking and pigmentation of the palisade tissue of the leaves. Anatomical changes include lateral and linear proliferation of phloem tubes of roots, the presence of spherical or sub spherical in growth within xylem vessels and blocking of xylem vessels of older leaves and roots (Nair, 1976; Nair and Aravindakshan, 1970). Unusual deposition of callus was recorded in sieve pores of roots and rachillae of diseased palms. Besides, the protophloem tissues were found crushed and necrotic and occluded with electron dense contents. These changes might adversely affect the functional property of phloem in the transport of synthesized food material from the source to the sink region (Pillai, 2000).

2.2.6 Index for quantifying intensity of yellowing

George *et al*. (1980) developed a formula for quantifying the intensity of yellowing after studying the association of the various symptoms in more than 2000 palms. Due weightage was given to foliar yellowing, necrosis and reduction in the size of the whole crown. I (intensity) = [(Y+N)/L+R] x 10 where Y and N are the sum of grade points for yellowing and necrosis, L is 50 per cent of the number of leaves on the crown and R is the grade point for reduction in size of the crown for the whole palm. Eight classes for yellowing with score value 0 to 7, three classes for necrosis with score value 0 to 2 and three classes for reduction in crown size with score value 0 to 1 were considered to estimate the yellowing intensity.

2.2.7 Summary of symptoms of yellowing in arecanut

The foregoing account of the symptoms of yellowing in arecanut reveals that appearance of yellowing in leaflets of 2-3 leaves of outermost whorl is the first visual symptom. Later other visual symptoms like necrosis and reduction in crown size become invariably associated with yellowing. The intensity of yellowing can be quantified. Yellowing can occur even in the absence of kernel discolouration and rotting of roots. Earlier investigators tried to identify the causal factors of yellowing namely drought, water logging, nutritional disorders and pests and diseases based on the pattern of appearance of yellowing in foliage of affected palms. Later it became evident that such a diagnostic procedure is erroneous as symptoms of foliar yellowing due to various causal factors often overlapped each other and differed from garden to garden.

2.3 CAUSES AND MANAGEMENT OF YELLOWING IN ARECANUT

The identification of causal factors involved in yellowing of areca palms based on foliar symptoms alone especially in the early stage of yellowing is not very reliable (Solomon, 1991; Ponnamma and Solomon, 2000). Nambiar (1949) observed that yellowing had some similarities with the root and leaf disease of coconut prevalent in localities like Muvattupuzha, Meenachil and Chalakkudi areas of central Kerala where yellowing was first reported succeeding a heavy flood. Menon (1960) suggested the possibility of virus like organisms being involved in yellowing of arecanut.

Rawther (1976) reported that yellowing affected palms treated with antibiotics like chlortetracycline (aureomycine) and tetracycline (achromycine) by root feeding at monthly and weekly intervals for a period of two years failed to recover. Basal application of aureofungin also gave negative results (Rawther, 1976). However, electron microscopic studies showed presence of phytoplasma in the young sieve elements of affected palms (Nair and Seliskar, 1978; Seliskar and Wilson, 1981). Yellowing affected palms treated with antibiotics failed to show any improvement. The limited samples examined at Indian Agricultural Research Institute and the Rothamstead Experimental Station, England have not recorded the presence of any pathogen in electron microscopy (Rawther, 1982).

Yellowing affected palms improved upon pneumatic pressure injection of antibiotics namely oxytetracycline, hostacycline, ledermycin, neomycin and gentamycin into bole of palms, while condition of pencillin and distilled water injected palms deteriorated, establishing the phytoplasmal etiology of yellowing. Electron microscopy examination showed presence of phytoplasma in three out of four areca seedlings with foliar symptoms. Transmission of phytoplasma from affected to healthy arecanut seedling using plant hopper (*Proutista moesta =Assamia moesta*) and dodder laurel (*Cassythia filiformis*) were successfully attempted under controlled conditions. (Solomon, 1991).

Various expert committees were constituted from time to time to look into the problem of yellowing and to make suitable recommendations to tackle it. Raychaudhuri committee constituted in the year 1960 (headed by Dr. S. P. Ray Chaudhuri, Head, Department of Plant Pathology, Indian Agricultural Research Institute, New Delhi) eliminated fungi, bacteria and insects from being the suspected causes and gave an opinion that soil condition plays an important role in yellowing. Pal committee constituted in the year 1960 (headed by Dr. N. L. Pal, Director, Central Tobacco Research Institute, Rajahmundry) made an exhaustive survey in Kerala and recommended investigations into the role of macro and micronutrients in the cause and spread of yellowing. Similarly, Lal committee (headed by Dr. S. B. Lal, Director, Coconut Research Station, Kayamkulam) after visiting affected gardens in Kerala and Karnataka in the year 1964 recommended various lines of work encompassing fungi, insects, virus, nematodes, macro and micro nutrients, soil management practices and drainage (Kotireddy, 1976). A multidisciplinary approach to tackle this problem was initiated only with the establishment of the Central Plantation Crops Research institute in 1970 (Rawther, 1982). Investigations carried out at Kerala Agricultural University supported the possible role of nutritional imbalances in the incidence of arecanut yellowing (Pushkarn *et al*.1999).

The causes of manifestation of the symptoms of yellowing have been reasoned out to be due to various factors. Some had earlier suspected it to be a disease caused by virus or phytoplasma. Besides involvement of bacteria, fungi, nematodes, root grubs and mites were suspected. Some scientists held the view that the problem was more due to want of proper management of garden and nutritional imbalances caused by excess moisture and inadequate drainage, leading to toxicity of aluminium, iron and manganese found in greater quantity in Malanad soils and deficiency of phosphorus, magnesium and zinc. Since no definite causative factors or pathogen or pest was identified till recently, it was decided to term the yellow leaf problem as ‘yellow leaf syndrome’ (Krishnamurthy and Vajranabhaiah, 2000).

In yellowing affected garden, attend to digging, loosening the garden soil and mulching (Krishnamurthy and Vajranabhaiah, 2000). Maintain the garden properly to keep affected palms in a healthy condition by adopting recommended manurial, cultural, plant protection and other management practices (KAU, 2002). Eradication of severely affected palms and development of cost effective and feasible management practices are important in controlling the yellowing. Satellite survey of yellowing affected arecanut tract using geographic information system would be helpful in identifying the extent of spread, intensity and incidence of yellowing. The intricacies of environmental and edaphic factors on the spread and incidence of yellowing are important and need to be investigated as they influence the incidence of yellowing (Chowdappa *et al*., 2002).

Factors namely climate, soil, topography, water availability, varieties, intercrops, plant nutrient, pests and diseases are often found to play a vital role in manifestation of yellowing symptoms in arecanut and hence reviewed below in detail.

2.3.1 Role of climate

Areca palms grow well with in the temperature range of 14°C - 36°C. However the crop is being grown in temperature ranges from 5°C (as in places like Mohitnagar, West Bengal) and at 40°C (Vittal in Karnataka and Kannara in Kerala) and there is more than 50% variation in yield due to climatic differences (Bhat and Sujatha, 2004). Nambiar (1949) reported that extremes of temperature and wide diurnal variations are not conducive for the healthy growth of arecanut palms. Though arecanut is grown under different agro climatic conditions, it is very sensitive to extreme climatic conditions (Bhat and Abdulkhader, 1982). The most important climatic factors that influence the growth and development of arecanut are temperature, altitude, relative humidity and rainfall. Regression analysis of weather variables of twelve years indicated that the arecanut yield is influenced by relative humidity, evapotranspiration and rainfall (Vijayakumar *et al*.,1991).

In Kerala, yellowing has been noticed in neglected gardens, on hill slopes where the palm is continually exposed to the scorching heat of the summer months from March – June without any irrigation (Menon, 1962). Samraj and Pailey (1965) observed that yellowing was more intense on the leaf lamina exposed to direct sunlight. Marked disintegration of chloroplasts was also noticed in the yellow regions. Paint the trunk with lime slurry or coat with Bordeaux mixture starting from the month of February, to protect from south westerly sun (Krishnamurthy and Vajranabhaiah, 2000).

Yellowing of leaves is more clearly seen in August after the onset of monsoon (Mohapatra *et al*., 1975). The symptom expression of yellow leaf is well pronounced soon after the monsoon, when maximum temperature is 30^oC-32^oC, night is cool and wind currents mild to heavy. These symptoms start during beginning of monsoon and reach a peak during September – October and later subside with the fall of affected leaves. The intensity of yellowing of the leaves is minimum in May i.e. before the onset of south west monsoon and maximum in August that is mid monsoon. Paradoxically, with the rise in temperature, the symptom expression is reduced. (Nair, 1976; Nagaraj *et al*., 1976). Symptoms start during the beginning of monsoon and reach peak during September-October and later subside due to fall of affected leaves (Vijayakumar *et al*.,1991). Yellowing starts appearing in the months of September-October continue, until next March-April and disappear or reduce in its intensity. It reappears in the next cycle during September-October and continues this for about three to four cycles after which the plant becomes weak (Kumaraswamy, 2000).

Field observations showed that in majority of yellow leaf affected palms, the symptoms get masked during January-August. i.e. palms fail to exhibit symptoms of yellowing. At the same time there are palms where masking of yellowing symptoms won’t occur even during January-August. This masking of yellowing happens when leaves with symptoms are shed and the freshly emerging leaves in the canopy remain green. The expression of foliar symptoms is thus to a great extent influenced by certain environmental factors. Presence of phytoplasma is detected even during January-August when the symptoms get masked showing that once the palm gets infected by phytoplasma, the palms continue to harbour the phytoplasma irrespective of the symptoms. (Solomon, 1991).

Chowdappa *et al*., (2000) observed that arecanut palms exhibit very clear symptoms of yellow leaf during 'wet' season (August-October). In a majority of the affected palms, the symptoms begin disappearing well before the onset of 'dry' season and remain symptom less during 'dry' season (December-May). Environmental variables therefore play an important role in manifestation of visible symptoms in the yellow leaf affected arecanut palms. A high evaporative demand in the atmosphere existed during 'dry' (December-May) period as indicated by high photosynthetically active radiation, temperature and vapour pressure deficit masking the yellowing symptoms. There was no soil moisture stress during both the 'dry' and 'wet' periods as the palms were irrigated, although atmospheric drought occurred during May. Probably the higher temperature recorded during 'dry' season may have a detrimental effect on the organism namely phytoplasma resulting in a temporary remission of symptoms. The leaf samples of the affected palms showed that the moisture touches the lowest level in June, the month of symptom emergence, by 59 percent. The corresponding value in healthy leaves was 71 percent. Root samples of the above groups did not vary much.

The foregoing account reveals that unirrigated palms exhibited symptoms of yellowing during summer (March-June) (Menon, 1962) while a majority of irrigated palms remained symptom less during December-May (Solomon, 1991; Chowdappa *et al*., 2000). Every year there are two definite peak periods in occurrence of maximum yellowing in arecanut. First peak period of maximum yellowing occurs during summer months from March-June (pre-monsoon). Main causal factors during this period are inadequate irrigation and exposure to scorching heat of the sun rather than phytoplasma as the prevailing high atmospheric temperature is detrimental to the organism. The second peak period of maximum yellowing falls on August-October (mid-monsoon). Main causal factors during this period are 'yellow leaf disease' caused by phytoplasma and ill effects of unfavourable soil physical condition which the palm experienced during early monsoon. Decrease in intensity of yellowing after September-October (post monsoon) can be attributed to reduction in rainfall and the consequent improvement in soil physical condition rather than solely on shedding of yellowing affected leaves alone. An adult arecanut palm has 7-12 open leaves on crown where leaf emergence and leaf fall are regular phenomena which keep occurring at a mean interval of 43 days (Ananda, 1999).

2.3.2 Role of soil and topography

Bhat and Mohapatra (1971) identified major soil groups of arecanut growing tracts. Arecanut is mostly grown in red/laterite soils in and around Western Ghat region, West Bengal and Assam, and clay loams in plains of Karnataka (Mohapatra,1977., Mohapatra and Bhat, 1982). Arecanut cultivation is predominant in gravelly laterite soils of red clay type of southern Kerala and coastal Karnataka (Nambiar, 1949). In plain region or mountain part of Karnataka, it is cultivated in fertile clay loam soils. In areas where tank irrigation is common practice, the soils may have admixture of tank silt. Deep black fertile clay loam soils supported luxuriant palm growth (Bhat and Sujatha, 2004).

Field survey at Koothattukulam, Annamanada, Punalur in Kerala and Jayapura in Karnataka showed that 85 percent of the yellowing affected gardens had laterite soil and the remaining black loamy soil. The texture of the soil was sandy to sandy loam in 80 percent of the cases. The soils were mostly shallow with 74 percent of the gardens having less than 50 cm depth of soil. The topography of the gardens was fairly level in 50 percent of the cases and in the remaining; it ranged from slight slope to steep hills. The intensity of soil erosion also varied from garden to garden. It was negligible in 40 percent of the gardens while the rest were subject to erosion to varying degrees (Nagaraj *et al*., 1976).

Aiyer (1966) reported that sticky clay, sandy, alluvial, brackish and calcareous soils are not suitable for arecanut cultivation. Studies have shown that under well drained deep soil conditions, the arecanut roots traverse down to about three meters and the roots confine to only about 1.40 meters under shallow soil condition (Bhat and Leela, 1969., Bhat, 1978). The property of lateritic soils of Malanad and coastal areas and high contents of Aluminium, Iron and Manganese in them lead to doubt a nutritional imbalance (toxicity of Aluminium, Iron and Manganese). Water logging and reduction in soil pH during monsoon, further strengthened the doubt that yellowing may be caused by these factors (Krishnamurthy and Vajranabhaiah, 2000).

2.3.3 Role of water availability

Irrigation has positive and significant effect on economics of arecanut (Dineshkumar and Mukundan, 1996., Latha and Palanisami. 1996). Abdulkhader *et al.* (1985) noticed yield reduction to the extent of 75 per cent with palms irrigated once in 20 days compared to palms irrigated once in five days.

Rawther and Abraham (1972) observed that irrigation coupled with manuring maintained the yield of yellowing affected palms at economic level. Field survey at Koothattukulam, Punalur in Kerala and Jayapura in Karnataka showed that of the yellowing affected gardens, 50 percent were being irrigated and the rest rainfed. At Annamananda, in Kerala, 82 percent of the gardens got submerged during monsoon. The drainage provided was adequate in only 37 percent of the gardens and almost nil to inadequate in the rest (Nagaraj *et al*., 1976). Water table was invariably high within the root zone of yellowing affected palms. Incidence of yellowing at water table height of 80 cm was high at 60 percent as against 7.3 percent at water table height of 155 cm (CPCRI, 1970).

Arecanut cannot withstand drought for a long time. Once affected by water stress, it may require two-three years to regain the normal vigour and yield. The death of palms due to moisture stress is not uncommon. In west cost of India, where more than 50 percent of arecanut is cultivated, rainfall is mostly confined to

June-November months. Monsoon is followed by a prolonged dry spell normally extending from November to May. Excess evaporation, faster rate of wind speed, greater vapour pressure gradient in the above ground atmosphere and rise in temperature are regular features during summer in these regions and as a result, the crop is invariably subjected to drought conditions (Bhat and Sujatha, 2004).

The effect of water relations on yellowing has not been well understood even though anatomical studies showed that it has a profound effect on the physical environment within the sieve tubes. The leaf samples of the affected palms showed that moisture touches the lowest level in June, the month of symptom emergence, by 59 percent. The corresponding value in healthy leaves was 71 percent. Root samples of the above groups did not vary much (Yadava *et al*., 1972).

Traditionally arecanut gardens are located in valleys surrounded by hills. Most of the area expansion in arecanut has also occurred in the valleys. This is because of delicate nature of arecanut palms which cannot withstand extremes of temperature and exposure to direct sun. During monsoon, water from the hill slopes gets collected in the valley leading to water logging. Dastagir (1963) recommended prevention of water logging in the arecanut garden by deepening the existing drains or by making new drains. Menon (1960) reported that water logging is one of the predisposing factors in the spread of yellowing in arecanut. In most cases, the water table is within the root zone of palms in yellowing affected garden. Water logging leads to reduced condition during rainy season. The common notion is that water logging will result in shifting of soil pH towards neutral. But in water logged arecanut gardens, soil pH increased from 5.01 to 6.08 during first 15 days of submergence and continuous submergence upto 90 days lead to considerable decrease of pH (4.27). The exchangeable aluminium was inversely related to changes in soil pH (Mohapatra *et al*., 1976). Mathai (1986) reported that very often, soils are ill drained and affected by excessive water from adjacent hills and slopes. Water logging in arecanut gardens is a seasonal phenomenon as during monsoon, water logging occurs and lowering of water table occurs along with withdrawal of monsoon.

Irrigation as well as drainage is equally important in the case of arecanut. Wherever flood, drip or sprinkler irrigation is provided, avoid continuous wetting of the garden even during summer. There should be alternate periods of wetting and drying of the garden. Provide adequate drainage with good gradient for the entire garden. Avoid water logging during kharif season and allow the soil to dry periodically (Krishnamurthy and Vajranabhaiah, 2000). Improve drainage conditions in the garden. Avoid water stagnation in the garden by providing drainage facilities (KAU, 2002).

2.3.4 Role of pest and diseases

A series of field trials were conducted to study the role of bacteria, phytoplasma and other pathogenic fungi. Tests were also taken up to explore the possibility of involment of mites, root grubs, nematodes and other pests. The results of all these studies ruled out the possibility of any specific pathogen or pathogens and or insect pest/pests causing the problem. The experimental results demonstrated that incurable phytoplasma or viroids or any other pathogen was not the cause for yellowing. There was yellowing of leaves in mite or root grub affected palms. It was not comparable to the typical symptoms of yellow leaf syndrome (Krishnamurthy and Vajranabhaiah, 2000).

Root grubs *Leucopholis burmesteri* Brenske and *Leucopholis lepidophora* Blanch feed on young roots of arecanut palm round the year resulting in yellowing of leaves, tapering of stem and reduction in number of bunches. The palm tends to form pencil like stem below the crown with leaves turning yellow. In the Maidan tracts of Karnataka, the white grubs are reported to be serious on nursery seedlings and young palms (Rao *et al*., 1961). Root grub is a major pest of arecanut in Kerala and Western Ghat region of Karnataka (Veeresh *et al*., 1982).

The incidence of pest is more in ill drained and low lying clayey soils. Higher the water table in the garden, the grubs is seen in top layers of soil.

Sundararaju (1984) reported that three nematicides viz. fensulfothion 50g ai $palm^{-1}$, aldicarb 10g ai $palm^{-1}$, DBCP 10 ml ai $palm^{-1}$ and neem cake 1.5 kg $palm^{-1}$ were applied against *Radopholus similes* on arecanut palm affected with yellowing. The result showed a decrease in incidence of yellowing and increase in yield in all treatments compared to control.

Basal stem rot or foot rot caused by *Ganoderma lucidum* Karst is a slow disease. The visual symptom of the disease is yellowing of the outer whorl of the leaves, which gradually spreads to the inner whorl of leaves. As the disease progresses, the entire crown becomes yellow leaving only the spear leaf green. In advanced stages, spindle also gets dried up and finally crown topples down leaving the bare stem. On the crown, the predominant symptom is wilting of leaves resembling severe drought. Tapering of stem and reduction in internodal length are other symptoms exhibited on crown. The internal tissues of the stem, mainly xylem and xylem parenchyma are damaged completely. Tyloses like outgrowths are seen inside xylem vessels (CPCRI, 1973). Root system exhibit varying degrees of discolouration and rotting. Roots of affected palms are brittle, dry and have a musty smell (Naidu *et al*., 1966). The uptake of nutrients and water are interrupted due to rotting of tissues of root and stem. Basal stem rot is recorded in Karnataka (Rawther, 1982) and from Kerala, Assam and West Bengal (Sharples, 1928). The disease is severe in neglected, ill drained and over crowded gardens (Venkatarajan, 1936). Lalithakumari (1969) observed the disease incidence more in hard, black loamy acid soils of higher iron and calcium contents. Palms in the age group of 5-10 years are more susceptible to the disease (Coleman and Rao, 1918).

KAU (2002) recommends adoption of need based plant protection measures against pest and disease in yellowing affected gardens. Krishnamurthy and Vajranabhaiah, (2000) recommends the following prophylactic plant protection measures in yellowing affected gardens involving spraying of Nuvacron at 1.5 ml litre^{-1} of water, twice in a year to the leaves or in the month of April, placement of Phorate 10 G at 20 g palm^{-1}at the base of the palm to control spindle bug and root grub. Besides, spray Dicofol 2.5 ml litre^{-1}of water to control mites. If the mites and spindle bugs are not adequately controlled then repeat the Dicofol spray after 15 days. Spray one per cent Bordeaux mixture once before the monsoon and the second at 25-30 days after the first spray to control bud rot as usual for arecanut garden.

2.3.5. Role of varieties, intercrops and indigenous management practices

There was a slackening of research efforts during late sixties and early seventies. One reason is that with high prices prevailing for arecanut, the farmers might have been managing the gardens efficiently. This better management helped in remission of yellowing symptoms and increased the productivity of gardens even if they were affected by this malady. Then as the prices fell in early seventies, the farmers began to neglect the garden which contributed towards an increase in the expression of symptoms. (Nair, 1976)

The cross combination of Saigon x mangala continued to give high yield and low yellowing index at Palode. In field trial with true Mangala and Mangala segregants, none of the true Mangalas showed yellowing (CPCRI, 1993). Ravindran *et al.* (2000) reported that out of six promising cultivars evaluated in multilocational trials, all were susceptible to yellowing even though Mangala variety recorded the lowest incidence of yellowing. Detailed experiment initiated at Palode, Kerala with two varieties of arecanut to evaluate their effect on the incidence of yellowing revealed that Managala and its segregants were superior to South Kanara Local. (Chowdappa *et al*., 2002)

Field survey at Koothattukulam, Annamanada, Punalur in Kerala and Jayapura in Karnataka showed that in 90 percent of the gardens, spacing was irregular and intercrops like coconut, pepper, banana, tapioca were being grown (Nagaraj *et al*., 1976). KAU (2002) recommends growing of cover crops in the affected garden. If possible grow intercrop of cowpea or any legume or green leaf manure plants in affected gardens (Krishnamurthy and Vajranabhaiah, 2000). A number of annual crops like paddy, sorghum, cowpea, vegetables and yams are grown as intercrops of arecanut palms (Abdulkhader and Antony, 1968., Abraham, 1974., Muralidharan, 1980., Bhat, 1974., Bhat and Abdulkhader, 1970., Thomas, 1978). Kakaty *et al.* (2002) reported that multistoreyed cropping system in arecanut plantations have been found to be effective in increasing yield and gross returns.

Result of an experiment with sub plots treatments namely cowpea, NB 21 (hybrid napier) and guinea grass grown in the interspaces of arecanut and main plot treatments namely with irrigation and without irrigation showed that there was no significant difference between main treatments as well as sub plot treatments with respect to yellowing incidence and yield of arecanut palms (Rawther *et al.*, 1979). A mixed farming with grass and dairy involving regular organic recycling yielded promising result. A general increase in yield in all treatments was observed though no significant difference on yellowing intensity could be recorded (CPCRI, 1983). Mixed cropping with fodder crops especially legumes resulted in decreased yellowing of affected palms. This might be because N fixed by legumes is available to arecanut. (Ramanandan and Abraham, 2000). A mixed cropping trial involving regular organic recycling in affected garden indicated that there was an increase in yield with cowpea, NB21(hybrid napier) fodder grass and guinea grass as mixed crops in arecanut garden (Chowdappa *et al*., 2002)

Arecanut farmers have successfully developed and used a mixture of coir pith compost, poultry manure, neem cake, urea, magnesium sulphate, copper sulphate and common salt to nurse yellowing affected palms back to health (Sunilkumar, 1999). It was observed that making a hole at the base of the trunk of affected palms allowed a viscous dark liquid to come out and such palms recoup temporarily from this malady (Chowdappa *et al*., 2002).

2.3.6 Role of plant nutrients

Early observation showed that it would be difficult to cure yellowing but the life of the palm could be prolonged and chlorosis checked by application of fertilizers and micronutrients (CPCRI, 1961). Lack of balanced nutrition and improper cultivation practices made the palms susceptible to yellowing. Hence numerous field and laboratory studies related to soil and nutrient management practices and their role in control of yellowing were investigated at different locations Menon (1960, 1961) and Dastagir (1963) observed that adverse soil conditions promote yellowing since incidence of yellowing could be reduced by preventing water logging, by liming and by dressing with fertilizer containing N, P, K and Zn in addition to the normal FYM and green manuring. Since yellowing is not amenable to control by any conventional plant protection measures, it became imperative to look into other means of containing it to obtain maximum economic returns from affected gardens (Rawther *et al*., 1979; Nair, 1994).

Since the review of research on nutrient management has been so extensive and a number of aspects are covered such as nitrogen, phosphorus, potassium, micronutrients and their ratios etc in each work, the review is presented after classifying them into ten year periods from 1960 onwards to avoid duplication.

2.3.6.1 Nutrient studies on yellowing in arecanut during 1960-1969

Soils of yellowing affected regions of Kerala were highly acidic with pH as low as 3.8 and were deficient in nitrogen, phosphorus and potassium (CPCRI, 1960, 1961, 1962). Preliminary studies using micronutrients showed that after five months of foliar application, there was general decrease in yellowing in manganese sulphate and zinc sulphate treated palms. But in case of copper sulphate, the yellowing was more severe in the treated palms compared to untreated control. Further experiments carried out revealed that the number of affected leaves is numerically decreased by foliar application of manganese sulphate and magnesium sulphate. In case of manganese sulphate spraying, palms whose crowns were completely destroyed had recovered forming fresh crop of green leaves. The application of fertilizers has shown a successive increase in the non-chlorotic leaves in affected palms (Menon and Kalyanikutty, 1961).

Most of arecanut palms are grown in poor leached soils. Soils in arecanut growing tracts are deficient in nitrogen, phosphorous and potassium. pH is very acidic varying from 4.0 to 5.5. All these favour occurrence of yellowing. Symptoms of yellowing were observed in plants namely *Jatropha curcas* Linn., *Canavalia ensiformis* D.C. and *Vigna* species grown around the root systems of the affected palms. Application of green leaf 25 lbs (11 kg), ammonium sulphate 5 oz (142 g), superphosphate 0.5 lbs (227 g), muriate of potash 4 oz (113 g), ferrous sulphate 2 oz (57 g), sodium borate 0.8 oz (23 g), manganese sulphate 2.4 oz (68 g), copper sulphate 0.8 ounce (23 g), zinc sulphate 0.8 oz (23 g) and sodium molybdate 0.8 oz (23 g) to yellowing affected palm was recommended by Indian Central Arecanut Committee. By adopting this manuring practice, the yellowing is not eradicated but the yield is increased (Menon, 1962).

Analytical studies revealed a relatively lower content of nitrogen in the soil around the bases of yellowing affected palms and in leaf samples from yellowing affected palms. With regard to content of phosphorous, potassium, calcium and magnesium, the differences between the two groups of soils and leaves were not consistent. Treatments involving various combinations of organic manure, lime 1 lb (454 g), NPK (calcium ammonium nitrate 0.5 lb (227 g), super phosphate 1 lb (454 g), muriate of potash 0.5 lb (227 g)), Bordeaux mixture 1%, manganese sulphate 0.25%, ferrous sulphate 2oz (6 g), borax 0.08 oz (2 g), copper sulphate 0.08 oz (2 g), zinc sulphate 0.08 oz (2 g) and ammonium molybdate 0.08 oz (2 g) were applied to soil of yellowing affected palms. Results revealed that palms to which NPK plus lime with or without zinc sulphate had been applied, responded well to the treatments as indicated by significant reduction in yellowing of the leaves. The next best response was noticed on palms to which soil application of NPK plus lime with boron and manganese had been given. The responses to other treatments were rather poor (Dastagir, 1963).

Soil fertility survey undertaken in affected districts of Trivandrum and unaffected districts of Tamilnadu namely Kanniyakumari and Karnataka namely Kanara revealed that most of the arecanut gardens there are sandy loam in texture, acidic in reaction, low to medium in available phosphorus, potassium and well supplied with nitrogen (Muhr *et al*., 1965). Samraj and Pailey (1965) noticed that symptoms similar to those of yellowing were expressed by application of boron to soil. However, subsequent studies at Vittal showed that yellowing caused by excessive boron was different from the symptoms of yellowing in arecanut.

Yellowing affected palm tissue contained more iron and higher CaO/MgO ratio compared to healthy palms, as the magnesium content was low in affected tissue. Leaf analysis revealed that nitrogen, potassium, calcium and manganese content of healthy palms were higher than affected palms. Application of fertilizers improved the condition of affected palms (CPCRI, 1967). Velappan (1969) analyzed soils from apparently healthy and affected gardens of Thiruvananthapuram district (Kerala). The soils from affected gardens were low in pH, organic carbon, available phosphorous and magnesium. Leaf of healthy palms contained higher amounts of nitrogen, phosphorous, magnesium and zinc than those of affected palms. He also noticed that toxicity of Mn, Cu, Bo and Zn in soil did not cause yellowing in arecanut seedlings. Yadava *et al.* (1973) observed that diseased soil contained higher amount of Fe and Al.

2.3.6.2 Nutrient studies on yellowing in arecanut during 1970-1979

Zinc deficiency showed some relationship to yellowing symptoms and leaves of yellowing affected palms contained lower amount of nitrogen, phosphorus, magnesium and zinc. CPCRI (1970) reported that application of macro and micronutrients reduced the intensity of yellowing and increased the yield and vigour of palms. The high water table in the root zone of affected palms gives rise to reduced condition particularly during rainy periods (CPCRI, 1971).

Deficiency of nitrogen, phosphorus and magnesium in affected palm and presence of normal quantities of potassium and calcium in healthy palms was observed at the beginning of expression of foliar symptoms (Yadava *et al*.,1973). Pot culture studies to investigate the role of major nutrient deficiencies in the development of yellowing did not produce symptoms typical of this malady (Yadava *et al*.,1972). The yellowing affected leaf tissues contained higher amounts of nitrogen, phosphorous and potassium. Typical yellowing symptoms could not be reproduced in pot culture experiments with deficiency of nitrogen and potassium (CPCRI, 1972). Leaf tissues of healthy palms were found to contain higher levels of nitrogen, phosphorus, potassium and magnesium when compared with that of affected palms (Yadava *et al*., 1973).

Healthy palms showed lower value for phosphorus and magnesium compared to affected palms. Zinc and aluminium content of healthy and affected palms did not show any appreciable difference. Yield was greatly enhanced by NPK with irrigation. Root tissues of yellowing affected palms from Kerala and Karnataka contained more aluminium and less nitrogen, phosphorus and potassium than those of healthy palms (CPCRI, 1974). Rawther and Abraham (1972) observed that application of NPK either alone or along with micronutrients with or with out irrigation during the dry season had no effect on development of yellowing during a period of eleven years.

Irrespective of the prevalence or absence of yellowing, the soils from both healthy and affected gardens are low in available Mn (3ppm), Zn (0.5ppm), Cu (0.5ppm), and B (0.1ppm). The content of Fe (2ppm) in soil was above the level of sufficiency. But content of Al in affected soils were higher than those of healthy tracts. When seedlings were grown in soils supplied with calcium, manganese, boron and zinc, the toxicity symptoms developed did not resemble those of yellowing. Yellowing manifestation can be due to the direct and indirect effect of the anaeraobic conditions prevailing around the palms and the probable role of exchangeable aluminium either directly or indirectly. Leaf analysis of affected palms revealed presence of more than 3 ppm of aluminium, a level considered dangerous to plants. It was suggested that in addition to liming of acid soils to neutrality, some of these essential micronutrients should also be added along with NPK fertilizers to reduce the severity of yellowing (Mohapatra *et al*., 1975). Soils of the affected tracts of Kerala and Karnataka showed higher contents of exchangeable aluminium and iron, but these elements when root fed did not produce any symptoms of yellowing (Mohapatra and Bhat, 1975., Mohapatra *et al*.,1975, 1976, Mathai, 1976).

Mathai (1976) reported the probable role of nutrient imbalances like high Ca/Mg ratio, low N, P and Zn; and disturbances of Mn/Fe ratio in inducing yellowing. Generally yellowing affected gardens are acidic and deficient in calcium. Still wider CaO/MgO ratio occurs in arecanut garden, because due to heavy rains, magnesium in leaf get leached out along with rain water (Mohapatra *et al*., 1976; Iyyer and Thampan, 1999).

Application of 50, 100 and 200 ppm P_2O_5 to soil correspondingly reduced the severity of yellowing and delayed the appearance of yellowing on the leaf. Hence except phosphorus, all other elements are sufficient in affected leaf tissues. Soils of yellowing affected gardens were found deficient in almost all major and micro nutrients (Mohapatra *et al*.,1976). Deficiency of phosphorous in affected garden soils were observed through deficiency symptoms expressed on test plants as well as low phosphorous content in the leaves. Analysis of leaf samples from healthy and yellowing affected arecanut palms from Kerala and Karnataka showed that except for leaf phosphorus values, which are low in healthy and affected palms from Kerala, the content of other nutrients were above the levels of sufficiency. (CPCRI, 1976).

A comprehensive soil survey in affected areas of Kerala and Karnataka showed that soils were high in organic carbon, low to medium in available phosphorus and potassium. The contents of iron, manganese, zinc and copper in these soils were above the level of sufficiency. The increase in soil acidity and clay content significantly increased the quantity of exchangeable aluminium in Kerala state. The increased quantity of exchangeable aluminium had an adverse effect on arecanut as evidenced from sand culture experiment to investigate the role of yellowing where addition of aluminium at 5, 10 and 20 ppm reduced leaf size and growth of palms. Pot culture studies for twelve years indicated that iron, manganese, zinc, copper and molybdenum did not produce the characteristic symptoms of yellowing. It was observed that the content of silica, phosphorous and potash were high in affected samples while percentage of nitrogen and calcium were high in healthy palms (CPCRI, 1976).

Field survey at Koothattukulam, Annamanada, Punalur in Kerala and Jayapura in Karnataka showed that manuring was not being practiced in 28 percent of the gardens and only bulky organic manures were being applied in 45 percent of the gardens. In the rest, both organic and inorganic manures were being applied. Treatments involving various combinations of cattle manure 11kg, NPK (ammonium sulphate 140g, super phosphate 225g and muriate of potash 115 g or wood ash 2 kg), lime 1 kg, ferrous sulphate 57g, sodium borate 23 g, zinc sulphate 23 g, manganese sulphate 68g, magnesium sulphate 68g per palm per year was applied to gardens at Koothattukulam, Annamanada, Punalur in Kerala and Jayapura in Karnataka from 1965 to 1969. Soil fertility status of experimental plots prior to application of treatments showed that soils were acidic with pH values ranging from 3.8 to 5.4. Organic carbon content was medium to high, deficient in nitrogen, phosphorous and potassium. In general, there was 0.02-55.34% increase in yield in Karnataka in the third and fourth year (i.e. 1968 and 1969) after the commencement of the experiment compared to the initial two years. In Kerala, there was reduction in yield (0.74-4.59%) in eight out of 13 treatments and increase in yield (2.41-10.04 percent) in the remaining five treatments (involving various combinations of lime, sodium borate, zinc sulphate, manganese sulphate and magnesium sulphate). The intensity of yellowing was minimum in May (i.e. before the onset of south-west monsoon) and maximum in august (i.e. mid monsoon). In Kerala centres, the various treatments failed to produce any significant changes in yellowing between May and August while in Karnataka, the data on yellowing was inconsistent. The kernel discolouration due to treatments was not significant in any of the centres. Thus apart from increase in yield, application of macro and micro nutrients showed no tangible improvement in the general condition of palms by way of either reduction in foliage yellowing or discolouration of kernel. Manuring with NPK and application of lime to correct the acidity were thus indicated from the above study (Nagaraj *et al*., 1976).

Yields from affected gardens can be increased considerably if they are supplied with adequate dosages of manures and plant protection measures and cultural operations are properly carried out. Although leaf tissue of yellowing affected palms had higher content of nitrogen, phosphorus and potassium, typical yellowing symptoms could not be produced in pot culture experiments with deficiency of nitrogen and potassium (Nair, 1976). Zinc deficiency showed some relationship to yellowing symptoms and leaves of yellowing affected palms were low in zinc and magnesium (Velappan, 1969).

It is useful to adopt proper management practices to get additional income from affected gardens (Kotireddy, 1976). Though foliar sprays with nitrogen, phosphorous and manganese increased their contents in leaf tissues, no effect on yellowing symptoms could be recorded (CPCRI, 1979). Mohapatra *et al*. (1979) reported inherently deficient levels of nitrogen, phosphorus, potassium and calcium and increased availability of iron and aluminium in soils of yellowing affected arecanut gardens.

2.3.6.3 Nutrient studies on yellowing in arecanut during 1980-1989

Bopiah and Bhat (1981) reported proliferation of microbes in root zone of arecanut following the combined application of organic manure, fertilizer and cultivation practices. Effect of foliar application of urea, diammonium phosphate and manganese sulphate on affected palms was studied. The yellowing index indicated a general decline in the condition of the palm. However, yield did not show any definite trend. Leaf analysis showed that nitrogen content increased by seven percent in the leaves of affected palms that received urea application and the level of manganese by hundred percent, which received manganese sulphate. Consequently, Fe/Mn ratio was lowered in the treated palms. Phosphorus application had no effect on the level of phosphorus in the leaves (CPCRI, 1981).

Application of additional 1 kg superphosphate delayed symptom expression on areca seedlings. Soil application of higher doses of phosphorus over the normal package increased the yield in released varieties and soil application of magnesium was found effective in containing yellowing (CPCRI, 1982). Since deficiency of phosphorus was observed in affected gardens, additional dose of one kg super phosphate was applied to the affected palms and these palms showed delayed expression of symptoms of yellowing (CPCRI, 1983). Trials conducted in farmer's field at Sampaje in Karnataka showed that application of 140 g nitrogen as urea, 500g phosphorous as single super phosphate, 150g potassium as muriate of potash, 85 kg dolomite and 5kg neem cake palm^{-1} reduced the intensity of yellowing (Nampoothiri *et al*.,1982).

Arecanut palms in early stages of yellowing were treated with seven chemicals viz. quintozene (Brassicol 75WP), carboxin (Vitavax), carbendazim (Bavistin WP), copperoxychlorides (Cupramar and Blue Copper-50), carbofuran ('Furadan 3G) and metham sodium. These chemicals were applied as soil drench at quarterly intervals for three years. The results showed that soil application of all these chemicals had no effect on the incidence of yellowing although there was an increase in yield in the Cupramar, Blue Copper-50 and Furadan 3G treated plots. The increase in yield may be due to the efficiency of chemicals in increasing yields, if not in checking the yellowing. The application of these chemicals to soil might have reduced the root rot, which is one of the major symptoms of yellowing thereby increasing the uptake of nutrients and in turn the yield (Chandramohan, 1979; Rawther, 1982)

Extensive surveys of healthy and affected gardens of Kerala and Karnataka revealed that nutrient contents do not differ significantly between healthy and affected samples in respect of both leaf and soils. However, some differences in nutrient status have been noticed between samples of both states. The Kerala gardens are lower in fertility status than those of Karnataka. The soils of both states are high in organic matter, low to medium in available phosphorous and potassium and contained adequate levels of Fe, Mn, Zn and Cu. Karnataka soils are neutral in pH while Kerala soils are slightly acidic. The contents of N, P, K, Ca, Mg, Fe, Zn and Cu in leaf samples from Kerala have been found to be lower than in those from Karnataka. Applications of NPK fertilizers + micronutrients have not improved the condition of affected palms at Palode. A comprehensive package plan trial using all major and micronutrients carried out in farmers' gardens in Kerala and Karnataka showed no tangible improvement in the general condition of the palms by way of either reduction in foliar yellowing or in the quality of Kernel. Though the yield of the treated palms registered a decrease in majority of the treatments in Kerala, a general improvement in yield has been recorded in all the treatments in Karnataka. Affected palms given foliar application of urea, diammonium phosphate and manganese sulphate have not improved the foliar condition or yield (Rawther, 1982).

Mathai (1986) reported increased availability of Fe in affected areas. Nutritional antagonism exists between Fe-Mn and Ca-Mg. Yellowing affected palms recorded higher Fe/Mn and CaO/MgO ratio compared to healthy palms due to lower levels of Manganese and Magnesium. He explained that wider Fe/Mn ratio is mainly due to excessive water from surrounding hills bringing in iron which accumulates in the valleys where arecanut is grown. Higher iron in soil ensured translocation of more of this element to shoots in affected palms. Excess iron is known to reduce the capacity to check the mobility of manganese in plant system and this could be the reason for lower manganese content in affected arecanut palms. Potassium is also deficient in yellowing affected gardens. Potassium and calcium are known to be involved in membrane permeability of all plants and a deficiency of both increases the permeability and enhances the metabolic leakage of magnesium from plant tissue.

The field experiments involving application of nitrogen as 100 g calcium ammonium nitrate, phosphorous as 80 g super phosphate and potassium as 140 g potassium chloride, lime as 4 kg dolomite palm^{-1} year^{-1} showed that the yellowing did not spread to the healthy arecanut seedlings. The contents of available N, P and K were optimum in soils from all the treatments. It was observed that foliar sprays of urea, diammonium phosphate and manganese sulphate did not show any improvements in the condition of the affected palms, but the palms which received manganese sulphate and diammonium phosphate showed some improvement in yield. Application of 57 g ferrous sulphate, 23 g sodium borate and 1.36g molybdenum trioxide and lime as dolomite 4kg palm^{-1} year^{-1} showed that the yellowing did not spread to the healthy arecanut seedlings. But the growth of many seedlings were stunted irrespective of the treatments (Gurumurthy, 1989).

2.3.6.4 Nutrient studies on yellowing in arecanut during the 1990-1999

Though application of magnesium yielded only negative results (CPCRI, 1974, 1981) the present management trials showed the beneficial effect of magnesium in containing yellowing. Plants which received NPK + Dolomite + Neem cake showed reduction in yellowing intensity. Addition of 120 g P_2O_5 over normal package of practices gave maximum yield in the management trial; however palms which received higher dose of potassium and magnesium recorded minimum yellowing intensity (CPCRI, 1990).

The incidence of yellowing was also low in treatments which received the application of high dose of phosphorus (Abraham *et al*.,1991). An experiment was laid out with normal package of practices, normal package+12kg cattle manure, normal package+120g P, Normal package+120g P+12 kg cattle manure. It was observed that incidence of yellowing was low in treatments which received the application of high dose of phosphorous. However the yield data did not show any significant difference between treatments. Calcium and magnesium status of soils of affected palms were considerably low as compared to healthy palms. Application of higher dose of magnesium showed no further improvement on the condition of palms at Karnataka (CPCRI, 1991; Abraham *et al*., 1991)

Yellowing affected palms were subjected to management practices namely 250 g $MgSO_4$, 250 g K_2O, 250 g $MgSO_4$ + 250 g K_2O, 500 g $MgSO_4$, 500 g K_2O, 500g $MgSO_4$ + 500g K_2O and a control. Pre and post treatment indexing of palms for yellowing revealed that there was no significant difference among treatments (CPCRI, 1993). Nair (1994) reported that one percent manganese sulphate foliar spray reduced the chlorosis of affected palms. Soils of yellowing affected gardens were acidic with low levels of soluble salts and boron, low to medium level of available phosphorus, potassium and sulphur where as organic carbon, calcium and magnesium were seen in adequate quantities (Guruswamy and Krishnamurthy 1994).

A comparison of plant nutrients of coconut and arecanut plantations in clay loam and sandy loam soils revealed that organic carbon and nitrogen were slightly higher in coconut plantations than arecanut plantations whereas phosphorous content were slightly lower in coconut plantations than arecanut plantations. In arecanut plantations, there is statistically significant difference in the levels of plant nutrients between different months with the size of microbial carbon, nitrogen and phosphorous being maximum during December and minimum during April-June The management practices of arecanut plantations in which fertilizers are used optimally (100:40:140 g $palm^{-1}$) and organic residue recycled with little disturbance in soil, the microbial biomass load was found to be higher which is a good indicator of available nutrients (Kumar *et al*., 1998)

Sulladmath *et al*., (1998) tried application of 500 g linseed cake + 500 g neem cake + 500 g lime + 1 litre cow urine to yellowing affected palms and concluded that none of them was useful in reducing yellowing in arecanut. They also concluded that the yellowing is not seed borne. Yellowing plants replanted on fresh soil with regular manuring and watering did not further develop the symptoms on new leaves.

2.3.6.5 Nutrient studies on yellowing in arecanut during 2000-2007

Kumaraswamy (2000) reported that soils of yellowing affected gardens recorded 21-80 ppm of exchangeable copper in soil as against a toxic level of 5-15 ppm. Excessive use, wrong method of preparation and application of Bordeaux mixture by farmers resulted in toxic levels of copper (21-80 ppm) in soil leading to accumulation of 40 ppm of copper in arecanut palm causing yellowing. The low content of magnesium in leaves of affected palms is attributed to high CaO/MgO ratio. As the magnesium is key component of chlorophyll, application of magnesium to the basins of palms has been suggested (Chowdappa *et al*., 2000). Toxicity of iron, aluminium, and manganese along with the deficiencies of phosphorus, magnesium and zinc, both individually and in various combinations, created in pots lead to the appearance of typical symptoms of yellowing in plants. Further application of iron and manganese at toxic doses either alone or together to the healthy palms in the field, also caused the appearance of yellow leaf symptoms. These studies showed that the problem is due to nutritional disorder (Krishnamurthy and Vajranabhaiah, 2000).

Soils of yellowing affected areas in both Kerala and Karnataka had lower pH, phosphorus and calcium compared to soils where palms were healthy. In Kerala, affected soils had lower magnesium, manganese and zinc while in Karnataka, affected soils had lower iron and copper. Tissues of yellowing affected palms had lower nitrogen, calcium, manganese, zinc and copper compared to healthy palms in both Kerala and Karnataka. In Kerala affected palms had lower potassium whereas in Karnataka, affected palms had lower phosphorus and aluminium. Incidence of yellowing was least in palms treated with higher dose of P, over and above the normal package resulting in enhanced yield (Ramanandan and Abraham, 2000).

The affected palms showed high leaf sap acidity (pH) of 3.29 as compared to 4.63 of healthy ones. Pot culture studies indicated that copper, molybdenum, zinc, manganese and iron did not produce the characteristic symptoms of yellowing. The content of silica, phosphorous and potash were high in affected samples while percentage of nitrogen, CaO were high in healthy palms. Affected palms contained higher CaO/MgO ratio and less nitrogen, potassium, calcium and manganese contents than healthy palm tissue. Root tissues were found to contain more aluminium and less nitrogen, phosphorus and potassium. As the magnesium is the key component of chlorophyll, application of magnesium to the basins of palms has been suggested. From field trials, it is apparent that soil and nutrient management had improved the condition of affected palms and increased yield to some extent or maintained the yield level. Thus it is essential to follow management recommendations in order to reduce the incidence of yellowing and to realize maximum economic returns from yellowing affected gardens (Chowdappa *et al*., 2002).

Field study conducted at Sullia, Karnataka indicated that addition of NPK fertilizers alone and in combination with dolomite did not help in ameliorating the yellowing. In a comprehensive package trail in farmers field at Sampaje in Karnataka, application of NPK+lime+boron and NPK+lime+zinc increased the yield by 20 percent and addition of NPK+dolomite+neem cake reduced the intensity of yellowing. There was better response to soil application of nitrogen, phosphorous and potassium together with lime, boron and manganese Addition of dolomite 4 and 8 kg palm^{-1}year^{-1} had no significant effect on the condition of yellowing of the palm. Application of higher dose of phosphorus 160g, dolomite 4 kg and farm yard manure 12 kg palm^{-1}year^{-1}with irrigation had no apparent effect on incidence of yellowing and yield of palms. However in another trial at Palode, lime and phosphate application resulted in lowest incidence of yellowing 13 percent compared to lime 33 percent and superphosphate alone 15 percent (Chowdappa *et al*., 2002)

In acidic soils, broadcast of lime at the rate of 500 g per palm once in two or three years and incorporation into soil by forking during March-April is recommended (KAU, 2002). Application of dolomite or lime at 85 g palm^{-1}and working it into the soil at the base of the palm during kharif is advisable (Krishnamurthy and Vajranabhaiah, 2000).

KAU (2002) recommends application of organic manure at the rate of 12kg each of compost and green leaves per palm per year. Apply the recommended dose of fertilizers namely N: P_2O_5: K_2O for adult palms @ 100:40:140 g palm^{-1} year^{-1}. In addition, apply 160 g of rock phosphate per palm in the affected garden. In addition to the above package of practices, Krishnamurthy and Vajranabhaiah (2000) recommend application of zinc oxide at 3.3 g or zinc sulphate at 8.5 g palm^{-1}, plus neem cake at 5kg palm^{-1} during kharif. For yellowing affected palms, Central Plantation Crops Research Institute recommends the same nutrient management strategy of Kerala Agricultural University. But instead of 160g rock phosphate palm^{-1}, application of 800 g rock phosphate palm^{-1} is recommended by Central Plantation Crops Research Institute (Nampoothiri *et al.,* 2000).

2.3.7 Summary of causes and management of yellowing

Entire garden must be scientifically cultivated and managed. The traditional low standard of cultivation definitely causes yellowing to increase further and aggravates the situation. When package of practices involving recommended manurial, cultural and plant protection measures were implemented in selected gardens continuously for a period of 2-3 years, it was found that yellowing affected palms recovered completely. This lead to the conclusion that yellowing is mainly due to nutritional disorders caused by inadequate management of arecanut gardens (Krishnamurthy and Vajranabhaiah, 2000).

Remove the severely affected palms and take up replanting (Krishnamurthy and Vajranabhaiah 2000). When only a few palms are affected in a garden remove them to prevent further spread of yellowing (KAU, 2002). The results of the nutrient management trials indicate that though yellowing cannot be completely eradicated, the general health of the affected palm and the economic yield could be improved.

MATERIALS

AND METHODS

3. MATERIALS AND METHODS

The research project on nutritional management of yellowing in arecanut was carried out from October 2003 to September 2006 to characterise the nature and intensity of yellowing in arecanut as well as the associated predisposing nutritional factors and to develop a management strategy to contain the yellowing in different toposequences. The details of materials used and methods adopted for the conduct of the three experiments are detailed below.

3.1 EXPERIMENT I. DEVELOPMENT OF A SCORING SYSTEM TO ASSESS THE INTENSITY OF YELLOWING

The objective of the experiment was to study the visual characteristics of yellowing affected arecanut palms to fix up indices for a scoring system to assess the intensity of yellowing. The extent of yellowing (Y), necrosis (N) and crown size reduction (R) were considered to quantify the intensity of yellowing. Observations on Y and N were taken from half the number of total leaves in crown (L). Since the symptoms generally appear on the lower leaves, observations were taken from these leaves. A total of three hundred palms, hundred palms each in toposequences viz. converted paddy field, garden land and terraced upland of Thrissur, Palakkad and Malappuram districts were carefully observed to fix grade points for yellowing, necrosis and crown size reduction. In this regard, a transit survey was undertaken to study arecanut palms grown at Vadakkenchery, Palakkad district representing converted paddy field; Edavanna, Malappuram district representing garden land and Assarikkad, Thrissur district representing terraced upland toposequences. Appropriate score values were allotted for Y, N and R and a yellowing index (I) was developed to classify the palms into healthy, mildly affected, moderately affected and severely affected which were tested on experimental palms in the Experiment III.

3.2 EXPERIMENT II. COMPARISON OF INCIDENCE OF YELLOWING AMONG CONVERTED PADDY FIELDS, GARDEN LANDS AND TERRACED UPLANDS

The scoring technique developed in the first experiment was utilized to compare the intensity and spread of arecanut yellowing in three toposequences, viz. converted paddy fields, garden lands and terraced uplands of selected fields in three districts of Central Kerala, i.e., Malappuram, Palakkad and Thrissur. Fields belonging to the three toposequences where serious incidence of yellowing was observed were identified in consultation with officers of the Agricultural Department. The varietal differences in the incidence of yellowing were recorded.

3.3 EXPERIMENT III. DEVELOPMENT OF A MANAGEMENT STRATEGY TO CONTAIN YELLOWING OF ARECANUT UNDER VARIOUS TOPOSEQUENCES.

With the objective to study the impact of nutrient management practices on soil productivity, crop growth and incidence of yellowing and to develop a management strategy to contain the malady under various toposequences, field experiments were laid out in three toposequences viz. converted paddy field, garden land and terraced upland respectively in the existing sixteen year old arecanut gardens of Mr. Ramachandran, Kunduvara House, Chuvannamannu P. O. Thrissur, Mr. K. C. Thomas, Kaimala House, Mandanchira, Kannara P. O. Thrissur and K. Usha, Thennamuchi, Karipakunnu House, Kuttala, Pattikad P.O. Thrissur in RBD using single plant plot with five replications. The details of the treatments are presented in the Table 3.1. The palms which were having a scoring index ranging from 40-55 were selected for the experiment (Figures 1a, 1b and 1c).

The treatment components such as sand, lime, farm yard manure and bone meal were applied basally during February in one split and the fertilizers were applied in two

Table 3.1 Treatments applied to yellowing affected arecanut palms in three experimental sites

	Converted paddy field	**Garden land**	**Terraced upland**
T_1	Farmers' practice (FP) – [10 kg Organic manure (OM) + 100 g Lime (L) palm^{-1}]	Farmers' practice (FP) – [5 kg Organic manure (OM) + 100 g Lime (L) + 100g Bone meal palm^{-1}]	Farmers' practice (FP) – [10 kg Organic manure (OM) + 100 g Lime (L) palm^{-1}]
T_2	Package of practices (POP) –[Deep drainage below the root zone (DD) + 12 kg OM + 500g L (once in 3 years) + 100:40:140 g NPK palm^{-1}]	Package of practices (POP) – [12 kg OM + 500g L (once in 3 years) + 100:40:140 g NPK palm^{-1}]	Package of practices (POP) – [12 kg OM + 500g L (once in 3 years) + 100:40:140 g NPK palm^{-1}]
T_3	FP + DD	FP + 5 kg organic manure palm^{-1} (OM) palm^{-1}	FP + 5 kg organic manure palm^{-1} (OM) palm^{-1}
T_4	FP + DD + 50g L + 10 kg Sand (S) + 100:40:140 g NPK palm^{-1}, N as Ammonium sulphate (A/S)	FP + 5 kg OM + 200 g Sodium silicate (SS) + 50g L + 100:40:140 g NPK palm^{-1}, N as Ammonium sulphate (A/S)	FP + 5 kg OM + 200 g Sodium silicate (SS) + 50g L + 100:40:140 g NPK palm^{-1}, N as Ammonium sulphate (A/S)
T_5	FP + DD + 50g L + 10 kg S + 100:40:140 g NPK palm^{-1}, N as Urea (U)	FP + 5 kg OM + 200 g SS + 50g L + 100:40:140 g NPK palm^{-1}, N as Urea (U)	FP + 5 kg OM + 200 g SS + 50g L + 100:40:140 g NPK palm^{-1}, N as Urea (U)
T_6	FP + DD + 50g L + 200 g Sodium silicate (SS) + 100:40:140 g NPK palm^{-1}, N as A/S	FP + 5 kg OM + 200 g SS + 50g L + 100:40:200 g NPK palm^{-1}, N as A/S	FP + 5 kg OM + 200 g SS + 50g L + 100:40:200 g NPK palm^{-1}, N as A/S
T_7	FP + DD + 50g L + 10 kg S + 200 g SS + 100:40:140 g NPK palm^{-1}, N as A/S	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S
T_8	FP + DD + 50g L + 10 kg S + 200 g SS + 100:40:200 g NPK palm^{-1}, N as A/S	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S + 60g Magnesium sulphate	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S + 60g Magnesium sulphate
T_9	FP + DD + 50g L + 10 kg S + 200 g SS + 100:40:200 g NPK palm^{-1}, N as A/S + 60g Magnesium sulphate	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S + 20g Zinc sulphate	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S + 20g Zinc sulphate
T_{10}	FP + DD + 50g L + 10 kg S + 200 g SS + 100:40:200 g NPK palm^{-1}, N as A/S + 20g Zinc sulphate	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S + 20g Borax	FP + 5 kg OM + 200 g SS +50g L + 100:40:250 g NPK palm^{-1}, N as A/S + 20g Borax
T_{11}	FP + DD + 50g L + 10 kg S + 200 g SS + 100:40:200 g NPK palm^{-1}, N as A/S + 20g Borax	FP + 5 kg OM + 200 g SS + 50g L + 100:40:200 g NPK palm^{-1}, N as U	FP + 5 kg OM + 200 g SS + 50g L + 100:40:200 g NPK palm^{-1}, N as U
T_{12}	FP + DD + 50g L + 10 kg S + 200 g SS + 100:40:200 g NPK palm^{-1}, N as U	FP + 5 kg OM + 200 g SS + 150g L + 100:40:250 g NPK palm^{-1}, N as U	FP + 5 kg OM + 200 g SS + 150g L + 100:40:250 g NPK palm^{-1}, N as U

Fig 1a. Layout of experiment in converted paddy field

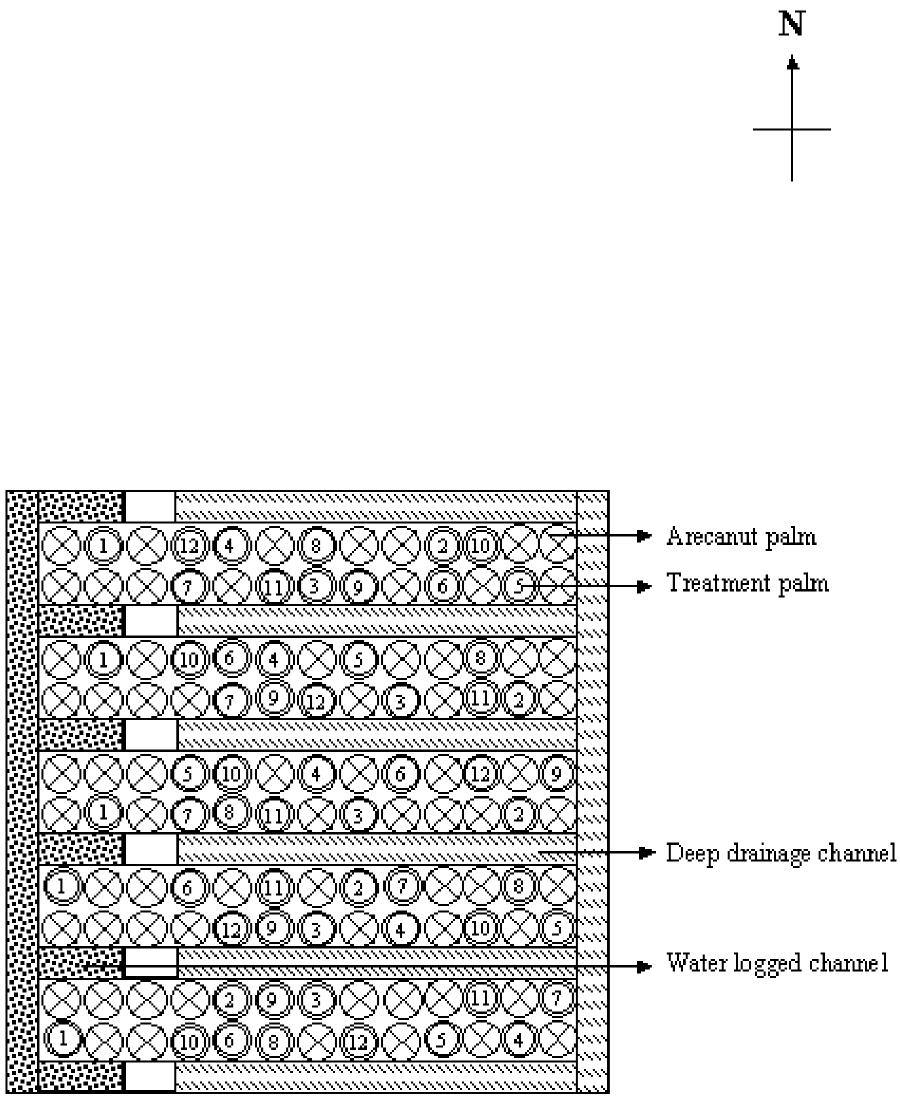


Fig 1b. Layout of experiment in garden land

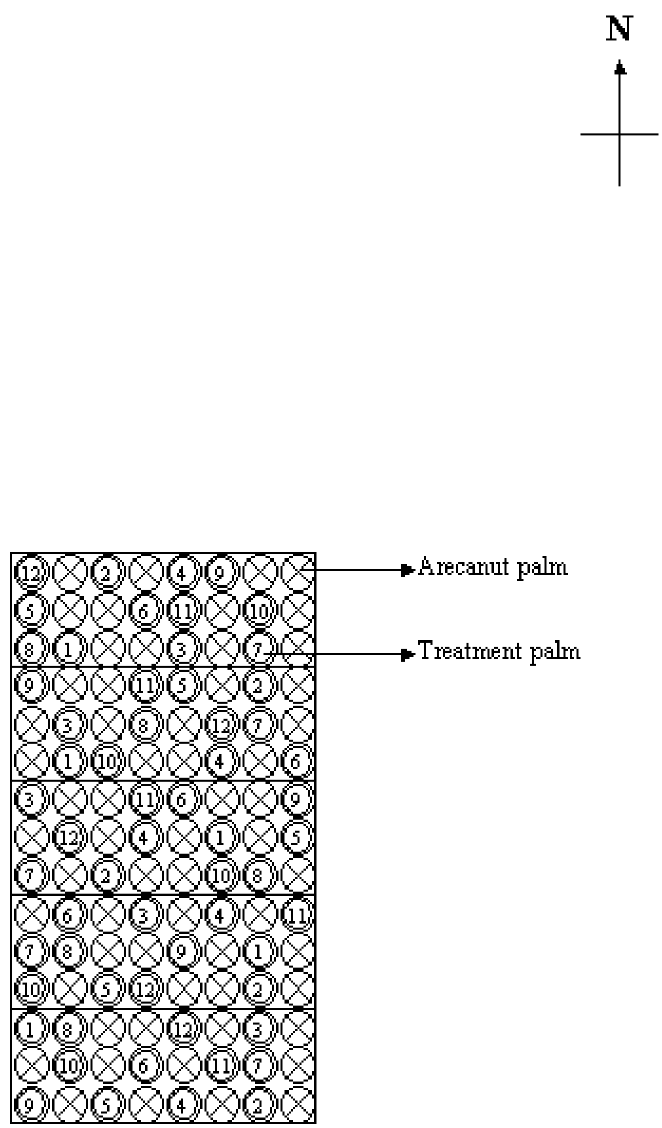
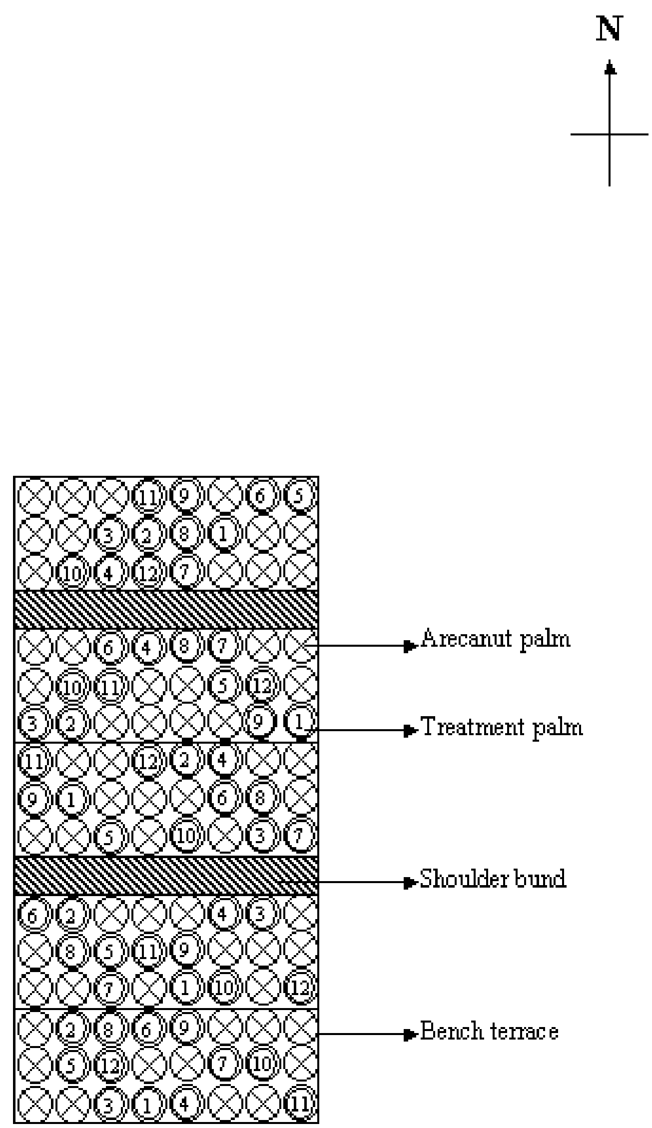


Fig 1c. Layout of experiment in terraced upland



equal splits during September every year after the intercultivation operation and opening of basins. The garden was kept free of weeds and surface crust was broken up by digging after cessation of monsoon during October-November. During summer months, the palms were irrigated once in 3-5 days. Drainage channels were constructed at 1 m depths below the root zone, between the rows to drain out water during periods of heavy rainfall and prevent water logging in arecanut grown in converted paddy fields.

3.3.1 Climate

The area experiences a humid tropical climate. The monthly averages of important meteorological parameters observed during the experimental period were collected from the observatory attached to the College of Horticulture and the data are presented in Appendix I and illustrated graphically in Figures 2a, 2b and 2c.

3.3.2 Soil

The physico chemical characteristics of the soil in the three experimental sites are presented in Table 3.2

3.3.3 Cropping history of the Field

The experimental fields were arecanut gardens lying neglected for the past two years prior to the layout of the experiment.

3.3.4 Crop Variety

All the three experimental sites were planted with local variety of arecanut.

Fig 2a. Weather parameters during the cropping period (October 2003 to September 2006)

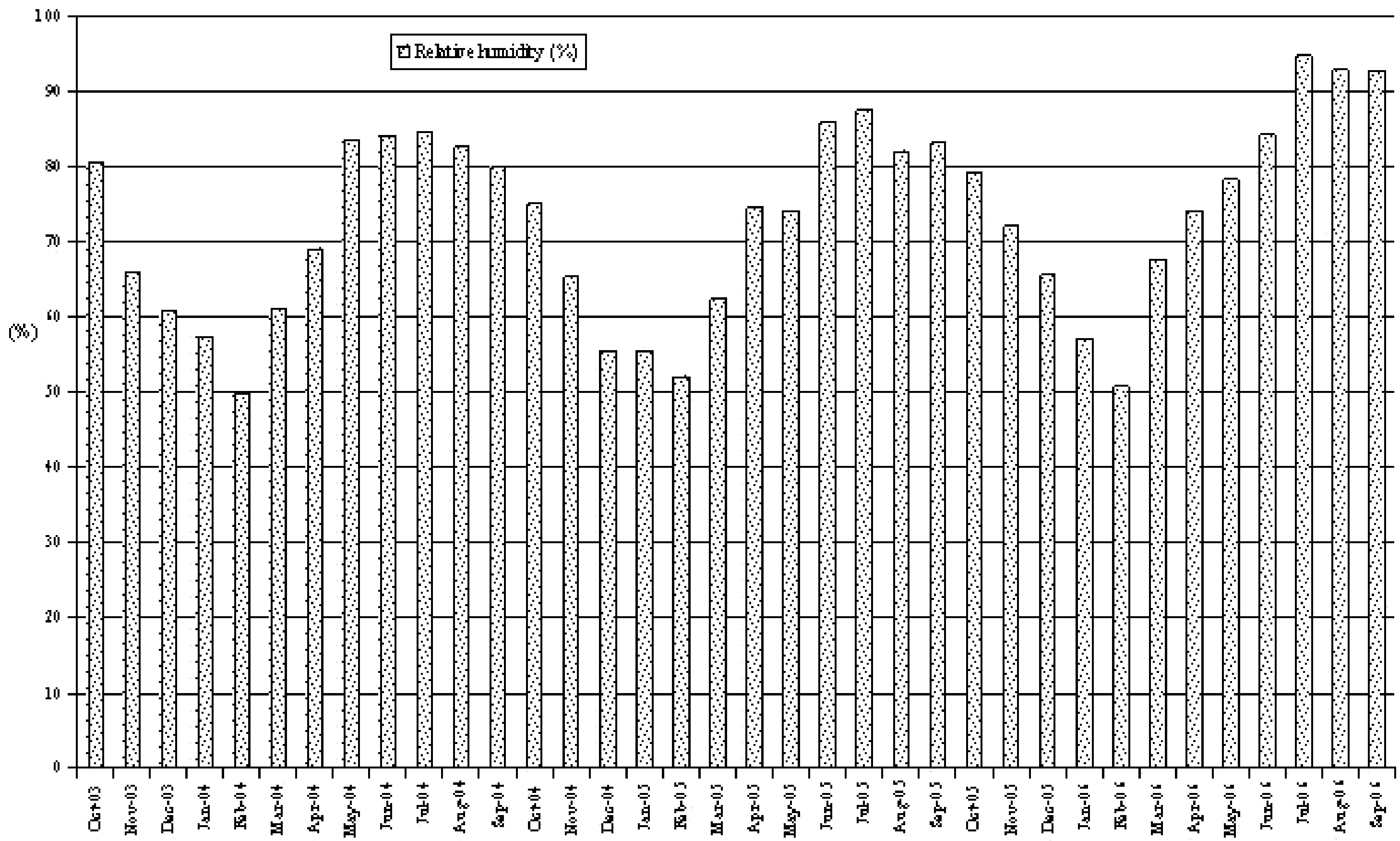


Fig 2b. Weather parameters during the cropping period (October 2003 to September 2006)

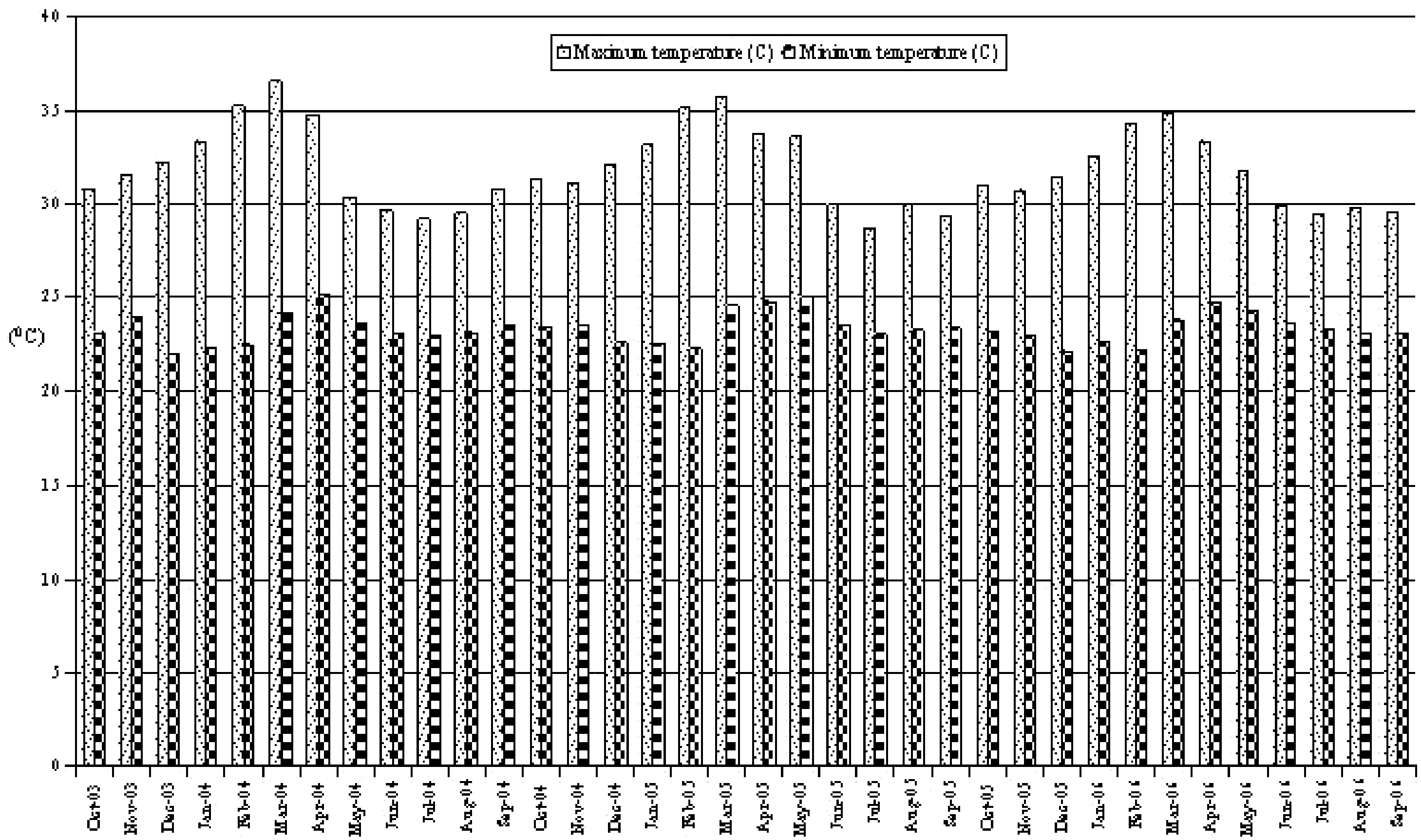
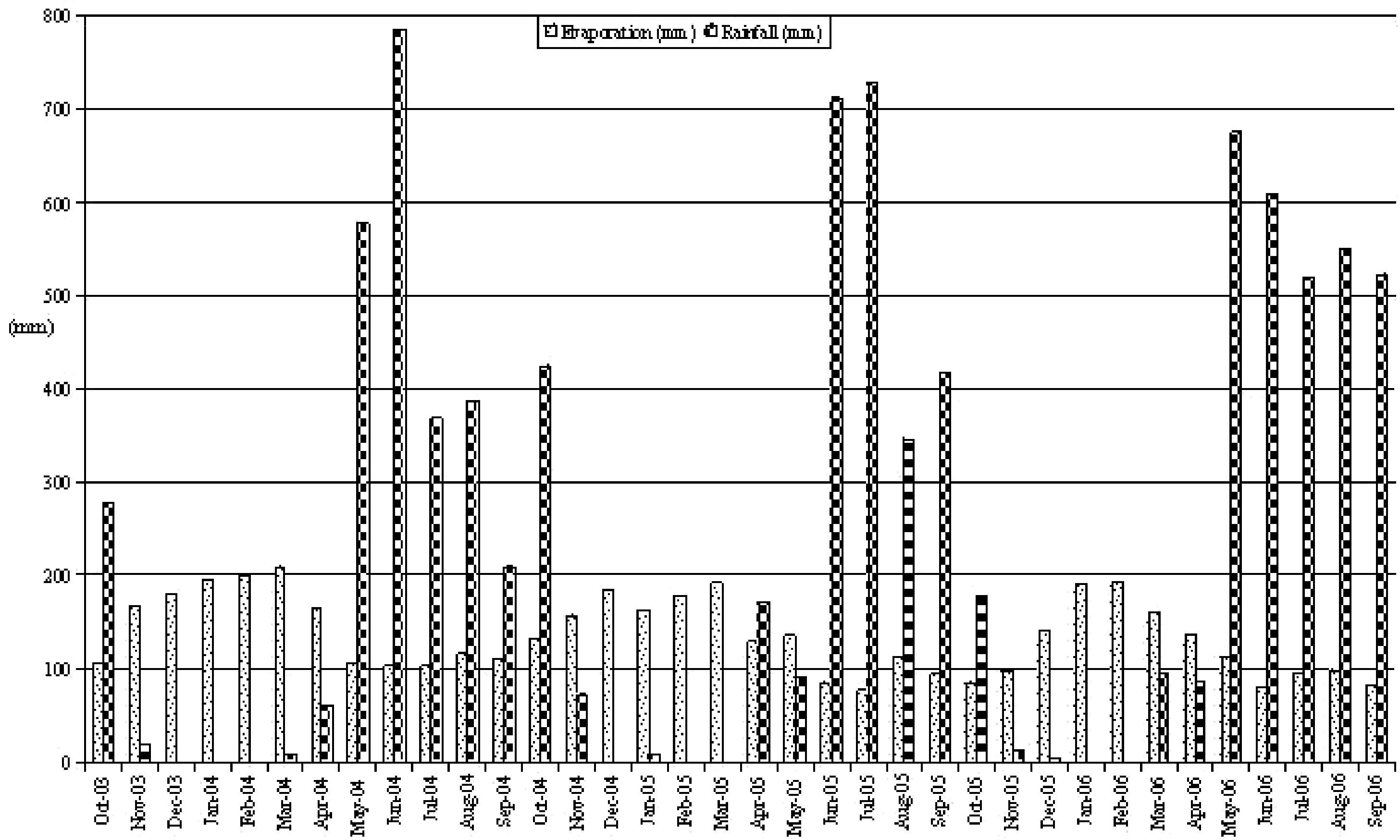


Fig 2c. Weather parameters during the cropping period (October 2003 to September 2006)



3.3.5 Manures and Fertilizers

Farmyard manure with an analytical value of 0.85, 0.25, 0.65 percent N, P_2O_5, K_2O respectively was used for the experiment. Urea (46 percent N), diammonium phosphate (46 percent P_2O_5, 18 percent N), ammonium sulphate (20.6 percent N, 24 percent S), muriate of postash (60 percent K_2O), sodium silicate (23 percent Si), magnesium sulphate (20 percent Mg), zinc sulphate (20 percent Zn), borax (11 percent B) and lime (54 percent Ca) were used as sources of plant nutrient.

3.3.6 Observations

A. Soil analysis

Soil samples were taken from top 0 to 25 cm and 25 to 50 cm depth. Soil samples collected before the start of the experiment were analysed for physical composition, organic carbon and pH. Available N, P_2O_5 K_2O, S, Fe, Mn, Zn, Cu, B, Al, total Si, exchangeable Ca and Mg, were also determined (Tables 3.2 and 3.3). During the period of experiment soil samples were taken twice every year. The first sampling was done during February and the second sampling during September before the application of fertilizer to the crop.

B. Plant analysis

Fourth fully opened leaf from the bottom of crown considered as index leaf was collected along with kernel and husk from each palm before the application of fertilizers twice a year during February and September and used for analysis of plant nutrients. The plant samples collected were dried to constant weight in an electric hot air oven at 80 ± 5^0C, ground into fine powder and used for chemical analysis to estimate the content of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Si and Al. Chlorophyll-a, chlorophyll-b, total chlorophyll content and leaf sap pH of index leaf were also analysed (Table 3.4).

Table 3.2 Soil characteristics of the experimental sites

A. Mechanical composition

Soil fractions (%)		Toposequence: Converted paddy field	Garden land	Terraced upland
1.	Sand	73.58	73.89	73.11
2.	Silt	09.14	06.16	07.59
3.	Clay	17.28	19.95	19.30
Soil Texture		Sandy loam	Sandy loam	Sandy loam

B. Chemical properties

		Converted paddy field Top*	Converted paddy field Bottom#	Garden land Top*	Garden land Bottom#	Terraced upland Top*	Terraced upland Bottom#
1.	Soil reaction, pH	4.10	4.68	5.30	5.15	5.76	5.19
2.	Organic carbon (%)	0.81	0.76	0.73	0.57	0.82	0.33
3.	Available N (kg ha^{-1})	223.92	179.00	210.25	160.67	293.67	221.67
4.	Available P_2O_5 (kg ha^{-1})	32.92	19.58	41.50	25.92	40.25	26.58
5.	Available K_2O (kg ha^{-1})	188.25	152.58	258.67	306.83	316.75	264.33
6.	Available Ca (kg ha^{-1})	709.08	811.58	1423.83	1212.75	949.67	825.08
7.	Available Mg (kg ha^{-1})	163.50	171.75	175.58	242.00	295.67	242.25
8.	Available S (kg ha^{-1})	17.50	24.42	13.00	9.67	11.58	7.33
9.	Available Fe (kg ha^{-1})	184.75	158.67	112.58	109.17	88.17	87.42
10.	Available Mn (kg ha^{-1})	61.50	76.50	65.00	78.00	39.00	21.75
11.	Available Zn (kg ha^{-1})	25.82	16.20	25.21	14.99	25.90	15.56
12.	Available Cu (kg ha^{-1})	19.03	19.62	16.28	18.86	19.18	18.02
13.	Available B (kg ha^{-1})	9.68	7.97	8.51	8.88	8.96	8.89
14.	Total Si (t ha^{-1})	392.75	371.08	347.92	346.92	317.83	314.33
15.	Available Al (kg ha^{-1})	99.75	90.17	90.58	91.50	91.92	90.67

*Top = 0 to 25 cm soil, # Bottom = 25 to 50 cm soil

Table 3.3 Method used for analysis of soil samples

A. Physical analysis of soil

Characters	Method	Reference
1. Mechanical composition	International Pipette method	(Piper, 1966)

B. Chemical analysis of soil

Characters	Method	Reference
1. pH	1 : 2. 5 soil solution ratio using pH meter with glass electrode	(Jackson, 1973)
2. Organic carbon	Walkley and Black rapid titration method	(Jackson, 1973)
3. Available N	Alkaline Permanganate Method	(Subbiah and Asija, 1956)
4. Available P_2O_5	Bray's Molybdenum blue colour Method	(Jackson, 1973)
5. Available K_2O	Ammonium Acetate extract method using flame photometer	(Jackson, 1973)
6. Exchangeable Ca, Mg	Ammonium acetate extract titration with EDTA	(Jackson, 1973)
7. Available S	Turbidimetric method	(Hesse, 1971)
8. Available Fe, Mn, Zn, Cu	DTPA extract method using Atomic Absorption Spectrophotometer	(Lindsay and Norvell, 1978)
9. Available B	Hot water soluble boron method using Azomethine-H	Wolf, 1974
10. Total Si	Blue Ammonium Molybdate colorimetric method with Sodium Hydroxide fusion	Kolthoff and Sandell, 1952
11. Available Al	Barium Chloride extract method using colorimeter (Aluminon method)	Jayman and Sivasubramaniam, 1974

Table 3.4 Method used for analysis of plant samples

Chemical analysis of plant

Characters	Method	Reference
1. Leaf sap pH	1: 2.5 leaf sample: water suspension using pH meter with glass electrode	(Jackson, 1973)
2. Chlorophyll	DMSO extract method	(Shoaf and Livm, 1976)
3. N	Microkjeldhal method	(Jackson, 1973)
4. P	Vanado-molybdo phosphoric yellow colour method	(Jackson, 1973)
5. K	Diacid extract method using flame photometer	(Jackson, 1973)
6. Ca, Mg	Diacid extract method using atomic absorption spectrophotometer	(Jackson, 1973)
7. S	Turbidimetric method	(Hart, 1961)
8. Fe, Mn, Zn, Cu	Diacid method using Atomic Absorption spectrophotometer	(Lindsay and Norvell, 1978)
9. B	Colorimetric method with Azomethine-H using diacid digest	Wolf, 1974
10. Si	Microdetermination method	Nayar *et al.*, 1975
11. Al	Aluminon colorimetric method	Jayman and Sivasubramaniam, 1974

C. Root damage

Roots of twenty five palms each in the three toposequences were sampled and examined for incidence of root rotting and root xylem blockage. For detection of root xylem blockage, transverse thin sections of sampled roots were stained in safranine for 10 minutes, washed 2 to 3 times with distilled water, mounted in a drop of 1percent glycerine and examined under light microscope.

D. Pests and disease studies

The important associated pests and diseases were studied. The incidence of phytoplasma as a causal agent was also investigated. For phytoplasma studies, roots of twenty five palms each in the three toposequences namely converted paddy field, garden land and terraced upland were sampled and examined for presence of phytoplasma in the root phloem. For detection of phytoplasma using Dienes' stain, transverse thin sections of sampled roots were stained with 0.2percent Dienes' stain (prepared by dissolving 2.5 g of methylene blue, 1.25 g azure II, 10 g of maltose and 0.25 g of sodium carbonate in 100 ml of distilled water) for 10 min, washed 2 to 3 times with distilled water, mounted in a drop of 1percent glycerine and examined under a light microscope (Deeley *et al*., 1979).

E. Yield and nut characters

Apart from scoring arecanut palms for yellowing using yellowing index, nuts from freshly harvested bunches were sampled before the application of fertilizers and morphological characters namely length, breadth and weight of fresh nuts; length, breadth and weight of fresh kernel; thickness and weight of fresh husk; length, breadth and weight of dry nuts; length, breadth and weight of dry kernel; and weight of dry husk and number of fresh fruits palm^{-1}. *Chali* yield palm^{-1} and recovery percentage were computed as follows:

$$\textit{Chali}\text{ yield palm}^{-1}\text{(kg)} = \frac{\text{Dry kernel weight (g) x No. of fruits palm}^{-1}}{1000}$$

$$\text{Recovery (\%)} = \frac{\text{Dry kernel weight (g) x 100}}{\text{Fresh nut weight (g)}}$$

3.4 STATISTICAL ANALYSIS

The data generated were subjected to analysis of variance (ANOVA) as applied to randomised block design (Panse and Sukhatme, 1985). Important correlation coefficients were estimated and tested for their significance (Snedecor and Cochran, 1967).

RESULTS

4. RESULTS

4.1 EXPERIMENT I. DEVELOPMENT OF A SCORING SYSTEM TO ASSESS THE INTENSITY OF YELLOWING

Experiment was undertaken during February 2004 to fix up indices for a scoring system to assess the intensity of yellowing in arecanut. Arecanut palms in farmers' field under three diverse toposequences viz. converted paddy field, garden land and terraced upland were studied for the experiment.

4.1.1 Allotment of score values

Yellowing index (I) was developed taking into consideration the intensity of yellowing and necrosis observed in the lower half number of leaves in the crown and reduction in crown size. Allotment of score values was as listed below.

A. Score for Yellowing (Y)

0.0 - Healthy
0.5 - Tip yellowing upto 25% leaflets
1.0 - Tip yellowing from 25% to 50% leaflets
1.5 - Tip yellowing from 50% to 75% leaflets
2.0 - Tip yellowing from 75% to 100% leaflets
2.5 - Marginal yellowing upto 25% leaflets
3.0 - Marginal yellowing from 25% to 50% leaflets
3.5 - Marginal yellowing from 50% to 75% leaflets
4.0 - Marginal yellowing from 75% to 100% leaflets
4.5 - Complete yellowing upto 25% leaflets

5.0 - Complete yellowing from 25% to 50% leaflets

5.5 - Complete yellowing from 50% to 75% leaflets

6.0 - Complete yellowing from 75% to 100% leaflets

B. Score for necrosis (N)

0.0 - Healthy

0.5 - Necrosis upto 25% leaflets

1.0 - Necrosis from 25% to 50% leaflets

1.5 - Necrosis from 50% to 75% leaflets

2.0 - Necrosis from 75% to 100% leaflets

C. Score for Crown size (R)

0.0 - Normal

0.5 - Reduced young leaf size

1.0 - Stem tapering

1.5 - Reduced young leaf size and stem tapering

2.0 - Whole crown size drastically reduced (stunted growth)

$$\text{Yellowing index (I)} = \{(Y+N)/L + R\} \times 10$$

	If value of I *is,*
0	– Healthy
< 20	– Mildly affected
20 - 50	– Moderately affected
> 50	– Severely affected

Y- Total score for yellowing for lower one-half of leaves in crown

N- Total score for necrosis for lower one-half of leaves in crown

R- Score for reduction in crown size

L- Half the number of leaves in crown

4.1.2 Testing of the yellowing index

The reliability of the yellowing index was tested by studying the correlation between the yellowing index and yield, elemental composition and chlorophyll content of leaf during pre-treatment (February 2004) and post-treatment (September 2006) periods in all the three toposequences viz, converted paddy field, garden land and terraced upland (Table 4.1).

4.1.2.1 Converted paddy field

N, P, K, Ca, Mg, S, B, Si, chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight, number of fruits and *chali* yield showed significant negative correlation with yellowing index during post-treatment period.

N, P, K, Ca, Mg, S, B, Si, chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight and number of fruits showed significant positive correlation with *chali* yield during post-treatment period.

4.1.2.2 Garden land

N, P, K, Ca, Mg, S, B, Si, chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight, number of fruits and *chali* yield showed significant negative

Table 4.1 Coefficients of correlation of leaf nutrient composition with yellowing index and *chali* yield of arecanut during pre-treatment (February 2004) and post-treatment (September 2006) periods

	Converted paddy field				Garden land				Terraced upland			
	Yellowing index		*Chali* yield		Yellowing index		*Chali* yield		Yellowing index		*Chali* yield	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Nitrogen	-0.197	-0.893**	0.190	0.960**	-0.055	-0.913**	0.133	0.922**	-0.231	-0.831**	0.182	0.920**
Phosphorus	-0.265	-0.838**	0.205	0.912**	-0.156	-0.871**	0.579**	0.892**	0.436*	-0.877**	0.284	0.952**
Potassium	-0.161	-0.911**	0.248	0.946**	0.365*	-0.796**	0.407*	0.872**	-0.213	-0.820**	0.163	0.902**
Calcium	-0.260	-0.748**	0.259	0.754**	-0.161	-0.916**	-0.588**	0.926**	0.415*	-0.840**	0.265	0.910**
Magnesium	-0.195	-0.842**	0.222	0.838**	0.346*	-0.537**	0.381*	0.575**	-0.214	-0.681**	0.145	0.568**
Sulphur	-0.220	-0.723**	0.215	0.623**	-0.158	-0.601**	-0.584**	0.628**	0.210	-0.014	0.257	-0.011
Iron	-0.202	-0.149	0.205	0.037	0.116	0.451*	0.156	-0.393*	-0.135	-0.311*	0.171	0.168
Manganese	-0.281	0.172	0.253	-0.256	-0.151	0.133	-0.576**	-0.169	0.434*	0.195	0.282	-0.178
Zinc	-0.186	0.054	0.217	0.195	0.355*	-0.034	0.385*	-0.019	-0.203	0.037	0.149	-0.186
Copper	-0.267	0.28	0.332*	-0.025	-0.143	-0.032	-0.569**	0.040	0.223	0.192	0.299	-0.249
Boron	0.119	-0.424*	0.020	0.519**	-0.469*	-0.579**	-0.144	0.592**	-0.114	-0.462*	0.146	0.334*
Silicon	-0.145	-0.765**	0.250	0.740**	0.133	-0.866**	0.202	0.942**	0.166	0.072	-0.564**	-0.095
Aluminium	-0.174	0.170	0.213	-0.137	0.100	-0.158	0.156	0.186	0.220	-0.078	-0.583**	0.076
Chlorophyll-a	-0.171	-0.958**	-0.077	0.846**	-0.557**	-0.917**	-0.125	0.966**	0.076	-0.869**	0.607**	0.858**
Chlorophyll -b	0.028	-0.953**	0.240	0.860**	0.374*	-0.916**	0.365*	0.978**	0.287	-0.878**	0.116	0.873**
Total Chlorophyll	0.047	-0.954**	0.089	0.846**	-0.127	-0.923**	0.235	0.978**	0.045	-0.857**	0.569**	0.841**
Yellowing index	1.000	1.000	0.155	-0.913**	1.000	1.000	0.677**	-0.971**	1.000	1.000	-0.105	-0.951**
Dry kernel weight	-0.292	-0.865**	0.053	0.967**	-0.466*	-0.919**	0.209	0.966**	0.426*	-0.909**	0.271	0.959**
Number of fruits	0.328*	-0.914**	0.680**	0.980**	0.744**	-0.965**	0.931**	0.981**	-0.385*	-0.931**	0.829**	0.979**
Chali yield	0.155	-0.913**	1.000	1.000	0.277	-0.971**	1.000	1.000	-0.105	-0.951**	1.000	1.000

correlation with yellowing index while Fe showed significant positive correlation with yellowing index during post-treatment period.

N, P, K, Ca, Mg, S, B, Si, chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight and number of fruits showed significant positive correlation with *chali* yield while Fe showed significant negative correlation with *chali* yield during post-treatment period.

4.1.2.3 Terraced upland

N, P, K, Ca, Mg, Fe, B chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight, number of fruits and *chali* yield showed significant negative correlation with yellowing index during post-treatment period.

N, P, K, Ca, Mg, B chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight and number of fruits showed significant positive correlation with *chali* yield during post-treatment period.

4.2 EXPERIMENT II. COMPARISON OF INCIDENCE OF YELLOWING AMONG CONVERTED PADDY FIELDS, GARDEN LANDS AND TERRACED UPLANDS

The experiment was undertaken during June 2004 – May 2005. The scoring system developed to assess the intensity of yellowing in arecanut in the first experiment was utilized to compare the intensity and spread of arecanut yellowing in the three districts of central Kerala namely Thrissur, Palakkad and Malappuram. Arecanut grown in farmers' field located in the three toposequences namely converted paddy field, garden land and terraced upland were surveyed in consultation with agriculture officers of the Krishi Bhavan located in Thrissur, Palakkad and Malappuram districts.

4.2.1 Incidence of yellowing in arecanut among various toposequences

The data on incidence of yellowing in arecanut among various toposequences viz. converted paddy field, garden land and terraced upland are presented in Table 4.2

4.2.1.1 Converted paddy field

In converted paddy fields of Thrissur district majority (34 percent) of arecanut palms were severely affected by yellowing. In Palakkad district, majority (53 percent) of arecanut palms were found to be healthy. In Malappuram district, majority (46 percent) of arecanut palms were found to be mildly affected by yellowing.

4.2.1.2 Garden land

In garden lands of Thrissur district, majority (39 percent) of arecanut palms were mildly affected by yellowing. Arecanut palms in majority of the garden lands in Palakkad (59 percent) and Malappuram (47 percent) districts were found to be healthy.

4.2.1.3 Terraced upland

In terraced uplands of Thrissur district, majority (45 percent) of arecanut palms were moderately affected by yellowing. Arecanut palms in majority of the terraced uplands in Palakkad (50 percent) and Malappuram (61 percent) districts were found to be healthy.

Table 4.2 Incidence of yellowing in arecanut among various toposequences

A. Thrissur district

Toposequence	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Converted paddy field	22	31	13	34
Garden land	33	39	11	17
Terraced upland	21	9	45	25

B. Palakkad district

Toposequence	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Converted paddy field	53	20	20	7
Garden land	59	13	18	10
Terraced upland	50	16	17	17

C. Malappuram district

Toposequence	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Converted paddy field	36	46	14	4
Garden land	47	34	16	3
Terraced upland	61	11	17	11

4.2.2 Varietal differences in the incidence of yellowing in arecanut

The data on varietal differences in the incidence of yellowing are presented in Table 4.3. Kasaragod local, Local, Mangala, Mohitnagar and Sumangali are the popular cultivated arecanut varieties of Thrissur, Palakkad and Malappuram districts of Kerala state.

4.2.2.1 Kasaragod local

Kasaragod local was found to be mildly affected by yellowing in Thrissur (46 percent), Palakkad (30 percent) and Malappuram (62 percent) districts.

4.2.2.2 Local

Local variety was found to be mildly affected by yellowing in Thrissur (64 percent), Palakkad (30 percent) and Malappuram (48 percent) districts.

4.2.2.3 Mangala

Mangala was found to be moderately affected by yellowing in Thrissur (37 percent), Palakkad (30 percent) and Malappuram (39 percent) districts.

4.2.2.4 Mohitnagar

Mohitnagar was found to be moderately affected by yellowing in Thrissur (39 percent), Palakkad (40 percent) and Malappuram (49 percent) districts.

Table 4.3 Varietal differences in the incidence of yellowing in arecanut

A. Thrissur district

Variety	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Kasargode local	8	46	37	9
Local	21	64	11	4
Mangala	22	25	37	16
Mohitnagar	15	31	39	15
Sumangala	17	33	42	8

B. Palakkad district

Variety	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Kasargode local	25	30	25	20
Local	25	30	20	25
Mangala	20	20	30	30
Mohitnagar	20	20	40	20
Sumangala	15	20	50	15

C. Malappuram district

Variety	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Kasargode local	13	62	10	15
Local	28	48	12	12
Mangala	23	15	39	23
Mohitnagar	17	17	49	17
Sumangala	25	10	50	15

4.2.2.5 Sumangala

Sumangala was found to be moderately affected by yellowing in Thrissur (42 percent), Palakkad (50 percent) and Malappuram (50 percent) districts.

4.3 EXPERIMENT III. DEVELOPMENT OF A MANAGEMENT STRATEGY TO CONTAIN YELLOWING OF ARECANUT UNDER VARIOUS TOPOSEQUENCES

Experiments were conducted during February 2004 to September 2006 to study the effect of nutrient management practices on the incidence of yellowing of arecanut grown under various toposequences viz. converted paddy field, garden land and terraced upland. The experiments were laid out in RBD using single plant plot with five replications. Sixty arecanut palms were selected for studying the effect of twelve different nutrient management practices under each toposequences.

Effect of nutrient management practices on chemical properties of soil, elemental composition of leaf, physiological and morphological characters of palms and yield and nut characters were studied and the data are presented below.

4.3.1 Converted paddy field

4.3.1.1 Effect of treatments on nutrient content in soil and index leaf

4.3.1.1.1 Nitrogen

Soil at 0-25 cm (Table 4.4) prior to application of treatments during February 2004 recorded available nitrogen content of 200 to 239 kg $ha^{-1}$with a mean of 224 kg ha^{-1}. All the treatments except farmers' practice (T_1) and deep drainage (T_3) resulted

Table 4.4 Effect of treatments on available nitrogen in soil and nitrogen content of arecanut palm in converted paddy field

A. Nitrogen (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	221	255	130	176	162	163	185
T_2	229	316	201	258	293	260	259
T_3	200	260	137	187	173	179	189
T_4	230	323	170	270	250	254	249
T_5	231	320	176	262	235	263	248
T_6	224	329	188	273	230	238	247
T_7	226	333	208	245	224	258	249
T_8	221	346	195	250	265	243	253
T_9	239	359	211	254	242	262	261
T_{10}	223	346	213	266	220	249	253
T_{11}	224	357	205	257	275	245	261
T_{12}	219	339	213	276	257	231	256
CD(0.05)	NS	51	29	39	38	37	10

B. Nitrogen (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	1.41	1.60	1.24	1.26	1.38	1.35	1.37
T_2	1.46	1.23	1.55	1.57	1.69	1.74	1.54
T_3	1.25	1.14	1.49	1.27	1.45	1.38	1.33
T_4	1.47	1.56	1.66	1.74	1.65	1.72	1.63
T_5	1.48	1.24	1.54	1.67	1.70	1.78	1.57
T_6	1.42	1.58	1.56	1.62	1.93	1.73	1.64
T_7	1.44	1.60	1.69	1.66	1.69	1.73	1.64
T_8	1.40	2.02	1.51	1.68	1.65	1.69	1.66
T_9	1.53	2.24	1.74	1.66	1.88	1.68	1.79
T_{10}	1.42	2.02	1.58	1.61	1.90	1.75	1.71
T_{11}	1.43	2.03	1.62	1.64	1.68	1.81	1.70
T_{12}	1.39	1.73	1.52	1.58	1.78	1.66	1.61
CD(0.05)	NS	0.245	0.240	0.239	0.266	0.258	0.205

in significantly higher nitrogen content of soil over the years. Treatments T_1 and T_3 were least effective in increasing available nitrogen in soil.

Index leaf of arecanut (Table 4.4) prior to application of treatments during February 2004 recorded nitrogen content of 1.25 to 1.53 percent with a mean of 1.43 percent. It was observed that all treatments except farmers' practice (T_1) and deep drainage (T_3) resulted in significantly higher nitrogen content of index leaf. In treatments T_1 and T_3 significantly lower nitrogen content was observed at each stage of observation. However in T_3, the enhancement in leaf nitrogen content was evidently more than T_1 from the second year onwards.

4.3.1.1.2 Phosphorus

Available soil phosphorus (Table 4.5) ranged from 29 to 35 kg ha^{-1} with a mean of 33 kg ha^{-1} before application of treatments. Pooled mean values showed that all treatments except farmers' practice (T_1) and deep drainage (T_3) resulted in significantly higher phosphorus content of soil. No significant variations in phosphorus content were observed due to treatments during the first year. However treatment T_1 during February 2005, treatments T_1 and T_3 during September 2005, February 2006 and September 2006 resulted in significant lowering of phosphorus content of soil. Treatments T_1 and T_3 were least effective in increasing available phosphorus in soil.

Phosphorus content of index leaf (Table 4.5) prior to application of treatments ranged from 0.15 to 0.17 percent with a mean of 0.16 percent. Pooled mean values showed that all treatments except farmers' practice (T_1) and deep drainage (T_3) resulted in significantly higher phosphorus content of index leaf. Treatment T_1 during September 2005, treatments T_1 and T_3 during September 2004, February 2005, February 2006 and September 2006 caused significant reduction in phosphorus

Table 4.5 Effect of treatments on available phosphorus in soil and phosphorus content of arecanut palm in converted paddy field

A. Phosphorus (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	32	33	24	12	10	15	21
T_2	33	34	32	26	27	32	31
T_3	35	36	32	13	14	16	24
T_4	32	38	42	26	25	27	32
T_5	32	37	35	21	21	34	30
T_6	33	37	37	20	20	32	30
T_7	33	37	33	22	19	33	30
T_8	35	37	35	24	26	29	31
T_9	33	34	33	20	23	24	28
T_{10}	34	33	36	25	22	33	31
T_{11}	34	33	35	25	24	28	30
T_{12}	29	32	42	25	23	31	30
CD(0.05)	NS	NS	3	4	3	5	2

B. Phosphorus (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.157	0.060	0.106	0.103	0.109	0.108	0.107
T_2	0.156	0.090	0.136	0.146	0.153	0.149	0.138
T_3	0.163	0.080	0.119	0.127	0.120	0.121	0.122
T_4	0.162	0.110	0.132	0.133	0.159	0.144	0.140
T_5	0.166	0.090	0.133	0.157	0.151	0.153	0.142
T_6	0.162	0.110	0.147	0.138	0.136	0.157	0.142
T_7	0.159	0.110	0.140	0.128	0.153	0.154	0.141
T_8	0.161	0.150	0.137	0.131	0.147	0.155	0.147
T_9	0.160	0.160	0.143	0.136	0.147	0.146	0.149
T_{10}	0.163	0.150	0.132	0.149	0.141	0.155	0.148
T_{11}	0.154	0.160	0.154	0.142	0.146	0.152	0.151
T_{12}	0.155	0.120	0.143	0.148	0.152	0.158	0.146
CD(0.05)	NS	0.018	0.021	0.021	0.022	0.023	0.019

content of index leaf. showed that treatments T_1 and T_3 were least effective in increasing phosphorus content of index leaf.

4.3.1.1.3 Potassium

Soil analysis of experimental field (Table 4.6) prior to application of treatments during February 2004 recorded available potassium content of 160 to 197 kg ha^{-1} with a mean of 188 kg ha^{-1}. Pooled mean values showed that application of higher rate of potassium (T_8, T_9, T_{10}, T_{11} and T_{12}) resulted in significantly higher potassium content of soil. Treatments T_1 and T_3 during September 2004, treatments T_1 and T_6 during February 2005, treatments T_1, T_2 and T_7 during September 2005, treatment T_1 during February 2006 and September 2006 significantly lowered potassium content of soil. Treatments T_8, T_9, T_{10}, T_{11} and T_{12} were highly effective in increasing the available potassium in soil.

The variation in potassium content of index leaf of arecanut (Table 4.6) prior to application of treatments during February 2004 ranged from 0.42 to 0.50 percent with a mean of 0.47 percent. Pooled mean values showed that application of higher rate of potassium (T_8, T_9, T_{10} and T_{11}) resulted in significantly higher potassium content of index leaf. Treatments T_1 and T_3 during September 2004, February 2005, September 2005, February 2006 and September 2006 significantly lowered potassium content of index leaf.

4.3.1.1.4 Calcium

Accumulation of available calcium in soil (Table 4.7) prior to application of treatments during February 2004 varied from 626 to 778 kg ha^{-1} with a mean of 709 kg ha^{-1}. Pooled mean values showed that all treatments except farmers' practice (T_1)

Table 4.6 Effect of treatments on available potassium in soil and potassium content of arecanut palm in converted paddy field

A. Potassium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	160	140	135	125	110	112	130
T_2	193	260	190	152	314	422	255
T_3	181	172	186	190	197	172	183
T_4	193	336	217	213	248	265	245
T_5	194	290	177	177	286	428	259
T_6	191	358	160	202	221	287	237
T_7	191	358	173	141	291	336	248
T_8	189	430	192	297	320	381	302
T_9	197	444	219	289	230	314	282
T_{10}	190	440	208	283	264	403	298
T_{11}	191	442	203	306	299	439	313
T_{12}	189	428	208	273	276	413	298
CD(0.05)	NS	56	27	36	41	55	31

B. Potassium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.46	0.34	0.53	0.45	0.49	0.49	0.46
T_2	0.48	0.46	0.68	0.61	0.60	0.66	0.58
T_3	0.42	0.45	0.54	0.43	0.49	0.52	0.47
T_4	0.48	0.57	0.66	0.65	0.60	0.68	0.60
T_5	0.48	0.47	0.73	0.55	0.69	0.65	0.59
T_6	0.47	0.58	0.70	0.56	0.60	0.67	0.60
T_7	0.47	0.60	0.75	0.63	0.68	0.63	0.62
T_8	0.46	0.74	0.75	0.60	0.65	0.63	0.64
T_9	0.50	0.85	0.73	0.64	0.65	0.69	0.68
T_{10}	0.47	0.78	0.73	0.60	0.63	0.70	0.65
T_{11}	0.47	0.82	0.74	0.55	0.68	0.63	0.65
T_{12}	0.46	0.62	0.65	0.64	0.60	0.62	0.60
CD(0.05)	NS	0.092	0.105	0.088	0.094	0.097	0.036

Table 4.7 Effect of treatments on available calcium in soil and calcium content of arecanut palm in converted paddy field

A. Calcium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	739	1050	834	672	896	627	803
T_2	690	2090	1298	1469	1460	1211	1370
T_3	660	1110	906	851	950	680	860
T_4	680	1416	1610	1501	1740	1647	1432
T_5	724	1416	1381	1613	1837	1300	1378
T_6	626	1416	1774	1445	1660	1049	1328
T_7	778	1611	1700	1344	1330	1154	1320
T_8	744	1758	1489	1568	1550	1434	1424
T_9	744	1790	1860	1702	1920	1680	1616
T_{10}	739	1770	1667	1389	1610	1613	1464
T_{11}	685	1770	1900	1235	1870	1009	1411
T_{12}	700	1758	1270	1523	1389	1098	1290
CD(0.05)	NS	256	231	220	245	199	115

B. Calcium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.187	0.260	0.300	0.342	0.440	0.420	0.325
T_2	0.185	0.380	0.471	0.424	0.589	0.639	0.448
T_3	0.194	0.330	0.380	0.414	0.543	0.521	0.397
T_4	0.193	0.410	0.480	0.520	0.580	0.612	0.466
T_5	0.197	0.380	0.432	0.520	0.557	0.593	0.447
T_6	0.193	0.410	0.463	0.440	0.557	0.585	0.441
T_7	0.189	0.420	0.388	0.440	0.563	0.623	0.437
T_8	0.192	0.420	0.384	0.480	0.627	0.564	0.444
T_9	0.191	0.520	0.408	0.502	0.600	0.687	0.485
T_{10}	0.194	0.420	0.452	0.474	0.640	0.532	0.452
T_{11}	0.183	0.470	0.432	0.420	0.560	0.548	0.435
T_{12}	0.184	0.420	0.432	0.467	0.640	0.548	0.448
CD(0.05)	NS	0.062	0.065	0.070	0.088	0.088	0.022

and deep drainage (T_3) resulted in significantly higher calcium content of soil. In the treatments T_1 and T_3 significantly lower calcium contents were observed in the second and third year than other treatments. It is to be noted that available calcium content as high as 2090 kg ha^{-1} was observed in T_2 during September 2005. Treatments T_1 and T_3 were least effective in increasing the available calcium in soil.

Index leaf of arecanut (Table 4.7) prior to application of treatments during February 2004 recorded calcium content of 0.18 to 0.20 percent with a mean of 0.19 percent. Pooled mean values showed that all treatments except farmers' practice (T_1) resulted in significantly higher calcium content of index leaf. Significant reduction in the leaf calcium content was observed over the years due to the continuous application of lime.

4.3.1.1.5 Magnesium

Comparison of available magnesium in different treatment plots (Table 4.8) prior to application of treatments during February 2004 showed that available magnesium ranged from 157 to 170 kg ha^{-1} with a mean of164 kg ha^{-1}. Pooled mean values showed that application of magnesium sulphate (T_9) resulted in significantly higher magnesium content of soil. Treatments manifested no significant variation in the magnesium content of soil during September 2006. However in treatment T_9 significant increase in the soil magnesium content was observed over the years.

Magnesium to the tune of 0.13 to 0.15 percent with a mean content of 0.14 percent was observed in the index leaf prior to the application of treatments (Table 4.8). Application of magnesium sulphate (T_9) resulted in significantly higher leaf magnesium content over the years.

Table 4.8 Effect of treatments on available magnesium in soil and magnesium content of arecanut palm in converted paddy field

A. Magnesium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	165	210	232	246	327	339	253
T_2	169	217	259	336	331	334	274
T_3	164	212	304	323	238	359	267
T_4	165	234	329	222	226	320	249
T_5	157	220	324	303	206	362	262
T_6	160	238	220	359	274	328	263
T_7	157	227	356	285	317	352	282
T_8	165	236	240	271	347	344	267
T_9	170	486	416	430	416	367	347
T_{10}	161	220	226	260	216	290	229
T_{11}	164	219	291	316	296	300	264
T_{12}	165	221	238	345	256	309	256
CD(0.05)	NS	36	44	50	47	NS	22

B. Magnesium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.139	0.040	0.120	0.163	0.190	0.184	0.139
T_2	0.144	0.120	0.184	0.240	0.264	0.281	0.206
T_3	0.126	0.120	0.173	0.170	0.196	0.192	0.163
T_4	0.145	0.150	0.155	0.216	0.264	0.251	0.197
T_5	0.146	0.150	0.178	0.212	0.250	0.262	0.200
T_6	0.141	0.180	0.188	0.233	0.240	0.248	0.205
T_7	0.142	0.180	0.219	0.224	0.264	0.278	0.218
T_8	0.139	0.230	0.168	0.240	0.274	0.276	0.221
T_9	0.151	0.350	0.254	0.278	0.315	0.328	0.263
T_{10}	0.141	0.230	0.175	0.214	0.270	0.253	0.214
T_{11}	0.141	0.230	0.171	0.238	0.264	0.253	0.216
T_{12}	0.138	0.210	0.188	0.225	0.240	0.265	0.211
CD(0.05)	NS	0.028	0.027	0.034	0.039	0.039	0.017

4.3.1.1.6 Sulphur

Average sulphur content in the top soil ranged from 17 to 18 kg ha^{-1} before the imposition of treatments (Table 4.9). Pooled mean values showed that lack of application of sulphur through ammonium sulphate (T_1, T_2, T_3, T_5 and T_{12}) significantly decreased sulphur content of soil. Treatments T_1, T_2 and T_3 during September 2004, treatments T_1, T_2, T_3, T_5 and T_{12} during February 2005, September 2005, February 2006, treatments T_1, T_3, T_5 and T_{12} during September 2006 significantly lower soil sulphur contents were observed. Treatments T_1, T_2, T_3, T_5 and T_{12} were least effective in increasing the available sulphur in soil.

Index leaf of arecanut (Table 4.9) prior to application of treatments during February 2004 recorded sulphur content of 0.087 to 0.093 percent with a mean of 0.09 percent. Pooled mean values showed that all treatments except farmers' practice (T_1) and deep drainage (T_3) resulted in significantly higher sulphur content of index leaf. Treatment T_1 during September 2004, treatments T_1, T_3, T_5 and T_{12} during February 2005 and September 2006, treatments T_1, T_3 and T_5 during September 2005, treatments T_1, T_3 and T_{12} during February 2006 significantly lowered sulphur content of index leaf.

4.3.1.1.7 Iron

Prior to application of treatments during February 2004, available iron content varied from 176 to 193 kg ha^{-1} with a mean of 185kg ha^{-1} (Table 4.10). Treatments did not manifest any significant variation in the iron content of soil over the years.

Index leaf of arecanut (Table 4.10) prior to application of treatments during February 2004 recorded iron content of 262 to 312 ppm with a mean of 293 ppm. The

Table 4.9 Effect of treatments on available sulphur in soil and sulphur content of arecanut palm in converted paddy field

A. Sulphur (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	18	19	43	31	30	27	28
T_2	18	27	44	35	33	29	31
T_3	17	21	37	32	31	25	27
T_4	17	57	56	47	48	37	44
T_5	18	33	45	34	32	22	30
T_6	17	62	61	48	45	36	45
T_7	18	68	58	46	42	40	45
T_8	18	75	66	49	43	39	48
T_9	17	87	64	50	50	45	52
T_{10}	18	82	55	45	52	42	49
T_{11}	17	70	63	52	47	43	49
T_{12}	17	41	41	36	27	24	31
CD(0.05)	NS	9	8	7	7	6	5

B. Sulphur (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.088	0.190	0.312	0.330	0.302	0.334	0.259
T_2	0.088	0.320	0.431	0.491	0.407	0.412	0.358
T_3	0.092	0.280	0.337	0.262	0.329	0.367	0.278
T_4	0.091	0.450	0.445	0.444	0.480	0.488	0.400
T_5	0.093	0.360	0.357	0.310	0.433	0.365	0.320
T_6	0.091	0.450	0.460	0.460	0.432	0.498	0.399
T_7	0.090	0.470	0.490	0.456	0.485	0.472	0.411
T_8	0.091	0.480	0.435	0.432	0.440	0.419	0.383
T_9	0.090	0.440	0.449	0.400	0.464	0.479	0.387
T_{10}	0.092	0.430	0.470	0.491	0.417	0.471	0.395
T_{11}	0.087	0.460	0.403	0.437	0.492	0.418	0.383
T_{12}	0.087	0.390	0.352	0.388	0.349	0.357	0.321
CD(0.05)	NS	0.075	0.081	0.091	0.102	0.102	0.057

Table 4.10 Effect of treatments on available iron in soil and iron content of arecanut palm in converted paddy field

A. Iron (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	185	185	201	274	290	410	257
T_2	189	191	203	245	323	392	257
T_3	176	194	215	233	287	430	256
T_4	183	200	206	270	301	442	267
T_5	186	204	218	254	298	352	252
T_6	181	168	212	280	310	422	262
T_7	189	188	204	235	283	404	251
T_8	193	183	200	261	280	460	263
T_9	182	173	198	229	307	370	243
T_{10}	191	179	211	241	316	342	247
T_{11}	180	176	209	266	337	380	258
T_{12}	182	164	195	250	330	359	247
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Iron (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	289	522	303	483	365	473	406
T_2	299	533	301	567	378	500	430
T_3	262	603	308	486	372	557	431
T_4	300	575	337	548	365	520	441
T_5	302	511	316	548	388	489	426
T_6	292	540	320	577	380	606	453
T_7	295	564	296	531	358	528	429
T_8	288	548	330	577	360	525	438
T_9	312	526	331	564	360	500	432
T_{10}	292	533	316	500	383	538	427
T_{11}	293	518	352	570	375	500	435
T_{12}	286	514	329	548	380	480	423
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

treatments failed to manifest any significant variation in the iron content of index leaf over the years.

4.3.1.1.8 Manganese

The available manganese was to the tune of 54 to 86 kg ha^{-1} in various treatment plots during February 2004 (Table 4.11). No significant variation in the manganese content of soil was noticed over the years.

The initial leaf manganese content ranged from 54 to 86 ppm before the treatment application (Table 4.11). The contents did not vary significantly due to the application of treatments.

4.3.1.1.9 Zinc

Available zinc content of soil at 0-25 cm (Table 4.12) prior to application of treatments during February 2004 ranged from 23 to 28 kg ha^{-1} with a mean of 26 kg ha^{-1}. Pooled mean values showed that in treatment involving application of zinc sulphate (T_{10}) significantly higher zinc content over the years was noticed.

The leaf zinc content before the application of treatments varied from 24 to 29 ppm with a mean of 27 ppm (Table 4.12). The highest zinc content as shown by the pooled mean was observed in T_{10}.

4.3.1.1.10 Copper

Comparison of different treatments plots showed that prior to application of treatments, available copper content of soil ranged from 17 to 21 kg ha^{-1} (Table 4.13).

Table 4.11 Effect of treatments on available manganese in soil and manganese content of arecanut palm in converted paddy field

A. Manganese (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	63	80	88	93	98	92	86
T_2	86	77	87	92	114	102	93
T_3	59	82	86	87	97	90	84
T_4	62	83	86	94	109	89	87
T_5	56	72	86	86	99	86	81
T_6	61	75	84	90	107	97	86
T_7	61	74	83	88	96	93	82
T_8	59	79	82	89	94	95	83
T_9	54	69	82	85	105	99	82
T_{10}	62	70	81	95	101	85	82
T_{11}	55	77	78	103	103	88	84
T_{12}	60	71	76	99	111	86	84
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

B. Manganese (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	197	190	175	142	169	157	172
T_2	195	201	183	156	175	153	177
T_3	204	200	188	138	172	161	177
T_4	203	195	178	157	171	162	178
T_5	208	181	170	150	174	153	173
T_6	203	175	170	141	182	151	170
T_7	199	184	178	146	178	143	171
T_8	202	175	170	154	165	155	170
T_9	201	180	169	146	175	161	172
T_{10}	205	200	165	160	176	153	176
T_{11}	192	183	176	144	172	159	171
T_{12}	194	174	169	142	171	154	167
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.12 Effect of treatments on available zinc in soil and zinc content of arecanut palm in converted paddy field

A. Zinc (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	25.5	26.9	26.0	26.7	26.5	21.4	25.5
T_2	26.4	24.9	24.6	25.3	25.3	23.0	24.9
T_3	23.1	25.6	27.4	28.3	24.0	21.9	25.1
T_4	26.5	27.4	26.2	27.4	26.2	24.4	26.3
T_5	26.6	24.6	28.0	23.4	27.8	26.7	26.2
T_6	25.8	27.2	25.7	24.6	24.6	22.6	25.1
T_7	26.0	25.2	25.1	24.2	23.2	27.8	25.3
T_8	25.5	26.2	27.3	25.5	22.2	23.9	25.1
T_9	27.5	24.2	24.0	22.6	25.7	29.0	25.5
T_{10}	25.7	33.0	35.5	36.3	35.0	37.1	33.8
T_{11}	25.9	26.7	23.4	26.0	25.1	25.5	25.4
T_{12}	25.3	23.6	26.7	29.4	27.0	23.5	25.9
CD(0.05)	NS	4.1	4.1	4.2	4.1	4.1	1.7

B. Zinc (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	26.8	24.3	22.2	24.7	25.4	22.0	24.2
T_2	27.7	24.2	25.2	26.0	25.3	23.7	25.3
T_3	24.3	23.3	24.7	27.6	26.0	24.5	25.1
T_4	27.8	23.8	21.1	28.0	25.6	24.3	25.1
T_5	28.0	24.5	21.6	25.0	26.2	26.0	25.2
T_6	27.1	23.5	24.5	26.0	26.8	22.0	25.0
T_7	27.4	21.0	24.5	24.9	29.0	24.0	25.1
T_8	26.8	23.6	22.7	27.9	29.0	25.0	25.8
T_9	29.0	22.6	24.6	27.0	28.0	21.9	25.5
T_{10}	27.1	26.3	25.2	27.0	27.0	24.7	26.2
T_{11}	27.2	25.5	26.2	25.7	28.3	23.0	26.0
T_{12}	26.6	23.2	25.3	28.0	24.5	25.0	25.4
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.13 Effect of treatments on available copper in soil and copper content of arecanut palm in converted paddy field

A. Copper (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	19.0	21.0	20.6	19.8	20.7	17.7	19.8
T_2	20.2	21.2	20.0	20.3	20.5	17.5	20.0
T_3	16.7	20.1	18.5	20.9	20.3	16.3	18.8
T_4	18.6	19.3	18.2	21.4	20.0	16.6	19.0
T_5	19.4	19.7	17.8	21.7	19.8	18.3	19.5
T_6	18.0	18.4	21.3	20.7	19.5	19.3	19.5
T_7	20.2	21.8	21.6	19.2	19.3	20.0	20.3
T_8	21.3	21.5	19.7	19.5	19.2	18.7	20.0
T_9	18.2	19.0	21.0	19.0	19.0	20.4	19.4
T_{10}	20.6	18.7	20.3	18.6	18.9	17.0	19.0
T_{11}	17.9	20.8	19.4	21.1	18.8	19.5	19.6
T_{12}	18.3	20.4	19.1	18.5	18.6	19.0	19.0
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Copper (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	8.1	13.4	7.4	13.6	12.7	15.1	11.7
T_2	8.0	14.4	7.2	13.8	12.5	14.3	11.7
T_3	8.4	13.8	7.2	13.2	11.4	14.1	11.3
T_4	8.3	14.5	6.7	13.4	11.4	16.0	11.7
T_5	8.5	15.0	6.9	14.9	12.4	13.5	11.9
T_6	8.4	13.6	6.5	15.3	11.8	14.7	11.7
T_7	8.2	12.0	6.3	15.1	11.2	15.7	11.4
T_8	8.3	14.5	6.2	15.1	11.7	15.7	11.9
T_9	8.3	11.8	6.2	14.5	11.6	13.3	10.9
T_{10}	8.4	14.6	6.2	15.2	12.0	14.2	11.8
T_{11}	7.9	13.3	6.9	13.1	11.6	14.1	11.2
T_{12}	8.0	13.1	6.3	14.2	12.3	15.4	11.6
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

However over the years, treatments failed to register any significant variation in available copper in soil.

Copper content of leaf (Table 4.13) prior to treatment application varied from 7.9 to 8.5 ppm with a mean of 8.23 ppm. Treatments resulted in no significant variation in leaf copper content over the years.

4.3.1.1.11 Boron

The variation in available boron content of soil was not marked during February 2004 and varied from 8.4 to 10.6 kg ha^{-1} (Table 4.14). But over the years, application of borax (T_{11}) resulted in significantly higher available boron in soil.

Boron content of leaf ranged from 56 to 61 percent prior to application of treatments (Table 4.14). Pooled analysis over the years showed that the boron content of index leaf was significantly highest with 114 ppm.

4.3.1.1.12 Silicon

Total soil silicon prior to treatment application varied from 355 to 428 t ha^{-1} (Table 4.15). Treatments failed to register any significant variation in total soil silicon over the years.

Leaf silicon content (Table 4.15) varied from 0.56 to 0.67 percent before application of treatments. Response to application of sodium silicate was not evident in the silicon content of leaf over the years.

Table 4.14 Effect of treatments on available boron in soil and boron content of arecanut palm in converted paddy field

A. Boron (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	9.26	8.77	10.04	7.26	9.30	8.66	8.88
T_2	10.30	8.34	8.66	8.29	8.40	7.64	8.61
T_3	8.80	7.75	8.66	7.75	7.40	8.29	8.11
T_4	9.90	9.04	8.60	7.96	8.97	8.56	8.84
T_5	10.61	9.15	9.67	8.07	8.73	8.00	9.04
T_6	8.40	8.99	9.42	9.10	9.04	8.88	8.97
T_7	10.06	8.45	8.85	7.48	8.18	9.15	8.70
T_8	9.10	8.07	8.35	8.48	7.70	7.86	8.26
T_9	9.47	8.88	9.04	8.80	7.96	9.04	8.87
T_{10}	9.69	9.42	8.80	7.00	9.20	8.45	8.76
T_{11}	10.36	11.57	12.44	11.20	11.60	10.80	11.33
T_{12}	10.17	8.66	8.66	7.64	8.80	8.77	8.78
CD(0.05)	NS	1.41	1.45	1.31	1.39	1.36	0.57

B. Boron (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	58	47	79	98	92	108	80
T_2	60	68	81	100	111	111	89
T_3	56	50	96	99	97	109	85
T_4	58	74	94	111	92	127	93
T_5	59	71	86	114	100	126	93
T_6	57	78	93	123	104	111	94
T_7	60	81	84	113	109	114	93
T_8	61	106	96	111	101	115	98
T_9	57	131	106	120	113	116	107
T_{10}	60	109	103	125	94	112	101
T_{11}	57	116	129	149	106	128	114
T_{12}	57	98	98	116	95	113	96
CD(0.05)	NS	13	15	18	15	NS	5

Table 4.15 Effect of treatments on total silicon in soil and silicon content of arecanut palm in converted paddy field

A. Silicon (t ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	388	358	365	370	412	428	387
T_2	365	366	410	401	426	363	389
T_3	417	395	377	426	402	457	412
T_4	406	414	430	430	363	440	414
T_5	375	387	381	377	398	413	389
T_6	428	409	363	365	357	376	383
T_7	370	377	353	354	422	450	388
T_8	355	374	417	410	381	420	393
T_9	381	385	388	420	418	444	406
T_{10}	420	350	392	417	391	402	395
T_{11}	410	420	372	392	408	392	399
T_{12}	398	404	399	383	371	433	398
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Silicon (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.62	0.60	0.68	0.72	0.76	0.76	0.69
T_2	0.64	0.64	1.04	1.25	1.18	1.22	1.00
T_3	0.56	0.59	1.07	1.33	1.15	1.18	0.98
T_4	0.65	0.80	0.98	1.19	1.22	1.27	1.02
T_5	0.65	0.71	1.06	1.20	1.14	1.16	0.99
T_6	0.63	0.86	0.94	1.23	1.24	1.25	1.03
T_7	0.64	0.89	0.97	1.29	1.21	1.26	1.04
T_8	0.62	1.06	0.91	1.21	1.11	1.24	1.03
T_9	0.67	1.43	0.94	1.11	1.05	1.20	1.07
T_{10}	0.63	1.19	0.99	1.32	1.26	1.22	1.10
T_{11}	0.63	1.31	0.86	1.31	1.21	1.30	1.10
T_{12}	0.62	1.01	0.89	1.31	1.07	1.22	1.02
CD(0.05)	NS	0.15	NS	NS	NS	NS	NS

4.3.1.1.13 Aluminium

Content of available aluminium in soil prior to treatment application varied from 89 to 106 kg ha^{-1} (Table 4.16). Application of treatments failed to bring about any significant variation in the aluminium content of soil over the years.

Index leaf of arecanut recorded aluminium content in the range of 224 to 267 ppm before application of treatments (Table 4.16). There was no significant variation in aluminium content of index leaf due to application of treatments over the years.

4.3.1.2 Effect of treatments on soil pH and organic carbon content of soil

Soil pH prior to application of treatments (Table 4.17) varied from 3.89 to 4.32. All treatments except farmers practice (T_1) and deep drainage (T_3) favourably increased soil pH over the years.

The organic carbon status of soil prior to application of treatments ranged from 0.72 to 0.86 percent (Table 4.17). Treatments failed to register any significant variation in soil organic carbon content over the years.

4.3.1.3 Effect of treatments on chlorophyll-a, chlorophyll-b, total chlorophyll and yellowing index

Before application of treatments leaf chlorophyll-a content varied from 0.15 to 0.16 percent (Table 4.18). The chlorophyll a content was significantly and consistently lower in T_1 and T_3 treatments where no inorganic fertilizers were applied. Application of magnesium sulphate (T_9) resulted in significant increase of leaf chlorophyll-a content over the years.

Table 4.16 Effect of treatments on available aluminium in soil and aluminium content of arecanut palm in converted paddy field

A. Aluminium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	99	93	94	107	100	104	99
T_2	102	106	104	97	104	116	105
T_3	89	88	107	102	105	108	100
T_4	102	100	96	94	111	110	102
T_5	103	99	101	104	106	117	105
T_6	100	100	110	103	112	112	106
T_7	101	102	104	101	115	106	105
T_8	98	102	105	110	107	112	106
T_9	106	110	99	93	102	96	101
T_{10}	99	98	108	96	118	99	103
T_{11}	100	97	102	109	98	113	103
T_{12}	98	100	97	99	109	102	101
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Aluminium (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	247	273	196	110	121	116	177
T_2	255	234	199	106	117	105	169
T_3	224	261	210	114	111	120	173
T_4	257	219	213	123	114	122	175
T_5	258	225	217	118	112	116	174
T_6	250	221	203	125	113	109	170
T_7	252	214	207	122	131	122	175
T_8	247	229	196	109	124	113	170
T_9	267	219	192	109	128	109	171
T_{10}	249	217	193	105	115	125	167
T_{11}	251	227	194	108	118	118	169
T_{12}	245	217	189	109	111	123	166
CD(0.05)	NS	35.812	NS	NS	NS	NS	NS

Table 4.17 Effect of treatments on soil pH and organic carbon content of soil in converted paddy field

A. Soil pH

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	4.03	4.09	4.06	4.11	4.27	4.24	4.13
T_2	4.19	5.70	5.49	5.37	5.49	5.71	5.33
T_3	4.28	4.14	4.12	4.20	4.40	4.27	4.24
T_4	3.89	5.09	5.17	5.30	5.43	5.89	5.13
T_5	4.04	5.06	5.38	5.50	5.69	5.45	5.19
T_6	4.32	5.11	5.20	5.34	5.56	5.60	5.19
T_7	3.97	5.11	5.27	5.24	5.34	5.80	5.12
T_8	4.08	5.17	5.43	5.71	5.78	5.65	5.30
T_9	4.05	5.44	5.46	5.60	5.66	6.01	5.37
T_{10}	4.26	5.17	5.22	5.40	5.46	5.37	5.15
T_{11}	3.98	5.39	5.33	5.52	5.84	5.49	5.26
T_{12}	4.10	5.16	5.11	5.80	5.75	5.98	5.32
CD(0.05)	NS	0.79	0.79	0.82	0.84	0.86	0.15

B. Organic carbon (%)

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.80	0.84	0.69	0.80	0.71	0.87	0.78
T_2	0.83	0.87	0.76	0.89	0.74	0.81	0.82
T_3	0.72	0.91	0.83	0.74	0.68	0.92	0.80
T_4	0.83	0.98	0.72	0.79	0.78	0.86	0.82
T_5	0.83	0.96	0.77	0.84	0.75	0.82	0.83
T_6	0.81	0.95	0.79	0.86	0.80	0.83	0.84
T_7	0.81	0.92	0.78	0.76	0.72	0.84	0.81
T_8	0.80	0.95	0.71	0.75	0.69	0.89	0.80
T_9	0.86	0.97	0.84	0.83	0.85	0.78	0.85
T_{10}	0.81	0.97	0.75	0.82	0.82	0.77	0.82
T_{11}	0.81	0.97	0.85	0.77	0.76	0.76	0.82
T_{12}	0.79	0.93	0.73	0.72	0.73	0.79	0.78
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

Table 4.18 Effect of treatments on chlorophyll-a and chlorophyll-b content of arecanut palm in converted paddy field

A. Chlorophyll-a (mg g^{-1})

Treatment	Chlorophyll-a						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.16	0.11	0.24	0.20	0.28	0.31	0.22
T_2	0.16	0.16	0.53	0.86	0.70	0.85	0.54
T_3	0.15	0.16	0.28	0.38	0.42	0.36	0.29
T_4	0.16	0.17	0.58	0.77	0.68	0.84	0.53
T_5	0.16	0.17	0.56	0.56	0.64	0.64	0.46
T_6	0.15	0.17	0.55	0.79	0.66	0.79	0.52
T_7	0.16	0.18	0.57	0.81	0.72	0.80	0.54
T_8	0.16	0.20	0.61	0.78	0.67	0.85	0.55
T_9	0.15	0.27	0.74	1.08	0.95	1.11	0.72
T_{10}	0.16	0.21	0.56	0.80	0.68	0.87	0.55
T_{11}	0.15	0.24	0.54	0.85	0.64	1.09	0.59
T_{12}	0.15	0.19	0.48	0.56	0.54	0.68	0.43
CD(0.05)	NS	0.028	0.088	0.129	0.108	0.135	NS

B. Chlorophyll-b (mg g^{-1})

Treatment	Chlorophyll-b						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.13	0.18	0.14	0.18	0.31	0.24	0.20
T_2	0.12	0.33	0.47	0.64	0.56	0.80	0.49
T_3	0.12	0.12	0.16	0.20	0.24	0.24	0.18
T_4	0.12	0.12	0.43	0.71	0.56	0.75	0.45
T_5	0.11	0.09	0.46	0.38	0.48	0.54	0.34
T_6	0.12	0.12	0.48	0.65	0.53	0.78	0.45
T_7	0.12	0.12	0.44	0.72	0.54	0.72	0.44
T_8	0.12	0.13	0.41	0.66	0.57	0.73	0.44
T_9	0.11	0.17	0.56	0.89	0.73	1.07	0.59
T_{10}	0.12	0.14	0.42	0.70	0.51	0.72	0.44
T_{11}	0.11	0.16	0.43	0.62	0.58	0.94	0.47
T_{12}	0.12	0.13	0.22	0.42	0.38	0.68	0.33
CD(0.05)	NS	0.018	0.068	0.106	0.087	0.120	0.020

Leaf chlorophyll-b content also followed almost similar pattern as that of chlorophyll-a. It varied from 0.11 to 0.13 percent prior to treatment application (Table 4.18). Application of magnesium sulphate (T_9) resulted in higher leaf chlorophyll-b content over the years. Farmers practice (T_1) and deep drainage (T_3) failed to significantly increase chlorophyll-b content over the years.

Treatment palms prior to application of treatments recorded total chlorophyll in the range of 0.42 to 0.45 percent (Table 4.19). Total chlorophyll of leaf was significantly increased by application of magnesium sulphate (T_9) over the years. Farmers practice (T_1) resulted in significantly lower total chlorophyll content of index leaf over the years.

Yellowing index of arecanut palms varied from 41 to 50 prior to treatment application (Table 4.19). Significant variation in the yellowing index was observed due to treatment effects. Provision of deep drainage (T_3) also was found to reduce yellowing significantly. Magnesium sulphate application (T_9) during second and third year significantly lowered the yellowing index. However farmers practice (T_1) failed to significantly reduce yellowing index over the years. Provision of deep drainage (T3) also was found to reduce yellowing significantly.

4.3.1.4 Effect of treatments on dry kernel weight, number of fruits palm^{-1} and chali yield palm^{-1}

In the treatment palms during the first year of application of treatments, dry kernel weight ranged from 5.55 to 6.75 g (Table 4.20). Compared to farmers practice (T_1) and deep drainage (T_3), all other treatments significantly increased dry kernel weight during second and third year of experiment.

Table 4.19 Effect of treatments on total chlorophyll content and yellowing index of arecanut palm in converted paddy field

A. Total chlorophyll (mg g^{-1})

Treatment	Total chlorophyll						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.44	0.42	0.57	0.49	0.76	0.68	0.56
T_2	0.45	0.68	1.17	1.61	1.43	1.79	1.19
T_3	0.42	0.41	0.62	0.69	0.82	0.72	0.61
T_4	0.44	0.44	1.19	1.60	1.40	1.72	1.13
T_5	0.44	0.44	1.20	1.06	1.28	1.30	0.95
T_6	0.43	0.45	1.21	1.55	1.35	1.70	1.12
T_7	0.45	0.46	1.18	1.65	1.43	1.65	1.14
T_8	0.45	0.48	1.20	1.56	1.40	1.71	1.13
T_9	0.43	0.58	1.52	2.13	1.88	2.43	1.50
T_{10}	0.45	0.49	1.16	1.62	1.37	1.73	1.14
T_{11}	0.43	0.55	1.15	1.60	1.39	2.10	1.20
T_{12}	0.43	0.46	0.88	1.10	1.09	1.49	0.91
CD(0.05)	NS	0.054	0.170	0.253	0.221	0.292	0.038

B. Yellowing index

Treatment	Yellowing index						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	41	38	38	33	36	33	37
T_2	45	21	30	15	23	12	24
T_3	44	34	34	32	34	28	34
T_4	47	18	23	15	24	14	24
T_5	42	28	26	16	22	16	25
T_6	47	16	28	13	18	11	22
T_7	45	15	24	16	18	12	22
T_8	50	13	22	13	24	15	23
T_9	42	9	17	10	13	5	16
T_{10}	44	10	27	18	24	9	22
T_{11}	47	10	30	17	19	7	22
T_{12}	49	27	28	19	18	16	26
CD(0.05)	NS	1.3	1.1	1.2	1.4	1.6	NS

Table 4.20 Effect of treatments on dry kernel weight and number of fruits palm^{-1} in converted paddy field

A. Dry kernel weight (g)

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006
T_1	5.86	6.07	6.48	6.14	0.62
T_2	6.20	6.86	7.17	6.74	0.97
T_3	5.55	5.85	6.30	5.90	0.75
T_4	6.19	6.81	7.52	6.84	1.33
T_5	5.97	6.62	7.21	6.60	1.24
T_6	6.37	6.94	7.53	6.95	1.16
T_7	6.66	7.13	7.83	7.21	1.17
T_8	6.56	7.07	7.90	7.18	1.34
T_9	6.75	7.14	7.93	7.27	1.18
T_{10}	6.57	7.06	7.92	7.18	1.35
T_{11}	6.37	6.97	7.61	6.98	1.24
T_{12}	6.34	6.90	7.62	6.95	1.28
CD(0.05)	NS	0.372	0.385	0.369	

B. Number of fruits palm^{-1}

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006
T_1	437	369	365	390	-72
T_2	432	381	490	434	58
T_3	451	374	365	397	-86
T_4	456	387	501	448	45
T_5	476	379	496	450	20
T_6	411	400	484	432	73
T_7	424	407	487	439	63
T_8	415	396	472	428	57
T_9	416	402	501	440	85
T_{10}	421	398	482	434	61
T_{11}	404	373	474	417	70
T_{12}	421	383	479	428	58
CD(0.05)	NS	NS	73	NS	

Number of fruits harvested per palm ranged from 404 to 416 nos. during first year of experiment (Table 4.20). Treatments failed to manifest any significant variation during second year. However during the third year all treatments except farmers practice (T_1) and deep drainage (T_3) significantly increased the number of fruits per palm.

The dry kernel (*chali*) yields of the treatment palms were recorded during the six harvests from February 2004 to September 2006 and is expressed as year total in Table 4.21. The 2004 yield was not significantly influenced by any of the treatments. However, significant increase in the *chali* yield was observed in the succeeding 2005 and 2006 yields in all the treatments except T_1 and T_3 where no inorganic fertilizers were applied. In Treatment T_1 where the farmers practice was followed, the yield was maintained at the lower level. However provision of deep drainage has improved the yield over farmers practice. In the individual years also significant yield difference was there between T_1, T_3 and the rest of the treatments. The difference between the yield prior to and the years after the application of treatments was highest for T_9 where the recommended magnesium was applied closely followed by T_{10} and T_{11} where zinc and boron respectively were applied. The yield in T_5 was commendably less where no sulphur was applied.

4.3.2 Garden land

4.3.2.1 Effect of treatments on nutrient content in soil and index leaf

4.3.2.1.1 Nitrogen

Treatment plots prior to application of treatments during February 2004 (Table 4.22) recorded available nitrogen content of 200 to 220 kg ha^{-1}with a mean of 210 kg ha^{-1}. Comparative evaluation of treatments revealed that farmers' practice (T_1)

Table 4.21 Effect of treatments on *chali* yield palm^{-1} in converted paddy field

A. *Chali* yield palm^{-1}(kg)

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006	
					kg palm^{-1}	kg ha^{-1}
T_1	2.56	2.24	2.37	2.39	-0.20	-274
T_2	2.68	2.61	3.51	2.94	0.83	1138
T_3	2.50	2.19	2.30	2.33	-0.21	-288
T_4	2.82	2.63	3.77	3.07	0.94	1289
T_5	2.84	2.51	3.58	2.98	0.73	1001
T_6	2.62	2.78	3.64	3.01	1.03	1412
T_7	2.82	2.90	3.81	3.18	0.99	1357
T_8	2.72	2.80	3.73	3.08	1.01	1385
T_9	2.81	2.87	3.97	3.22	1.16	1590
T_{10}	2.77	2.81	3.82	3.13	1.05	1440
T_{11}	2.57	2.60	3.60	2.93	1.03	1412
T_{12}	2.67	2.64	3.65	2.99	0.98	1344
CD(0.05)	NS	0.212	0.250	0.258		

Table 4.22 Effect of treatments on available nitrogen in soil and nitrogen content of arecanut palm in garden land

A. Nitrogen (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	210	239	125	125	201	176	179
T_2	215	291	232	238	278	264	253
T_3	200	240	188	138	213	188	195
T_4	208	317	226	230	308	301	265
T_5	212	297	224	235	295	276	257
T_6	206	317	238	263	290	265	263
T_7	215	320	230	259	281	270	263
T_8	220	371	237	251	286	293	276
T_9	207	368	242	289	317	326	291
T_{10}	217	371	232	245	304	313	280
T_{11}	206	297	251	221	300	256	255
T_{12}	207	310	226	215	272	251	247
CD(0.05)	NS	49	34	36	44	42	NS

B. Nitrogen (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	1.99	1.66	1.42	1.40	1.42	1.39	1.55
T_2	1.86	1.73	1.95	1.73	1.74	1.96	1.83
T_3	1.78	1.66	1.43	1.43	1.45	1.40	1.53
T_4	1.83	1.80	1.73	1.94	1.90	1.74	1.82
T_5	1.95	1.80	1.95	1.83	1.99	1.83	1.89
T_6	1.69	2.02	1.97	1.79	2.04	1.86	1.90
T_7	1.79	2.09	1.89	1.86	1.88	1.95	1.91
T_8	1.81	2.38	1.80	1.71	1.85	1.87	1.90
T_9	1.86	2.09	1.85	1.78	1.97	1.89	1.91
T_{10}	1.99	2.09	1.80	1.87	1.86	1.91	1.92
T_{11}	1.85	1.80	1.73	1.91	1.91	1.81	1.84
T_{12}	1.89	1.95	1.80	1.98	1.93	1.76	1.89
CD(0.05)	NS	0.294	0.275	0.273	0.284	0.275	0.161

and organic manure application (T_3) failed to significantly increase nitrogen content of soil over the years.

Observations on index leaf of arecanut (Table 4.22) prior to application of treatments during February 2004 showed nitrogen content of 1.69 to 1.99 percent with a mean of 1.86 percent. All treatments except farmers' practice (T_1) and organic manure application (T_3) significantly increased nitrogen content of index leaf during second and third year of experiment.

4.3.2.1.2 Phosphorus

Available soil phosphorus (Table 4.23) ranged from 37 to 47 kg ha^{-1} with a mean of 42 kg ha^{-1} before application of treatments. Comparatively lower phosphorus content of soil was resulted in farmers' practice (T_1) and organic manure application (T_3) treatments during second and third year of experiment.

Results showed that phosphorus content of index leaf (Table 4.23) prior to application of treatments ranged from 0.21 to 0.24 percent with a mean of 0.23 percent. Both farmers' practice (T_1) and organic manure application (T_3) did not result in enhancing phosphorus content of index leaf over the years.

4.3.2.1.3 Potassium

Mean available potassium content of 259 kg ha^{-1} was recorded (Table 4.24) prior to application of treatments during February 2004. Available potassium content of soil ranged from 246 to 271 kg ha^{-1}. Treatments namely farmers' practice (T_1) and organic manure application (T_3) failed to bring about significant increase in the available potassium in soil.

Table 4.23 Effect of treatments on available phosphorus in soil and phosphorus content of arecanut palm in garden land

A. Phosphorus (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	47	48	30	26	22	24	33
T_2	41	48	49	39	33	40	42
T_3	42	45	32	27	23	26	33
T_4	42	45	49	47	38	42	44
T_5	41	45	47	45	35	35	41
T_6	37	45	43	43	39	37	41
T_7	39	46	41	44	30	37	40
T_8	45	48	43	46	40	41	44
T_9	38	47	46	38	34	39	40
T_{10}	43	48	46	41	31	38	41
T_{11}	38	42	41	36	36	36	38
T_{12}	45	48	48	35	41	37	42
CD(0.05)	NS	NS	12	8	7	9	NS

B. Phosphorus (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.244	0.142	0.136	0.131	0.156	0.157	0.161
T_2	0.225	0.153	0.194	0.162	0.210	0.205	0.192
T_3	0.230	0.147	0.137	0.133	0.161	0.156	0.161
T_4	0.240	0.186	0.183	0.180	0.201	0.195	0.198
T_5	0.219	0.153	0.198	0.180	0.210	0.207	0.195
T_6	0.236	0.189	0.173	0.184	0.200	0.205	0.198
T_7	0.236	0.189	0.166	0.173	0.196	0.213	0.195
T_8	0.232	0.236	0.193	0.164	0.204	0.190	0.203
T_9	0.209	0.195	0.169	0.175	0.204	0.207	0.193
T_{10}	0.241	0.227	0.168	0.182	0.201	0.203	0.204
T_{11}	0.216	0.155	0.191	0.185	0.196	0.191	0.189
T_{12}	0.232	0.156	0.193	0.178	0.199	0.204	0.194
CD(0.05)	NS	0.027	0.027	0.026	0.030	0.030	0.008

Table 4.24 Effect of treatments on available potassium in soil and potassium content of arecanut palm in garden land

A. Potassium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	258	242	130	120	110	161	170
T_2	265	314	287	314	291	439	318
T_3	246	245	115	161	132	186	181
T_4	256	315	325	534	455	465	392
T_5	261	314	268	336	449	403	338
T_6	253	398	365	520	426	452	402
T_7	265	476	381	511	269	465	394
T_8	271	495	269	448	244	426	359
T_9	254	480	246	495	440	474	398
T_{10}	267	490	224	476	408	480	391
T_{11}	253	393	246	381	381	426	347
T_{12}	255	471	291	543	336	380	379
CD(0.05)	NS	63	43	68	56	65	NS

B. Potassium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.85	0.50	0.53	0.49	0.50	0.52	0.56
T_2	0.79	0.52	0.67	0.68	0.63	0.68	0.66
T_3	0.76	0.51	0.51	0.50	0.49	0.51	0.54
T_4	0.78	0.68	0.87	0.67	0.65	0.65	0.72
T_5	0.83	0.53	0.73	0.64	0.63	0.69	0.67
T_6	0.72	0.71	0.75	0.73	0.70	0.65	0.71
T_7	0.90	0.71	1.00	0.70	0.67	0.62	0.77
T_8	0.86	0.93	0.74	0.73	0.63	0.64	0.75
T_9	0.86	0.75	0.90	0.77	0.61	0.69	0.76
T_{10}	0.85	0.76	0.70	0.75	0.67	0.63	0.73
T_{11}	0.79	0.70	0.94	0.65	0.70	0.62	0.73
T_{12}	0.80	0.67	0.88	0.68	0.63	0.66	0.72
CD(0.05)	NS	0.101	0.118	0.102	0.097	0.097	0.057

The variation in potassium content of index leaf of arecanut (Table 4.24) prior to application of treatments during February 2004 ranged from 0.72 to 0.90 percent with a mean of 0.82 percent. Significantly lower potassium content of index leaf was noticed in treatments namely farmers' practice (T_1) and organic manure application (T_3) over the years. Significantly higher potassium contents were observed in treatments receiving higher amount of potassium of 200 to 250 g palm^{-1} than those supplied with 140 g palm^{-1}.

4.3.2.1.4 Calcium

Available calcium in soil (Table 4.25) prior to application of treatments during February 2004 varied from 1294 to 1510 kg ha^{-1} with a mean of 1424 kg ha^{-1}. Significantly lower calcium contents were observed in treatments namely farmers' practice (T_1) and organic manure application (T_3) during the second and third year of experiment. In T_2 where lime application was done in single dose once in three years, accumulation of available calcium as high as 3078 kg ha^{-1} was observed during September 2004.

A perusal of the data on calcium content of index leaf (Table 4.25) prior to application of treatments during February 2004 showed that calcium content ranged from 0.41 to 0.48 percent with a mean of 0.45 percent. All treatments except farmers' practice (T_1) resulted in significantly higher calcium content of index leaf during second and third year of experiment.

4.3.2.1.5 Magnesium

Data on available magnesium in soil (Table 4.26) prior to application of treatments during February 2004 showed that available magnesium ranged from 155

Table 4.25 Effect of treatments on available calcium in soil and calcium content of arecanut palm in garden land

A. Calcium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	1510	1850	1090	672	915	896	1156
T_2	1394	3028	1830	1254	1747	1336	1765
T_3	1424	1880	1170	980	951	987	1352
T_4	1489	2246	1670	1702	1578	1882	1607
T_5	1353	2000	1610	1210	1320	1837	1555
T_6	1462	2490	2530	1434	1713	1568	1866
T_7	1461	2490	2340	1075	1299	1523	1698
T_8	1434	2640	2650	1523	1389	1434	1845
T_9	1294	2588	2750	1389	1345	1747	1852
T_{10}	1490	2637	1935	1840	1523	1300	1788
T_{11}	1335	2060	1740	1120	1882	1381	1586
T_{12}	1440	2100	2180	1299	1837	1613	1745
CD(0.05)	NS	374	306	308	236	235	NS

B. Calcium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.478	0.423	0.380	0.443	0.535	0.488	0.458
T_2	0.441	0.470	0.528	0.643	0.720	0.634	0.573
T_3	0.450	0.423	0.369	0.440	0.538	0.502	0.454
T_4	0.471	0.517	0.485	0.580	0.680	0.637	0.562
T_5	0.428	0.470	0.485	0.622	0.744	0.687	0.573
T_6	0.462	0.517	0.528	0.598	0.740	0.716	0.594
T_7	0.462	0.517	0.528	0.661	0.680	0.643	0.582
T_8	0.453	0.564	0.480	0.560	0.715	0.733	0.584
T_9	0.409	0.564	0.563	0.620	0.749	0.646	0.592
T_{10}	0.471	0.564	0.528	0.640	0.702	0.644	0.592
T_{11}	0.422	0.517	0.490	0.583	0.730	0.726	0.578
T_{12}	0.455	0.517	0.528	0.568	0.680	0.712	0.577
CD(0.05)	NS	0.077	0.076	0.090	0.106	0.100	0.051

Table 4.26 Effect of treatments on available magnesium in soil and magnesium content of arecanut palm in garden land

A. Magnesium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	183	238	330	283	309	390	289
T_2	171	246	317	287	220	352	265
T_3	164	246	345	250	229	414	275
T_4	168	249	340	242	326	398	287
T_5	179	263	325	269	283	326	274
T_6	155	240	314	208	303	385	268
T_7	193	253	276	237	250	382	265
T_8	184	317	398	334	380	482	349
T_9	184	243	305	257	292	377	276
T_{10}	183	234	283	228	267	336	255
T_{11}	170	237	296	219	213	369	251
T_{12}	173	239	267	276	317	355	271
CD(0.05)	NS	39	49	41	45	60	#

- pooling not possible as errors homogenous and interaction absent.

B. Magnesium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.204	0.162	0.218	0.206	0.265	0.272	0.221
T_2	0.191	0.247	0.233	0.243	0.312	0.369	0.266
T_3	0.182	0.190	0.218	0.209	0.274	0.276	0.225
T_4	0.188	0.247	0.247	0.270	0.312	0.313	0.263
T_5	0.200	0.247	0.227	0.258	0.312	0.373	0.270
T_6	0.173	0.303	0.259	0.264	0.330	0.292	0.270
T_7	0.215	0.303	0.255	0.264	0.288	0.336	0.277
T_8	0.205	0.332	0.304	0.320	0.391	0.434	0.331
T_9	0.205	0.303	0.230	0.240	0.300	0.325	0.267
T_{10}	0.204	0.303	0.230	0.265	0.312	0.295	0.268
T_{11}	0.189	0.247	0.251	0.264	0.300	0.351	0.267
T_{12}	0.193	0.275	0.240	0.276	0.316	0.317	0.270
CD(0.05)	NS	0.041	0.037	0.039	0.048	0.051	0.013

to 193 kg ha^{-1} with a mean of 176 kg ha^{-1}. Application of magnesium sulphate (T_8) resulted in significantly higher magnesium content of soil with a mean content of 349 kg ha^{-1}. Treatments except T_8 manifested no significant variation in the magnesium content of soil over the years.

At pre treatment application stage during February 2004, magnesium in the index leaf (Table 4.26) ranged from 0.17 to 0.22 percent with a mean content of 0.20 percent. The effect of application of magnesium sulphate (T_8) was significantly evident in index leaf during second and third year of experiment and the content varied from 0.302 to 0.434 percent with a mean of 0.331 percent.

4.3.2.1.6 Sulphur

Observations on sulphur content in the top soil showed that available sulphur ranged from 12 to 14 kg ha^{-1} before the imposition of treatments (Table 4.27). Treatments namely farmers' practice (T_1) and organic manure application (T_3) during September 2004, February 2005 and September 2006, treatments T_2, T_5, T_{11} and T_{12} during September 2005 and treatments T_1, T_2, T_3, T_5 and T_{11} during February 2006 resulted in significantly lower soil sulphur contents. In the sulphur applied treatments, the content of sulphur was 34-35 kg ha^{-1}.

Variation in sulphur content of index leaf (Table 4.27) prior to application of treatments during February 2004 ranged from 0.22 to 0.26 percent with a mean of 0.24 percent. All treatments involving application of ammonium sulphate (T_4, T_6, T_7, T_8, T_9 and T_{10}) resulted in significantly higher sulphur content of index leaf ranging from 0.30 percent to 0.348 percent during second and third year of experiment.

Table 4.27 Effect of treatments on available sulphur in soil and sulphur content of arecanut palm in garden land

A. Sulphur (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	14	15	13	24	18	18	17
T_2	13	21	30	23	19	31	23
T_3	13	18	14	24	17	17	17
T_4	14	33	41	39	38	44	35
T_5	12	23	29	20	16	33	22
T_6	13	33	45	32	36	48	34
T_7	13	34	38	42	29	47	34
T_8	13	41	44	35	27	45	34
T_9	12	37	40	45	32	46	35
T_{10}	14	39	42	33	34	43	34
T_{11}	12	27	22	21	20	32	22
T_{12}	13	28	24	18	21	31	23
CD(0.05)	NS	5	5	5	4	6	NS

B. Sulphur (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.255	0.210	0.216	0.218	0.212	0.216	0.221
T_2	0.235	0.268	0.377	0.340	0.334	0.326	0.313
T_3	0.240	0.226	0.286	0.288	0.280	0.223	0.257
T_4	0.251	0.309	0.306	0.313	0.310	0.362	0.309
T_5	0.228	0.293	0.274	0.259	0.317	0.335	0.284
T_6	0.246	0.353	0.327	0.381	0.307	0.341	0.326
T_7	0.246	0.376	0.314	0.393	0.353	0.364	0.341
T_8	0.242	0.365	0.365	0.381	0.383	0.354	0.348
T_9	0.218	0.353	0.327	0.360	0.362	0.383	0.334
T_{10}	0.251	0.300	0.378	0.360	0.387	0.368	0.341
T_{11}	0.225	0.250	0.280	0.250	0.215	0.236	0.243
T_{12}	0.243	0.278	0.271	0.206	0.219	0.230	0.241
CD(0.05)	NS	0.072	0.070	0.062	0.068	0.053	0.013

4.3.2.1.7 Iron

Available iron content of soil at 0-25 cm (Table 4.28) prior to application of treatments during February 2004 ranged from 102 to 119 kg ha^{-1} with a mean of 113 kg ha^{-1}. Pooled mean values showed that treatments failed to cause significant variation in zinc content of soil over the years.

The leaf iron content before the application of treatments varied from 256 to 281 ppm with a mean of 269 ppm (Table 4.28). Treatments did not impart any significant variation in the iron content of leaf over the years.

4.3.2.1.8 Manganese

Available soil manganese prior to treatment application varied from 58 to 69 t ha^{-1} (Table 4.29). Treatments failed to register any significant variation in available soil manganese over the years.

Leaf manganese content (Table 4.29) varied from 158 to 184 ppm before application of treatments. Response to application of treatments was not evident in the manganese content of leaf over the years.

4.3.2.1.9 Zinc

Comparison of different treatments plots showed that prior to application of treatments, available zinc content of soil ranged from 24 to 26 kg ha^{-1} (Table 4.30). Highest zinc content as shown by the pooled mean was observed in T_9 where zinc sulphate was applied in the basin at 20 g $palm^{-1}$.

Table 4.28 Effect of treatments on available iron in soil and iron content of arecanut palm in garden land

A. Iron (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	119	116	170	190	309	254	193
T_2	110	123	167	180	283	298	194
T_3	113	114	173	208	317	271	199
T_4	118	119	158	186	326	283	198
T_5	107	110	168	181	305	267	190
T_6	116	117	171	178	296	287	194
T_7	115	110	166	203	280	290	194
T_8	113	111	175	213	287	245	191
T_9	102	121	163	210	290	274	193
T_{10}	118	112	166	204	337	261	200
T_{11}	106	109	165	200	276	306	194
T_{12}	114	108	161	192	301	278	192
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Iron (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	269	425	265	442	345	431	363
T_2	275	481	262	472	358	446	382
T_3	256	475	268	456	383	467	384
T_4	266	469	313	467	386	460	394
T_5	271	416	279	494	352	430	374
T_6	263	460	280	461	378	435	380
T_7	275	482	259	445	372	445	380
T_8	281	453	307	475	356	408	380
T_9	264	428	307	447	397	442	381
T_{10}	278	471	272	470	347	422	377
T_{11}	263	423	320	445	358	426	372
T_{12}	265	468	293	439	375	440	380
CD(0.05)	NS	NS	43.931	NS	NS	NS	NS

Table 4.29 Effect of treatments on available manganese in soil and manganese content of arecanut palm in garden land

A. Manganese (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	64	76	86	97	97	86	84
T_2	66	78	81	89	89	91	83
T_3	58	79	79	102	93	88	83
T_4	67	74	85	90	94	94	84
T_5	67	78	83	95	104	96	87
T_6	65	75	83	87	101	92	84
T_7	66	81	79	100	88	91	84
T_8	64	80	82	104	91	79	83
T_9	69	82	84	94	98	87	86
T_{10}	65	80	81	90	103	91	85
T_{11}	65	76	80	107	86	90	84
T_{12}	64	75	84	92	100	82	83
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

B. Manganese (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	184	145	93	125	151	172	145
T_2	170	146	104	119	126	154	136
T_3	174	145	107	114	139	156	139
T_4	182	160	93	126	141	167	145
T_5	165	149	105	117	124	158	136
T_6	178	149	90	127	143	162	142
T_7	178	159	103	118	127	167	142
T_8	175	154	100	132	139	165	144
T_9	158	134	93	109	144	169	134
T_{10}	182	131	88	121	141	154	136
T_{11}	163	139	100	124	144	152	137
T_{12}	176	153	111	134	140	164	146
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.30 Effect of treatments on available zinc in soil and zinc content of arecanut palm in garden land

A. Zinc (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	25.2	27.2	25.9	27.6	25.1	21.5	25.4
T_2	25.8	26.6	27.4	21.5	26.5	20.4	24.7
T_3	24.0	28.0	26.3	23.0	24.8	21.3	24.6
T_4	25.0	26.8	26.2	26.7	28.0	22.6	25.9
T_5	25.4	26.2	25.5	24.8	24.2	23.0	24.9
T_6	24.7	25.7	24.4	20.6	25.6	21.7	23.8
T_7	25.8	23.9	27.0	23.5	23.9	24.5	24.8
T_8	26.4	26.0	25.0	24.0	27.0	22.2	25.1
T_9	24.8	33.9	35.2	36.6	37.7	33.7	33.6
T_{10}	26.0	24.6	26.7	22.2	26.0	20.8	24.4
T_{11}	24.6	23.3	24.0	26.0	23.7	21.9	23.9
T_{12}	24.8	25.5	23.9	25.5	24.6	23.4	24.6
CD(0.05)	NS	4.2	4.1	4.0	4.2	3.7	1.659

B. Zinc (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	24.7	23.3	21.3	22.0	27.0	23.5	23.6
T_2	23.0	21.1	20.0	24.3	23.0	24.3	22.6
T_3	22.1	22.3	20.5	23.0	28.0	26.7	23.8
T_4	22.7	24.7	20.1	22.0	27.0	24.0	23.4
T_5	24.2	25.6	20.9	24.7	25.8	25.8	24.5
T_6	20.9	24.6	19.9	24.0	27.0	26.5	23.8
T_7	26.0	23.2	19.7	24.6	25.0	23.9	23.7
T_8	24.8	24.1	22.6	23.0	27.0	26.0	24.6
T_9	24.8	22.8	22.3	22.0	26.0	25.0	23.8
T_{10}	24.7	25.8	22.7	25.0	25.7	25.0	24.8
T_{11}	22.9	21.6	21.3	24.4	24.8	23.0	23.0
T_{12}	23.4	21.9	24.2	24.3	23.8	26.0	23.9
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Zinc content of leaf (Table 4.30) prior to treatment application varied from 21 to 26 ppm with a mean of 24 ppm. Treatments resulted in no significant variation in leaf zinc content over the years. No increase in zinc content of leaf was observed in the treatment where zinc sulphate was applied.

4.3.2.1.10 Copper

Content of available copper in soil prior to treatment application varied from 15 to 17 kg ha^{-1} (Table 4.31). Application of treatments failed to bring about any significant variation in the copper content of soil over the years.

Index leaf of arecanut recorded copper content in the range of 10.2 to 11.9 percent before application of treatments (Table 4.31). There was no significant variation in copper content of index leaf due to application of treatments over the years.

4.3.2.1.11 Boron

Prior to application of treatments during February 2004, available boron content varied from 7.6 to 9.4 kg ha^{-1} with a mean of 8.5 kg ha^{-1} (Table 4.32). Application of borax (T_{10}) resulted in significant increase to 10.86 kg ha^{-1} in the boron content of soil over the years.

Index leaf of arecanut (Table 4.32) prior to application of treatments during February 2004 recorded boron content of 81 to 87 percent with a mean of 84 ppm. The leaf boron content when borax was applied was significantly higher in treatment (T_{10}) during the second year of experiment. However during the third year treatments did not manifest any significant variation in the boron content of index leaf. The

Table 4.31 Effect of treatments on available copper in soil and copper content of arecanut palm in garden land

A. Copper (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	17.2	17.7	18.2	17.0	17.5	17.0	17.4
T_2	16.0	17.5	19.3	15.9	16.3	15.4	16.7
T_3	16.3	18.3	17.1	17.7	18.2	15.2	17.1
T_4	16.8	18.5	18.1	16.1	17.2	17.5	17.4
T_5	15.6	17.0	18.5	18.0	17.6	17.9	17.4
T_6	16.7	17.5	17.9	15.7	18.5	16.9	17.2
T_7	16.6	18.6	17.6	17.3	15.8	18.8	17.4
T_8	16.4	19.5	18.8	18.6	16.9	15.7	17.6
T_9	15.0	18.3	17.8	19.1	17.8	16.5	17.4
T_{10}	16.9	17.1	16.8	17.6	19.2	17.3	17.5
T_{11}	15.4	17.4	17.4	16.4	15.2	18.4	16.7
T_{12}	16.4	16.8	19.1	16.7	18.7	16.1	17.3
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Copper (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	11.9	12.8	9.7	17.5	12.2	14.6	13.1
T_2	10.9	13.0	8.3	16.6	12.2	15.3	12.7
T_3	11.2	13.4	9.4	18.6	11.9	17.4	13.6
T_4	11.7	14.0	9.7	16.3	12.8	16.8	13.6
T_5	10.6	14.6	9.7	18.1	13.0	15.5	13.6
T_6	11.5	14.6	7.7	15.7	12.3	17.1	13.1
T_7	11.5	14.0	9.2	16.5	12.8	15.4	13.2
T_8	11.3	13.8	9.6	15.7	13.0	14.4	12.9
T_9	10.2	13.8	8.9	15.1	13.0	16.0	12.8
T_{10}	11.7	14.3	9.9	15.5	13.3	16.0	13.4
T_{11}	10.5	13.5	9.2	17.8	13.1	17.2	13.5
T_{12}	11.3	13.7	8.9	15.8	12.9	16.9	13.2
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.32 Effect of treatments on available boron in soil and boron content of arecanut palm in garden land

A. Boron (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	8.29	8.56	8.18	8.04	7.80	7.85	8.12
T_2	8.94	7.75	7.89	8.85	8.40	7.67	8.25
T_3	8.40	8.64	7.53	9.33	8.88	8.20	8.50
T_4	9.24	8.00	8.68	7.91	8.25	8.48	8.43
T_5	8.77	8.23	8.47	9.06	9.20	7.49	8.54
T_6	8.56	9.12	8.32	8.29	7.44	8.03	8.29
T_7	7.96	8.40	7.75	7.72	8.70	8.65	8.20
T_8	8.13	9.52	8.00	8.52	9.06	6.94	8.36
T_9	7.80	8.88	7.25	7.47	8.00	7.26	7.78
T_{10}	9.36	11.74	10.26	11.84	11.36	10.60	10.86
T_{11}	9.06	9.28	7.39	8.73	8.61	8.40	8.58
T_{12}	7.60	8.80	8.90	9.60	9.36	7.10	8.56
CD(0.05)	NS	1.41	1.28	1.39	1.38	1.27	0.553

B. Boron (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	83	71	98	104	113	116	97
T_2	82	97	106	110	125	124	107
T_3	86	73	94	107	114	110	97
T_4	85	147	105	105	128	128	116
T_5	87	101	103	111	121	115	106
T_6	86	149	111	115	109	120	115
T_7	84	151	104	131	108	122	117
T_8	85	190	119	113	115	131	126
T_9	85	164	93	115	127	125	118
T_{10}	86	231	178	167	130	139	155
T_{11}	81	106	92	139	134	118	112
T_{12}	82	108	98	106	111	123	105
CD(0.05)	NS	21	17	18	NS	NS	9.245

mean content of boron applied treatment was 155 ppm against 97 to 126 ppm in treatments where boron was not applied.

4.3.2.1.12 Silicon

The total silicon was to the tune of 312 to 381 t ha^{-1} in various treatment plots during February 2004 (Table 4.33). No significant variation in the silicon content of soil was noticed over the years.

The initial leaf silicon content ranged from 0.51 to 0.56 percent before the treatment application (Table 4.33). The contents did not vary significantly due to the application of treatments. External application of silicon as sodium silicate did not result in enhancement of plant silicon content.

4.3.2.1.13 Aluminium

Soil available aluminium prior to application of treatments (Table 4.34) varied from 83 to 99 kg ha^{-1}. Any significant change in available aluminium content was not observed due to treatments.

The aluminium status of index leaf prior to application of treatments ranged from 124 to 136 ppm (Table 4.34). Treatments did not register any significant variation in leaf aluminium content over the years.

4.3.2.2 Effect of treatments on soil pH and organic carbon content of soil

The variation in soil pH was not marked during February 2004 and varied from 5.08 to 5.47 (Table 4.35). But over the years, all treatments except farmers’

Table 4.33 Effect of treatments on total silicon in soil and silicon content of arecanut palm in garden land

A. Silicon (t ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	381	359	365	381	357	320	361
T_2	323	377	333	355	350	335	346
T_3	330	317	343	317	383	350	340
T_4	345	366	370	370	337	314	350
T_5	312	330	309	330	307	303	315
T_6	317	344	381	305	377	310	339
T_7	361	305	390	363	363	382	361
T_8	337	323	351	375	343	341	345
T_9	353	371	375	341	329	357	354
T_{10}	373	352	323	347	323	370	348
T_{11}	375	335	357	325	370	329	349
T_{12}	368	314	363	337	315	317	336
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Silicon (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.53	0.56	0.71	0.88	0.92	0.96	0.76
T_2	0.55	0.58	0.77	1.14	1.17	1.32	0.92
T_3	0.51	0.56	0.92	0.92	0.94	0.94	0.80
T_4	0.53	0.51	0.91	1.20	1.36	1.31	0.97
T_5	0.54	0.68	0.93	1.10	1.28	1.34	0.98
T_6	0.52	0.64	0.89	1.14	1.29	1.24	0.95
T_7	0.55	0.65	0.84	1.19	1.22	1.26	0.95
T_8	0.56	0.68	0.87	1.29	1.29	1.29	1.00
T_9	0.53	0.67	0.81	1.16	1.40	1.32	0.98
T_{10}	0.55	0.68	0.83	1.32	1.30	1.24	0.99
T_{11}	0.52	0.68	0.79	1.27	1.34	1.26	0.98
T_{12}	0.53	0.64	0.78	1.32	1.30	1.28	0.98
CD(0.05)	NS	0.07	NS	NS	NS	NS	NS

Table 4.34 Effect of treatments on available aluminium in soil and aluminium content of arecanut palm in garden land

A. Aluminium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	91	91	89	83	87	92	89
T_2	95	89	98	88	90	88	91
T_3	83	82	92	96	84	94	88
T_4	90	92	94	91	88	89	91
T_5	92	96	81	93	91	84	90
T_6	86	94	88	94	98	87	91
T_7	93	93	80	83	82	91	87
T_8	99	97	90	99	93	95	95
T_9	88	85	83	85	95	99	89
T_{10}	96	100	86	87	86	86	90
T_{11}	85	95	96	84	86	97	90
T_{12}	89	87	85	89	83	82	86
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Aluminium (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	130	149	111	97	91	82	110
T_2	133	122	107	90	82	80	102
T_3	124	137	100	85	77	86	102
T_4	129	104	95	86	88	87	98
T_5	131	126	97	91	84	88	103
T_6	127	110	95	90	79	83	97
T_7	133	118	96	83	90	81	100
T_8	136	120	95	88	76	91	101
T_9	128	118	93	86	75	84	97
T_{10}	134	123	89	86	80	88	100
T_{11}	127	118	97	83	75	86	98
T_{12}	128	119	90	85	82	83	98
CD(0.05)	NS	18.974	NS	NS	NS	NS	NS

Table 4.35 Effect of treatments on soil pH and organic carbon content of soil in garden land

A. Soil pH

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	5.41	4.77	4.71	4.43	4.58	4.55	4.74
T_2	5.47	6.73	6.22	5.68	5.84	5.87	5.97
T_3	5.44	4.84	4.83	4.52	4.52	4.49	4.77
T_4	5.13	6.32	6.03	6.30	6.06	6.00	5.97
T_5	5.29	6.40	6.13	6.20	5.96	5.78	5.96
T_6	5.34	6.41	6.25	5.56	5.74	5.93	5.87
T_7	5.39	6.57	6.18	5.49	5.78	6.06	5.91
T_8	5.24	6.38	6.32	5.62	6.20	6.28	6.01
T_9	5.37	6.47	6.08	5.80	6.18	6.15	6.01
T_{10}	5.31	6.45	5.96	6.06	5.87	5.84	5.91
T_{11}	5.10	6.53	6.29	5.93	6.09	5.90	5.97
T_{12}	5.08	6.47	6.05	5.84	5.90	6.20	5.92
CD(0.05)	NS	0.97	0.91	0.88	0.90	0.90	0.170

B. Organic carbon (%)

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.78	0.83	0.83	0.81	0.75	0.79	0.80
T_2	0.72	0.82	0.75	0.75	0.77	0.74	0.76
T_3	0.73	0.85	0.74	0.73	0.73	0.71	0.75
T_4	0.77	0.84	0.81	0.76	0.73	0.68	0.76
T_5	0.70	0.77	0.79	0.76	0.79	0.84	0.77
T_6	0.75	0.87	0.85	0.80	0.72	0.78	0.79
T_7	0.75	0.83	0.82	0.83	0.83	0.72	0.80
T_8	0.74	0.82	0.80	0.78	0.85	0.69	0.78
T_9	0.67	0.80	0.77	0.82	0.87	0.77	0.78
T_{10}	0.77	0.86	0.75	0.79	0.74	0.71	0.77
T_{11}	0.69	0.74	0.78	0.85	0.82	0.75	0.77
T_{12}	0.74	0.81	0.81	0.86	0.80	0.81	0.81
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

practice (T_1) and organic manure application (T_3) resulted in significantly higher soil pH.

Soil organic carbon content ranged from 0.67 to 0.78 percent prior to application of treatments (Table 4.35). Pooled analysis over the years showed that the organic carbon content of soil was not significantly influenced by treatments.

4.3.2.3 Effect of treatments on chlorophyll-a, chlorophyll-b, total chlorophyll and yellowing index

Leaf chlorophyll-a content varied from 0.50 to 0.54 percent (Table 4.36). During second and third year, the chlorophyll-a content was significantly and consistently higher in index leaf due to application of magnesium sulphate (T_8).

Almost similar pattern as that of chlorophyll-a was followed by leaf chlorophyll-b content. It varied from 0.40 to 0.48 percent prior to treatment application (Table 4.36). Application of magnesium sulphate (T_8) resulted in higher leaf chlorophyll-b content over the years. Farmers practice (T_1) and organic manure application (T_3) failed to bring about any significant increase of chlorophyll-b content over the years.

Total chlorophyll in treatment palms prior to application of treatments ranged from 1.06 to 1.19 percent (Table 4.37). Total chlorophyll of leaf was significantly increased by application of magnesium sulphate (T_8) over the years with a mean content of 1.68 mg g^{-1}. Farmers practice (T_1) and organic manure application (T_3) resulted in significantly lower total chlorophyll content of index leaf over the years.

Arecanut palms recorded varying yellowing index from 40 to 50 prior to treatment application (Table 4.37). Significant variation in the yellowing index was

Table 4.36 Effect of treatments on chlorophyll-a and chlorophyll-b content of arecanut palm in garden land

A. Chlorophyll-a (mg g^{-1})

Treatment	Chlorophyll-a						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.52	0.24	0.50	0.61	0.58	0.61	0.51
T_2	0.52	0.26	0.55	0.79	0.66	1.08	0.64
T_3	0.54	0.24	0.51	0.64	0.59	0.76	0.55
T_4	0.54	0.20	0.58	0.87	0.69	1.12	0.67
T_5	0.54	0.27	0.52	0.82	0.64	1.12	0.65
T_6	0.54	0.24	0.57	0.81	0.63	1.10	0.65
T_7	0.52	0.24	0.57	0.87	0.61	1.10	0.65
T_8	0.54	0.25	0.82	1.11	0.97	1.13	0.80
T_9	0.54	0.28	0.53	0.83	0.62	1.07	0.65
T_{10}	0.54	0.28	0.51	0.80	0.68	1.11	0.65
T_{11}	0.50	0.28	0.58	0.82	0.66	1.07	0.65
T_{12}	0.52	0.29	0.56	0.85	0.64	1.07	0.66
CD(0.05)	NS	0.029	0.089	0.130	0.103	0.173	NS

B. Chlorophyll-b (mg g^{-1})

Treatment	Chlorophyll-b						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.46	0.20	0.45	0.48	0.43	0.46	0.41
T_2	0.42	0.28	0.47	0.74	0.61	0.88	0.57
T_3	0.40	0.22	0.48	0.51	0.41	0.48	0.42
T_4	0.42	0.38	0.50	0.65	0.55	0.88	0.56
T_5	0.44	0.30	0.49	0.66	0.60	0.87	0.56
T_6	0.42	0.38	0.45	0.70	0.57	0.86	0.56
T_7	0.48	0.38	0.46	0.75	0.62	0.86	0.59
T_8	0.46	0.66	0.63	0.92	0.75	0.89	0.72
T_9	0.46	0.40	0.44	0.69	0.53	0.82	0.56
T_{10}	0.46	0.42	0.46	0.67	0.57	0.84	0.57
T_{11}	0.42	0.32	0.43	0.72	0.60	0.85	0.56
T_{12}	0.44	0.32	0.48	0.70	0.52	0.82	0.55
CD(0.05)	NS	0.027	0.074	0.111	0.090	0.120	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.37 Effect of treatments on total chlorophyll content and yellowing index of arecanut palm in garden land

A. Total chlorophyll

Treatment	Total chlorophyll						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	1.08	0.55	1.05	1.19	1.19	1.21	1.05
T_2	1.08	0.66	1.12	1.63	1.43	2.11	1.34
T_3	1.11	0.57	1.18	1.25	1.17	1.38	1.11
T_4	1.10	0.69	1.27	1.62	1.40	2.13	1.37
T_5	1.11	0.68	1.11	1.59	1.40	2.12	1.34
T_6	1.10	0.74	1.12	1.62	1.37	2.11	1.34
T_7	1.11	0.74	1.22	1.72	1.40	2.09	1.38
T_8	1.19	1.10	1.62	2.14	1.88	2.17	1.68
T_9	1.14	0.80	1.16	1.63	1.31	2.02	1.34
T_{10}	1.10	0.84	1.16	1.59	1.42	2.09	1.37
T_{11}	1.06	0.70	1.20	1.65	1.43	2.06	1.35
T_{12}	1.07	0.72	1.23	1.66	1.35	2.03	1.34
CD(0.05)	NS	0.057	0.177	0.257	0.220	0.218	0.057

B. Yellowing index

Treatment	Yellowing index						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	40	47	56	49	44	38	46
T_2	40	38	23	17	20	16	26
T_3	40	45	38	38	28	36	38
T_4	42	37	30	22	20	18	28
T_5	40	37	28	12	17	16	25
T_6	41	37	25	17	19	9	25
T_7	49	37	23	11	14	9	24
T_8	44	28	17	8	12	7	19
T_9	44	36	17	19	12	9	23
T_{10}	45	29	24	15	18	10	24
T_{11}	50	37	22	14	15	9	25
T_{12}	47	37	24	15	18	10	25
CD(0.05)	NS	1.7	1.4	1.3	1.8	1.6	NS

observed due to treatment effects. Application of inorganic fertilizers was found to reduce the index value consistently and significantly. In farmers practice (T_1) and organic manure application (T_3), where no fertilizers were applied, it ranged in the higher side between 38 to 57 in T_1 and 28 to 40 in T_3. Magnesium sulphate application (T_8) significantly lowered the yellowing index over the years and the mean index was as low as 19.

4.3.2.4 Effect of treatments on dry kernel weight, number of fruits palm^{-1} and chali yield palm^{-1}

During the first year of application of treatments, dry kernel weight in the treatment palms ranged from 5.81 to 7.01 g (Table 4.38). Compared to farmers practice (T_1) and organic manure application (T_3), all other treatments significantly increased dry kernel weight during second and third year of experiment. Application of ammonium sulphate ((T_4, T_6, T_7, T_8, T_9 and T_{10}) significantly increased the dry kernel weight.

Data presented in Table 4.38 showed that number of fruits harvested per palm ranged from 393 to 463 nos. during first year of experiment. Treatments failed to manifest any significant variation during second year. However during the third year all treatments except farmers practice (T_1) and organic manure application (T_3) significantly increased the number of fruits per palm.

During 2004 (Table 4.39), *chali* yield was not significantly influenced by any treatments and ranged from 2.48 to 2.92 kg palm^{-1}. Significantly higher *chali* yield over the years was observed in treatment palms due to application of ammonium sulphate ((T_4, T_6, T_7, T_8, T_9 and T_{10}). All treatments except farmers practice (T_1) and organic manure application (T_3) where no inorganic fertilizers were applied showed no significant increase in *chali* yield over the years. However organic manure

Table 4.38 Effect of treatments on dry kernel weight and number of fruits palm^{-1} in garden land

A. Dry kernel weight (g)

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006
T_1	5.84	5.77	5.98	5.86	0.14
T_2	6.11	6.67	7.06	6.61	0.95
T_3	5.81	5.89	6.18	5.96	0.37
T_4	6.87	7.26	7.59	7.24	0.72
T_5	6.30	6.84	7.06	6.73	0.76
T_6	6.90	7.30	7.63	7.28	0.73
T_7	6.85	7.22	7.57	7.21	0.72
T_8	7.01	7.34	7.73	7.36	0.72
T_9	6.91	7.33	7.67	7.30	0.76
T_{10}	7.01	7.39	7.60	7.33	0.59
T_{11}	6.06	6.66	6.88	6.53	0.82
T_{12}	6.08	6.69	6.94	6.57	0.86
CD(0.05)	NS	0.226	0.257	0.184	

B. Number of fruits palm^{-1}

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006
T_1	425	381	372	393	-53
T_2	429	409	482	440	53
T_3	437	388	364	396	-73
T_4	393	408	491	431	98
T_5	419	403	510	444	91
T_6	394	410	480	428	86
T_7	403	426	501	443	98
T_8	402	419	516	446	114
T_9	423	393	488	435	65
T_{10}	409	414	505	443	96
T_{11}	463	422	527	471	64
T_{12}	450	407	506	454	56
CD(0.05)	NS	NS	75	NS	

Table 4.39 Effect of treatments on *chali* yield palm^{-1} in garden land

A. *Chali* yield palm^{-1}(kg)

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006	
					kg palm^{-1}	kg ha^{-1}
T_1	2.48	2.20	2.22	2.30	-0.26	-356
T_2	2.62	2.73	3.40	2.92	0.78	1069
T_3	2.54	2.29	2.25	2.36	-0.29	-398
T_4	2.70	2.96	3.73	3.13	1.03	1412
T_5	2.64	2.76	3.60	3.00	0.96	1316
T_6	2.72	2.99	3.66	3.12	0.94	1289
T_7	2.76	3.08	3.79	3.21	1.03	1412
T_8	2.82	3.07	3.99	3.29	1.17	1604
T_9	2.92	2.88	3.74	3.18	0.82	1124
T_{10}	2.87	3.06	3.84	3.25	0.97	1330
T_{11}	2.80	2.81	3.62	3.08	0.82	1124
T_{12}	2.74	2.72	3.51	2.99	0.78	1069
CD(0.05)	NS	0.239	0.347	0.191		

application (T_3) has improved the yield over farmers practice (T_1). An increasing yield trend was observed for the treatments which received nitrogen and potassium at higher rates.

4.3.3 Terraced upland

4.3.3.1 Effect of treatments on nutrient content in soil and index leaf

4.3.3.1.1 Nitrogen

Observations on nitrogen content in the top soil showed that available nitrogen ranged from 267 to 312 kg ha^{-1} with a mean of 294 kg ha^{-1} before the imposition of treatments (Table 4.40). Treatments namely farmers' practice (T_1) and organic manure application (T_3) failed to significantly increase soil nitrogen contents.

Variation in nitrogen content of index leaf (Table 4.40) prior to application of treatments during February 2004 ranged from 1.42 to 1.56 percent with a mean of 1.49 percent. All treatments involving farmers' practice (T_1) and organic manure application (T_3) failed to significantly increase nitrogen content of index leaf during second and third year of experiment.

4.3.3.1.2 Phosphorus

Soil available phosphorus prior to application of treatments (Table 4.41) varied from 25 to 65 kg $ha^{-1}$with a mean of 40 kg ha^{-1}. Farmers' practice (T_1) failed to significantly increase available phosphorus in soil during second and third year of experiment.

Table 4.40 Effect of treatments on available nitrogen in soil and nitrogen content of arecanut palm in terraced upland

A. Nitrogen (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	312	226	204	151	208	232	222
T_2	288	294	301	289	328	293	299
T_3	294	240	248	238	219	237	246
T_4	307	317	294	314	339	326	316
T_5	279	300	285	351	364	300	313
T_6	301	329	289	301	316	290	304
T_7	301	336	278	314	298	314	307
T_8	296	397	259	276	325	320	312
T_9	267	352	280	263	334	309	301
T_{10}	307	371	262	314	310	295	310
T_{11}	275	304	268	281	320	286	289
T_{12}	297	317	263	276	351	303	301
CD(0.05)	NS	50	42	45	49	46	21

B. Nitrogen (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	1.49	1.24	1.27	1.22	1.31	1.32	1.31
T_2	1.53	1.73	1.66	1.70	1.65	1.65	1.65
T_3	1.42	1.36	1.29	1.23	1.30	1.31	1.32
T_4	1.48	2.02	1.85	1.64	1.70	1.76	1.74
T_5	1.51	1.87	1.66	1.60	1.59	1.70	1.66
T_6	1.46	2.02	1.56	1.68	1.82	1.71	1.71
T_7	1.53	2.09	1.77	1.77	1.76	1.73	1.78
T_8	1.56	2.38	1.73	1.70	1.67	1.69	1.79
T_9	1.47	2.16	1.71	1.68	1.59	1.69	1.72
T_{10}	1.54	2.31	1.72	1.63	1.60	1.72	1.75
T_{11}	1.46	1.95	1.66	1.49	1.68	1.64	1.65
T_{12}	1.47	1.95	1.99	1.57	1.62	1.58	1.70
CD(0.05)	NS	0.295	0.248	0.240	0.253	0.252	NS

Table 4.41 Effect of treatments on available phosphorus in soil and phosphorus content of arecanut palm in terraced upland

A. Phosphorus (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	33	29	18	15	17	15	21
T_2	61	65	97	75	63	26	65
T_3	25	28	24	22	28	18	24
T_4	31	30	28	26	34	32	30
T_5	29	21	27	25	31	20	26
T_6	28	26	26	24	38	25	28
T_7	28	27	27	23	36	27	28
T_8	63	63	82	72	70	19	62
T_9	57	59	91	69	65	26	61
T_{10}	65	68	83	71	66	40	66
T_{11}	30	26	19	26	37	29	28
T_{12}	33	31	29	27	38	31	32
CD(0.05)	NS	NS	6	5	7	6	3.18

B. Phosphorus (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.206	0.120	0.111	0.103	0.110	0.115	0.127
T_2	0.210	0.170	0.137	0.141	0.134	0.146	0.156
T_3	0.204	0.129	0.109	0.102	0.111	0.114	0.128
T_4	0.206	0.202	0.144	0.151	0.155	0.148	0.167
T_5	0.195	0.170	0.140	0.137	0.137	0.153	0.155
T_6	0.199	0.205	0.144	0.149	0.155	0.149	0.167
T_7	0.195	0.207	0.158	0.135	0.135	0.147	0.163
T_8	0.205	0.220	0.139	0.128	0.134	0.145	0.162
T_9	0.211	0.207	0.148	0.128	0.149	0.144	0.165
T_{10}	0.200	0.210	0.154	0.126	0.141	0.142	0.162
T_{11}	0.204	0.170	0.144	0.125	0.157	0.143	0.157
T_{12}	0.205	0.172	0.140	0.137	0.135	0.152	0.157
CD(0.05)	NS	0.028	0.021	0.020	0.021	0.022	NS

The phosphorus status of index leaf prior to application of treatments ranged from 0.20 to 0.21 percent (Table 4.41). Treatments namely farmers' practice (T_1) and organic manure application (T_3) consistently recorded lower phosphorus content in leaves than those which received the inorganic fertilizers.

4.3.3.1.3 Potassium

Data on available potassium in soil (Table 4.42) prior to application of treatments during February 2004 showed that available potassium ranged from 288 to 336 kg ha^{-1} with a mean of 317 kg ha^{-1}. Application of organic manure (T_3) and farmers' practice (T_1) failed to significantly increase potassium content of soil over the years.

At pre treatment application stage during February 2004, potassium in the index leaf (Table 4.42) ranged from 0.64 to 0.70 percent with a mean content of 0.67 percent. Application of organic manure (T_3) and farmers' practice (T_1) failed cause significant increase in potassium content of index leaf over the years. Treatment T_8 which received K at higher rate together with magnesium sulphate resulted in the highest leaf potassium content.

4.3.3.1.4 Calcium

Comparison of different treatments plots showed that prior to application of treatments, available calcium content of soil ranged from 905 to 993 kg ha^{-1} (Table 4.43) with a mean of 950 kg ha^{-1}. During September 2004, highest calcium content of soil was observed in treatment plots under package of practices (T_2)

Calcium content of leaf (Table 4.43) prior to treatment application varied from 0.25 to 0.27 percent with a mean of 950 percent. Farmers' practice (T_1) and

Table 4.42 Effect of treatments on available potassium in soil and potassium content of arecanut palm in terraced upland

A. Potassium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	336	179	151	114	119	126	171
T_2	310	242	276	426	453	440	358
T_3	317	186	157	134	161	137	182
T_4	331	246	323	363	314	474	342
T_5	301	246	204	460	471	435	353
T_6	325	300	294	457	336	462	362
T_7	325	358	337	464	426	381	382
T_8	319	385	213	446	298	343	334
T_9	288	358	226	336	444	426	346
T_{10}	332	381	248	440	464	417	380
T_{11}	297	297	333	403	474	450	376
T_{12}	320	353	340	381	381	403	363
CD(0.05)	NS	48	41	61	61	62	37

B. Potassium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.67	0.51	0.45	0.46	0.45	0.46	0.50
T_2	0.69	0.65	0.75	0.62	0.62	0.63	0.66
T_3	0.64	0.52	0.43	0.47	0.46	0.46	0.50
T_4	0.66	0.70	0.75	0.57	0.59	0.67	0.66
T_5	0.68	0.65	0.56	0.63	0.59	0.62	0.62
T_6	0.66	0.74	0.74	0.61	0.61	0.69	0.67
T_7	0.69	0.75	0.57	0.63	0.68	0.62	0.66
T_8	0.70	0.80	0.74	0.61	0.63	0.67	0.69
T_9	0.66	0.77	0.62	0.66	0.63	0.58	0.65
T_{10}	0.69	0.77	0.73	0.59	0.63	0.65	0.68
T_{11}	0.66	0.73	0.59	0.64	0.62	0.62	0.64
T_{12}	0.66	0.69	0.65	0.62	0.58	0.67	0.65
CD(0.05)	NS	0.106	0.099	0.091	0.091	0.095	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.43 Effect of treatments on available calcium in soil and calcium content of arecanut palm in terraced upland

A. Calcium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	949	1367	850	703	743	823	906
T_2	973	2979	1828	1120	1299	1195	1566
T_3	905	1430	910	739	806	851	940
T_4	941	1953	2410	1284	1049	1404	1507
T_5	957	1800	2170	1076	1613	1344	1493
T_6	929	2002	2290	1210	1344	1534	1552
T_7	972	2051	1960	1372	1560	1138	1509
T_8	993	2539	1640	1012	1120	1275	1430
T_9	933	2051	1559	990	1165	1493	1365
T_{10}	981	2246	1720	1155	1080	1299	1414
T_{11}	928	1840	1505	1410	1106	1566	1393
T_{12}	935	1856	1430	1033	1523	1240	1336
CD(0.05)	NS	325	276	176	195	202	145

B. Calcium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.262	0.330	0.300	0.377	0.380	0.355	0.334
T_2	0.268	0.420	0.456	0.524	0.520	0.527	0.452
T_3	0.261	0.340	0.298	0.382	0.386	0.367	0.339
T_4	0.262	0.470	0.409	0.543	0.600	0.572	0.476
T_5	0.249	0.420	0.452	0.472	0.569	0.573	0.456
T_6	0.254	0.470	0.442	0.550	0.576	0.657	0.492
T_7	0.249	0.470	0.408	0.527	0.575	0.532	0.460
T_8	0.262	0.610	0.455	0.520	0.589	0.591	0.504
T_9	0.269	0.520	0.468	0.480	0.543	0.591	0.479
T_{10}	0.255	0.560	0.456	0.498	0.560	0.524	0.476
T_{11}	0.261	0.420	0.460	0.480	0.560	0.525	0.451
T_{12}	0.262	0.470	0.435	0.517	0.592	0.586	0.477
CD(0.05)	NS	0.070	0.065	0.076	0.083	0.084	NS

organic manure application (T_3) resulted in significantly lower calcium content of index leaf over the years.

4.3.3.1.5 Magnesium

The available magnesium was to the tune of 284 to 307 kg ha^{-1} in various treatment plots during February 2004 (Table 4.44). Application of magnesium sulphate (T_8) resulted in significant increase in the magnesium content of soil over the years with a mean content of 390 kg ha^{-1}.

The initial leaf magnesium content ranged from 0.24 to 0.26 percent before the treatment application (Table 4.44). Magnesium sulphate application (T_8) significantly increased the leaf magnesium content 0.424 percent during September 2006.

4.3.3.1.6 Sulphur

Available sulphur content of soil at 0-25 cm (Table 4.45) prior to application of treatments during February 2004 ranged from 10 to 12 kg ha^{-1} with a mean of 12 kg ha^{-1}. Application of ammonium sulphate (T_4, T_6, T_7, T_8, T_9 and T_{10}) caused significant increase in sulphur content of soil over the years.

The leaf sulphur content before the application of treatments varied from 0.270 to 0.283 percent (Table 4.45). Treatments involving application ammonium sulphate (T_4, T_6, T_7, T_8, T_9 and T_{10}) significantly increased the sulphur content of leaf during second year of experiment up to 0.491 percent. However during third year, no significant variation in sulphur content of leaf was observed.

Table 4.44 Effect of treatments on available magnesium in soil and magnesium content of arecanut palm in terraced upland

A. Magnesium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	290	322	316	310	288	332	310
T_2	288	356	280	337	244	323	305
T_3	302	344	335	329	267	300	313
T_4	300	347	314	305	224	260	292
T_5	307	347	325	317	304	262	310
T_6	300	360	303	319	278	359	320
T_7	294	363	265	290	235	351	300
T_8	299	440	406	393	377	428	390
T_9	296	352	276	293	260	268	291
T_{10}	302	377	270	287	231	305	295
T_{11}	284	377	292	300	224	371	308
T_{12}	286	357	285	283	253	278	290
CD(0.05)	NS	57	47	49	42	51	24

B. Magnesium (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.250	0.170	0.207	0.216	0.287	0.297	0.238
T_2	0.256	0.250	0.224	0.240	0.337	0.335	0.274
T_3	0.238	0.180	0.220	0.240	0.303	0.300	0.247
T_4	0.248	0.310	0.249	0.278	0.324	0.315	0.287
T_5	0.252	0.250	0.230	0.256	0.351	0.333	0.279
T_6	0.245	0.340	0.230	0.260	0.346	0.338	0.293
T_7	0.256	0.340	0.220	0.264	0.336	0.353	0.295
T_8	0.262	0.400	0.388	0.328	0.424	0.414	0.369
T_9	0.246	0.340	0.232	0.271	0.335	0.331	0.293
T_{10}	0.258	0.351	0.242	0.264	0.340	0.335	0.298
T_{11}	0.244	0.260	0.227	0.269	0.322	0.357	0.280
T_{12}	0.246	0.260	0.240	0.283	0.327	0.353	0.285
CD(0.05)	NS	0.045	0.036	0.040	0.052	0.052	NS

Table 4.45 Effect of treatments on available sulphur in soil and sulphur content of arecanut palm in terraced upland

A. Sulphur (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	11	13	24	30	27	26	22
T_2	12	18	30	28	27	23	23
T_3	10	14	26	31	24	25	22
T_4	12	37	43	39	38	38	35
T_5	12	18	32	29	28	22	24
T_6	12	39	44	38	38	35	34
T_7	12	43	41	40	37	40	35
T_8	11	50	43	42	37	33	36
T_9	12	45	39	41	36	37	35
T_{10}	12	47	42	38	35	36	35
T_{11}	12	21	26	31	23	24	23
T_{12}	11	24	29	32	25	22	24
CD(0.05)	NS	5	5	6	5	5	3

B. Sulphur (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.277	0.130	0.200	0.252	0.230	0.683	0.295
T_2	0.283	0.260	0.358	0.369	0.389	0.658	0.386
T_3	0.276	0.150	0.254	0.274	0.220	0.616	0.298
T_4	0.277	0.340	0.433	0.308	0.365	0.623	0.391
T_5	0.263	0.290	0.345	0.382	0.310	0.621	0.369
T_6	0.269	0.350	0.435	0.478	0.363	0.664	0.427
T_7	0.263	0.360	0.433	0.433	0.340	0.648	0.413
T_8	0.277	0.390	0.442	0.480	0.353	0.676	0.436
T_9	0.285	0.380	0.455	0.476	0.306	0.631	0.422
T_{10}	0.270	0.380	0.469	0.491	0.365	0.647	0.437
T_{11}	0.276	0.340	0.345	0.377	0.335	0.645	0.386
T_{12}	0.277	0.370	0.317	0.366	0.543	0.658	0.422
CD(0.05)	NS	0.069	0.060	0.052	NS	NS	NS

4.3.3.1.7 Iron

Content of available iron in soil prior to treatment application varied from 79 to 94 kg ha^{-1} (Table 4.46). Application of treatments did not cause any significant variation in the iron content of soil over the years.

Index leaf of arecanut recorded iron content in the range of 79 to 94 ppm before application of treatments (Table 4.46). There was no significant variation in iron content of index leaf due to application of treatments over the years.

4.3.3.1.8 Manganese

Treatment plots prior to application of treatments during February 2004 (Table 4.47) recorded available manganese content of 37 to 41 kg ha^{-1}. Significant variation in manganese content of soil was not observed due to the effect of treatments.

Observations on index leaf of arecanut (Table 4.47) prior to application of treatments during February 2004 showed manganese content of 129 to 140 ppm with a mean of 135 ppm. No significant variation in manganese content of index leaf over the years was observed in any of the treatments.

4.3.3.1.9 Zinc

Mean available zinc content of 26 kg ha^{-1} was recorded (Table 4.48) prior to application of treatments during February 2004. Available zinc content of soil ranged from 23 to 28 kg ha^{-1}. Application of zinc sulphate (T_9) brought about significant increase in the available zinc in soil.

Table 4.46 Effect of treatments on available iron in soil and iron content of arecanut palm in terraced upland

A. Iron (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	87	101	85	101	99	98	95
T_2	90	103	87	102	95	82	93
T_3	79	83	82	104	94	89	89
T_4	91	99	86	99	87	95	93
T_5	91	96	87	92	90	84	90
T_6	88	91	83	106	85	80	89
T_7	89	95	84	103	88	86	91
T_8	87	85	86	90	92	92	88
T_9	94	88	85	97	103	90	93
T_{10}	88	93	86	108	93	93	93
T_{11}	88	89	85	94	97	87	90
T_{12}	86	87	84	96	83	97	89
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Iron (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	304	394	305	454	385	432	379
T_2	284	426	282	446	398	421	376
T_3	272	420	314	465	385	454	385
T_4	280	383	324	430	407	441	378
T_5	298	433	268	441	383	449	379
T_6	258	370	271	441	420	460	370
T_7	320	412	285	479	404	481	397
T_8	306	400	286	466	425	486	395
T_9	306	368	259	503	442	465	391
T_{10}	304	414	278	441	416	472	388
T_{11}	282	368	256	426	404	449	364
T_{12}	288	347	269	454	395	426	363
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.47 Effect of treatments on available manganese in soil and manganese content of arecanut palm in terraced upland

A. Manganese (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	39	86	75	104	107	100	85
T_2	40	88	73	102	110	96	85
T_3	37	89	82	106	95	89	83
T_4	39	91	76	93	92	99	82
T_5	39	86	81	89	112	97	84
T_6	38	90	83	108	91	91	84
T_7	40	89	78	92	94	90	80
T_8	41	90	76	87	105	98	83
T_9	38	92	80	100	100	94	84
T_{10}	40	87	84	95	102	93	84
T_{11}	38	88	77	97	97	95	82
T_{12}	39	87	74	98	99	101	83
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

B. Manganese (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	136	112	105	106	122	144	121
T_2	139	103	115	94	123	132	118
T_3	135	108	96	102	119	142	117
T_4	136	101	117	107	126	151	123
T_5	129	111	110	101	119	125	116
T_6	132	103	102	90	126	141	116
T_7	129	94	107	112	119	141	117
T_8	136	110	119	103	127	141	123
T_9	140	97	114	106	129	135	120
T_{10}	132	89	98	108	125	144	116
T_{11}	135	105	105	109	126	144	121
T_{12}	136	101	99	106	114	143	116
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

Table 4.48 Effect of treatments on available zinc in soil and zinc content of arecanut palm in terraced upland

A. Zinc (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	27.8	25.4	26.3	22.4	24.5	24.8	25.2
T_2	25.3	24.4	25.7	22.8	25.1	25.3	24.8
T_3	25.9	25.2	28.2	23.3	22.6	26.4	25.3
T_4	27.3	25.9	24.6	21.7	21.5	21.0	23.7
T_5	24.4	24.4	27.1	21.3	26.0	22.0	24.2
T_6	26.7	24.8	25.6	23.7	21.3	22.8	24.2
T_7	26.7	26.0	26.2	25.7	23.0	25.8	25.6
T_8	26.1	24.0	27.6	20.6	23.8	28.7	25.1
T_9	23.1	33.7	34.8	34.0	33.0	37.2	32.6
T_{10}	27.3	24.8	27.4	24.4	21.9	27.0	25.5
T_{11}	24.0	25.6	23.9	24.0	23.4	27.6	24.7
T_{12}	26.2	24.0	25.4	24.8	22.2	24.0	24.4
CD(0.05)	NS	4.0	4.1	3.8	3.8	4.2	1.7

B. Zinc (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	27.5	21.8	23.0	23.0	23.0	25.8	24.0
T_2	28.2	21.0	23.9	23.0	24.0	25.0	24.2
T_3	26.2	21.8	21.6	25.0	26.0	25.0	24.3
T_4	27.3	22.8	21.8	22.3	23.0	24.0	23.5
T_5	27.7	21.2	22.3	24.8	26.0	23.7	24.3
T_6	26.9	21.3	23.6	23.7	25.0	23.1	23.9
T_7	28.2	23.0	24.2	22.0	24.0	24.1	24.2
T_8	28.8	22.8	25.1	25.0	25.0	26.3	25.5
T_9	27.1	20.2	22.7	23.8	23.0	26.0	23.8
T_{10}	28.4	21.8	23.9	25.0	27.0	25.0	25.2
T_{11}	26.9	20.6	22.2	24.3	23.0	23.9	23.5
T_{12}	27.1	20.5	21.8	23.6	24.0	26.3	23.9
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

The variation in zinc content of index leaf of arecanut (Table 4.48) prior to application of treatments during February 2004 ranged from 26 to 29 ppm. No significant increase in zinc content of index leaf was noticed in treatment namely application of zinc sulphate (T_9) over the years.

4.3.3.1.10 Copper

Prior to application of treatments during February 2004, available copper content varied from 18 to 20 kg ha^{-1} (Table 4.49). Application of treatments failed to cause any significant increase in the copper content of soil over the years.

Index leaf of arecanut (Table 4.49) prior to application of treatments during February 2004 recorded copper content of 7.0 to 7.5 ppm Copper content of index leaf failed to be significantly influenced by application of treatments.

4.3.3.1.11 Boron

Available boron in soil (Table 4.50) prior to application of treatments during February 2004 varied from 8.3 to 9.8 kg ha^{-1}. Significantly higher boron content was observed in treatment which received borax (T_{10}) over the years of experiment.

A perusal of the data on boron content of index leaf (Table 4.50) prior to application of treatments during February 2004 showed that boron content ranged from 8.3 to 9.8 percent. Treatment involving application of borax (T_{10}) resulted in significantly higher boron content of index leaf during second year of experiment. However during the third year, borax application (T_{10}) failed to impart any significant variation in boron content of index leaf.

Table 4.49 Effect of treatments on available copper in soil and copper content of arecanut palm in terraced upland

A. Copper (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	18.9	17.3	18.2	17.8	17.5	16.7	17.7
T_2	19.6	15.4	16.2	18.2	17.2	15.6	17.0
T_3	18.3	14.8	18.4	17.6	18.2	17.3	17.4
T_4	19.6	17.1	16.9	18.3	15.9	17.4	17.5
T_5	19.8	18.0	19.2	16.1	16.1	18.3	17.9
T_6	19.1	16.0	17.8	16.9	15.6	15.9	16.9
T_7	19.4	16.4	19.1	16.5	16.6	18.5	17.7
T_8	18.7	16.9	18.8	15.8	16.8	18.8	17.6
T_9	19.9	16.6	17.3	17.2	18.6	16.9	17.7
T_{10}	19.0	18.2	17.6	19.1	17.7	17.7	18.2
T_{11}	19.3	18.6	18.6	16.8	19.0	16.3	18.1
T_{12}	18.5	17.7	16.5	18.8	19.4	19.3	18.4
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Copper (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	7.3	13.4	5.7	15.0	10.2	17.4	11.5
T_2	7.5	13.6	5.9	15.9	11.0	17.0	11.8
T_3	7.3	13.9	6.4	15.6	12.7	18.3	12.4
T_4	7.3	13.9	6.6	15.9	10.9	16.7	11.9
T_5	7.0	13.3	5.6	14.7	11.8	15.1	11.2
T_6	7.1	12.1	5.9	16.3	11.1	14.5	11.2
T_7	7.0	13.8	6.4	16.4	12.3	17.2	12.2
T_8	7.3	13.6	6.5	16.6	11.5	15.6	11.9
T_9	7.5	11.4	6.8	16.5	10.9	14.9	11.3
T_{10}	7.1	13.2	6.2	14.9	11.7	17.2	11.7
T_{11}	7.3	11.7	5.6	14.5	11.0	15.4	10.9
T_{12}	7.3	11.7	6.5	15.3	10.9	15.9	11.3
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

Table 4.50 Effect of treatments on available boron in soil and boron content of arecanut palm in terraced upland

A. Boron (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	9.44	8.60	8.66	8.40	9.26	8.61	8.83
T_2	9.28	8.80	8.73	8.16	9.71	8.07	8.79
T_3	9.60	8.48	8.10	9.73	8.88	9.04	8.97
T_4	8.59	9.48	8.80	9.42	9.60	8.66	9.09
T_5	8.40	8.54	9.10	8.73	8.66	8.93	8.73
T_6	8.70	8.35	8.98	9.48	9.47	9.36	9.06
T_7	9.11	8.25	8.60	8.85	9.04	9.20	8.84
T_8	8.85	9.33	8.54	9.20	9.15	8.45	8.92
T_9	8.29	9.20	8.35	9.04	8.40	8.29	8.60
T_{10}	9.81	11.68	11.48	11.49	11.87	11.74	11.35
T_{11}	8.99	9.29	9.29	9.10	9.42	8.77	9.14
T_{12}	8.48	8.98	9.54	8.60	8.99	9.60	9.03
CD(0.05)	NS	1.43	1.39	1.44	1.47	1.43	0.55

B. Boron (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	77	69	94	105	133	128	101
T_2	72	92	117	109	136	135	110
T_3	69	73	94	125	128	139	105
T_4	71	116	118	122	135	137	116
T_5	75	92	107	131	139	133	113
T_6	65	116	116	120	128	131	113
T_7	81	129	108	128	142	136	121
T_8	77	145	109	117	131	134	119
T_9	77	131	106	115	125	141	116
T_{10}	77	168	140	153	145	143	138
T_{11}	71	96	116	126	143	140	115
T_{12}	73	97	116	123	123	140	112
CD(0.05)	NS	17	17	19	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

4.3.3.1.12 Silicon

The variation in total soil silicon was not marked during February 2004 and varied from 285 to 355 t ha^{-1} (Table 4.51). But over the years, all treatments failed to significantly increase total silicon in soil.

Leaf silicon content ranged from 0.58 to 0.68 percent prior to application of treatments (Table 4.51). Pooled analysis over the years showed that the leaf silicon content was not significantly influenced by treatments.

4.3.3.1.13 Aluminium

Data on available soil aluminium (Table 4.52) ranged from 84 to 99 kg ha^{-1} with a mean of 92 kg ha^{-1} before application of treatments. Aluminium content of soil remained unaffected by treatment application over the years.

Results showed that aluminium content of index leaf (Table 4.52) prior to application of treatments ranged from 173 to 202 ppm. Any significant change in aluminium content of index leaf was not observed due to the effect of treatments.

4.3.3.2 Effect of treatments on soil pH and organic carbon content of soil

Soil pH prior to treatment application varied from 5.56 to 5.99 (Table 4.53). Treatments namely farmers' practice (T_1) and organic manure application (T_3) failed to register any significant increase in soil pH over the years.

Soil organic carbon content (Table 4.53) varied from 0.78 to 0.85 percent before application of treatments. Response to application of organic manure (T_3) was highly evident in the increased organic matter content of soil over the years.

Table 4.51 Effect of treatments on total silicon in soil and silicon content of arecanut palm in terraced upland

A. Silicon (t ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	300	350	308	320	320	353	325
T_2	320	343	330	332	285	290	317
T_3	316	357	300	352	342	286	326
T_4	355	337	317	310	305	307	322
T_5	285	301	283	326	323	312	305
T_6	335	316	339	285	277	296	308
T_7	310	289	351	314	336	317	320
T_8	328	307	328	305	328	301	316
T_9	343	296	346	309	312	323	322
T_{10}	325	323	337	359	352	330	338
T_{11}	305	310	291	339	292	340	313
T_{12}	292	330	321	296	316	300	309
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Silicon (%)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.68	0.68	0.70	1.16	1.19	1.27	0.95
T_2	0.62	0.62	0.63	1.14	1.14	1.19	0.89
T_3	0.64	0.69	0.66	1.13	1.31	1.25	0.95
T_4	0.67	0.60	0.65	1.13	1.35	1.25	0.94
T_5	0.61	0.60	0.62	1.18	1.30	1.21	0.92
T_6	0.65	0.66	0.78	1.06	1.27	1.26	0.95
T_7	0.65	0.63	0.73	1.08	1.22	1.19	0.92
T_8	0.64	0.73	0.82	1.16	1.20	1.23	0.96
T_9	0.58	0.60	0.78	1.04	1.20	1.30	0.92
T_{10}	0.67	0.66	0.83	1.04	1.10	1.28	0.93
T_{11}	0.60	0.63	0.60	1.06	1.25	1.22	0.89
T_{12}	0.64	0.65	0.68	1.10	1.23	1.29	0.93
CD(0.05)	NS	0.07	0.11	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.52 Effect of treatments on available aluminium in soil and aluminium content of arecanut palm in terraced upland

A. Aluminium (kg ha^{-1})

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	99	99	94	88	84	98	94
T_2	89	87	91	84	95	89	89
T_3	90	96	92	82	89	90	90
T_4	97	92	95	83	98	96	94
T_5	87	88	89	87	94	90	89
T_6	95	90	85	96	87	92	91
T_7	94	85	88	86	86	83	87
T_8	91	94	99	95	96	81	93
T_9	84	83	96	93	91	94	90
T_{10}	98	89	86	99	97	88	93
T_{11}	86	95	83	90	90	86	88
T_{12}	93	98	90	91	93	85	91
CD(0.05)	NS	NS	NS	NS	NS	NS	NS

B. Aluminium (ppm)

Treatment	Leaf						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	202	220	136	84	97	92	138
T_2	186	163	145	85	96	91	128
T_3	190	210	137	84	94	95	135
T_4	199	173	147	86	91	99	132
T_5	181	165	137	91	107	94	129
T_6	195	160	129	87	98	91	127
T_7	195	173	139	83	93	90	129
T_8	191	164	131	87	98	104	129
T_9	173	155	138	85	93	98	124
T_{10}	199	165	136	103	95	94	132
T_{11}	178	157	136	93	107	96	128
T_{12}	192	163	138	98	109	91	132
CD(0.05)	NS	27.013	NS	NS	NS	NS	NS

Table 4.53 Effect of treatments on soil pH and organic carbon content of soil in terraced upland

A. Soil pH

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	5.90	4.60	4.65	4.52	4.36	4.49	4.75
T_2	5.78	6.22	5.85	6.00	6.28	5.68	5.97
T_3	5.80	4.58	4.60	4.46	4.30	4.40	4.69
T_4	5.82	6.03	6.20	6.28	6.25	6.09	6.11
T_5	5.77	5.93	6.15	6.15	5.55	6.15	5.95
T_6	5.97	6.12	6.03	6.12	6.15	5.80	6.03
T_7	5.99	6.15	5.85	6.03	5.62	5.96	5.93
T_8	5.56	5.84	6.06	5.87	5.85	6.03	5.87
T_9	5.67	5.90	5.75	6.31	5.46	6.12	5.87
T_{10}	5.60	6.06	6.00	6.09	5.75	5.74	5.87
T_{11}	5.64	5.80	5.93	6.35	5.34	5.62	5.78
T_{12}	5.58	6.00	5.90	6.37	6.00	5.87	5.95
CD(0.05)	NS	0.90	0.89	0.92	0.88	0.89	0.18

B. Organic carbon (%)

Treatment	0-25 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.82	0.81	0.76	0.73	0.97	0.87	0.83
T_2	0.84	0.94	0.86	0.75	0.84	0.80	0.84
T_3	0.78	1.22	1.17	1.16	1.18	1.11	1.10
T_4	0.81	0.87	0.83	0.66	0.93	0.90	0.83
T_5	0.82	0.88	0.88	0.97	0.82	0.79	0.86
T_6	0.80	0.86	0.92	0.87	0.75	0.82	0.84
T_7	0.84	0.92	0.78	0.93	0.90	0.76	0.85
T_8	0.85	0.90	0.90	0.69	0.95	0.89	0.87
T_9	0.80	0.95	0.82	0.79	0.86	0.93	0.86
T_{10}	0.84	0.96	0.84	0.89	0.80	0.86	0.87
T_{11}	0.80	0.85	0.79	0.84	0.89	0.74	0.82
T_{12}	0.80	0.83	0.87	0.81	0.77	0.72	0.80
CD(0.05)	NS	0.14	0.14	0.13	0.14	0.13	0.03

4.3.3.3 Effect of treatments on chlorophyll-a, chlorophyll-b, total chlorophyll and yellowing index

Variation in leaf chlorophyll-a content ranged from 0.36 to 0.42 percent (Table 4.54). Due to application of magnesium sulphate (T_8), the chlorophyll-a content was significantly and consistently higher in index leaf during the third year of experiment. Farmers practice (T_1) and organic manure application (T_3) failed to significantly increase chlorophyll-a content of index leaf over the years.

Similar trend as that of chlorophyll-a was exhibited by leaf chlorophyll-b content. It varied from 0.32 to 0.36 percent prior to treatment application (Table 4.54). However farmers practice (T_1) and organic manure application (T_3) did not result in any significant increase of chlorophyll-b content over the years.

The mean total chlorophyll in treatment palms prior to application of treatments ranged from 0.81 to 0.91 percent (Table 4.55). Significant increase in total chlorophyll of leaf was recorded due to application of magnesium sulphate (T_8) over the years. Total chlorophyll content of index leaf was not significantly influenced by farmers practice (T_1) and organic manure application (T_3) over the years.

During February 2004, prior to treatment application (Table 4.55) arecanut palms registered yellowing index ranging from 45 to 55. Yellowing index recorded significant reduction due to magnesium sulphate application (T_8) over the years. Farmers practice (T_1) failed to bring about significant reduction in yellowing index over the years.

Table 4.54 Effect of treatments on chlorophyll-a and chlorophyll-b content of arecanut palm in terraced upland

A. Chlorophyll-a (mg g^{-1})

Treatment	Chlorophyll-a						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.38	0.32	0.34	0.40	0.42	0.48	0.39
T_2	0.40	0.52	0.64	0.86	0.73	0.98	0.69
T_3	0.36	0.40	0.40	0.48	0.49	0.55	0.45
T_4	0.40	0.66	0.64	0.86	0.75	0.94	0.71
T_5	0.40	0.58	0.66	0.82	0.68	0.92	0.68
T_6	0.40	0.66	0.67	0.84	0.70	0.86	0.69
T_7	0.40	0.68	0.67	0.80	0.84	0.95	0.72
T_8	0.38	0.88	0.60	0.89	0.98	1.22	0.83
T_9	0.42	0.68	0.61	0.87	0.69	0.97	0.71
T_{10}	0.40	0.78	0.66	0.88	0.73	1.03	0.75
T_{11}	0.40	0.60	0.70	0.83	0.77	0.95	0.71
T_{12}	0.38	0.62	0.68	0.82	0.76	0.91	0.70
CD(0.05)	NS	0.094	0.085	0.092	0.104	0.147	#

- pooling not possible as errors homogenous and interaction absent.

B. Chlorophyll-b (mg g^{-1})

Treatment	Chlorophyll-b						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.34	0.22	0.28	0.32	0.38	0.40	0.32
T_2	0.34	0.50	0.49	0.70	0.53	0.79	0.56
T_3	0.34	0.22	0.31	0.38	0.40	0.42	0.35
T_4	0.34	0.52	0.46	0.78	0.62	0.75	0.58
T_5	0.32	0.30	0.50	0.68	0.56	0.73	0.52
T_6	0.34	0.52	0.49	0.68	0.54	0.78	0.56
T_7	0.32	0.54	0.51	0.72	0.55	0.74	0.56
T_8	0.34	0.76	0.64	0.79	0.78	1.02	0.72
T_9	0.36	0.56	0.46	0.73	0.59	0.81	0.59
T_{10}	0.34	0.62	0.52	0.77	0.63	0.83	0.62
T_{11}	0.34	0.40	0.48	0.69	0.57	0.76	0.54
T_{12}	0.34	0.42	0.44	0.75	0.66	0.77	0.56
CD(0.05)	NS	0.070	0.075	0.102	0.093	0.122	#

- pooling not possible as errors homogenous and interaction absent.

Table 4.55 Effect of treatments on total chlorophyll content and yellowing index of arecanut palm in terraced upland

A. Total chlorophyll (mg g^{-1})

Treatment	Total chlorophyll						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	0.85	0.68	0.77	0.85	0.91	1.02	0.85
T_2	0.82	1.16	1.28	1.70	1.38	1.89	1.37
T_3	0.81	0.74	0.86	1.01	1.00	1.10	0.92
T_4	0.85	1.30	1.25	1.78	1.49	1.82	1.42
T_5	0.85	1.00	1.30	1.64	1.35	1.78	1.32
T_6	0.84	1.32	1.31	1.66	1.35	1.79	1.38
T_7	0.83	1.37	1.32	1.66	1.51	1.85	1.42
T_8	0.82	1.73	1.38	1.82	1.89	2.47	1.69
T_9	0.91	1.37	1.21	1.73	1.40	1.91	1.42
T_{10}	0.85	1.53	1.32	1.80	1.47	1.99	1.49
T_{11}	0.86	1.07	1.32	1.66	1.46	1.85	1.37
T_{12}	0.83	1.11	1.26	1.70	1.54	1.81	1.38
CD(0.05)	NS	0.103	0.172	0.253	0.213	0.307	NS

B. Yellowing index

Treatment	Yellowing index						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	55	53	45	42	47	39	47
T_2	54	33	27	19	22	16	29
T_3	49	43	39	39	37	35	40
T_4	52	26	29	19	24	22	29
T_5	45	29	24	20	22	19	27
T_6	53	26	20	18	21	16	26
T_7	53	26	22	19	22	13	26
T_8	48	18	18	17	17	11	22
T_9	52	24	18	18	21	14	24
T_{10}	47	23	23	19	22	14	25
T_{11}	51	27	26	18	23	14	27
T_{12}	53	26	29	20	24	11	27
CD(0.05)	NS	1.1	1.1	0.9	1.2	1.3	#

- pooling not possible as errors homogenous and interaction absent.

4.3.3.4 Effect of treatments on dry kernel weight, number of fruits palm^{-1} and chali yield palm^{-1}

In the treatment palms, the weight of dry kernel during the first year of application of treatments ranged from 5.78 to 7.01 g (Table 4.56). Farmers practice (T_1) and organic manure application (T_3) failed to significantly increase dry kernel weight during second and third year of experiment. Significant increase in the dry kernel weight was brought about by application of ammonium sulphate ((T_4, T_6, T_7, T_8, T_9 and T_{10}).

In the first year of experiment, the number of fruits harvested per palm ranged from 432 to 500 nos (Table 4.56). Even though treatments failed to manifest any significant variation during second year, all treatments except farmers practice (T_1) and organic manure application (T_3) significantly increased the number of fruits per palm during the third year of experiment.

Chali yield during 2004 (Table 4.57) ranged from 2.72 to 3.45 kg palm^{-1} and was not significantly influenced by any treatments. Application of ammonium sulphate ((T_4, T_6, T_7, T_8, T_9 and T_{10}) resulted in significantly higher *chali* yield over the years in treatment palms. Farmers practice (T_1) and organic manure application (T_3) where no inorganic fertilizers were applied resulted in no significant increase in *chali* yield over the years. However the resulting yield increase due to organic manure application (T_3) was found to be more than that of farmers practice (T_1). The higher *chali* yields were resulted in treatments which received sulphur as well as higher rate of potash application as observed in treatments T_1, T_8, T_9 and T_{10}. The highest yield of 3.96 kg palm^{-1} during 2006 were observed for the treatment which received sulphur, higher rate of potassium and boron. To get a better comparison, yield ha^{-1} was also calculated.

Table 4.56 Effect of treatments on dry kernel weight and number of fruits palm^{-1} in terraced upland

A. Dry kernel weight (g)

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006
T_1	5.78	6.02	6.27	6.02	0.49
T_2	6.11	6.86	7.36	6.78	1.25
T_3	5.96	6.22	6.43	6.20	0.47
T_4	6.87	7.47	7.99	7.44	1.12
T_5	6.30	6.88	7.57	6.92	1.27
T_6	6.90	7.70	8.19	7.60	1.29
T_7	6.85	7.46	8.15	7.49	1.30
T_8	7.01	7.66	8.04	7.57	1.03
T_9	6.91	7.47	8.07	7.48	1.16
T_{10}	7.01	7.60	8.19	7.60	1.18
T_{11}	6.06	6.85	7.30	6.74	1.24
T_{12}	6.08	6.86	7.27	6.74	1.19
CD(0.05)	NS	0.322	0.387	0.316	

B. Number of fruits palm^{-1}

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006
T_1	478	367	350	398	-128
T_2	471	409	484	455	13
T_3	465	375	354	398	-111
T_4	437	414	474	442	37
T_5	432	419	483	445	51
T_6	418	423	463	435	45
T_7	434	419	455	436	21
T_8	438	414	477	443	39
T_9	441	432	481	451	40
T_{10}	437	434	484	452	47
T_{11}	472	408	467	449	-5
T_{12}	461	408	482	450	21
CD(0.05)	NS	NS	71	NS	

Table 4.57 Effect of treatments on *chali* yield palm^{-1} in terraced upland

A. *Chali* yield palm^{-1}(kg)

Treatment	2004	2005	2006	Pooled Mean	Difference between 2004 to 2006	
					kg palm^{-1}	kg ha^{-1}
T_1	2.76	2.21	2.20	2.39	-0.56	-768
T_2	2.88	2.80	3.56	3.08	0.68	932
T_3	2.77	2.33	2.28	2.46	-0.49	-672
T_4	3.00	3.09	3.78	3.29	0.78	1069
T_5	2.72	2.88	3.66	3.09	0.94	1289
T_6	2.88	3.26	3.79	3.31	0.91	1248
T_7	2.97	3.12	3.71	3.27	0.74	1015
T_8	3.07	3.17	3.83	3.36	0.77	1056
T_9	3.05	3.23	3.88	3.38	0.83	1138
T_{10}	3.06	3.30	3.96	3.44	0.91	1248
T_{11}	2.86	2.79	3.41	3.02	0.55	754
T_{12}	2.80	2.80	3.50	3.04	0.70	960
CD(0.05)	NS	0.226	0.245	0.242		

4.3.4 Effect of treatments on nutrients in 25-50 cm soil, nutrient content of kernel and husk, pH in 25-50 cm soil, organic carbon content in 25-50 cm soil, leaf sap pH and morphological characters of yellowing affected arecanut palm in converted paddy field, garden land and terraced upland

Effect of nutrient management practices on nutrients in 25-50 cm soil, nutrient content of kernel and husk, pH in 25-50 cm soil, organic carbon content in 25-50 cm soil, leaf sap pH and morphological characters of yellowing affected arecanut palm in converted paddy field (Appendices 2-21), garden land (Appendices 22-41) and terraced upland (Appendices 42-61) were studied.

4.3.5 Root damage and pests and disease studies in yellowing affected arecanut palms in various toposequences

The data on incidence of root rotting and root xylem blockage observed in yellowing affected arecanut palms grown in all the three toposequences viz. converted paddy field, garden land and terraced upland are presented below. Presence of phytoplasma as evidenced by Dienes' staining was detected in root phloem of some of the yellowing affected arecanut palms grown in all the three toposequences namely converted paddy field, garden land and terraced upland. In some cases presence of both root xylem blockage and Dienes' staining of root phloem in the same palm were observed and the data is presented below.

4.3.4.1 Incidence of root rot

Roots of some of the yellowing affected palms grown in converted paddy field were found to become discoloured, growth restricted and after becoming dark brown gradually rot. Rotting of roots was mainly restricted to converted paddy fields and recorded an incidence of 16 percent (Table 4.58). Yellowing affected arecanut palms grown in both garden land and terraced upland were found to be free from incidence of root rotting.

4.3.4.2 Incidence of root xylem blockage

Mean incidence of root xylem blockage (21.3 percent) was observed in yellowing affected arecanut palms (Table 4.58). The highest incidence of root xylem blockage (24 percent) was noticed in yellowing affected arecanut palms grown in converted paddy field and lowest incidence of root xylem blockage (20 percent) was recorded in yellowing affected arecanut palms grown in both and garden land and terraced upland.

4.3.4.3 Incidence of Dienes' staining of root phloem

Incidence of Dienes' staining of root phloem which is an indication of presence of phytoplasma was observed in 20 percent of yellowing affected arecanut palms (Table 4.58). Highest incidence of Dienes' staining of root phloem (24 percent) was observed in yellowing affected arecanut palms grown in garden land and lowest incidence of Dienes' staining of root phloem (16 percent) was observed in yellowing affected arecanut palms grown converted paddy field.

4.1.4.4. Incidence of both root xylem blockage and Dienes' staining of root phloem in the same palm

Mean incidence of both root xylem blockage and Dienes' staining of root phloem in the same yellowing affected arecanut palm was observed in 10.7 percent of palms (Table 4.58). Yellowing affected arecanut palms grown in both converted

4.58 Root damage and pests and disease studies in yellowing affected arecanut palms in various toposequences

Toposequence	Incidence of root rot (%)	Incidence of root xylem blockage (%)	Incidence of Dienes' staining of root phloem (%)	Incidence of both root xylem blockage and Dienes' staining of root phloem in the same palm (%)
Converted paddy field	16	24	16	12
Garden land	0	20	24	8
Terraced upland	0	20	20	12
Mean	5.3	21.3	20.0	10.7

paddy field and terraced upland (12 percent) recorded the highest incidence of both root xylem blockage and Dienes' staining of root phloem. Yellowing affected arecanut palms grown in garden land showed the least incidence (8 percent) of both root xylem blockage and Dienes' staining of root phloem.

DISCUSSION

5. DISCUSSION

5.1 EXPERIMENT I. DEVELOPMENT OF A SCORING SYSTEM TO ASSESS THE INTENSITY OF YELLOWING

Yellowing is a widespread malady in the arecanut growing tracts. The visual symptoms appear on the crown and it was required to develop a scoring index to assess the intensity of yellowing taking into account the morphological aspects of the crown viz. number of leaves, extent of yellowing, necrosis and reduction in crown size.

The index earlier developed by George et al. (1980) was modified by studying the visual characteristics of yellowing affected arecanut palms in toposequences viz. converted paddy field, garden land and terraced upland of Thrissur, Palakkad and Malappuram districts. The earlier index had considered only eight classes for yellowing with score values 0-8, three classes for necrosis with score values 0-2 and three classes for reduction in crown size with score values 0-1. In the present investigation, thirteen classes for yellowing with score value 0 to 6, five classes for necrosis with score value 0 to 2 and five classes for reduction in crown size with score value 0 to 2 were assigned to estimate the yellowing intensity which widened the accuracy of the index. The provision of a multiplication factor of 10 had made the index a whole figure which leads to easy comparison of varying incidences of yellowing.

The present index ranges from 0-100 denoting the intensity of yellowing. The modified yellowing index (I) = $\{(Y+N)/L + R\} \times 10$ where Y and N are total of grade points for yellowing and necrosis, L is 50 per cent of the number of leaves on the crown and R is the grade point for reduction in size of the crown for the whole palm. The palms were classified as healthy if the I value is 0, mildly affected if it is less than 20, moderately affected if it is between 20 to 50 and severely affected if it is more than 50 (Plate 1). Since the present yellowing index utilizes 13 classes in place of earlier 8 classes to score yellowing, 5 classes in place of earlier 3 classes to score necrosis and 5 classes in

Plate 1. Yellowing affected arecanut palms classified based on scoring index

place of earlier 3 classes to score reduction in crown size it had resulted in enhanced precision in quantifying yellowing.

The reliability of the yellowing index thus developed was tested by studying the correlation between the yield, elemental composition and chlorophyll content of leaf with yellowing index during pre treatment (February 2004) and post treatment (September 2006) period in all the three toposequences viz. converted paddy field, garden land and terraced upland in the Experiment III. During pre treatment period, most of the leaf nutrient contents of experimental palms did not have significant correlation with yellowing as the palms selected were in a uniform state of yellowing ranging from 41-50 in converted paddy field, 40-50 in garden land and 45-55 in terraced upland. Over a period of three years, application of treatments resulted in reduction of yellowing index in experimental palms to the level of 5-33 in converted paddy field, 7-38 in garden land and 11-39 in terraced upland. There was variation in leaf nutrient status, yield and yellowing index during post treatment period resulting in significant negative correlation between the yield, elemental composition and chlorophyll content of leaf with yellowing index.

In the converted paddy field, after three years of treatment effects on arecanut palms, during the post treatment period, the plant contents of N, P, K, Ca, Mg, S, B and Si had significant negative correlation with yellowing index. Similarly chlorophyll-a, chlorophyll-b and total chlorophyll showed significant negative correlation with yellowing index. The yield attributes such as dry kernel weight, number of fruits palm^{-1} and *chali* yield also showed significant negative correlation with the yellowing index. Yellowing is a symptomatic expression of sub optimal concentration of nutrients particularly N and Mg which is directly related with the formation of chlorophyll. N and S are essential in the formation of amino acids and are responsible for increasing the growth and dry matter production of plants. The significant negative correlation at one percent level validates the reliability of the scoring system developed. The treatments have resulted in the maintenance of optimum concentration of nutrients which resulted in a favorable internal nutritional environment in plants and thereby the production and maintenance of chlorophyll. Yellowing symptoms can be developed due to the non-formation of chlorophyll as well as chlorophyll degradation. It can also be developed in the leaves due to the mobility of N into new leaves in case of inadequate supply or absorption of nitrogen during the formation of new leaves. Other elements such as P, S, Ca, K, B and Si with their differential roles as structural, enzymatic and translocative nutrients in plants have also resulted in growth and development particularly formation and maintenance of chlorophyll and production of dry kernel weight. The non-significant and highly significant relationship between the yellowing index and the above growth and yield characters of the plant during pre and post treatment application respectively, clearly validate the reliability of yellowing index developed for using it in converted paddy field situation to denote the intensity of arecanut yellowing.

In the garden land situation during pre treatment period, the newly developed yellowing index was found to be negatively correlated with boron, chlorophyll-a and dry kernel weight and positively correlated with K, Mg, Zn, chlorophyll b and number of fruits. During post treatment period, N, P, K, Ca, Mg, S, B, Si, chlorophyll a, chlorophyll b, total chlorophyll, dry kernel weight, number of fruits and *chali* yield were negatively correlated with yellowing. The negative correlation of B and chlorophyll a with yellowing indicate the improvement in their contents for reducing yellowing index. The treatments improved the elemental and chlorophyll composition of leaves and negative correlations were observed with yellowing index which validates the reliability of the index to judge the intensity of yellowing under garden land.

During pre treatment period, the newly developed yellowing index in terraced upland was found to be negatively correlated with number of fruits and positively correlated with P, Ca, Mn and dry kernel weight. Yellowing index during post-treatment period showed highly significant negative correlation with N, P, K, Ca, Mg, Fe, B, chlorophyll-a, chlorophyll-b, total chlorophyll, dry kernel weight, number of fruits and *chali* yield The significant negative correlation validates the consistency of the yellowing index in effectively quantifying the intensity of yellowing in terraced upland.

The highly significant negative correlation of the leaf elemental composition, growth and yield parameters with the yellowing index of experimental arecanut palm during post treatment period, in all the three toposequences viz. converted paddy field, garden land and terraced upland clearly validated the reliability of the index under different growing situations and treatments.

5.2 EXPERIMENT II. COMPARISON OF INCIDENCE OF YELLOWING AMONG CONVERTED PADDY FIELDS, GARDEN LANDS AND TERRACED UPLANDS

Survey was done in three districts of Central Kerala, i.e., Malappuram, Palakkad and Thrissur in three toposequences, viz. converted paddy fields, garden lands and terraced uplands. The yellowing index developed in experiment I was utilized in the survey. The intensity and spread of arecanut yellowing among the various toposequences and varietal differences in the incidence of yellowing were recorded.

Comparing the incidence of yellowing among various toposequences in all the three districts namely Thrissur, Palakkad and Malappuram (Table 5.1), it could be seen that about 46 percent of the arecanut palms in garden land remained healthy. Among the three toposequences, garden land seemed to be inherently more productive due to its physiographic layout. It prevented leaching to a certain extent and thereby retained adequate soil moisture and leachable nutrients. Proper aerobic condition was also maintained in garden land and the root system was apparently more healthy resulting in adequate uptake of nutrients and water. Thus the soil environment of garden lands had the optimum resources to sustain arecanut cultivation and resulted in the lowest percentage of severely affected palms.

The percentage of healthy palms were lowest (37 percent) in the converted paddy field situation (Table 5.1). The moderately affected and severely affected palms altogether constituted another 31 percent. The converted paddies lacked deep drainage as observed in several locations which resulted in an unfavorable rhizosphere situation for arecanut. The anaerobic soil environment, accumulation of excessive native elements

TABLE 5.1 Incidence of yellowing in arecanut among various toposequences averaged over the districts of Thrissur, Palakkad and Malappuram

Toposequence	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Converted paddy field	37	32	16	15
Garden land	46	29	15	10
Terraced upland	44	12	26	18

Table 5.2 Varietal differences in the incidence of yellowing in arecanut averaged over the districts of Thrissur, Palakkad and Malappuram

Variety	Incidence of yellowing (%)			
	Healthy	Mildly affected	Moderately affected	Severely affected
Kasargode local	15	46	24	15
Local cultivars	25	47	14	14
Mangala	22	20	35	23
Mohitnagar	17	23	43	17
Sumangala	19	21	47	13

such as iron, manganese etc in toxic levels, root decay and unavailability of nutrients due to transformation into unavailable form lead to a lower and imbalanced uptake of nutrients which made the palms unhealthy as reported by Mohapatra *et al*. (1975). It predisposed the palms to other pests and disease incidence too, thus collectively reducing the growth and yield of palm.

In terraced upland system, the percentage of mildly affected palms were lowest recording only 12 percent (Table 5.1). However the percentage of healthy palms (44 percent) was equal to both moderately affected and severely affected palms put together. It indicated the existence of different rhizosphere environment within each terrace, between inner and outer palms of each terrace where the water accumulation, content and retension of soil moisture and leaching of nutrients vary. Palms in the transcient zone were affected mildly with lower percentage of 12 observed in their incidence of yellowing.

Comparing the incidence of yellowing among various cultivated varieties in all the three districts namely Thrissur, Palakkad and Malappuram, it was seen that irrespective of the districts in which they are cultivated, higher percentage of the healthy (25 percent) and mildly affected (47 percent) arecanut palms were local cultivars (Table 5.2). These local cultivars were raised from the seedlings of selected palms grown in the regions which showed good soil and climate adaptability in the region, and resistance to pest and disease incidences. This can be compared to the ‘elite palm’ concept of coconut in the highly root wilt affected area where seedlings are raised from the root wilt resistant and high yielding coconut palms.

The local cultivars resulted in lowest percent of moderately affected and severely affected group with 14 percent each. In case of Kasargod local, though 15 percent was in the category of healthy, about 46 percent was mildly affected. High yielding varieties such as Mangala, Mohitnagar and Sumangala behaved similarly and it was found that a good percentage of the palms were moderately or severely affected. The survey revealed the genetic superiority of the local cultivars in countering incidence of yellowing.

Ravindran *et al.* (2000) had reported that out of six promising cultivars evaluated namely South Kanara, Mohitnagar, Mangala, Sumangala and Sreemangala in multilocational trials, all were susceptible to yellowing even though Mangala variety recorded the lowest incidence of yellowing. But in the present study Mangala, Sumangala and Mohitnagar showed a high degree of yellowing.

5.3 EXPERIMENT III DEVELOPMENT OF A MANAGEMENT STRATEGY TO CONTAIN YELLOWING OF ARECANUT UNDER VARIOUS TOPOSEQUENCES.

A nutrient management strategy to contain yellowing of arecanut under various toposequences was implemented in selected farmers' field in each toposequences of Thrissur district (Plate 2). Prevailing management practice adopted by farmers of the locality to contain yellowing was recorded and included as one of the treatments in each of the toposequences. Effect of application of organic manure over and above the farmers practice was studied. Existing package of practices recommendation (KAU, 2002) was also applied as one of the treatments. Other treatments involved provision of deep drainage, application of lime, sand, sodium silicate, magnesium sulphate, zinc sulphate, ammonium sulphate, borax, urea and three levels of N:K ratio. Root studies of yellowing affected palms were also undertaken in the experimental field.

5.3.1 Rhizosphere nutrient content

Under converted paddy field, the application of nutrients through inorganic fertilizers were found to significantly increase the nutrient contents in soil. Though the organic carbon content of the soil varied from 0.72 to 0.83 at the pre treatment stage (Table 4.17) which is theoretically considered enough to sustain the productivity of the soil, it did not reflect in the available nutrient contents of the soil particularly nitrogen. Available nitrogen content varied only from 200-239 kg ha^{-1} which showed that an expected C:N relationship for a productive soil is not existing in the soil and the reason is mainly attributed to the physicochemical properties of the soil. In converted paddy field where the soil remain partially or fully anaerobic due to water stagnation during several

A. Converted paddy field

B. Garden land

C. Terraced upland

Plate 2. Toposequences

months of the year, the mineralisation of nutrients will be improper. The soil pH value (Table 4.17) which vary from 3.89 to 4.28 also points to the defective mineralisation. The deep drainage provided (T_3) over the farmers' practice (T_1) has clearly improved the soil physicochemical properties as evidenced from the increased pH at all the observation stages with a pooled mean increase from 4.13 to 4.24. These changes have also brought about consistent increase in the available nitrogen content, though not reached at statistically significant level, at every stage of observation during the three years with a pooled mean increase from 185 to 189 kg ha^{-1}.

The inherent defect in the mineralisation process was evident from the content of all other nutrients too. There was a consistent increase in the available phosphorus content with a significant pooled mean difference in the deep drainage treatment over farmers' practice. This rate was relatively narrow than a preferred 10:1 (Tisdale *et al.,* 1975) and was found to widen with the imposition of deep drainage and other treatments. Potassium contents in the rhizosphere as shown by pooled mean (Table 4.6) were almost proportionally higher with enhanced rate of potassium application. The calcium content were relatively lower in T_1 and T_3 where it was not applied. Results showed that 500 g of calcium oxide application once in three years (T_2), though maintained pH at > 5, affected absorption of other nutrients. A significantly lower pooled mean leaf phosphorus content of 0.138 (Table 4.5) was observed in farmers' practice treatment (T_1) compared to all other treatments where lime has been applied at 150 g every year. This might be due to the reduced uptake of phosphorus in an excess calcium situation in the soil. Deepa (2001) has reported reduced uptake of phosphorus in the presence of high calcium content due to formation of insoluble calcium phosphate. She also suggested about the possibility of inactivation of both phosphorus and calcium in plants if taken up in imbalanced proportions. In all the treatments where nitrogen and magnesium were given as sulphate sources. significantly higher sulphur content was observed at all the observations. The zinc and boron contents were also significantly higher due to its external application. The non applied elements viz. iron, manganese, copper and aluminium did not show any significant variations. Though silicon was applied through sodium silicate and sand, total silicon content did not show significant increase. Silicon constitutes 23 to 35 percent of soil and the added quantity may be relatively too low to make a difference at the statistically significant level.

In the garden land and terraced uplands, where more similarities rather than differences in physicochemical characters occur, the nutrient contents in rhizosphere were almost similar. As observed in the converted paddy field situations, applied nutrients except silicon, the contents of nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc and boron were high, evidently due to their external application. The reason attributed to non significance in the variation of silicon content variation in the converted paddy field is valid here also. The soil pH was relatively high in garden land and terraced upland due to the obvious reason of variations in soil type and water status. In T_3 of both garden land and terraced upland, where 500 g lime was applied, once in three years, resulted in high calcium content and consequently higher pH immediately after the application, but this state could not be continued as observed in the later observations. Split application of lime at 150 g per annum maintained constant calcium content and pH of soil.

5.3.2 Leaf elemental composition and chlorophyll content

5.3.2.1 Leaf elemental composition

Elemental composition in plants is having a direct bearing on growth and yield of any plant. In case of arecanut, the fourth leaf from top which is considered as the index leaf (Mohapatra and Bhat, 1985) gives a representative content of nutrient elements and chlorophyll content of leaves. Among the mineral elements, nitrogen is the most important element followed by sulphur, which govern the growth, being the components of aminoacids and thereby protein. Phosphorus, the energy currency of the plant, potassium the osmoregulator, calcium with its role in cell wall formation, nitrogen and magnesium as chlorophyll formers and other nutrient elements as enzyme activators etc are having important roles in growth, development and sink formation. The failure of any nutrient element to be present in adequate quantity, or its disproportionate presence when compared to other nutrients can result in an unfavorable nutritional environment within the plant which may predispose the plant to attack by external pests and diseases or inappropriate physiological process ultimately resulting in reduced dry matter production or yield.

A perusal of the data on the leaf elemental composition of arecanut palm grown under converted paddy field conditions showed that deep drainage imposed over the farmers' treatment had resulted in the enhanced nutrient concentrations. In case of nitrogen, this increase has occurred from the second year onwards. But in case of all other nutrients, the increase was not pronounced even after six months of provision of deep drainage. An increase in the available nutrients in the rhizosphere had been observed as mentioned earlier in the case of nutrient mineralisation. However uptake need not be in proportion with the mineralisation due to various factors operating in soil particularly the disproportionate quantities of the elements in soil and the cationic and anionic competition for absorption by roots. A soil to be productive, the nutrient ions should be present in available forms, in correct quantity, and correct proportions under the critical stages.

Fertilizer application had significantly improved the leaf nutrient contents. In case of nitrogen, the mean increase was from 1.54 to 1.79 percent compared to 1.33 to 1.37 in unfertilized treatments. The highest nitrogen content of 1.79 percent was observed in magnesium sulphate applied treatment and may be due to multiple effect of production of more chlorophyll and in turn production of more protoplasm. The highest mean content of phosphorus was observed in the borax applied treatment with significant difference in observations at six months and one year after application. The leaf content of other nutrients were also significantly higher in the treatments where these were provided through fertilizers. The magnesium content was as high as 0.263 percent in magnesium sulphate applied treatment so also the case with sulphur, zinc and boron. Any of the non applied elements showed no significant difference in their content. Though not significant, the silicon content in farmers treatment was as low as 0.69 percent.

The nitrogen content of leaves were noticeably higher in garden land than terraced upland irrespective of the treatments as evidenced by the pooled mean values (Tables 4.22 and 4.40). In T_1 and T_3 where no inorganic fertilizers were applied, it was 1.55 and 1.53 percent against 1.31 and 1.32 percent respectively in garden land and terraced upland. Whereas in other fertilizer applied treatments, the means varied from 1.82 to 1.92 percent in garden land and 1.65 to 1.79 in terraced upland. It is notable that similar variations in nutrient content between garden land and terraced upland were observed in all other nutrients. Though both the toposequences had an aerobic environment and similar nutrient transformation dynamics, chances for leaching of nutrients were more and hence unavailability of enough nutrients particularly during rainy season, in terraced uplands. Also it had been seen that the available nutrient contents in the rhizosphere is lower in terraced upland than garden land. Uptake and translocation was guided by several factors. Even the nutrients less liable to leaching such as phosphorus also could be at a deficient level if nitrogen and potassium were inadequate. Potassium is well known for its role in helping translocation of nutrients in plants.

5.3.2.2 Leaf chlorophyll content

Chlorophyll being a primary protenaceous product and the seat of photosynthesis, its content in plant is very much indicative of physiological and growth processes taking place in the plant. The stress developed due to climate and soil characteristics particularly deficiency and excess of nutrient elements largely affect the biosynthetic pathway of chlorophyll development.

A perusal of data on total chlorophyll and its component parts chlorophyll-a and chlorophyll-b (Tables 4.18, 4.19, 4.36, 4.37, 4.54 and 4.55) in all the three toposequences clearly showed that stress effects were more in converted paddy fields where as other two toposequences behaved similarly with an edge over the garden land, nitrogen and magnesium being essential for adequate chlorophyll formation, the supply of these along with other elements influencing in their higher uptake were proved to be highly essential to increase the chlorophyll-a, chlorophyll-b and thereby total chlorophyll. Irrespective of the toposequences, significantly higher chlorophyll contents were observed in fertilizer applied than non applied treatments. Magnesium sulphate application resulted in the highest chlorophyll concentration irrespective of the toposequences. Menon and Kalyanikutty (1961) have reported similar results. An increasing trend in the chlorophyll components and total chlorophyll is observed in treatments where nitrogen was applied through ammonium sulphate than urea, indicating the role of sulphur in enhancing chlorophyll content. Such increasing trends were noted in garden land and from terraced upland toposequences also in treatments where the N:K ratio were changed from the existing recommendation 1:1.4 to 1:2 and 1:2.5. A notable increase in total chlorophyll was observed in borax applied treatment in terraced upland indicating the need for application of boron in terraced upland. Being an anion, the possibility of leaching is more in the case of boron. Boron is involved in cell wall metabolism along with calcium (Srivastava, 1999). Since sugars can form borate complexes, it is suggested that sugars move in plant in this form. Boron also plays an important role in stimulating growth of pollen tubes that may influence the percentage of nut set.

The variation in development of chlorophyll components throw light in to the management practices to be adopted in particular toposequence. Percentage change in the chlorophyll content of index leaf during first year (pre treatment) and at the end of third year (post treatment) in the three different ecosystems are presented in Figures 3a, 4a and 5a.

An analysis of the illustrations revealed that the percentage change due to the modified management practices (by way of imposing treatments) was notably more even with more than 500 percent in magnesium sulphate applied treatment in converted paddy field situation than in garden land and terraced upland. Another notable difference is the development of chlorophyll components. The percent change of chlorophyll-b was higher and more pronounced than chlorophyll-a under converted paddy land and terraced upland than the garden land. The larger increase in chlorophyll-b as against small increases in chlorophyll-a is indicative of relative proportion of chlorophyll-a and b. At sub optimal nutrient concentrations particularly nitrogen, chlorophyll-a alone will develop and

Figure 3a Percentage change in chlorophyll content of index leaf from first year (2004) to third year (2006) of experiment in converted paddy field

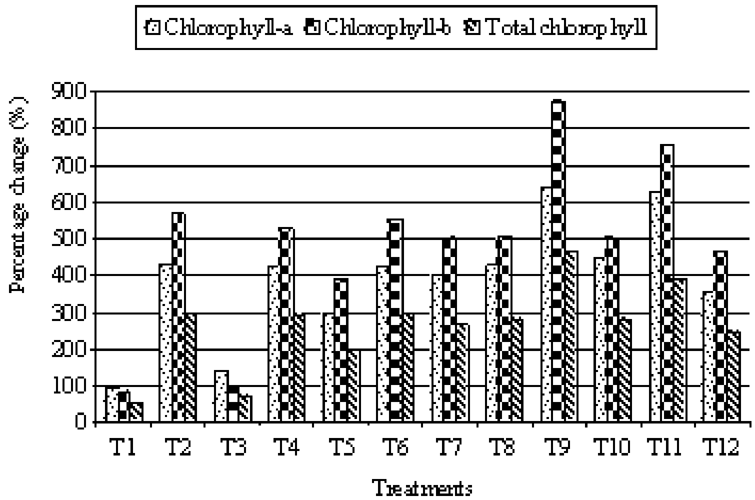


Figure 3b Percentage change in yellowing index from first year (2004) to third year (2006) of experiment in converted paddy field

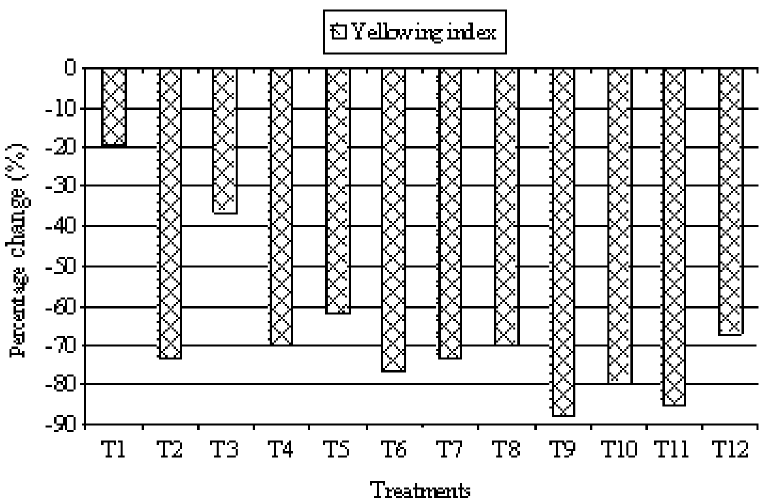


Figure 4a Percentage change in chlorophyll content of index leaf from first year (2004) to third year (2006) of experiment in garden land

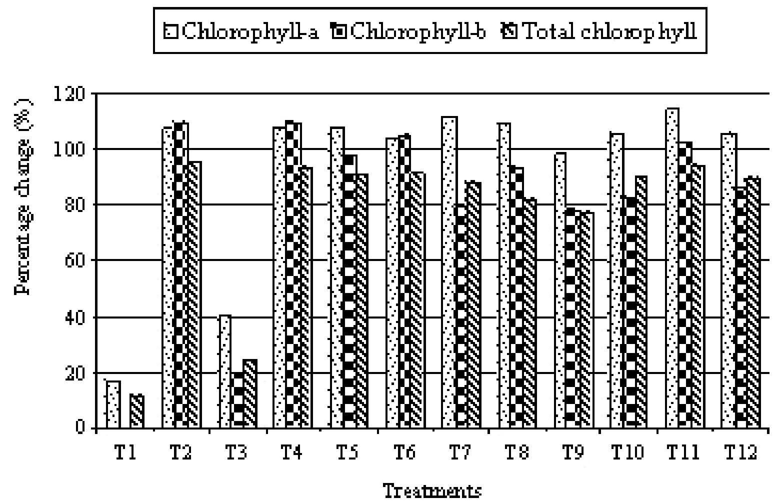


Figure 4b Percentage change in yellowing index from first year (2004) to third year (2006) of experiment in garden land

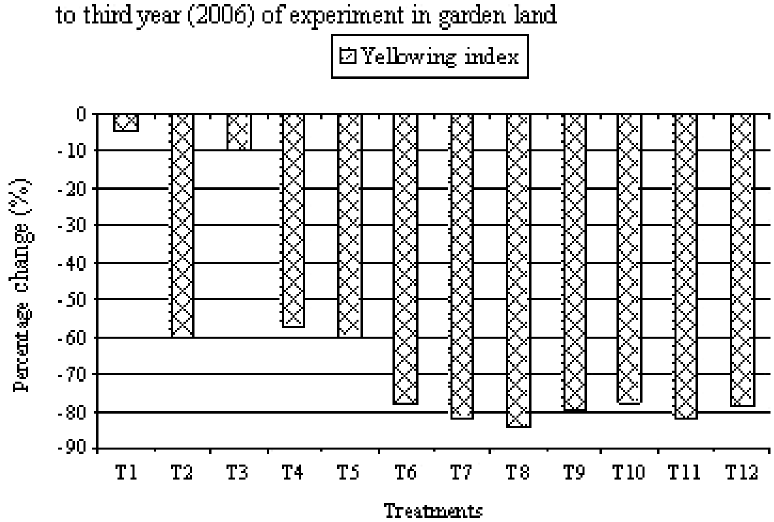


Figure 5a Percentage change in chlorophyll content of index leaf from first year (2004) to third year (2006) of experiment in terraced land

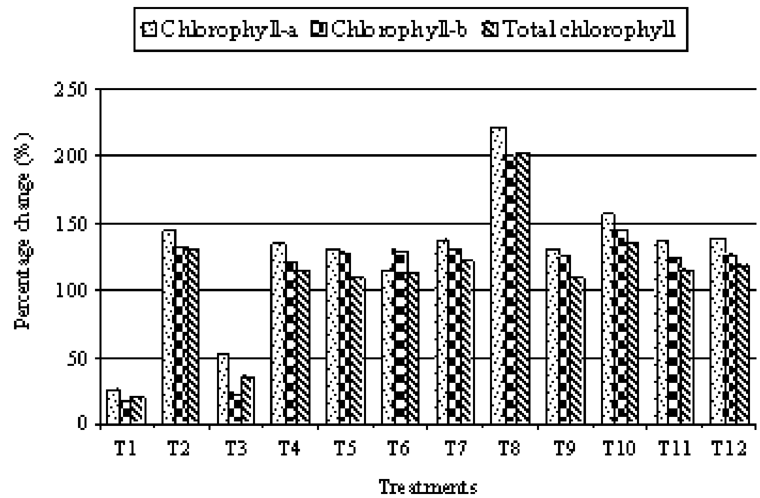
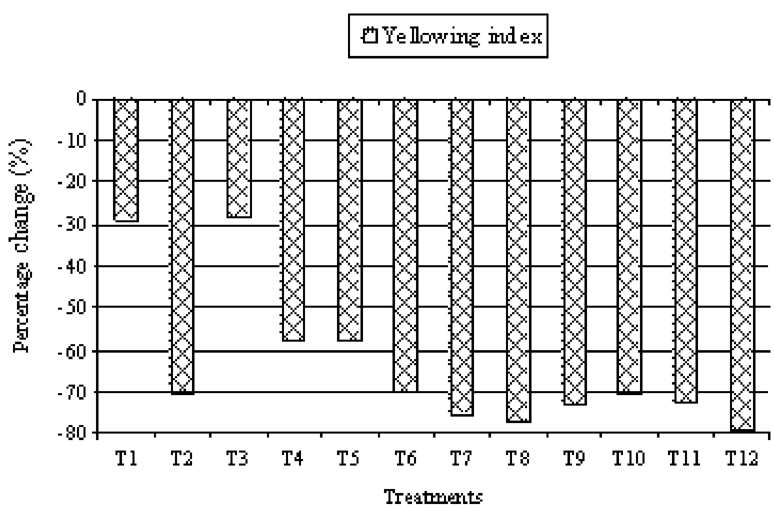


Figure 5b Percentage change in yellowing index from first year (2004) to third year (2006) of experiment in terraced land



chlorophyll-b believed to be developed from chlorophyll-a fail to develop because of inhibition in the concerned reaction mechanism (Bridgit and Potty, 1992). This incidentally will explain the reason for low productivity under low nutrient concentrations as chlorophyll-b known to be the acceptor of radiant energy which is subsequently furnished to the real site of synthesis. Mayers and French (1960) reported that photosynthetic efficiency will be maximum only in the two pigment system process. A deficiency in one will bring about more than proportionate reduction in assimilation rate. The data also indicated that the stress effects leading to formation of sub optimal levels of chlorophyll are more in converted paddy fields. Between garden land and terraced upland, garden lands possess a favorable soil environment and hence more responsive to normal management packages.

5.3.3 Yellowing index

The yellowing index developed in the experiment I was utilized to analyze the treatment effects on symptomatic expression of arecanut yellowing. The index is indicative of the percentage leaf area affected by yellowing, necrosis and extent of tapering of crowns. The index was having highly significant correlation with the post treatment yield in all the three toposequences (Table 4.1). The treatment palm were selected in the range of moderate yellowing with possible minimum variation in the incidence of yellowing as evidenced by the statistical non significance in variations among palms. The yellowing indices varied between 41-49 in converted paddy fields, 40-50 in garden land and 47-55 in terraced upland.

In the converted paddy field, deep drainage has lowered the incidence significantly from 33 to 28 after three years. Indices had further reduced in the range of 5 to 16 in other treatments depending on the merit. It was as low as 5 in the magnesium sulphate applied treatment. Variation from green to yellow colour of the leaf is indicative of the leaf chlorophyll status. Both the defective chlorophyll formation process and disintegration of chlorophyll can lead to yellowing. The role of nutrients in the formation of chlorophyll is already discussed. Being a highly mobile element even nitrogen in the chlorophyll can be mobilized to younger leaves in a nitrogen deficient situation in the plant and yellowing can be resulted.

Application of additional quantity of organic manure has reduced the yellowing index significantly probably through its long term effect on maintenance of soil productivity by various ways. As in the converted paddy field, the imposition of fertilizer treatments has reduced the yellowing index significantly. Percentage change in yellowing index between pre and post treatment observations are illustrated in figures 3b, 4b and 5b. An overview of the graphs indicated that garden land responded relatively better to the selected management practices than converted paddy and terraced upland.

5.3.4 Yield and yield attributes

The yield of arecanut normally expressed as *chali* yield is the product of number of fruits palm^{-1} and dry kernel weight. The effect of treatments on *chali* yield palm^{-1} in converted paddy field, garden land and terraced upland is presented in tables 4.21, 4.39 and 4.57. The percentage change in the yield attributes such as dry kernel weight and number of fruits palm^{-1} and the *chali* yield due to treatment effects in converted paddy field, garden land and terraced upland are illustrated in figures 6a, 6b, 7a, 7b, 8a and 8b.

In the converted paddy field, the highest yield of 3.97 kg palm^{-1} year^{-1} was obtained for the treatment which received 100:40:200g NPK, 60 g magnesium sulphate and nitrogen as ammonium sulphate with an N:K ratio of 1:2 (T_9). The highest yield difference between the pre and post treatment harvests was also observed for this particular treatment. Similar high yields were resulted in other treatments also which received sulphur and high rate of potash. This yield increase was resulted from a 20 percent increase in the nut weight and 17 percent increase in the dry kernel weight as observed in the figure 6a. Consequently a 41 percent yield increase was observed in the *chali* yield for the particular treatment (T_9) (Figure 6b). In T_1 and T_3 where no inorganic fertilizers were given, there was decrease in the number of fruits. The number of nuts is decided at the time of spikelet differentiation happening approximately eighteen months

Figure 6a Percentage change in dry kernel weight and number of fruits palm^{-1} from first year (2004) to third year (2006) of experiment in converted paddy field

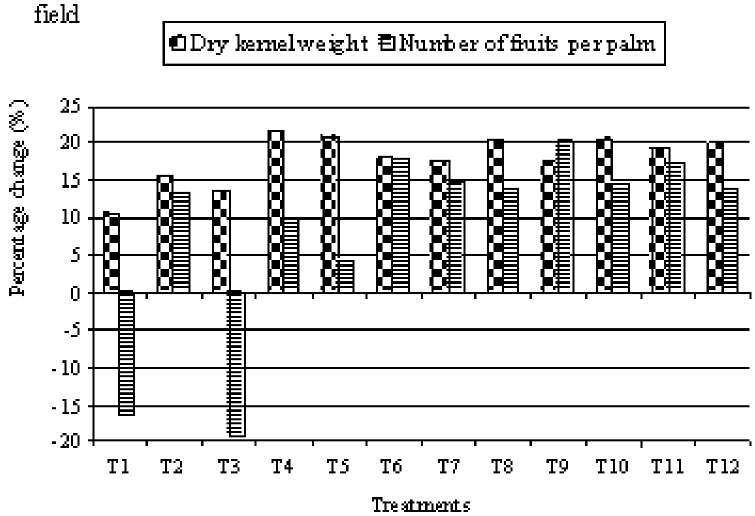


Figure 6b Percentage change in chali yield from first year (2004) to third year (2006) of experiment in converted paddy field

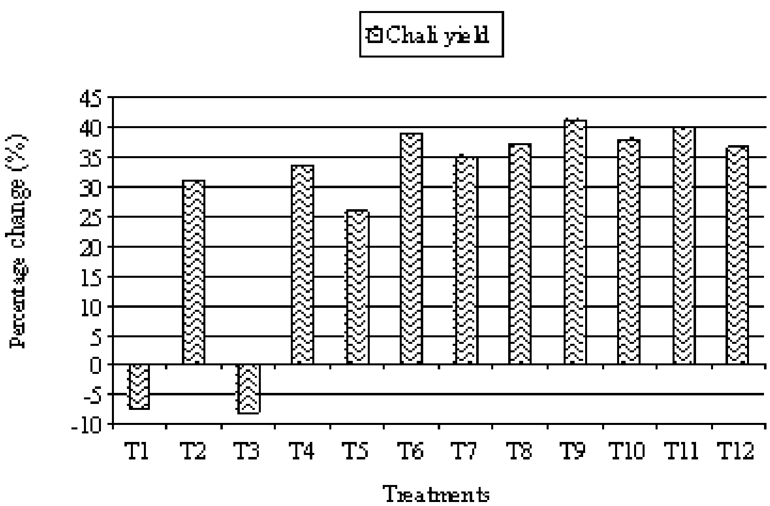


Figure 7a Percentage change in dry kernel weight and number of fruits palm^{-1} from first year (2004) to third year (2006) of experiment in garden land

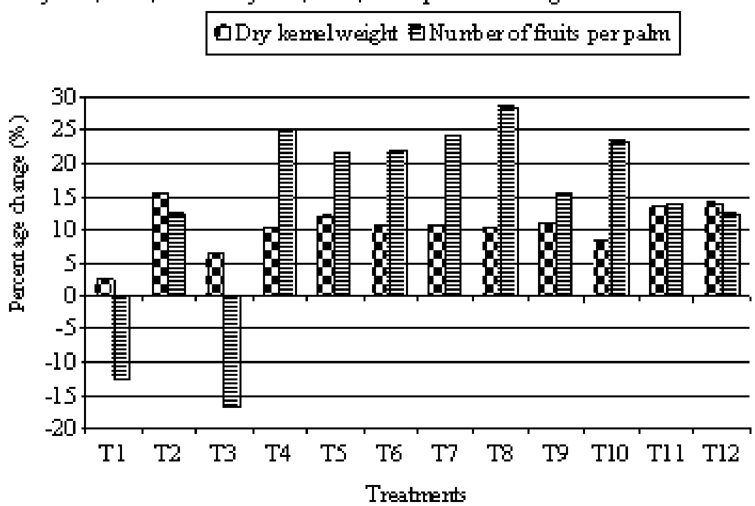


Figure 7b Percentage change in chali yield from first year (2004) to third year (2006) of experiment in garden land

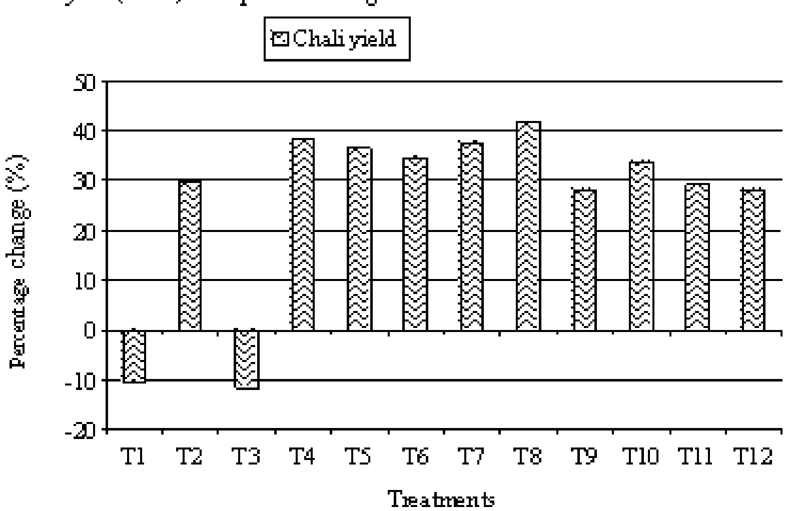


Figure 8a Percentage change in dry kernel weight and number of fruits palm^{-1} from first year (2004) to third year (2006) of experiment in terraced upland

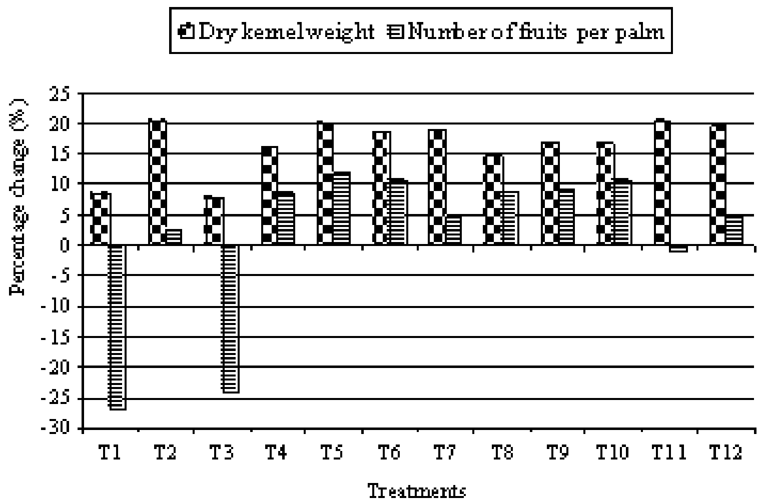
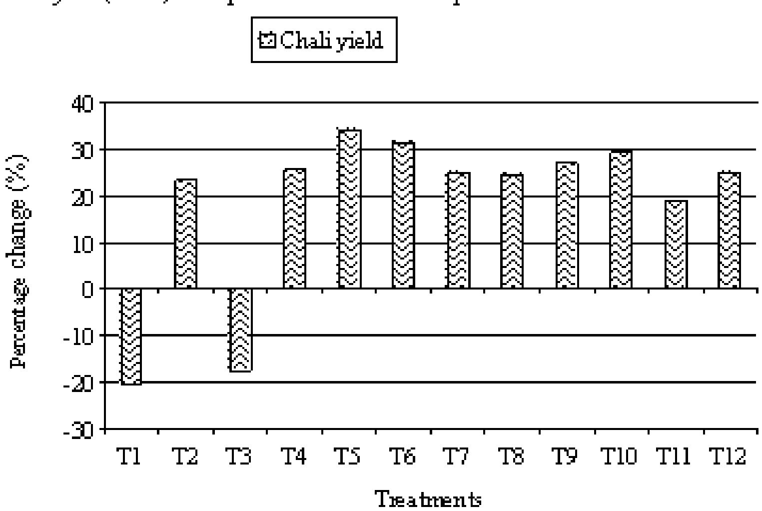


Figure8b Percentage change in chali yield from first year (2004) to third year (2006) of experiment in terraced upland



before harvest. Any stress either in the form of nutrient or water may reduce the nut number (Ananda, 2004).

In the garden land, the highest yield of 3.99 kg $palm^{-1}$ during the third year harvest was observed for a similar treatment which received nitrogen as ammonium sulphate, magnesium sulphate and higher rate of potassium. The fertilizer rate applied was 100: 40: 250 g NPK. In this treatment, the percentage change in the *chali* yield between pre and post treatment harvest was 41 percent constituted by a 10 percent increase in the dry kernel weight and a 28 percent increase in the nut number. Here also non application of fertilizers caused 10-11 percent decrease in *chali* yield constituted by a 12-17 percent decrease in the number of nuts and 2-6 percent decrease in dry kernel weight. The treatment supplied with borax also produced relatively higher yield of 3.84 kg $palm^{-1}$.

In the terraced upland situation also, the highest *chali* yields of 3.96, 3.88 and 3.83 kg $palm^{-1}$ were resulted in the treatments receiving zinc, borax and magnesium sulphate. In all these treatments, the fertilizer application rate was 100:40:250 g NPK with N:K ratio of 1:2.5, and contained a sulphur fertilizer source too. These treatments registered relatively higher percentage change in dry kernel weight, number of fruits and *chali* yield between the pre and post treatment harvests.

The higher yield registered in some of the treatments is the consequent effect of optimum growth and development of the palms taken place in the different toposequences. The availability and uptake of nutrients are influenced by changes in the soil reaction, organic matter content, and proportion of the nutrients present in the soil and water. The nutrients taken up may involve further in various physiological process such as production of protoplasm, chlorophyll and ultimately the photosynthates and its translocation to the sink. An unfavorable external nutritional environment in the rhizosphere and internal nutritional environment within the plant may disrupt all the physiological processes within the plant. The chlorophyll formation as well as its malfunction and degradation can happen which may turn the plant unhealthy.

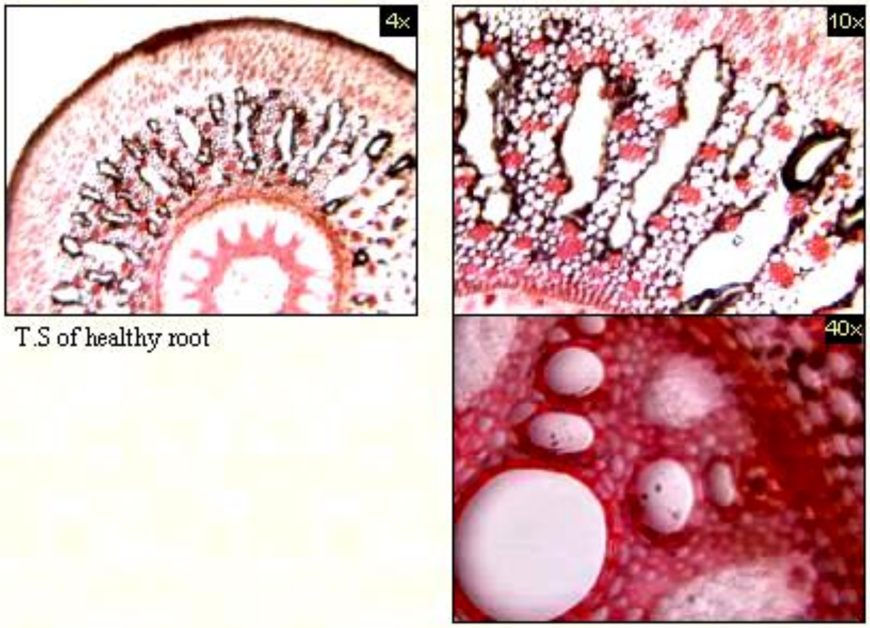
5.3.2 Root studies of yellowing affected arecanut palms

Roots are regarded as the primary organs of mineral absorption. In the root, the site of most active uptake is 1-2mm behind root apex as this is the region of cell expansion. The growth and development of roots are the most important factors influencing the uptake of nutrients by plants. The more extensive the root system, the more nutrients have an opportunity to reach the roots by mass flow and diffusion.

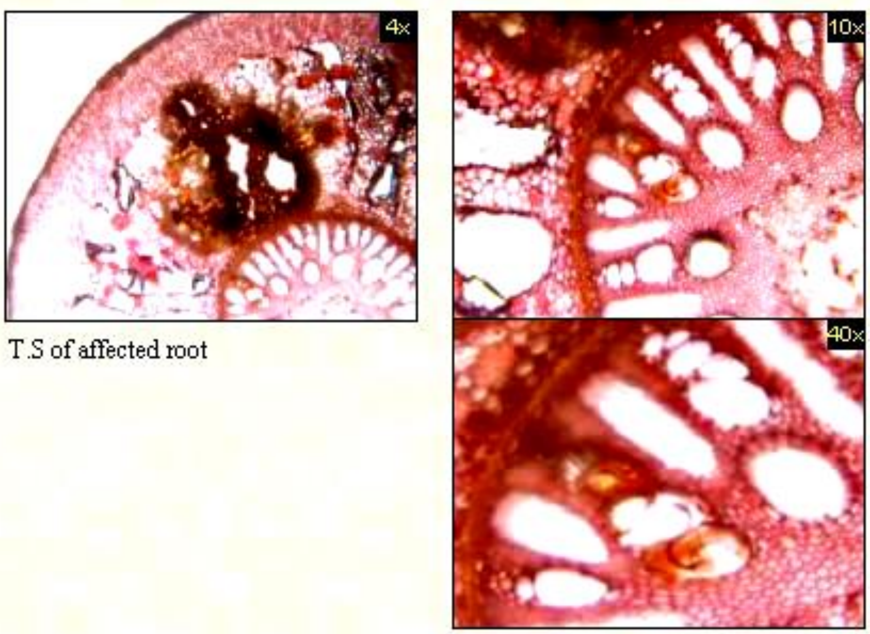
In the present study, incidence of root rot in yellowing affected palms showed that root rotting was confined to converted paddy field while garden land and terraced upland were relatively free from root rot. Nair and Rawther (2000) had reported that tips and absorbing regions of young roots of yellowing affected arecanut palms turn dark and gradually rot. Outer cortex becomes discoloured and degenerated. Tyloses occur in the xylem vessels of about 60 percent of old roots (Nair, 1976). In the present study, blockage of root xylem was noticed in yellowing affected palms. The highest incidence of root xylem blockage was recorded in converted paddy field (Plate 3).

The involvement of phytoplasma in the incidence of yellowing was explored by several workers (Nair and Seliskar, 1978; Seliskar and Wilson, 1981). In this study also such an attempt was made utilizing the roots of healthy and affected palms. Incidence of Dienes' staining of root phloem (phytoplasma metabolise and creates a blue colour) is an indication of presence of phytoplasma. Highest incidence of Dienes' staining of root phloem was observed in garden land (Plate 4).

In certain instances, incidence of both root xylem blockage and Dienes' staining of root phloem were found to occur in the same yellowing affected palm and such incidences were least noticed in garden land. This points to the fact that root rotting, root xylem blockage and presence of phytoplasma in the phloem are either directly or indirectly interfering with transport of plant nutrients and translocation of photosynthates inside plant resulting in yellowing.

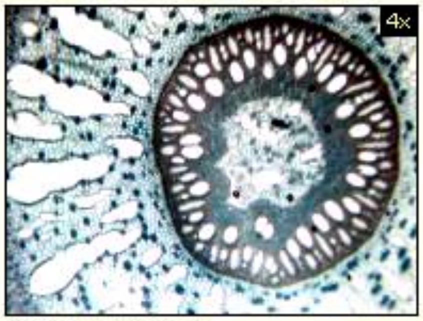


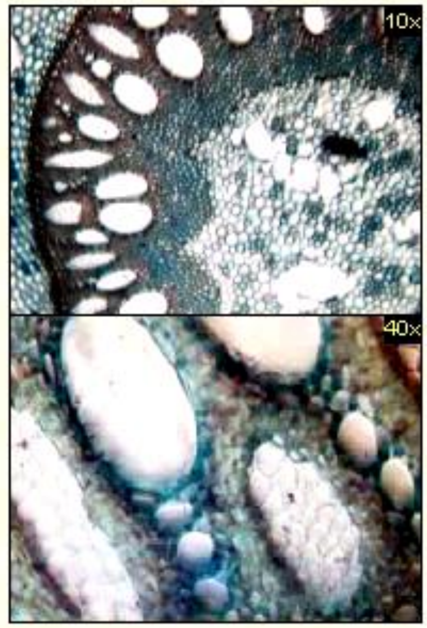
T.S of healthy root



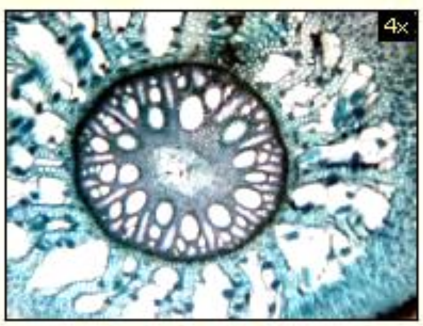
T.S of affected root

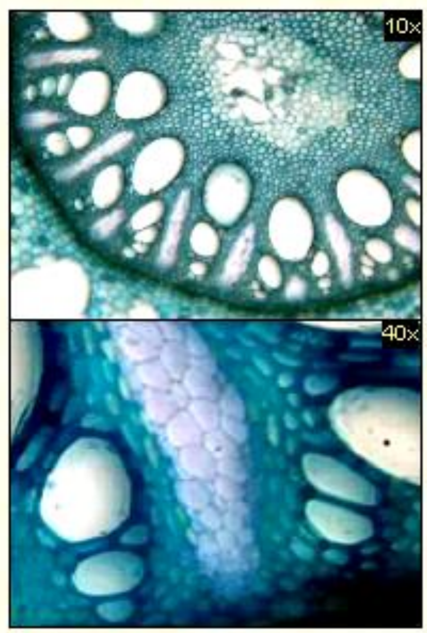
Plate 3. Xylem blocked in affected root





T.S of healthy root





T.S of affected root

Plate 4. Phloem stained by Dienes' stain

5.3.3 Recommendations to contain yellowing

The differential effect of applied treatments on the growth, development and yield formation were studied and a set of packages to contain the yellowing of arecanut are formulated.

In the converted paddy situation, deep drainage channels are to be provided to keep the water below the root zone during monsoon and undertake periodic cleaning of drainage channels to facilitate better drainage. 150 g lime palm^{-1} year^{-1} may be applied in the basin opened during February. A minimum of 10 kg palm^{-1} organic manure as farmyard manure/compost may be provided. Inorganic fertilizer application may be done @100:40:200g NPK palm^{-1} year^{-1} in two splits in February and September including any sulphur containing fertilizer source and 60 g magnesium sulphate under irrigated conditions.

In garden land situation also, lime, organic manure and magnesium sulphate may be applied as in converted paddy field. Fertilizer @100:40:250g NPK palm^{-1} year^{-1} in two splits in February and September including any sulphur containing fertilizer source and borax @ 20 g palm^{-1} year^{-1} under irrigated conditions.

In terraced upland situation, 150 g lime and a minimum of 15 kg organic manure palm^{-1} year^{-1} may be applied in basins. Fertilizer @100:40:250g NPK in two splits in February and September, 60 g magnesium sulphate, 20 g borax and 20 g zinc sulphate palm^{-1} year^{-1} under irrigated conditions including a sulphur containing fertilizer source.

Appropriate pest and disease control measures are to be undertaken in all the toposequences.

5.3.4 Future line of work

The present investigations indicated that yellowing of arecanut gardens definitely lead to yield reduction and hence emphasized the importance of managing yellowing affected palms on a long term basis. The experiments on perennial crops in farmers fields have inherent limitations in bringing out the exact effects of treatments due to variations in variety, age and management practices. Long term interdisciplinary experiments starting from the planting of seedlings adopting the best treatments now observed can be taken up. It is indicated at several instances that imbalanced elemental concentration within the plant weakens the plant system and predisposes to the disease causing organisms. The blockage of phloem and xylem vessels which makes constraints to upward and downward movement of nutrients, water and photosynthates initially result from unfavorable nutritional environment within the plant. The role of organic manure sources such as non-edible oil cakes and enriched compost including vermi and coir pith compost should be experimented to contain the yellowing in arecanut. The role of biofertilizers in maintaining both land and crop productivity could be experimented. The effect of micronutrients in relation to their critical limits in soil and plant should be explored to contain the yellowing and there by improve the productivity.

SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSION

The research project entitled "Nutritional management of yellowing in arecanut" was conducted for three years from October 2003 to September 2006 to characterise the nature and intensity of yellowing in arecanut as well as the associated predisposing nutritional factors and to develop a management strategy to contain the yellowing in different toposequences. The salient research results obtained are presented below.

Development of yellowing index

- The index earlier developed by George *et al.* (1980) was modified as Yellowing index (I) = {(Y+N)/L + R} x 10, where Y is the total score for yellowing, N is the total score for necrosis, R is the score for reduction in crown size and L is half the number of leaves in crown, to quantify the incidence of arecanut yellowing.
- The modified yellowing index utilizes 13 classes in place of earlier 8 classes to score yellowing, 5 classes in place of earlier 3 classes to score necrosis and 5 classes in place of earlier 3 classes to score reduction in crown size. Thus compared to earlier developed index, the present yellowing index has enhanced the precision in quantifying yellowing.
- Most of the leaf nutrient contents of experimental palms during pre treatment period did not have significant correlation with yellowing index as the palms selected were in a uniform state of yellowing, index ranging from 41-50 in converted paddy field, 40-50 in garden land and 45-55 in terraced upland.
- The highly significant negative correlation of the leaf elemental composition, growth and yield parameters with the yellowing index of experimental arecanut palm in all the three toposequences viz,. converted paddy field, garden land and terraced upland clearly validated the reliability of the index under different growing situations and treatments.
- The treatments resulted in reduction of yellowing index by 5-33 in converted paddy field, 7-38 in garden land and 11-39 in terraced upland during post treatment period bringing about favorable variations in leaf nutrient status and yield.

Survey

- The survey conducted in Thrissur, Palakkad and Malappuram district to study the intensity of arecanut yellowing among the three toposequences utilizing the newly developed yellowing index showed that highest percentage of healthy palms existed in garden land situations. Among the three toposequences, garden land was found to be inherently more productive and supportive to arecanut cultivation than converted paddy field and terraced upland due to its topographical advantage.
- The severity of the yellowing incidence was more in terraced uplands followed by converted paddy field, possibly due to the imbalanced availability and uptake of nutrient elements aggravated by excessive leaching of nutrient elements in terraced uplands, and due to impeded drainage in converted paddy field.
- Survey also showed that local cultivars remained healthier than any of the popular varieties such as Kasargode local, Mangala, Mohitnagar and Sumangala.

Nutritional studies in converted paddy field

- Provision of deep drainage and additional lime application have created a condition congenial for balanced uptake of nutrients as shown by enhanced calcium, magnesium and sulphur contents and reduced phosphorus contents in leaf.
- The deep drainage treatment increased the nut weight and kernel weight by 3.5g and 1.5 g respectively. This increase has helped to maintain the yield even with a reduction in number of nuts palms^{-1} occurred over the years in unfertilized treatments.
- In converted paddy field, farmers' practice involving application of organic manure and lime over three year period resulted in lowering of yellowing index from 41 to 33. However the *chali* yield showed a decrease of 274 kg ha^{-1} over pre treatment level.
- Provision of deep drainage to palms under farmers' practice decreased yellowing index from 44 to 28 and *chali* yield by 288 kg ha^{-1} from the pre treatment levels.

- Farmers' practice and provision of deep drainage had brought about an increase in dry kernel weight by 0.62 g and 0.75 g, respectively along with a decrease in number of fruits palm^{-1} to the tune of 72 and 86 numbers respectively over three years period. This reduction in the number of fruits resulted in decreased *chali* yield for both these treatments.
- Treatments involving application of inorganic fertilizers to palms under farmers' practice along with provision of deep drainage resulted in reduction of yellowing index ranging from 42 to 50 at pre treatment period to 5 to 16 during post treatment period. This resulted in an increase of 0.97 to 1.35 g dry kernel weight and 20 to 85 numbers of fruits palm^{-1} contributing to increased *chali* yield of 1000 to 1590 kg ha^{-1} during post treatment period.
- All treatments involving application of inorganic fertilizers in addition to organic manure and provision of deep drainage had significantly increased the *chali* yield during second and third year of experiment. This showed that yellowing affected palms gave more response to integrated nutrient management than to application of organic manure alone.
- During the three years of experiment, palms treated with magnesium sulphate showed significant reduction in yellowing index compared to all other treatments. Application of magnesium resulted in significantly higher contents of magnesium, chlorophyll-a, chlorophyll-b and total chlorophyll in the index leaf which in turn lowered the yellowing index.
- Comparison of yellowing index and *chali* yield in palms applied with ammonium sulphate showed that sulphur did not play any definite role in reduction of yellowing index but had a pivotal role in enhancing the *chali* yield mainly through increase of number of nuts palm^{-1} and to a certain extent through increase of dry kernel weight.
- Yellowing affected palms treated with ammonium sulphate in addition to magnesium sulphate recorded highest *chali* yield of 2.87 and 3.97 kg palm^{-1} during second and third year of experiment respectively and also recorded lower yellowing index of 5 during post treatment period.

- ♦ Application of fertilizers at 100:40:140 g palm^{-1} in conjunction with deep drainage and additional lime application increased the *chali* yield by 1001 to 1138 kg ha^{-1}. Sulphur application along with this has further increased the yield to the level of 1289 to 1412 kg ha^{-1} under converted paddy field.
- ♦ Changing the N:K ratio to supply nutrients at 100:40:200 g NPK palm^{-1} increased the yield by 1138 to 1344 kg ha^{-1}. S application together with this enhanced rate further increased the yield by 1385 to 1590 kg ha^{-1} under converted paddy field.
- ♦ Enhanced rate of potassium, combined with magnesium and sulphur application resulted in the highest *chali* yield of 3.22 kg palm^{-1} (4415 kg ha^{-1}). This treatment resulted in the least yellowing index and highest content of chlorophyll, nitrogen, sulphur and magnesium in the plant under converted paddy field.
- ♦ Applied micronutrients like boron and zinc failed to bring about significant change in yellowing index and *chali* yield as these micro nutrients were already present in adequate quantities in the experimental field.
- ♦ Silica applied through sand or sodium silicate also failed to bring about significant change in yellowing index and *chali* yield as silica was inherently present in the experimental field with sandy loam texture.

The recommendations for yellowing affected palms grown in converted paddy field can be summarized as follows:

- ⊗ Provide deep drainage channels so as to keep the water below the root zone during monsoon and undertake periodic cleaning of drainage channels to facilitate better drainage.
- ⊗ 150 g lime palm^{-1} year^{-1} may be applied in the basin opened during February.
- ⊗ A minimum of 10 kg organic manure palm^{-1} as farmyard manure/compost may be applied.
- ⊗ Inorganic fertilizer application may be done @100:40:200g NPK palm^{-1} year^{-1} in two splits in February and September under irrigated conditions.
- ⊗ A sulphur containing fertilizer either ammonium sulphate or ammonium phosphate sulphate (Factumphos) may be included.

- ⊗ Magnesium sulphate @ 60 g palm year^{-1} may be included as a source of magnesium to yellowing affected palms.
- ⊗ The routine fungicide and insecticide application may be carried out.

Nutritional studies in garden land

- ♦ Farmers' practice involving application of organic manure, lime and bone meal over three year period resulted in lowering of yellowing index from 40 to 38. However the *chali* yield showed a decrease of 356 kg ha^{-1} over pre treatment level.
- ♦ Additional application of 5 kg organic manure to palms over the farmers' practice of application of 5 kg organic manure showed a decrease in yellowing index from 40 to 30 and a reduction in *chali* yield to the tune of 398 kg ha^{-1} over pre treatment levels.
- ♦ Under garden land situation, application of additional 5 kg organic manure without inorganic fertilizers has not reflected in the yield increase but has improved the leaf elemental composition particularly nitrogen, phosphorus, sulphur and magnesium. This had brought about an increase in dry kernel weight by 0.37 g however fruit number had been reduced by 73 nuts palm^{-1}
- ♦ Inorganic fertilizer application resulted in reduction of yellowing index ranging from 40 to 50 at pre treatment period to 7 to 18 during post treatment period. This resulted in an increase of 0.59 to 0.95 g dry kernel weight and 53 to 114 numbers of fruits palm^{-1} contributing to increased *chali* yield of 1069 to 1608 kg ha^{-1} during post treatment period.
- ♦ Additional quantity of lime had helped to increase the soil pH and thereby availability and content of calcium in plants.
- ♦ Fertilizer application at 100:40:140 g NPK palm^{-1} increased the yield by 1069 kg ha^{-1}. Additional organic manure @5 kg palm^{-1} increased the yield by 1316 kg ha^{-1} over pre experiment yield.
- ♦ Application of magnesium sulphate @ 60 g palm^{-1} resulted in significant reduction in yellowing index and increased magnesium content of index leaf

leading to significantly higher chlorophyll-a, chlorophyll-b and total chlorophyll contents.

- ♦ Enhancement of N:K ratio to 1:2 or 1:2.5 without sulphur application did not increase the yield. However together with sulphur application, notable yield increase by 1289 kg ha^{-1} at 1:2 and by 1412 kg ha^{-1} at 1:2.5 ratio was resulted under garden land.
- ♦ Highest yield of 3.99 kg $palm^{-1}$ (5470 kg ha^{-1}) which was 1604 kg more than pre application of treatments was resulted from the treatment which received 100:40:250 g NPK combined with 60 g of magnesium sulphate. Nitrogen application through ammonium sulphate was better than urea since it contains sulphur.
- ♦ Boron application as 20 g borax has also increased yield by 0.97 kg $palm^{-1}$ resulting in 5265 kg ha^{-1} which was 1330 kg more than pre application of treatments under garden land.
- ♦ Application of zinc and silicon did not result in any significant change in yellowing index and *chali* yield.

The recommendations for yellowing affected palms grown in garden land can be summarized as follows:

- ⊗ 150 g lime and a minimum of 10 kg organic manure, 60 g magnesium sulphate per palm per year may be applied as in case of converted paddy field
- ⊗ Fertilizer @100:40:250g NPK $palm^{-1}$ $year^{-1}$ in two splits in February and September by way of including any sulphur containing fertilizer source under irrigated conditions can be adopted.
- ⊗ Borax @ 20 g palm $year^{-1}$ may be included as a source of boron to yellowing affected palms.
- ⊗ Recommended plant protection measures may be adopted.

Nutritional studies in terraced upland

- ♦ Farmers' practice involving application of organic manure, and lime over three year period resulted in lowering of yellowing index from 55 to 39. Additional application of organic manure to palms under farmers' practice showed a decrease in yellowing index from 49 to 35.

- ♦ Addition of organic manure or farmers' practice had brought about an increase in dry kernel weight by 0.47 g. However the number of fruits per palm decreased by 111 numbers over three years period.
- ♦ Addition of inorganic fertilizers over farmers' practice resulted in reduction of yellowing index ranging from 45 to 54 at pre treatment period to 22 to 29 during post treatment period. This resulted in an increase of 1.03 to 1.30 g dry kernel weight and 13 to 51 numbers of fruits palm^{-1} contributing to increased *chali* yield of 754 to 1289 kg ha^{-1} during post treatment period.
- ♦ As in case of converted paddy field and garden land, application of magnesium resulted in significantly higher magnesium content of index leaf leading to significantly higher chlorophyll-a, chlorophyll-b and total chlorophyll contents which in turn lowered the yellowing index. It increased the nitrogen, phosphorus, potassium, calcium and magnesium contents of leaves.
- ♦ Nutrient application through sulphur containing fertilizers have found to increase the yield considerably. Fertilizer application at 100:40:250 g NPK palm^{-1} with 20 g borax was found to give 3.44 kg palm^{-1} (4716 kg ha^{-1}) and with 20 g zinc sulphate gave 3.38 kg palm^{-1} (4634 kg ha^{-1})
- ♦ Application of silicon through sodium silicate failed to bring about significant change in yellowing index and *chali* yield.

The recommendations for yellowing affected palms grown in terraced upland can be summarized as follows:

- ⊗ 150 g lime and a minimum of 15 kg organic manure palm^{-1} year^{-1} may be applied as in case of garden land.
- ⊗ Fertilizer @100:40:250g NPK in two splits in February and September, 60 g magnesium sulphate and 20 g borax and 20 g zinc sulphate palm^{-1} year^{-1} under irrigated conditions including a sulphur containing fertilizer source.
- ⊗ Routine pest and disease control measures may be undertaken.

Root studies

- The incidence of root rot confined mainly to yellowing affected palms grown in converted paddy field and was absent in garden land and terraced upland.
- Higher incidence (24 percent) of root xylem blockage was detected in yellowing affected palms under converted paddy field than in both garden land and terraced upland (20 percent). Root xylem blockage was noticed in yellowing affected palms irrespective of toposequences.
- The possibility of involvement of phytoplasma as revealed by Dienes technique in causing yellowing was indicated in 16 percent of the affected palms in converted paddy field, 24 percent in garden land and 20 percent in terraced upland.
- Incidence of both root xylem blockage and presence of phytoplasma in root phloem were found to occur simultaneously in the same yellowing affected palm.
- Arecanut palms which were free from incidence of root rotting, root xylem blockage and presence of phytoplasma exhibited yellowing irrespective of the toposequences under which they were cultivated.

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APPENDICES

Appendix 1 Weather parameters during the cropping period

(October 2003 – September 2006)

Monthly Average	Relative humidity (%)	Maximum temperature (^{o}C)	Minimum temperature (^{o}C)	Evaporation (mm)	Rainfall (mm)
Oct-03	80.63	30.81	23.09	106	277
Nov-03	66.08	31.54	23.97	167	018
Dec-03	60.68	32.19	21.96	180	000
Jan-04	57.39	33.35	22.27	195	000
Feb-04	49.86	35.22	22.47	199	000
Mar-04	61.19	36.50	24.19	209	009
Apr-04	68.98	34.77	25.21	165	060
May-04	83.50	30.40	23.65	107	579
Jun-04	84.05	29.63	23.08	102	786
Jul-04	84.56	29.25	22.98	103	370
Aug-04	82.63	29.51	23.12	117	387
Sep-04	80.03	30.80	23.58	111	209
Oct-04	75.10	31.35	23.38	133	425
Nov-04	65.37	31.14	23.57	157	072
Dec-04	55.56	32.10	22.65	184	000
Jan-05	55.52	33.17	22.56	163	008
Feb-05	52.09	35.11	22.33	179	000
Mar-05	62.42	35.73	24.59	193	000
Apr-05	74.43	33.72	24.80	128	171
May-05	74.08	33.59	25.01	136	089
Jun-05	85.92	29.94	23.55	084	711
Jul-05	87.48	28.67	23.03	076	728
Aug-05	82.00	29.92	23.29	112	347
Sep-05	83.22	29.38	23.35	095	416
Oct-05	79.19	30.99	23.20	086	178
Nov-05	72.15	30.68	22.92	097	012
Dec-05	65.65	31.45	22.13	140	003
Jan-06	57.13	32.48	22.59	190	000
Feb-06	50.86	34.27	22.25	193	000
Mar-06	67.60	34.80	23.79	161	095
Apr-06	74.10	33.37	24.65	136	086
May-06	78.35	31.80	24.29	113	676
Jun-06	84.20	29.91	23.59	081	609
Jul-06	94.77	29.49	23.26	095	519
Aug-06	92.87	29.80	23.06	098	551
Sep-06	92.63	29.58	23.02	082	522

Appendix 2 Effect of treatments on available nitrogen in soil and nitrogen content of arecanut palm in converted paddy field

Treatment	Available nitrogen in 25-50 cm soil (kg ha^{-1})							Nitrogen content of kernel (%)							Nitrogen content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	186	215	165	190	195	215	194	0.76	0.46	0.68	0.69	0.69	0.69	0.66	0.87	0.50	0.77	0.73	0.76	0.74	0.73
T_2	174	270	229	267	292	281	252	0.79	0.62	0.71	0.76	0.71	0.79	0.73	0.81	0.68	0.76	0.79	0.75	0.79	0.76
T_3	167	222	159	196	204	203	192	0.69	0.61	0.74	0.71	0.74	0.78	0.71	0.78	0.67	0.72	0.75	0.78	0.74	0.74
T_4	172	278	219	289	257	280	249	0.79	0.79	0.69	0.65	0.76	0.78	0.74	0.80	0.86	0.77	0.73	0.76	0.74	0.78
T_5	183	273	218	265	286	272	249	0.80	0.63	0.71	0.67	0.74	0.70	0.71	0.85	0.69	0.76	0.79	0.76	0.79	0.77
T_6	158	278	222	276	262	290	248	0.77	0.80	0.71	0.75	0.73	0.71	0.74	0.74	0.88	0.78	0.80	0.75	0.77	0.78
T_7	196	278	223	270	301	284	259	0.78	0.81	0.72	0.77	0.73	0.69	0.75	0.92	0.89	0.84	0.79	0.77	0.76	0.83
T_8	188	291	232	250	270	275	251	0.76	1.02	0.75	0.78	0.73	0.69	0.79	0.88	1.12	0.81	0.78	0.79	0.75	0.85
T_9	188	342	226	262	280	270	261	0.82	1.13	0.84	0.77	0.72	0.71	0.83	0.88	1.24	0.93	0.83	0.75	0.78	0.90
T_{10}	186	291	238	301	265	265	258	0.77	1.02	0.81	0.74	0.77	0.74	0.81	0.87	1.12	0.79	0.80	0.77	0.75	0.85
T_{11}	173	317	248	259	276	276	258	0.77	1.03	0.74	0.75	0.79	0.74	0.80	0.81	1.12	0.83	0.79	0.78	0.75	0.85
T_{12}	177	284	240	286	273	278	256	0.75	0.88	0.72	0.74	0.78	0.81	0.78	0.83	0.96	0.79	0.79	0.76	0.75	0.81
CD(0.05)	NS	44	34	41	41	42	16	NS	0.124	NS	NS	NS	NS		NS	0.136	NS	NS	NS	NS	

Appendix 3 Effect of treatments on available phosphorus in soil and phosphorus content of arecanut palm in converted paddy field

Treatment	Available phosphorus in 25-50 cm soil (kg ha^{-1})							Phosphorus content of kernel (%)							Phosphorus content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	20	21	9	9	8	8	12	0.135	0.062	0.116	0.113	0.111	0.114	0.108	0.150	0.066	0.112	0.108	0.119	0.125	0.113
T_2	20	23	16	18	17	16	18	0.139	0.093	0.120	0.114	0.122	0.129	0.120	0.140	0.099	0.123	0.116	0.117	0.125	0.120
T_3	20	22	9	10	9	8	13	0.122	0.083	0.110	0.116	0.119	0.128	0.113	0.134	0.088	0.110	0.120	0.113	0.124	0.115
T_4	20	23	14	19	16	17	18	0.140	0.114	0.121	0.117	0.113	0.127	0.122	0.138	0.121	0.110	0.118	0.113	0.122	0.120
T_5	20	23	12	18	13	18	17	0.140	0.093	0.110	0.121	0.124	0.112	0.117	0.147	0.099	0.120	0.114	0.124	0.118	0.120
T_6	20	22	13	17	13	15	17	0.136	0.114	0.121	0.124	0.124	0.118	0.123	0.127	0.121	0.110	0.118	0.115	0.122	0.119
T_7	20	22	13	15	14	15	16	0.137	0.114	0.116	0.120	0.124	0.120	0.122	0.158	0.121	0.110	0.116	0.115	0.122	0.124
T_8	18	21	15	19	15	16	17	0.134	0.155	0.108	0.117	0.128	0.123	0.128	0.151	0.164	0.123	0.116	0.121	0.125	0.133
T_9	19	22	13	16	13	20	17	0.145	0.166	0.125	0.129	0.119	0.125	0.135	0.151	0.175	0.118	0.115	0.124	0.118	0.134
T_{10}	19	21	14	17	14	17	17	0.136	0.155	0.120	0.114	0.117	0.108	0.125	0.150	0.164	0.112	0.115	0.118	0.115	0.129
T_{11}	20	22	15	19	16	14	17	0.136	0.166	0.120	0.124	0.116	0.126	0.131	0.139	0.175	0.123	0.116	0.117	0.122	0.132
T_{12}	19	22	15	18	12	19	17	0.133	0.124	0.110	0.121	0.118	0.123	0.122	0.142	0.132	0.110	0.114	0.120	0.124	0.124
CD(0.05)	NS	NS	2	3	2	2	1	NS	0.018	NS	NS	NS	NS		NS	0.019	NS	NS	NS	NS	

Appendix 4 Effect of treatments on available potassium in soil and potassium content of arecanut palm in converted paddy field

Treatment	Available potassium in 25-50 cm soil (kg ha^{-1})							Potassium content of kernel (%)							Potassium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	155	135	125	116	105	108	124	0.35	0.24	0.35	0.34	0.36	0.32	0.33	0.92	0.52	0.77	0.74	0.82	0.82	0.76
T_2	151	166	138	134	112	167	145	0.36	0.33	0.38	0.34	0.35	0.35	0.35	0.86	0.61	0.80	0.74	0.72	0.83	0.76
T_3	149	145	152	144	154	115	143	0.31	0.32	0.41	0.38	0.39	0.37	0.36	0.82	0.60	0.78	0.79	0.78	0.75	0.75
T_4	150	167	132	145	160	117	145	0.36	0.40	0.44	0.36	0.38	0.33	0.38	0.84	0.68	0.79	0.76	0.75	0.84	0.78
T_5	154	167	125	121	153	113	139	0.36	0.33	0.42	0.35	0.38	0.36	0.37	0.90	0.61	0.81	0.76	0.75	0.81	0.77
T_6	146	167	119	115	164	103	136	0.35	0.41	0.43	0.40	0.34	0.37	0.38	0.78	0.69	0.86	0.78	0.73	0.78	0.77
T_7	158	168	129	146	169	108	146	0.35	0.43	0.43	0.39	0.37	0.33	0.38	0.97	0.71	0.85	0.80	0.73	0.83	0.81
T_8	155	190	102	141	157	151	149	0.35	0.52	0.46	0.39	0.38	0.33	0.40	0.92	0.80	0.84	0.89	0.71	0.80	0.83
T_9	155	198	112	100	134	156	143	0.37	0.60	0.41	0.39	0.37	0.35	0.41	0.92	0.88	0.78	0.80	0.73	0.84	0.83
T_{10}	155	190	187	106	117	162	153	0.35	0.55	0.41	0.37	0.38	0.36	0.41	0.92	0.83	0.84	0.82	0.77	0.80	0.83
T_{11}	151	195	198	128	148	129	158	0.35	0.58	0.43	0.36	0.36	0.32	0.40	0.85	0.86	0.88	0.85	0.73	0.84	0.83
T_{12}	152	190	110	112	152	140	143	0.34	0.44	0.40	0.34	0.33	0.33	0.36	0.87	0.72	0.87	0.81	0.76	0.81	0.81
CD(0.05)	NS	12	16	18	22	20	12	NS	0.065	NS	NS	NS	NS		NS	0.108	NS	NS	NS	NS	

Appendix 5 Effect of treatments on available calcium in soil and calcium content of arecanut palm in converted paddy field

Treatment	Available calcium in 25-50 cm soil (kg ha^{-1})							Calcium content of kernel (%)							Calcium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	802	977	904	806	851	834	862	0.142	0.108	0.184	0.160	0.174	0.189	0.160	0.200	0.141	0.226	0.243	0.200	0.233	0.207
T_2	829	1700	1267	1659	1434	1626	1419	0.147	0.158	0.179	0.185	0.169	0.194	0.172	0.187	0.206	0.223	0.238	0.223	0.244	0.220
T_3	726	977	936	896	888	870	882	0.129	0.137	0.188	0.160	0.177	0.188	0.163	0.179	0.179	0.229	0.214	0.219	0.247	0.211
T_4	832	1235	1505	1523	1542	1200	1306	0.148	0.171	0.172	0.170	0.186	0.164	0.168	0.184	0.222	0.242	0.211	0.214	0.234	0.218
T_5	838	1259	1372	1749	1280	1480	1330	0.149	0.158	0.193	0.173	0.183	0.179	0.172	0.196	0.206	0.220	0.207	0.240	0.229	0.216
T_6	811	1291	1704	1336	1254	1298	1282	0.144	0.171	0.160	0.160	0.178	0.190	0.167	0.169	0.222	0.215	0.226	0.212	0.236	0.213
T_7	818	1316	1452	1247	1240	1800	1312	0.145	0.175	0.169	0.160	0.172	0.184	0.168	0.211	0.228	0.240	0.251	0.235	0.220	0.231
T_8	800	1411	1400	1702	1400	1686	1400	0.142	0.175	0.157	0.188	0.179	0.168	0.168	0.201	0.228	0.237	0.223	0.259	0.231	0.230
T_9	866	1469	1650	1426	1178	1759	1391	0.154	0.217	0.168	0.169	0.191	0.170	0.178	0.201	0.282	0.250	0.219	0.249	0.228	0.238
T_{10}	809	1455	1613	1568	1344	1433	1370	0.144	0.175	0.166	0.166	0.165	0.192	0.168	0.200	0.228	0.234	0.257	0.220	0.235	0.229
T_{11}	813	1445	1667	1767	1299	1770	1460	0.144	0.196	0.175	0.182	0.188	0.175	0.177	0.185	0.255	0.245	0.231	0.226	0.246	0.231
T_{12}	795	1348	1316	1613	1211	1520	1300	0.141	0.175	0.164	0.170	0.167	0.187	0.167	0.189	0.228	0.231	0.215	0.231	0.233	0.221
CD(0.05)	NS	210	219	233	198	233	93	NS	0.026	NS	NS	NS	NS		NS	0.033	NS	NS	NS	NS	

Appendix 6 Effect of treatments on available magnesium in soil and magnesium content of arecanut palm in converted paddy field

Treatment	Available magnesium in 25-50 cm soil (kg ha^{-1})							Magnesium content of kernel (%)							Magnesium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	182	217	226	270	294	240	238	0.175	0.109	0.188	0.185	0.214	0.227	0.183	0.270	0.167	0.229	0.186	0.188	0.226	0.211
T_2	168	212	360	287	329	292	275	0.181	0.147	0.205	0.184	0.212	0.230	0.193	0.252	0.225	0.278	0.182	0.194	0.236	0.228
T_3	172	207	317	317	345	268	271	0.159	0.147	0.196	0.163	0.208	0.199	0.179	0.241	0.225	0.256	0.188	0.204	0.220	0.222
T_4	180	219	374	253	283	282	265	0.182	0.162	0.183	0.177	0.193	0.196	0.182	0.248	0.246	0.268	0.203	0.210	0.259	0.239
T_5	163	214	285	262	269	257	242	0.183	0.162	0.179	0.194	0.202	0.222	0.190	0.264	0.246	0.261	0.220	0.185	0.230	0.234
T_6	176	217	262	273	340	259	255	0.177	0.176	0.211	0.191	0.184	0.225	0.194	0.229	0.268	0.235	0.200	0.198	0.212	0.224
T_7	176	215	350	257	257	301	259	0.179	0.176	0.184	0.174	0.198	0.217	0.188	0.284	0.268	0.249	0.196	0.212	0.241	0.242
T_8	173	220	308	285	323	253	260	0.175	0.200	0.192	0.172	0.183	0.208	0.188	0.272	0.304	0.243	0.193	0.206	0.217	0.239
T_9	156	261	428	366	424	359	332	0.189	0.257	0.219	0.183	0.187	0.204	0.206	0.272	0.391	0.223	0.225	0.215	0.248	0.262
T_{10}	180	204	240	302	366	248	257	0.177	0.200	0.186	0.185	0.190	0.231	0.195	0.270	0.304	0.230	0.215	0.220	0.251	0.248
T_{11}	161	185	327	310	309	244	256	0.177	0.200	0.201	0.158	0.181	0.212	0.188	0.250	0.304	0.226	0.209	0.186	0.221	0.233
T_{12}	174	190	335	295	353	276	270	0.174	0.190	0.215	0.180	0.209	0.201	0.195	0.255	0.290	0.233	0.212	0.195	0.232	0.236
CD(0.05)	NS	33	49	46	52	43	17	NS	0.027	NS	NS	NS	NS		NS	0.041	NS	NS	NS	NS	

Appendix 7 Effect of treatments on available sulphur in soil and sulphur content of arecanut palm in converted paddy field

Treatment	Available sulphur in 25-50 cm soil (kg ha^{-1})							Sulphur content of kernel (%)							Sulphur content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	24	13	24	29	31	32	25	0.016	0.013	0.124	0.157	0.126	0.153	0.098	0.142	0.223	0.169	0.147	0.207	0.185	0.179
T_2	24	17	23	27	28	33	25	0.016	0.022	0.128	0.135	0.136	0.147	0.097	0.141	0.212	0.173	0.177	0.201	0.165	0.178
T_3	25	15	23	32	32	31	26	0.014	0.019	0.146	0.148	0.123	0.152	0.100	0.147	0.229	0.190	0.170	0.184	0.184	0.184
T_4	25	33	32	41	51	42	37	0.016	0.031	0.123	0.145	0.131	0.135	0.097	0.146	0.221	0.179	0.169	0.193	0.168	0.179
T_5	25	20	22	34	32	29	27	0.017	0.024	0.144	0.143	0.124	0.150	0.100	0.149	0.214	0.183	0.162	0.210	0.192	0.185
T_6	25	37	33	41	53	42	38	0.016	0.031	0.137	0.154	0.128	0.137	0.101	0.146	0.221	0.174	0.166	0.188	0.163	0.176
T_7	24	38	29	45	59	40	39	0.016	0.032	0.126	0.161	0.134	0.142	0.102	0.143	0.242	0.188	0.155	0.177	0.188	0.182
T_8	25	41	29	44	55	44	40	0.016	0.039	0.125	0.153	0.143	0.134	0.102	0.145	0.219	0.192	0.183	0.182	0.174	0.183
T_9	24	48	31	46	49	43	40	0.017	0.057	0.134	0.160	0.141	0.154	0.111	0.144	0.267	0.198	0.160	0.186	0.167	0.187
T_{10}	25	44	30	42	45	44	38	0.016	0.043	0.132	0.141	0.121	0.149	0.100	0.147	0.223	0.168	0.175	0.175	0.182	0.178
T_{11}	23	40	29	43	47	39	37	0.016	0.052	0.140	0.164	0.145	0.138	0.109	0.138	0.242	0.176	0.152	0.197	0.177	0.180
T_{12}	24	25	23	31	35	30	28	0.016	0.033	0.141	0.136	0.139	0.145	0.102	0.139	0.223	0.195	0.173	0.203	0.195	0.188
CD(0.05)	NS	5	4	6	7	6	3	NS	0.005	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 8 Effect of treatments on available iron in soil and iron content of arecanut palm in converted paddy field

Treatment	Available iron in 25-50 cm soil (kg ha^{-1})							Iron content of kernel (ppm)							Iron content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_{1}	155	161	225	243	290	365	240	207	237	202	200	204	240	215	258	245	215	222	179	204	221
T_{2}	162	167	213	257	287	379	244	215	243	212	240	212	218	223	246	226	240	230	186	231	227
T_{3}	161	162	209	226	304	420	247	231	208	224	226	216	213	220	261	211	195	225	190	240	220
T_{4}	160	168	207	234	297	374	240	239	257	207	194	196	211	217	251	223	203	239	176	219	219
T_{5}	164	166	215	240	281	392	243	210	218	215	220	229	230	220	223	234	210	215	194	250	221
T_{6}	160	164	220	253	314	410	254	256	213	197	213	225	235	223	215	195	199	198	164	235	201
T_{7}	157	159	224	248	326	340	242	248	214	220	231	220	234	228	234	229	227	234	187	218	222
T_{8}	160	166	217	262	309	378	248	213	220	195	218	192	233	212	238	240	213	219	172	227	218
T_{9}	158	164	218	223	278	400	240	226	249	206	204	207	232	221	264	214	233	218	160	223	219
T_{10}	162	160	211	220	275	385	235	227	226	228	209	223	228	224	266	233	218	220	183	257	230
T_{11}	152	162	223	229	270	357	232	222	225	222	234	201	213	220	250	222	222	228	198	242	227
T_{12}	153	158	222	213	321	350	236	235	231	235	230	186	210	221	237	231	220	210	167	212	213
CD(0.05)	NS	NS	NS	NS	NS	NS	#	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

- pooling not possible as errors homogenous and interaction absent.

Appendix 9 Effect of treatments on available manganese in soil and manganese content of arecanut palm in converted paddy field

Treatment	Available manganese in 25-50 cm soil (kg ha^{-1})							Manganese content of kernel (ppm)							Manganese content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_{1}	75	74	90	87	80	90	82	30.9	27.3	26.5	27.0	27.8	30.7	28.4	26.0	27.0	31.7	27.8	32.3	31.9	29.5
T_{2}	103	75	86	85	79	84	85	34.0	28.5	31.0	32.6	33.4	32.3	32.0	30.5	26.5	33.7	30.0	33.7	30.0	30.7
T_{3}	75	74	92	80	92	79	82	27.8	32.3	31.2	32.1	29.0	34.0	31.1	28.5	32.0	28.0	31.4	30.0	28.5	29.7
T_{4}	75	80	87	84	83	80	81	32.5	30.7	29.5	28.2	28.7	28.3	29.7	26.9	31.4	29.8	32.1	31.6	31.4	30.5
T_{5}	71	73	89	84	77	77	79	29.6	28.2	28.5	28.9	31.4	29.8	29.4	28.1	28.6	28.3	30.7	26.9	29.0	28.6
T_{6}	73	70	88	88	89	87	82	30.3	31.2	27.5	27.8	32.5	27.3	29.4	29.4	30.1	31.0	27.3	28.7	27.6	29.0
T_{7}	71	76	90	82	86	83	82	29.0	29.4	27.0	33.4	29.6	28.0	29.4	32.0	25.6	28.9	33.0	27.4	30.9	29.6
T_{8}	75	79	93	90	82	86	84	31.6	33.4	26.1	30.5	30.9	32.0	30.8	30.0	29.5	30.3	28.5	32.8	33.2	30.7
T_{9}	77	72	91	77	75	82	79	28.5	27.8	30.0	29.6	32.0	33.4	30.2	31.0	28.0	32.7	29.6	31.0	27.0	29.9
T_{10}	73	78	96	76	74	79	79	27.6	31.6	32.0	30.7	30.5	29.0	30.2	27.6	30.9	29.4	28.0	29.4	30.4	29.3
T_{11}	75	71	91	91	73	93	82	33.4	28.9	31.6	31.6	28.2	33.0	31.1	29.0	30.6	27.8	34.0	30.5	28.0	30.0
T_{12}	75	77	94	74	84	81	81	31.0	30.1	28.1	31.2	34.0	31.0	30.9	26.5	29.0	33.4	29.0	28.2	32.6	29.8
CD(0.05)	NS	NS	NS	NS	NS	NS	#	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

- pooling not possible as errors homogenous and interaction absent.

Appendix 10 Effect of treatments on available zinc in soil and zinc content of arecanut palm in converted paddy field

Treatment	Available zinc in 25-50 cm soil (kg ha^{-1})							Zinc content of kernel (ppm)							Zinc content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_{1}	16.9	18.8	21.1	18.7	24.0	22.3	20.3	9.50	9.22	9.60	8.80	8.80	9.36	9.21	8.99	8.91	9.89	8.71	8.61	8.99	9.02
T_{2}	15.8	21.3	20.0	21.6	23.0	19.1	20.1	8.09	8.93	8.64	8.88	8.34	8.72	8.60	8.25	8.45	8.56	8.61	8.72	9.26	8.64
T_{3}	15.1	20.9	21.3	19.5	21.0	22.6	20.1	9.80	8.77	9.20	9.34	9.10	9.04	9.21	9.09	9.01	8.99	9.08	9.35	9.09	9.10
T_{4}	15.5	19.6	19.4	20.4	20.4	23.4	19.8	8.87	9.08	8.95	8.38	8.40	9.09	8.80	8.45	8.58	9.17	9.79	8.45	8.61	8.84
T_{5}	16.5	20.3	21.7	19.9	21.3	21.3	20.2	9.03	8.06	9.36	9.68	9.33	9.52	9.16	8.34	8.72	8.13	9.26	8.88	8.45	8.63
T_{6}	14.3	18.3	20.2	18.5	22.6	20.4	19.0	9.15	8.41	8.56	8.50	8.48	8.07	8.53	8.66	8.28	8.66	9.47	8.36	8.14	8.60
T_{7}	17.8	21.7	22.5	18.0	20.8	21.8	20.4	9.61	8.65	8.72	8.99	9.29	8.29	8.93	9.70	9.16	8.88	8.50	9.73	8.56	9.09
T_{8}	17.0	19.8	20.9	18.3	21.7	23.9	20.3	9.41	8.54	8.80	9.89	8.57	8.61	8.97	8.56	8.79	9.28	8.92	9.10	8.33	8.83
T_{9}	17.0	19.5	20.6	22.6	25.1	20.9	20.9	9.29	8.11	9.05	9.10	8.88	8.88	8.88	9.47	8.22	9.65	8.80	9.54	8.88	9.09
T_{10}	16.9	26.4	28.5	26.3	29.5	29.0	26.1	8.68	8.18	9.15	9.49	8.98	8.50	8.83	9.26	8.15	9.48	8.98	9.20	9.79	9.14
T_{11}	15.6	19.1	22.0	19.1	23.7	20.0	19.9	8.35	8.32	8.48	8.63	9.52	9.81	8.85	8.18	8.54	8.80	8.34	8.91	9.47	8.71
T_{12}	16.0	20.4	19.8	21.0	22.0	20.7	20.0	8.52	8.24	9.79	9.21	8.32	9.20	8.88	8.80	9.27	8.34	8.86	8.22	8.72	8.70
CD(0.05)	NS	3.2	3.3	3.2	3.6	3.5	1.3	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 11 Effect of treatments on available copper in soil and copper content of arecanut palm in converted paddy field

Treatment	Available copper in 25-50 cm soil (kg ha^{-1})							Copper content of kernel (ppm)							Copper content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_{1}	19.2	18.8	19.7	19.3	17.6	20.2	19.1	16.6	17.3	18.6	16.8	17.9	12.9	16.7	16.5	15.9	19.2	18.0	17.9	19.5	17.8
T_{2}	19.0	19.6	20.2	21.0	18.3	19.4	19.6	14.6	17.7	16.4	18.2	18.7	11.4	16.2	17.4	17.6	19.6	18.4	18.5	17.3	18.1
T_{3}	20.1	18.6	19.8	20.2	19.7	17.9	19.4	17.7	18.0	17.5	17.8	16.5	10.4	16.3	15.6	16.3	19.0	17.3	15.6	16.7	16.8
T_{4}	19.9	20.1	21.0	18.9	20.0	18.4	19.7	15.0	16.1	16.7	17.4	15.8	17.2	16.4	15.9	18.8	16.4	16.9	16.5	17.7	17.0
T_{5}	20.5	20.2	20.4	18.6	21.7	20.9	20.4	15.5	18.4	17.9	17.2	17.6	11.1	16.3	19.1	16.7	17.3	15.5	16.6	18.6	17.3
T_{6}	20.0	18.0	21.2	20.7	20.4	18.2	19.7	15.8	18.8	15.9	15.6	18.4	13.9	16.4	16.7	18.0	16.7	17.6	17.1	18.2	17.4
T_{7}	19.5	20.6	21.3	21.6	19.4	19.1	20.2	17.0	15.8	16.8	18.6	17.3	11.2	16.1	16.3	17.3	17.0	18.7	17.4	16.0	17.1
T_{8}	19.8	20.3	21.8	21.8	17.9	21.5	20.5	15.3	17.0	16.3	16.0	18.0	15.3	16.3	17.0	18.6	17.9	15.9	18.0	17.5	17.5
T_{9}	19.7	20.0	21.5	21.3	18.9	21.2	20.4	16.4	19.2	17.1	15.2	16.1	12.2	16.0	18.2	19.1	18.4	16.7	16.1	18.8	17.9
T_{10}	20.1	17.9	21.7	19.5	19.1	20.5	19.8	17.2	16.7	19.5	16.6	15.6	11.3	16.2	18.6	16.9	18.5	16.4	15.8	17.0	17.2
T_{11}	18.7	19.5	20.6	19.9	20.9	19.8	19.9	18.3	16.4	18.3	19.1	19.1	10.4	16.9	17.6	19.4	15.9	19.0	19.1	19.1	18.3
T_{12}	18.9	19.3	20.7	18.3	21.1	18.8	19.5	16.1	15.2	19.1	17.6	16.9	17.5	17.1	19.5	18.3	17.7	16.3	15.5	16.5	17.3
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 12 Effect of treatments on available boron in soil and boron content of arecanut palm in converted paddy field

Treatment	Available boron in 25-50 cm soil (kg ha^{-1})							Boron content of kernel (ppm)							Boron content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	8.52	7.41	7.47	6.89	8.25	8.88	7.90	23.1	14.2	33.2	31.6	29.2	30.0	26.9	37.0	18.6	28.0	30.8	28.5	28.4	28.6
T_2	7.91	7.28	7.35	7.43	8.47	8.07	7.75	23.8	20.6	30.7	33.4	31.6	26.8	27.8	34.6	27.0	32.8	31.4	30.8	30.8	31.2
T_3	8.65	8.13	6.83	7.60	7.96	7.43	7.77	20.9	15.2	33.7	31.0	28.3	30.6	26.6	33.1	19.8	30.9	32.3	27.3	30.1	28.9
T_4	7.49	8.56	7.91	7.16	8.09	7.86	7.84	23.9	22.6	31.2	30.7	27.8	31.9	28.0	34.1	29.5	33.5	29.7	26.7	27.5	30.2
T_5	8.48	8.40	6.97	8.66	7.89	8.45	8.14	24.1	21.6	32.8	30.0	30.9	26.5	27.7	36.3	28.3	31.4	29.2	29.4	32.3	31.1
T_6	7.31	8.00	7.66	7.05	7.75	8.23	7.67	23.3	23.7	28.0	32.6	32.6	29.3	28.3	31.4	31.0	32.5	28.7	31.5	27.0	30.3
T_7	7.20	7.72	7.16	8.23	7.64	7.60	7.59	23.5	24.4	28.7	32.3	33.4	27.6	28.3	39.0	32.0	31.7	30.3	27.4	29.0	31.6
T_8	8.29	8.66	8.72	7.75	7.48	8.29	8.20	23.0	32.0	32.0	29.4	32.0	28.2	29.4	37.3	41.9	29.7	28.1	30.1	31.3	33.1
T_9	7.60	8.80	6.62	7.96	7.25	8.77	7.83	24.9	39.6	29.6	29.0	28.9	27.5	29.9	37.3	51.8	30.5	27.3	29.0	26.2	33.7
T_{10}	8.40	8.91	8.18	7.32	7.39	7.70	7.98	23.3	33.2	32.5	28.3	27.0	32.6	29.5	37.0	43.4	29.0	26.7	26.0	28.0	31.7
T_{11}	8.13	10.60	10.40	10.33	10.26	10.43	10.03	23.4	35.0	27.3	31.4	30.1	28.7	29.3	34.3	45.8	34.3	31.7	32.3	32.1	35.1
T_{12}	7.71	7.53	8.40	8.45	8.61	8.61	8.22	22.9	29.8	30.1	27.8	29.8	31.2	28.6	35.1	39.0	28.7	25.7	28.0	29.5	31.0
CD(0.05)	NS	1.32	1.21	1.25	1.27	1.31	0.53	NS	3.964	NS	NS	NS	NS		NS	5.184	NS	NS	NS	NS	

Appendix 13 Effect of treatments on total silicon in soil and silicon content of arecanut palm in converted paddy field

Treatment	Total silicon in 25-50 cm soil (t ha^{-1})							Silicon content of kernel (%)							Silicon content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	361	396	357	422	396	371	384	0.078	0.075	0.079	0.076	0.078	0.072	0.076	0.076	0.064	0.072	0.073	0.077	0.072	0.072
T_2	387	350	350	371	373	361	365	0.076	0.070	0.071	0.073	0.073	0.078	0.073	0.070	0.073	0.073	0.077	0.072	0.074	0.073
T_3	396	361	377	393	406	384	386	0.079	0.077	0.074	0.069	0.067	0.065	0.072	0.072	0.075	0.074	0.069	0.066	0.073	0.071
T_4	404	410	410	387	357	347	386	0.070	0.080	0.073	0.068	0.076	0.080	0.075	0.077	0.063	0.067	0.068	0.075	0.077	0.071
T_5	340	402	396	357	351	395	373	0.073	0.065	0.083	0.067	0.073	0.068	0.072	0.080	0.066	0.066	0.068	0.076	0.069	0.071
T_6	381	387	402	406	367	418	394	0.067	0.077	0.077	0.070	0.075	0.067	0.072	0.071	0.070	0.072	0.071	0.070	0.064	0.070
T_7	367	368	330	414	341	377	366	0.063	0.074	0.066	0.074	0.069	0.071	0.069	0.074	0.072	0.062	0.070	0.067	0.065	0.068
T_8	347	381	367	347	418	423	381	0.069	0.068	0.076	0.065	0.072	0.074	0.071	0.078	0.069	0.065	0.067	0.074	0.070	0.070
T_9	375	343	363	398	387	390	376	0.066	0.072	0.069	0.065	0.070	0.075	0.070	0.067	0.065	0.069	0.067	0.069	0.075	0.069
T_{10}	412	355	390	377	381	406	387	0.075	0.076	0.067	0.063	0.065	0.076	0.070	0.075	0.067	0.067	0.065	0.065	0.071	0.068
T_{11}	330	415	380	363	345	355	365	0.071	0.078	0.081	0.071	0.068	0.069	0.073	0.073	0.074	0.076	0.075	0.068	0.067	0.072
T_{12}	353	374	337	337	363	412	363	0.068	0.063	0.075	0.061	0.074	0.073	0.069	0.064	0.077	0.075	0.065	0.071	0.068	0.070
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 14 Effect of treatments on available aluminium in soil and aluminium content of arecanut palm in converted paddy field

Treatment	Available aluminium in 25-50 cm soil (kg ha^{-1})							Aluminium content of kernel (ppm)							Aluminium content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	93	102	87	100	95	87	94	396	339	207	256	222	195	269	292	253	199	227	241	219	239
T_2	88	89	98	105	104	92	96	409	334	237	234	227	219	277	273	251	222	242	233	215	239
T_3	83	98	96	91	93	93	92	358	334	254	226	207	226	268	261	272	237	222	198	242	239
T_4	85	95	103	99	89	102	96	410	321	218	222	237	210	270	269	259	233	218	211	209	233
T_5	90	92	98	96	98	94	95	413	323	220	219	245	241	277	286	282	217	223	225	196	238
T_6	81	94	102	97	91	90	92	400	323	222	230	219	222	269	248	230	204	215	219	231	224
T_7	99	103	90	95	97	96	97	403	323	225	246	234	234	278	307	251	243	231	202	214	241
T_8	97	101	103	102	90	97	99	395	329	213	217	248	202	267	294	234	248	210	235	227	241
T_9	96	100	95	94	88	99	95	427	333	230	214	231	207	274	294	270	242	206	217	206	239
T_{10}	94	106	100	88	92	91	95	399	319	264	211	196	214	267	292	228	213	199	195	223	225
T_{11}	87	97	83	92	86	89	89	401	319	245	240	240	223	278	271	217	240	235	229	200	232
T_{12}	89	91	93	93	101	100	95	392	316	229	206	213	229	264	277	280	227	192	206	237	236
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	39.000	NS	NS	NS	NS	

Appendix 15 Effect of treatments on soil pH and organic carbon content of soil in converted paddy field

Treatment	Soil pH in 25-50 cm soil							Organic carbon content of 25-50 cm soil						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	4.63	4.24	4.08	4.11	4.08	4.10	4.21	0.80	0.82	0.73	0.83	0.80	0.78	0.79
T_2	4.71	5.78	5.81	5.60	5.40	6.03	5.56	0.74	0.80	0.85	0.77	0.75	0.79	0.78
T_3	4.60	4.30	4.14	4.17	4.11	4.20	4.25	0.71	0.75	0.76	0.82	0.73	0.82	0.76
T_4	4.83	5.30	5.59	5.80	5.90	5.90	5.55	0.73	0.76	0.81	0.79	0.77	0.90	0.79
T_5	4.66	5.26	5.20	5.74	5.18	5.52	5.26	0.78	0.79	0.74	0.75	0.76	0.88	0.78
T_6	4.65	5.33	5.74	5.50	5.52	6.20	5.49	0.67	0.74	0.83	0.88	0.74	0.76	0.77
T_7	4.61	5.37	5.30	5.71	5.30	6.12	5.40	0.84	0.87	0.79	0.70	0.71	0.83	0.79
T_8	4.67	5.44	5.27	5.90	6.10	5.62	5.50	0.80	0.86	0.75	0.71	0.85	0.87	0.81
T_9	4.70	5.65	5.48	5.43	5.74	5.37	5.40	0.80	0.84	0.73	0.85	0.78	0.84	0.81
T_{10}	4.62	5.48	5.37	5.24	6.20	5.17	5.35	0.80	0.85	0.77	0.78	0.82	0.86	0.81
T_{11}	4.78	5.53	5.43	5.30	5.20	5.74	5.33	0.74	0.78	0.87	0.74	0.84	0.74	0.78
T_{12}	4.72	5.39	5.12	6.20	5.05	5.84	5.39	0.75	0.79	0.78	0.73	0.73	0.89	0.78
CD(0.05)	NS	0.82	0.81	0.85	0.84	0.86	0.19	NS	NS	NS	NS	NS	NS	NS

Appendix 16 Effect of treatments on leaf sap pH of arecanut palm in converted paddy field

Treatment	Leaf sap pH						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	3.91	3.30	3.28	3.01	3.20	3.36	3.34
T_2	3.88	4.17	3.26	3.33	3.19	3.10	3.49
T_3	4.06	3.36	3.03	3.34	3.11	3.33	3.37
T_4	4.03	4.22	3.11	3.34	3.07	3.25	3.50
T_5	4.13	4.21	3.27	3.18	3.24	3.29	3.55
T_6	4.04	4.24	3.21	3.21	3.14	3.23	3.51
T_7	3.96	4.24	3.36	3.32	3.15	3.18	3.54
T_8	4.02	4.28	3.22	3.08	3.25	3.41	3.54
T_9	3.99	4.32	3.30	2.93	3.27	3.24	3.51
T_{10}	4.07	4.28	3.39	3.14	2.92	3.23	3.51
T_{11}	3.83	4.32	3.05	3.04	3.44	3.15	3.47
T_{12}	3.85	4.28	3.53	3.30	3.05	3.41	3.57
CD(0.05)	NS	0.632	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Appendix 17 Effect of treatments on morphological characters of arecanut palm in converted paddy field

Treatment	Fresh nut length (cm)							Fresh nut breadth (cm)							Fresh nut weight (g)			
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	2004	2005	2006	Mean
T_1	5.64	5.03	5.86	5.65	5.18	5.95	5.55	4.06	3.48	4.02	3.59	3.90	3.92	3.83	29.30	30.25	30.70	30.08
T_2	5.82	5.40	5.05	5.47	5.27	5.78	5.47	3.79	3.74	4.18	3.55	3.73	4.04	3.84	30.80	39.90	39.55	36.75
T_3	5.11	5.35	5.65	6.18	5.97	5.43	5.61	3.63	3.52	4.15	3.53	4.14	3.53	3.75	28.10	31.25	31.60	30.32
T_4	5.85	5.63	5.09	5.38	5.49	5.09	5.42	3.74	3.79	3.85	3.74	3.91	3.63	3.78	30.95	39.05	40.10	36.70
T_5	5.89	5.54	5.60	5.52	5.80	4.95	5.55	3.98	3.77	4.12	4.14	3.43	3.67	3.85	32.25	39.35	39.65	37.08
T_6	5.70	5.94	5.23	5.30	5.15	5.84	5.53	3.44	3.80	3.97	3.72	4.07	3.80	3.80	30.25	40.20	40.15	36.87
T_7	5.75	5.96	5.45	5.13	5.37	5.68	5.56	4.28	3.82	3.54	3.99	3.96	3.73	3.89	33.85	38.40	39.95	37.40
T_8	5.63	6.02	5.28	5.93	5.02	5.20	5.51	4.09	4.03	4.08	3.78	3.67	3.47	3.85	32.80	40.05	40.80	37.88
T_9	6.08	6.08	5.71	5.78	4.80	5.56	5.67	4.09	4.35	3.76	3.57	4.06	4.14	3.99	33.35	38.15	38.70	36.73
T_{10}	5.69	6.06	5.49	5.00	5.60	5.37	5.53	4.06	4.18	4.10	3.84	3.78	3.57	3.92	33.45	38.90	39.95	37.43
T_{11}	5.71	6.07	5.94	5.26	4.87	5.30	5.52	3.77	4.33	3.92	3.62	3.52	3.40	3.76	32.15	40.50	41.00	37.88
T_{12}	5.59	6.00	5.96	4.83	5.71	5.62	5.62	3.85	3.89	3.66	3.96	4.17	3.83	3.89	32.25	39.00	40.20	37.15
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS		NS	5.862	5.943	

Appendix 18 Effect of treatments on morphological characters of arecanut palm in converted paddy field (Contd…)

Treatment	**Fresh kernel length (cm)**							**Fresh kernel breadth (cm)**							**Fresh kernel weight (g)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	2.18	1.68	2.12	2.11	2.06	2.20	2.06	2.60	1.65	2.45	2.60	2.56	2.54	2.40	12.7	9.7	11.1	11.4	11.3	11.2	11.2
T_2	2.25	2.18	2.59	2.73	2.86	2.81	2.57	2.43	2.10	3.09	3.37	3.21	3.48	2.95	11.3	11.8	14.9	15.1	14.3	14.4	13.6
T_3	1.97	1.73	2.12	2.07	2.13	2.15	2.03	2.33	1.70	2.48	2.54	2.49	2.48	2.34	11.2	9.9	11.3	11.2	11.3	11.2	11.0
T_4	2.26	2.38	2.68	2.56	2.80	2.83	2.58	2.40	2.22	3.20	3.40	3.19	3.28	2.95	11.1	12.0	14.6	14.8	15.0	14.7	13.7
T_5	2.27	2.21	2.62	2.84	2.83	2.72	2.58	2.55	2.11	3.19	3.30	3.26	3.27	2.95	12.8	11.9	14.6	14.6	14.7	14.5	13.8
T_6	2.20	2.40	2.86	2.61	2.64	2.80	2.58	2.21	2.25	3.13	3.25	3.35	3.25	2.91	10.6	12.1	14.7	14.1	14.6	14.3	13.4
T_7	2.22	2.40	2.65	2.64	2.68	2.90	2.58	2.74	2.32	3.30	3.28	3.12	3.52	3.05	13.3	12.2	14.5	14.6	14.6	14.7	14.0
T_8	2.17	2.58	2.60	2.58	2.73	2.70	2.56	2.62	2.41	3.15	3.32	3.25	3.40	3.02	12.0	12.4	14.9	13.8	14.4	14.6	13.7
T_9	2.35	2.91	2.88	2.80	2.87	2.76	2.76	2.62	2.90	3.14	3.26	3.29	3.34	3.09	12.9	12.9	13.9	14.3	14.5	14.5	13.8
T_{10}	2.20	2.68	2.57	2.68	2.60	2.65	2.56	2.60	2.57	3.23	3.23	3.17	3.35	3.03	12.7	12.6	14.2	14.9	14.9	14.8	14.0
T_{11}	2.20	2.86	2.74	2.77	2.76	2.73	2.68	2.41	2.69	3.20	3.35	3.28	3.37	3.05	11.9	12.9	14.1	14.9	14.8	14.5	13.8
T_{12}	2.16	2.57	2.72	2.65	2.89	2.87	2.64	2.47	2.35	3.22	3.25	3.23	3.44	2.99	12.4	12.4	14.4	14.5	14.8	14.4	13.8
CD(0.05)	NS	0.364	0.402	0.399	0.409	0.414		NS	0.347	0.472	0.491	0.482	0.497		NS	1.829	2.155	2.161	2.177	2.154	

Appendix 19 Effect of treatments on morphological characters of arecanut palm in converted paddy field (Contd…)

Treatment	**Dry nut length (cm)**							**Dry nut breadth (cm)**							**Dry nut weight (g)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	5.44	5.05	5.12	5.18	5.21	5.19	5.20	3.54	3.04	3.09	3.24	3.16	3.28	3.22	11.2	8.9	11.6	12.8	12.9	13.2	11.8
T_2	5.62	5.20	5.65	5.87	5.78	6.09	5.70	3.31	3.11	3.40	3.78	3.64	3.54	3.46	11.0	10.9	14.7	17.3	16.3	17.4	14.6
T_3	4.93	5.13	5.20	5.07	5.27	5.15	5.12	3.17	3.05	3.07	3.14	3.16	3.30	3.15	10.1	9.0	12.0	13.0	13.3	13.5	11.8
T_4	5.64	5.34	5.62	5.74	5.96	5.58	5.65	3.26	3.32	3.28	3.65	3.22	3.40	3.35	10.9	11.0	14.5	16.5	16.9	17.4	14.6
T_5	5.68	5.29	6.06	5.65	5.62	6.00	5.72	3.47	3.19	3.40	3.37	3.77	3.68	3.48	11.3	10.9	15.7	15.6	17.0	16.8	14.6
T_6	5.50	5.46	5.90	5.80	5.56	5.67	5.65	3.00	3.34	3.25	3.52	3.24	3.47	3.30	10.3	11.0	15.8	16.3	16.3	17.7	14.6
T_7	5.55	5.49	5.77	5.97	6.12	5.73	5.77	3.73	3.42	3.47	3.77	3.27	3.45	3.52	11.7	11.1	14.9	15.6	15.9	18.0	14.5
T_8	5.43	5.51	5.71	5.84	6.06	5.93	5.75	3.56	3.56	3.23	3.34	3.85	3.62	3.53	11.3	11.5	16.2	15.9	17.0	17.9	15.0
T_9	5.87	5.99	5.52	6.03	5.80	6.05	5.88	3.56	3.71	3.81	3.96	3.31	3.86	3.70	11.7	11.7	14.9	15.4	16.7	16.2	14.4
T_{10}	5.49	5.63	5.96	5.68	5.68	6.16	5.77	3.54	3.59	3.86	3.86	3.42	3.91	3.70	11.3	11.4	15.1	15.7	17.0	16.9	14.6
T_{11}	5.51	5.94	6.18	5.93	5.88	5.80	5.87	3.28	3.68	3.26	3.40	3.23	3.98	3.47	10.8	11.3	15.7	16.9	17.1	17.6	14.9
T_{12}	5.39	5.50	5.80	6.15	5.92	5.87	5.77	3.35	3.43	3.53	3.65	3.21	3.90	3.51	10.9	11.1	15.1	16.2	16.7	17.4	14.6
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS		NS	1.664	2.271	2.415	2.480	2.576	

Appendix 20 Effect of treatments on morphological characters of arecanut palm in converted paddy field (Contd…)

Treatment	Dry kernel length (cm)							Dry kernel breadth (cm)							Recovery percentage (%)			
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	2004	2005	2006	Mean
T_1	1.77	1.60	1.73	1.83	1.90	1.87	1.78	1.98	2.01	2.22	2.21	2.18	2.21	2.14	20.00	20.07	21.11	20.39
T_2	1.83	1.91	2.28	2.25	2.49	2.52	2.21	1.85	2.59	2.72	2.78	2.65	2.78	2.56	20.13	17.19	18.13	18.48
T_3	1.60	1.60	1.77	1.79	1.84	1.82	1.74	1.77	2.16	2.15	2.16	2.13	2.24	2.10	19.75	18.72	19.94	19.47
T_4	1.84	1.93	2.33	2.22	2.34	2.41	2.18	1.82	2.70	2.96	2.93	2.83	2.87	2.68	20.00	17.44	18.75	18.73
T_5	1.85	1.92	2.24	2.24	2.37	2.43	2.17	1.94	2.59	2.81	2.81	2.78	2.89	2.64	18.51	16.82	18.18	17.84
T_6	1.79	1.96	2.22	2.30	2.51	2.34	2.19	1.68	2.71	2.92	2.80	2.64	2.81	2.59	21.06	17.26	18.75	19.03
T_7	1.81	1.97	2.19	2.38	2.33	2.48	2.19	2.08	2.83	2.76	2.75	2.75	2.92	2.68	19.68	18.57	19.60	19.28
T_8	1.77	1.98	2.26	2.26	2.41	2.33	2.17	1.99	2.95	2.80	2.86	2.87	2.80	2.71	20.00	17.65	19.36	19.01
T_9	1.91	2.19	2.23	2.34	2.43	2.58	2.28	1.99	2.90	2.89	2.89	2.80	2.84	2.72	20.24	18.72	20.49	19.82
T_{10}	1.79	2.14	2.29	2.37	2.40	2.38	2.23	1.98	2.92	2.93	2.96	2.84	2.86	2.75	19.64	18.15	19.82	19.21
T_{11}	1.79	2.15	2.25	2.32	2.46	2.54	2.25	1.83	2.63	2.86	2.84	2.70	2.95	2.64	19.81	17.21	18.56	18.53
T_{12}	1.75	1.97	2.31	2.29	2.35	2.46	2.19	1.87	2.65	2.70	2.83	2.73	2.90	2.61	19.66	17.69	18.96	18.77
CD(0.05)	NS	0.30	0.34	0.34	0.36	0.36		NS	0.40	0.42	0.42	0.41	0.43		NS	NS	NS	

Appendix 21 Effect of treatments on morphological characters of arecanut palm in converted paddy field (Contd…)

Treatment	Fresh husk thickness (cm)							Fresh husk weight (g)							Dry husk weight (g)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	0.49	0.54	0.53	0.58	0.56	0.53	0.54	20.5	15.8	18.4	19.6	19.6	19.4	18.9	4.73	3.69	5.17	5.85	5.86	6.04	5.22
T_2	0.51	0.53	0.56	0.59	0.53	0.57	0.55	19.2	19.3	23.2	26.7	24.4	26.0	23.1	4.88	4.56	6.36	8.03	7.36	8.04	6.54
T_3	0.45	0.54	0.59	0.53	0.58	0.54	0.54	19.0	16.1	19.6	20.4	20.4	20.3	19.3	4.28	3.74	5.54	5.98	6.20	6.30	5.34
T_4	0.51	0.53	0.55	0.54	0.55	0.58	0.54	18.9	20.0	22.9	25.8	25.0	25.5	23.0	4.90	4.63	6.35	7.44	7.66	7.99	6.50
T_5	0.52	0.53	0.57	0.59	0.53	0.57	0.55	20.2	19.6	25.6	23.9	26.0	24.3	23.2	4.94	4.60	7.15	6.85	7.85	7.48	6.48
T_6	0.50	0.52	0.53	0.52	0.51	0.53	0.52	17.7	20.1	25.9	25.7	24.5	26.9	23.5	4.78	4.64	7.37	7.61	7.33	8.38	6.69
T_7	0.50	0.52	0.55	0.58	0.53	0.53	0.54	21.9	20.2	24.0	23.7	23.5	27.1	23.4	4.82	4.68	6.70	6.80	6.93	8.52	6.41
T_8	0.49	0.52	0.58	0.52	0.52	0.55	0.53	20.5	20.6	26.3	25.1	25.8	26.8	24.2	4.72	4.94	7.50	7.43	7.77	8.28	6.77
T_9	0.53	0.43	0.55	0.54	0.55	0.52	0.52	20.2	20.8	24.4	23.7	24.8	23.6	22.9	5.10	4.77	6.80	6.89	7.57	7.14	6.38
T_{10}	0.50	0.51	0.58	0.56	0.57	0.59	0.55	20.9	20.7	24.9	23.7	25.7	24.5	23.4	4.77	4.81	6.99	6.83	7.66	7.48	6.42
T_{11}	0.50	0.46	0.55	0.57	0.57	0.58	0.54	18.8	20.7	25.9	26.2	26.4	26.3	24.0	4.79	4.60	7.38	7.74	7.85	8.14	6.75
T_{12}	0.49	0.52	0.57	0.53	0.58	0.54	0.54	19.2	20.5	24.3	24.8	25.0	26.2	23.3	4.69	4.62	6.82	7.34	7.54	8.12	6.52
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	3.003	3.674	3.736	3.736	3.826		NS	0.695	1.033	1.097	1.124	1.186	

Appendix 22 Effect of treatments on available nitrogen in soil and nitrogen content of arecanut palm in garden land

Treatment	Available nitrogen in 25-50 cm soil (kg ha^{-1})							Nitrogen content of kernel (%)							Nitrogen content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	158	228	147	155	208	191	181	0.94	0.85	0.90	0.93	0.94	0.92	0.91	1.06	1.00	1.06	1.03	1.02	1.04	1.03
T_2	157	275	196	286	289	284	248	0.96	0.88	0.93	0.94	0.92	0.95	0.93	1.05	1.04	1.02	1.04	1.02	0.99	1.03
T_3	164	229	137	168	194	196	181	0.89	0.85	0.89	0.92	0.91	0.93	0.90	1.10	1.00	1.03	1.00	1.03	1.01	1.03
T_4	163	285	188	301	339	267	257	0.93	0.92	0.96	0.92	0.94	0.92	0.93	1.09	1.08	1.01	1.01	1.03	1.05	1.04
T_5	167	281	210	293	301	293	257	0.95	0.92	0.97	0.97	0.94	0.91	0.94	1.12	1.08	1.06	1.00	1.02	1.04	1.05
T_6	163	287	201	260	296	270	246	0.92	1.03	0.95	0.98	0.95	0.98	0.97	1.10	1.21	1.05	1.02	1.00	1.03	1.07
T_7	160	294	185	263	321	289	252	0.96	1.07	0.95	0.98	0.96	0.93	0.98	1.08	1.25	1.06	1.02	1.00	1.02	1.07
T_8	162	303	190	239	326	315	256	0.98	1.21	1.05	0.99	0.96	0.93	1.02	1.09	1.43	1.12	1.02	0.99	1.01	1.11
T_9	161	294	193	314	334	306	267	0.92	1.07	1.02	0.96	0.95	0.91	0.97	1.08	1.25	1.11	1.02	1.05	1.01	1.09
T_{10}	164	297	207	254	314	278	252	0.97	1.07	0.99	0.95	0.94	0.91	0.97	1.10	1.25	1.08	1.03	1.01	1.03	1.09
T_{11}	154	283	188	292	273	262	242	0.92	0.92	0.97	0.94	0.95	0.96	0.94	1.04	1.08	1.10	1.02	1.04	1.01	1.05
T_{12}	155	284	184	251	280	301	243	0.93	1.00	0.94	0.95	0.94	0.97	0.95	1.05	1.17	1.08	1.02	1.03	1.00	1.06
CD(0.05)	NS	43	29	41	46	43	NS	NS	0.150	NS	NS	NS	NS		NS	0.176	NS	NS	NS	NS	

Appendix 23 Effect of treatments on available phosphorus in soil and phosphorus content of arecanut palm in garden land

Treatment	Available phosphorus in 25-50 cm soil (kg ha^{-1})							Phosphorus content of kernel (%)							Phosphorus content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	26	25	17	14	14	15	19	0.185	0.112	0.129	0.125	0.129	0.135	0.136	0.207	0.124	0.131	0.122	0.129	0.130	0.141
T_2	30	34	29	29	28	29	30	0.190	0.121	0.133	0.125	0.127	0.135	0.138	0.206	0.134	0.124	0.128	0.132	0.135	0.143
T_3	24	24	16	15	15	17	19	0.176	0.116	0.134	0.131	0.125	0.130	0.135	0.215	0.128	0.126	0.134	0.136	0.130	0.145
T_4	25	27	25	25	22	23	25	0.183	0.147	0.143	0.127	0.131	0.120	0.142	0.214	0.163	0.128	0.124	0.131	0.128	0.148
T_5	24	26	21	20	22	22	23	0.187	0.121	0.140	0.129	0.123	0.130	0.138	0.219	0.134	0.135	0.126	0.129	0.135	0.146
T_6	22	25	24	22	20	24	23	0.181	0.149	0.128	0.121	0.127	0.134	0.140	0.214	0.165	0.129	0.136	0.133	0.129	0.151
T_7	23	26	20	22	21	25	23	0.189	0.149	0.130	0.127	0.124	0.133	0.142	0.210	0.165	0.125	0.129	0.133	0.139	0.150
T_8	32	35	28	29	29	29	30	0.194	0.186	0.134	0.126	0.129	0.123	0.149	0.213	0.206	0.125	0.133	0.130	0.135	0.157
T_9	28	34	27	26	26	31	29	0.182	0.154	0.139	0.137	0.130	0.134	0.146	0.212	0.170	0.135	0.139	0.134	0.136	0.154
T_{10}	31	35	26	27	30	31	30	0.191	0.179	0.142	0.132	0.127	0.137	0.151	0.216	0.198	0.135	0.123	0.131	0.127	0.155
T_{11}	22	26	24	24	19	23	23	0.181	0.122	0.137	0.130	0.135	0.132	0.139	0.203	0.135	0.130	0.126	0.130	0.134	0.143
T_{12}	24	27	25	24	25	24	25	0.182	0.123	0.131	0.137	0.133	0.137	0.141	0.204	0.136	0.126	0.131	0.127	0.134	0.143
CD(0.05)	NS	NS	17	17	16	18	NS	NS	0.021	NS	NS	NS	NS		NS	0.024	NS	NS	NS	NS	

Appendix 24 Effect of treatments on available potassium in soil and potassium content of arecanut palm in garden land

Treatment	Available potassium in 25-50 cm soil (kg ha^{-1})							Potassium content of kernel (%)							Potassium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	325	202	182	112	87	122	172	0.76	0.63	0.65	0.65	0.66	0.64	0.67	1.85	1.51	0.78	0.73	0.70	0.82	1.06
T_2	300	291	320	437	148	246	290	0.78	0.75	0.80	0.82	0.86	0.84	0.81	1.83	1.56	0.74	0.69	0.79	0.81	1.07
T_3	307	224	208	130	98	110	179	0.73	0.64	0.66	0.70	0.68	0.64	0.68	1.92	1.53	0.70	0.72	0.82	0.84	1.09
T_4	321	314	341	336	175	240	288	0.76	0.86	0.94	0.86	0.70	0.73	0.81	1.91	2.05	0.72	0.76	0.70	0.79	1.15
T_5	292	301	325	358	167	275	286	0.77	0.77	0.94	0.88	0.76	0.79	0.82	1.95	1.59	0.68	0.75	0.70	0.82	1.08
T_6	315	382	352	424	204	270	324	0.75	0.90	0.92	0.94	0.82	0.75	0.85	1.91	2.14	0.69	0.66	0.80	0.82	1.17
T_7	315	460	314	381	190	267	321	0.78	0.90	0.98	0.94	0.82	0.70	0.85	1.87	2.14	0.68	0.78	0.70	0.79	1.16
T_8	309	480	283	318	212	229	305	0.80	1.18	0.96	0.96	0.76	0.81	0.91	1.90	2.80	0.74	0.68	0.80	0.78	1.28
T_9	279	465	291	457	196	280	328	0.75	0.95	1.04	0.88	0.82	0.84	0.88	1.89	2.26	0.76	0.71	0.70	0.80	1.19
T_{10}	321	471	363	446	222	286	351	0.79	0.96	0.96	0.88	0.74	0.77	0.85	1.92	2.29	0.75	0.77	0.76	0.80	1.22
T_{11}	288	374	337	325	184	299	301	0.75	0.89	0.88	0.84	0.72	0.79	0.81	1.81	2.11	0.79	0.74	0.78	0.75	1.16
T_{12}	310	460	328	410	157	259	321	0.75	0.85	0.96	0.84	0.80	0.84	0.84	1.82	2.01	0.75	0.67	0.82	0.85	1.15
CD(0.05)	NS	61	48	58	28	39	NS	NS	0.129	0.138	0.131	0.139	0.134		NS	0.306	NS	NS	NS	NS	

Appendix 25 Effect of treatments on available calcium in soil and calcium content of arecanut palm in garden land

Treatment	Available calcium in 25-50 cm soil (kg ha^{-1})							Calcium content of kernel (%)							Calcium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	1226	1022	670	851	906	942	936	0.182	0.161	0.195	0.206	0.184	0.192	0.187	0.285	0.258	0.237	0.233	0.240	0.229	0.247
T_2	1252	1900	1291	1426	1658	1848	1562	0.186	0.179	0.208	0.185	0.205	0.175	0.190	0.294	0.287	0.223	0.238	0.215	0.208	0.244
T_3	1219	1049	780	942	941	978	985	0.173	0.161	0.207	0.223	0.182	0.188	0.189	0.258	0.258	0.234	0.245	0.220	0.244	0.243
T_4	1226	1563	1413	1830	1345	1778	1526	0.180	0.196	0.200	0.205	0.193	0.170	0.191	0.296	0.315	0.218	0.237	0.211	0.238	0.252
T_5	1163	1327	1345	1381	1520	1345	1347	0.183	0.179	0.211	0.186	0.208	0.182	0.192	0.297	0.287	0.222	0.232	0.237	0.235	0.252
T_6	1189	1563	1628	1345	1702	1821	1541	0.178	0.196	0.201	0.220	0.183	0.191	0.195	0.288	0.315	0.239	0.225	0.229	0.227	0.254
T_7	1163	1611	1520	1882	1280	1646	1517	0.186	0.196	0.220	0.200	0.217	0.186	0.201	0.291	0.315	0.220	0.210	0.206	0.221	0.244
T_8	1222	1807	1094	1489	1792	1543	1491	0.190	0.214	0.204	0.187	0.200	0.195	0.198	0.284	0.344	0.240	0.213	0.227	0.223	0.255
T_9	1259	1640	1211	1453	1850	1880	1549	0.179	0.214	0.228	0.213	0.196	0.201	0.205	0.307	0.344	0.229	0.245	0.235	0.233	0.266
T_{10}	1193	1758	1460	1613	1613	1435	1512	0.188	0.214	0.222	0.211	0.188	0.206	0.205	0.287	0.344	0.238	0.214	0.232	0.218	0.256
T_{11}	1219	1416	1160	1792	1435	1584	1434	0.178	0.196	0.207	0.195	0.185	0.205	0.194	0.289	0.315	0.231	0.242	0.218	0.245	0.257
T_{12}	1222	1465	1800	1552	1747	1489	1546	0.179	0.196	0.216	0.192	0.191	0.197	0.195	0.282	0.315	0.236	0.240	0.200	0.231	0.251
CD(0.05)	NS	242	204	236	240	245	NS	NS	0.029	NS	NS	NS	NS		NS	0.047	NS	NS	NS	NS	

Appendix 26 Effect of treatments on available magnesium in soil and magnesium content of arecanut palm in garden land

Treatment	Available magnesium in 25-50 cm soil (kg ha^{-1})							Magnesium content of kernel (%)							Magnesium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	239	293	280	274	267	267	270	0.202	0.149	0.192	0.219	0.187	0.219	0.195	0.283	0.295	0.287	0.300	0.304	0.301	0.295
T_2	247	293	357	336	312	257	300	0.207	0.193	0.222	0.206	0.224	0.209	0.210	0.281	0.302	0.294	0.274	0.270	0.317	0.290
T_3	217	293	258	332	287	264	275	0.193	0.163	0.219	0.229	0.204	0.202	0.202	0.294	0.300	0.300	0.328	0.289	0.314	0.304
T_4	248	322	385	212	278	273	286	0.200	0.193	0.197	0.215	0.220	0.184	0.202	0.292	0.313	0.305	0.273	0.287	0.268	0.290
T_5	250	294	370	256	327	254	292	0.204	0.193	0.224	0.201	0.217	0.197	0.206	0.299	0.313	0.316	0.294	0.301	0.278	0.300
T_6	242	294	377	310	323	239	297	0.198	0.223	0.215	0.222	0.201	0.212	0.212	0.293	0.315	0.320	0.321	0.312	0.326	0.314
T_7	244	282	336	344	305	245	293	0.207	0.223	0.209	0.209	0.214	0.215	0.213	0.287	0.310	0.282	0.287	0.283	0.284	0.289
T_8	239	355	455	425	440	324	373	0.211	0.238	0.207	0.199	0.210	0.186	0.209	0.291	0.363	0.332	0.282	0.320	0.281	0.311
T_9	258	300	374	234	363	238	294	0.199	0.223	0.194	0.225	0.196	0.205	0.207	0.289	0.306	0.323	0.312	0.297	0.295	0.304
T_{10}	241	294	237	355	300	250	280	0.209	0.223	0.203	0.198	0.193	0.190	0.203	0.295	0.304	0.309	0.278	0.292	0.275	0.292
T_{11}	242	294	307	296	340	260	290	0.197	0.193	0.202	0.193	0.191	0.193	0.195	0.277	0.295	0.350	0.332	0.328	0.290	0.312
T_{12}	237	298	242	320	350	248	283	0.199	0.208	0.190	0.195	0.189	0.210	0.198	0.279	0.295	0.337	0.305	0.276	0.300	0.299
CD(0.05)	NS	NS	52	50	52	41	NS	NS	0.031	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 27 Effect of treatments on available sulphur in soil and sulphur content of arecanut palm in garden land

Treatment	Available sulphur in 25-50 cm soil (kg ha^{-1})							Sulphur content of kernel (%)							Sulphur content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	10	11	17	23	23	14	16	0.032	0.018	0.197	0.184	0.201	0.212	0.141	0.326	0.174	0.213	0.161	0.204	0.191	0.212
T_2	10	12	34	21	27	30	22	0.030	0.023	0.199	0.183	0.215	0.217	0.145	0.334	0.222	0.182	0.192	0.218	0.190	0.223
T_3	10	12	15	24	25	14	17	0.029	0.020	0.185	0.179	0.194	0.195	0.134	0.311	0.188	0.207	0.158	0.182	0.209	0.209
T_4	10	17	46	34	39	41	31	0.030	0.045	0.215	0.209	0.204	0.215	0.153	0.323	0.422	0.186	0.170	0.191	0.178	0.245
T_5	9	13	32	25	21	32	22	0.032	0.026	0.206	0.191	0.207	0.227	0.148	0.329	0.243	0.178	0.188	0.179	0.184	0.217
T_6	9	17	44	37	38	38	30	0.027	0.048	0.190	0.205	0.219	0.203	0.149	0.319	0.459	0.217	0.180	0.210	0.201	0.264
T_7	9	18	45	36	36	39	30	0.034	0.050	0.192	0.200	0.193	0.190	0.143	0.334	0.478	0.211	0.158	0.198	0.176	0.259
T_8	10	23	43	32	37	38	30	0.032	0.067	0.211	0.185	0.184	0.200	0.147	0.341	0.635	0.176	0.163	0.177	0.172	0.277
T_9	10	20	47	35	41	39	32	0.032	0.066	0.221	0.213	0.203	0.209	0.157	0.321	0.625	0.191	0.183	0.187	0.196	0.284
T_{10}	9	21	42	33	40	40	31	0.032	0.053	0.224	0.188	0.182	0.178	0.143	0.337	0.498	0.196	0.167	0.175	0.183	0.259
T_{11}	10	13	30	26	22	27	21	0.030	0.031	0.219	0.194	0.187	0.210	0.145	0.319	0.290	0.204	0.174	0.184	0.175	0.224
T_{12}	10	13	31	22	23	31	21	0.031	0.033	0.188	0.219	0.212	0.223	0.151	0.321	0.314	0.202	0.185	0.195	0.179	0.233
CD(0.05)	NS	3	6	5	5	5	NS	NS	0.006	NS	NS	NS	NS		NS	0.060	NS	NS	NS	NS	

Appendix 28 Effect of treatments on available iron in soil and iron content of arecanut palm in garden land

Treatment	Available iron in 25-50 cm soil (kg ha^{-1})							Iron content of kernel (ppm)							Iron content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	110	119	110	190	179	235	157	206	257	238	208	230	215	226	231	231	230	251	220	235	233
T_2	113	112	116	167	198	226	155	237	236	213	250	241	239	236	215	228	226	233	219	241	227
T_3	110	115	112	186	190	242	159	232	238	243	230	228	233	234	212	239	219	228	240	234	229
T_4	110	121	116	168	185	219	153	232	231	233	245	234	235	235	206	233	215	242	202	237	223
T_5	105	113	113	174	212	253	162	223	211	214	226	238	220	222	244	227	244	210	242	222	231
T_6	107	122	110	163	177	229	151	234	249	242	257	245	224	242	222	235	235	206	230	210	223
T_7	105	109	113	179	201	223	155	240	233	221	234	217	231	229	225	238	239	238	228	228	233
T_8	110	115	115	170	183	248	157	229	241	246	236	204	227	231	219	230	237	220	221	236	227
T_9	113	115	108	182	193	238	158	243	254	225	218	233	248	237	236	224	199	230	235	226	225
T_{10}	107	110	117	177	204	261	163	232	238	253	223	196	229	229	226	229	214	223	238	214	224
T_{11}	110	112	107	157	181	268	156	238	243	209	240	214	226	228	247	207	222	244	213	232	228
T_{12}	110	120	109	161	187	231	153	229	224	228	214	240	240	229	229	205	209	217	210	238	218
CD(0.05)	NS	NS	NS	NS	NS	NS	#	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

- pooling not possible as errors homogenous and interaction absent.

Appendix 29 Effect of treatments on available manganese in soil and manganese content of arecanut palm in garden land

Treatment	Available manganese in 25-50 cm soil (kg ha^{-1})							Manganese content of kernel (ppm)							Manganese content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	81	80	79	89	92	89	85	27.6	28.0	30.3	30.9	30.5	32.6	30.0	32.3	31.7	29.0	32.0	32.6	29.6	31.2
T_2	76	76	82	99	100	100	89	32.5	33.0	31.7	31.6	31.4	30.5	31.8	26.7	34.0	33.3	31.2	29.0	33.4	31.3
T_3	73	80	86	103	97	88	88	29.5	27.3	28.9	32.8	32.3	32.0	30.5	27.2	30.9	33.9	29.6	33.2	28.5	30.6
T_4	75	75	79	101	106	94	88	31.5	30.6	28.5	30.5	27.3	28.6	29.5	31.0	28.0	28.7	33.7	27.0	30.7	29.9
T_5	80	79	80	97	94	106	89	27.3	32.0	27.0	28.2	31.7	32.5	29.8	29.0	32.6	28.0	29.0	32.1	34.0	30.8
T_6	69	75	85	90	91	102	85	33.0	26.7	32.8	27.8	32.6	27.3	30.0	28.6	30.3	30.5	28.0	31.4	31.6	30.1
T_7	85	77	78	107	96	92	89	28.7	31.4	31.2	33.5	27.6	33.2	30.9	30.0	33.4	31.0	31.6	30.7	28.3	30.8
T_8	82	78	78	92	95	97	87	30.0	29.2	30.0	29.6	28.3	29.0	29.4	27.5	31.4	31.7	26.9	28.7	32.6	29.8
T_9	82	77	81	95	98	99	89	31.0	28.9	34.3	32.5	33.4	30.0	31.7	30.4	29.6	27.6	32.6	27.8	27.8	29.3
T_{10}	81	73	80	105	103	104	91	26.8	27.6	31.0	27.0	28.9	28.3	28.3	27.0	32.3	32.5	30.5	33.7	29.0	30.8
T_{11}	75	74	81	87	93	95	84	28.3	30.0	29.2	29.0	29.8	31.0	29.6	31.5	28.7	29.6	33.0	28.2	31.0	30.3
T_{12}	77	79	84	93	102	90	88	32.0	28.3	27.8	30.0	31.0	27.8	29.5	28.0	27.0	27.3	27.6	29.8	32.0	28.6
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 30 Effect of treatments on available zinc in soil and zinc content of arecanut palm in garden land

Treatment	**Available zinc in 25-50 cm soil (kg ha^{-1})**							**Zinc content of kernel (ppm)**							**Zinc content of husk (ppm)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_{1}	14.7	18.1	19.8	21.7	20.7	19.3	19.1	8.16	8.40	8.78	8.40	8.99	9.92	8.78	8.43	8.77	8.37	8.80	9.42	8.58	8.73
T_{2}	14.6	17.5	20.6	22.7	22.6	21.0	19.8	8.34	8.50	8.29	8.56	9.20	9.52	8.74	8.54	8.50	9.90	9.60	8.66	8.91	9.02
T_{3}	15.3	17.8	19.4	20.0	21.3	20.7	19.1	8.45	8.72	8.66	8.29	9.36	9.42	8.82	8.07	9.42	9.15	9.04	8.50	8.72	8.82
T_{4}	15.2	18.4	21.1	21.3	21.0	22.0	19.8	8.76	9.09	9.04	9.09	8.61	9.04	8.94	9.01	8.99	8.29	9.52	8.32	8.65	8.80
T_{5}	15.6	18.0	20.9	23.4	22.0	20.1	20.0	8.98	9.70	9.29	9.20	8.13	8.77	9.01	8.94	9.92	9.63	8.77	8.77	8.53	9.09
T_{6}	15.2	18.8	20.3	22.2	20.4	20.6	19.6	9.58	8.45	8.89	9.60	9.83	9.26	9.27	8.87	8.06	8.79	8.93	8.56	8.85	8.68
T_{7}	14.9	17.0	21.5	19.4	22.1	21.3	19.4	8.86	9.31	8.68	9.36	8.50	9.20	8.99	8.71	9.28	8.63	9.10	9.07	8.78	8.93
T_{8}	15.2	19.2	21.0	21.0	21.7	21.7	20.0	9.19	8.61	9.47	9.76	8.40	8.66	9.02	8.30	9.60	8.96	8.61	9.29	8.98	8.96
T_{9}	15.0	24.8	27.3	28.8	28.9	28.0	25.5	9.09	9.52	8.56	8.07	8.66	8.45	8.73	8.15	9.69	8.46	9.35	8.90	8.22	8.80
T_{10}	15.3	18.6	20.0	20.6	21.2	19.8	19.3	8.64	8.06	9.76	8.99	9.60	8.08	8.85	8.64	9.09	9.47	8.50	9.90	8.33	8.99
T_{11}	14.4	17.2	19.0	19.1	21.5	23.0	19.0	8.55	8.93	9.10	9.42	8.72	9.09	8.97	8.80	8.88	9.26	9.77	9.17	8.07	8.99
T_{12}	14.5	17.6	19.6	21.8	23.0	22.3	19.8	9.34	8.80	8.49	8.72	8.34	8.88	8.76	9.09	9.15	9.36	8.29	9.69	8.43	9.00
CD(0.05)	NS	2.9	3.2	3.4	3.5	3.4	1.252	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 31 Effect of treatments on available copper in soil and copper content of arecanut palm in garden land

Treatment	**Available copper in 25-50 cm soil (kg ha^{-1})**							**Copper content of kernel (ppm)**							**Copper content of husk (ppm)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_{1}	19.7	17.3	17.3	17.5	15.8	17.4	17.5	16.4	17.3	16.5	15.2	16.1	19.0	16.8	15.7	16.6	17.0	17.9	17.9	18.8	17.3
T_{2}	19.8	16.6	18.9	16.4	16.5	18.8	17.8	18.6	18.0	15.8	15.9	18.2	18.3	17.5	15.3	18.9	17.9	19.1	18.4	16.0	17.6
T_{3}	18.8	16.1	18.0	16.0	18.2	17.0	17.4	16.0	16.1	17.9	16.7	17.8	17.6	17.0	16.9	15.8	17.4	15.4	17.2	16.0	16.4
T_{4}	19.5	17.0	17.1	16.7	19.2	16.0	17.6	17.9	16.8	19.0	19.1	19.5	17.3	18.3	18.1	18.3	15.5	18.3	16.5	15.6	17.1
T_{5}	17.8	15.3	16.5	17.0	18.8	19.2	17.4	14.9	18.7	18.6	17.8	17.6	17.5	17.5	17.7	17.3	17.6	17.2	19.1	18.1	17.8
T_{6}	18.1	16.4	18.2	14.9	15.6	16.4	16.6	17.4	17.8	16.8	18.7	18.4	18.5	17.9	18.3	17.8	16.8	17.4	16.8	16.4	17.3
T_{7}	17.5	15.6	16.9	15.6	16.3	16.6	16.4	15.5	19.8	18.2	17.4	16.6	16.0	17.2	18.6	18.1	18.4	18.0	17.6	15.8	17.7
T_{8}	19.2	16.0	16.2	17.7	17.6	16.8	17.3	17.7	15.7	19.4	16.4	19.0	19.8	18.0	16.1	19.0	18.6	16.8	15.7	16.7	17.1
T_{9}	19.9	15.2	18.7	18.0	17.3	18.5	17.9	16.9	18.4	17.2	16.1	18.7	16.5	17.3	17.9	19.1	19.5	17.7	18.7	17.2	18.3
T_{10}	18.4	15.8	15.9	17.3	18.6	19.5	17.6	15.8	19.4	18.4	17.7	15.7	17.8	17.5	17.2	16.4	18.8	17.6	18.8	19.3	18.0
T_{11}	18.6	14.6	17.7	14.6	16.8	18.0	16.7	18.4	16.4	17.4	18.2	16.9	17.0	17.4	18.9	15.2	15.9	15.8	17.4	17.5	16.8
T_{12}	19.0	14.8	17.5	15.3	17.9	17.7	17.0	16.6	17.7	17.7	17.2	17.4	17.9	17.4	16.5	16.9	16.4	16.4	18.2	17.0	16.9
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 32 Effect of treatments on available boron in soil and boron content of arecanut palm in garden land

Treatment	Available boron in 25-50 cm soil (kg ha^{-1})							Boron content of kernel (ppm)							Boron content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	9.60	7.48	8.40	9.04	9.29	9.40	8.87	31.1	18.3	31.9	33.0	31.4	33.0	29.8	42.6	22.0	27.6	29.4	33.7	32.1	31.2
T_2	8.66	8.56	8.04	9.29	8.91	9.20	8.78	31.9	24.9	29.6	34.3	34.4	28.7	30.6	42.3	30.1	28.4	28.9	29.0	32.5	31.9
T_3	7.96	7.91	8.48	9.46	8.68	9.60	8.68	29.7	18.8	27.3	30.1	27.8	31.7	27.6	44.2	22.6	27.2	32.5	30.1	30.5	31.2
T_4	8.56	9.31	9.54	8.66	8.40	8.61	8.85	30.8	37.7	30.9	28.8	33.7	30.3	32.0	43.9	45.4	29.8	33.0	27.0	28.0	34.5
T_5	9.09	8.13	8.98	8.29	8.11	8.32	8.49	31.4	25.8	28.7	32.5	32.3	29.0	29.9	44.9	31.2	31.0	31.7	30.9	29.8	33.2
T_6	9.73	9.60	9.20	9.65	9.44	8.73	9.39	30.5	38.4	33.2	32.3	30.5	31.4	32.7	44.0	46.3	30.4	29.8	32.3	30.9	35.6
T_7	8.18	9.04	7.85	9.14	8.98	9.17	8.73	31.9	38.7	27.6	29.4	29.8	32.6	31.7	43.2	46.6	28.9	33.9	33.2	28.5	35.7
T_8	8.99	8.34	8.16	8.56	9.17	8.85	8.68	32.6	48.8	26.7	32.1	33.2	29.5	33.8	43.8	58.9	31.4	31.0	33.0	26.7	37.5
T_9	9.42	8.77	8.29	8.93	8.54	8.22	8.70	30.6	42.1	31.6	31.6	32.8	27.8	32.7	43.5	50.8	33.2	30.7	32.0	33.2	37.2
T_{10}	8.34	11.52	11.74	11.68	11.68	11.70	11.11	32.1	59.4	32.5	33.5	29.0	30.7	36.2	44.3	71.6	32.2	33.5	32.8	34.1	41.4
T_{11}	8.80	7.32	8.60	8.80	9.35	8.98	8.64	30.4	27.3	30.0	30.9	28.5	26.8	29.0	41.7	32.9	32.8	30.2	31.4	29.0	33.0
T_{12}	9.26	7.70	8.80	8.45	8.80	8.47	8.58	30.7	27.8	28.2	28.0	32.0	28.3	29.2	42.0	33.6	31.7	28.3	28.0	30.1	32.3
CD(0.05)	NS	1.37	1.37	1.44	1.43	1.43	0.585	NS	5.316	NS	NS	NS	NS		NS	6.411	NS	NS	NS	NS	

Appendix 33 Effect of treatments on total silicon in soil and silicon content of arecanut palm in garden land

Treatment	Total silicon in 25-50 cm soil (t ha^{-1})							Silicon content of kernel (%)							Silicon content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	363	343	346	347	347	341	348	0.078	0.075	0.067	0.075	0.066	0.073	0.072	0.071	0.076	0.079	0.070	0.073	0.064	0.072
T_2	351	332	323	341	383	351	347	0.079	0.068	0.075	0.076	0.068	0.064	0.072	0.076	0.073	0.065	0.065	0.068	0.076	0.070
T_3	313	351	355	385	327	347	346	0.075	0.076	0.078	0.071	0.064	0.076	0.073	0.068	0.079	0.076	0.074	0.070	0.070	0.073
T_4	333	360	377	314	367	333	347	0.080	0.069	0.070	0.069	0.078	0.068	0.072	0.073	0.069	0.067	0.073	0.075	0.074	0.072
T_5	377	366	339	327	320	357	348	0.069	0.065	0.082	0.068	0.076	0.071	0.072	0.066	0.077	0.078	0.063	0.072	0.062	0.070
T_6	360	373	360	307	355	367	354	0.074	0.073	0.072	0.065	0.070	0.079	0.072	0.064	0.067	0.077	0.073	0.078	0.071	0.072
T_7	371	387	371	355	341	303	355	0.076	0.072	0.069	0.065	0.074	0.076	0.072	0.074	0.065	0.069	0.069	0.068	0.066	0.068
T_8	325	320	314	373	375	317	337	0.063	0.078	0.074	0.067	0.065	0.066	0.069	0.078	0.078	0.075	0.075	0.074	0.067	0.075
T_9	341	339	364	363	335	375	353	0.076	0.063	0.077	0.078	0.070	0.067	0.072	0.069	0.071	0.074	0.067	0.077	0.069	0.071
T_{10}	385	309	345	370	304	361	346	0.072	0.077	0.077	0.073	0.072	0.077	0.075	0.076	0.074	0.077	0.075	0.065	0.065	0.072
T_{11}	307	327	332	320	315	325	321	0.071	0.080	0.080	0.077	0.075	0.075	0.076	0.075	0.070	0.073	0.071	0.075	0.071	0.072
T_{12}	337	314	352	333	330	383	342	0.066	0.070	0.076	0.076	0.073	0.069	0.072	0.079	0.066	0.071	0.076	0.063	0.068	0.071
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 34 Effect of treatments on available aluminium in soil and aluminium content of arecanut palm in garden land

Treatment	Available aluminium in 25-50 cm soil (kg ha^{-1})							Aluminium content of kernel (ppm)							Aluminium content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	89	99	93	83	92	85	90	280	180	211	202	233	222	221	177	242	246	217	227	203	219
T_2	88	83	92	87	86	86	87	287	188	225	246	225	214	231	176	230	203	204	235	213	210
T_3	95	93	98	92	85	91	92	267	195	182	195	237	227	217	184	240	196	198	225	218	210
T_4	93	96	90	91	87	83	90	278	190	213	207	242	223	225	182	219	210	251	199	243	217
T_5	99	95	88	96	82	82	90	282	216	188	215	207	231	223	187	214	213	210	248	226	216
T_6	94	91	83	94	83	88	89	274	202	203	223	211	195	218	183	203	227	243	241	248	224
T_7	90	89	90	82	90	96	89	287	222	220	213	195	209	224	179	206	241	223	244	238	222
T_8	92	93	99	89	94	99	94	293	192	198	240	206	244	229	182	220	223	240	218	246	221
T_9	91	92	96	85	88	92	91	275	183	206	220	199	235	220	181	231	206	233	220	223	216
T_{10}	97	97	95	90	82	89	92	289	194	193	234	229	203	224	184	222	216	227	231	229	218
T_{11}	84	86	85	97	96	94	90	274	206	216	230	220	219	227	173	238	237	215	209	195	211
T_{12}	86	88	86	88	98	85	88	276	185	185	229	217	240	222	174	225	234	222	214	233	217
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 35 Effect of treatments on soil pH and organic carbon content of soil in garden land

Treatment	Soil pH in 25-50 cm soil							Organic carbon content of 25-50 cm soil (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	5.21	4.58	4.36	4.30	4.61	4.74	4.63	0.58	0.79	0.74	0.73	0.78	0.81	0.74
T_2	5.25	6.18	5.84	5.87	6.12	6.33	5.93	0.59	0.83	0.83	0.74	0.75	0.83	0.76
T_3	5.28	4.71	4.46	4.43	4.47	4.71	4.68	0.57	0.77	0.75	0.71	0.69	0.82	0.72
T_4	5.09	5.65	5.60	5.71	5.90	6.15	5.68	0.58	0.78	0.79	0.88	0.85	0.84	0.79
T_5	5.14	5.78	6.03	6.24	6.40	6.48	6.01	0.55	0.74	0.76	0.75	0.71	0.86	0.73
T_6	5.28	6.03	6.28	6.10	5.80	6.28	5.96	0.56	0.81	0.80	0.85	0.77	0.84	0.77
T_7	5.13	5.74	6.12	6.26	6.10	6.38	5.96	0.55	0.75	0.80	0.81	0.79	0.85	0.76
T_8	5.12	5.84	5.78	5.93	6.00	6.06	5.79	0.58	0.80	0.85	0.84	0.82	0.87	0.79
T_9	5.05	5.80	6.06	5.65	6.30	6.20	5.84	0.59	0.82	0.81	0.86	0.84	0.79	0.78
T_{10}	5.20	5.96	5.71	5.78	6.00	5.98	5.77	0.56	0.73	0.78	0.77	0.74	0.80	0.73
T_{11}	5.06	6.12	5.90	6.20	6.20	6.40	5.98	0.57	0.80	0.83	0.76	0.81	0.78	0.76
T_{12}	5.00	5.87	6.19	6.12	6.23	5.98	5.90	0.58	0.78	0.85	0.79	0.88	0.77	0.77
CD(0.05)	NS	0.89	0.88	0.90	0.92	0.94	0.170	NS	NS	NS	NS	NS	NS	NS

Appendix 36 Effect of treatments on leaf sap pH of arecanut palm in garden land

Treatment	Leaf sap pH						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	3.53	4.10	3.24	3.31	3.25	3.34	3.46
T_2	3.30	4.20	3.07	3.45	3.43	3.19	3.44
T_3	3.16	4.18	3.31	2.94	3.18	3.40	3.36
T_4	3.25	4.26	3.16	3.40	3.24	3.48	3.46
T_5	3.46	4.22	3.29	3.20	3.06	3.39	3.44
T_6	2.99	4.26	3.24	3.18	3.29	3.66	3.44
T_7	3.72	4.30	3.31	3.12	3.44	3.15	3.51
T_8	3.55	4.40	3.24	3.11	3.10	3.73	3.52
T_9	3.55	4.34	3.24	3.46	3.25	3.59	3.57
T_{10}	3.53	4.40	3.14	3.53	3.67	3.47	3.62
T_{11}	3.27	4.24	3.10	3.13	3.22	3.36	3.39
T_{12}	3.34	4.24	3.08	3.28	3.39	3.48	3.47
CD(0.05)	NS	NS	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Appendix 37 Effect of treatments on morphological characters of arecanut in garden land

Treatment	Fresh nut length (cm)							Fresh nut breadth (cm)							Fresh nut weight (g)			
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	2004	2005	2006	Mean
T_1	5.80	5.01	5.55	5.98	5.30	5.40	5.51	4.13	4.01	4.06	4.27	3.97	4.01	4.07	30.30	31.20	30.55	30.68
T_2	5.94	5.20	5.25	5.53	5.30	5.69	5.48	4.10	4.08	3.98	3.99	4.19	3.98	4.05	31.30	40.65	40.80	37.58
T_3	5.53	5.14	5.36	5.76	5.40	5.86	5.51	4.29	4.06	4.48	4.17	4.36	3.94	4.22	31.15	31.10	31.30	31.18
T_4	5.75	5.56	5.03	5.91	5.56	5.50	5.55	4.26	4.46	3.89	4.12	4.08	4.62	4.24	33.15	38.40	40.80	37.45
T_5	5.85	5.35	5.93	5.33	5.20	5.62	5.55	4.36	4.27	4.69	4.07	4.52	3.91	4.30	33.20	39.85	40.30	37.78
T_6	5.68	5.61	5.72	5.62	5.80	5.17	5.60	4.27	4.58	3.78	4.53	4.28	4.17	4.27	32.75	40.10	40.70	37.85
T_7	5.94	5.61	5.80	5.87	5.43	5.26	5.65	4.18	4.62	4.14	4.62	4.49	4.37	4.41	32.95	40.00	40.40	37.78
T_8	6.07	5.95	5.87	5.22	4.95	5.05	5.52	4.24	4.86	4.28	4.34	3.87	4.51	4.35	32.90	39.20	40.50	37.53
T_9	5.70	5.85	5.98	5.44	5.94	5.79	5.78	4.21	4.82	4.22	3.96	4.12	4.33	4.28	33.25	41.10	41.40	38.58
T_{10}	5.99	5.88	5.09	5.82	5.09	5.11	5.50	4.30	4.85	4.60	4.03	4.61	4.07	4.41	33.45	39.70	40.60	37.92
T_{11}	5.67	5.37	5.62	5.69	5.68	5.32	5.56	4.04	4.28	4.17	4.41	4.23	4.12	4.21	31.85	39.65	40.10	37.20
T_{12}	5.72	5.50	5.47	5.08	5.18	5.93	5.48	4.07	4.39	4.40	4.21	4.42	4.22	4.28	31.85	39.45	41.00	37.43
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS		NS	5.922	6.021	

Appendix 38 Effect of treatments on morphological characters of arecanut palm in garden land (Contd…)

Treatment	**Fresh kernel length (cm)**							**Fresh kernel breadth (cm)**							**Fresh kernel weight (g)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	2.20	2.02	2.17	2.15	2.21	2.18	2.15	2.56	2.01	2.58	2.65	2.57	2.55	2.49	12.9	10.1	11.1	11.1	11.2	11.2	11.3
T_2	2.25	2.46	2.87	2.81	2.84	2.67	2.65	2.54	2.48	3.40	3.32	3.35	3.29	3.06	12.0	13.3	14.2	14.2	14.8	14.3	13.8
T_3	2.10	2.02	2.23	2.10	2.24	2.13	2.14	2.65	2.04	2.51	2.59	2.61	2.58	2.50	13.6	10.3	11.1	11.1	11.2	11.2	11.4
T_4	2.18	2.52	2.81	2.89	2.70	2.78	2.65	2.64	2.57	3.34	3.49	3.32	3.34	3.12	13.8	13.7	14.6	15.0	14.8	14.6	14.4
T_5	2.22	2.46	2.78	2.75	2.90	2.72	2.64	2.70	2.54	3.37	3.30	3.44	3.30	3.11	13.5	13.4	14.6	14.2	14.4	14.5	14.1
T_6	2.15	2.55	2.88	2.80	2.72	2.73	2.64	2.64	2.59	3.46	3.46	3.52	3.44	3.18	13.4	13.7	14.6	14.3	14.8	14.9	14.3
T_7	2.25	2.57	2.81	2.76	2.92	2.80	2.69	2.59	2.59	3.32	3.23	3.28	3.28	3.05	13.3	13.8	14.3	14.7	14.8	14.6	14.3
T_8	2.30	2.84	2.83	2.85	2.70	2.86	2.73	2.63	2.91	3.30	3.52	3.32	3.35	3.17	13.2	14.2	14.3	15.0	14.7	14.7	14.3
T_9	2.16	2.76	2.92	2.72	2.80	2.75	2.69	2.61	2.83	3.37	3.37	3.24	3.26	3.11	13.5	14.0	14.4	14.9	14.6	14.8	14.4
T_{10}	2.27	2.82	2.75	2.78	2.76	2.81	2.70	2.66	2.87	3.43	3.35	3.50	3.37	3.20	13.9	14.1	14.6	14.6	14.3	14.4	14.3
T_{11}	2.15	2.49	2.80	2.83	2.98	2.83	2.68	2.50	2.54	3.25	3.40	3.37	3.25	3.05	12.9	13.4	14.5	14.6	14.2	14.4	14.0
T_{12}	2.17	2.52	2.85	2.90	2.89	2.89	2.70	2.52	2.55	3.28	3.26	3.40	3.39	3.07	12.3	13.6	14.7	14.9	14.3	14.6	14.1
CD(0.05)	NS	0.38	0.42	0.42	0.42	0.41		NS	0.39	0.50	0.50	0.50	0.50		NS	2.0	2.2	2.2	2.2	2.2	

Appendix 39 Effect of treatments on morphological characters of arecanut palm in garden land (Contd…)

Treatment	**Dry nut length (cm)**							**Dry nut breadth (cm)**							**Dry nut weight (g)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	5.70	5.57	5.46	5.47	5.38	5.49	5.51	3.64	3.02	3.06	3.17	3.21	3.20	3.22	11.0	8.3	12.4	12.5	12.9	13.1	11.7
T_2	5.84	5.69	6.17	5.84	6.16	6.10	5.96	3.61	3.13	3.64	3.19	3.94	3.43	3.49	11.1	10.3	16.2	16.0	17.1	17.8	14.8
T_3	5.43	5.65	5.43	5.44	5.44	5.41	5.47	3.78	3.10	3.07	3.16	3.14	3.22	3.24	11.1	8.5	12.1	12.7	13.1	13.6	11.8
T_4	5.65	5.74	5.66	5.98	5.60	5.74	5.73	3.75	3.40	3.46	3.50	3.65	3.32	3.51	11.2	11.8	15.2	15.7	17.0	17.4	14.7
T_5	5.75	5.70	6.26	6.23	5.87	6.04	5.97	3.84	3.26	3.73	3.63	3.87	3.44	3.63	11.4	10.3	15.7	16.5	17.4	16.9	14.7
T_6	5.58	5.78	5.97	5.69	6.33	5.86	5.87	3.76	3.54	3.13	3.86	3.24	3.49	3.50	11.2	11.9	15.2	16.7	16.5	18.0	14.9
T_7	5.84	5.80	5.89	6.02	6.08	5.96	5.93	3.68	3.59	3.53	3.67	3.61	3.67	3.62	11.2	12.0	15.1	16.6	17.6	16.5	14.9
T_8	5.97	6.46	6.22	5.80	6.27	6.31	6.17	3.74	3.96	3.22	3.60	3.76	3.29	3.59	11.4	12.5	15.2	15.9	16.8	17.9	14.9
T_9	5.61	6.28	6.04	5.73	6.39	5.70	5.95	3.71	3.66	3.52	3.68	3.58	3.80	3.66	11.1	12.1	15.8	17.2	17.2	18.3	15.3
T_{10}	5.89	6.35	5.78	6.05	5.72	6.07	5.98	3.78	3.74	3.48	3.51	3.26	3.90	3.61	11.5	12.3	15.6	16.4	17.2	17.1	15.0
T_{11}	5.57	5.72	6.11	5.78	5.64	6.23	5.84	3.56	3.33	3.80	3.45	3.48	3.54	3.53	10.8	10.3	15.9	16.0	16.6	17.4	14.5
T_{12}	5.62	5.73	5.72	6.25	5.79	6.15	5.88	3.58	3.35	3.65	3.35	3.59	3.25	3.46	10.9	10.4	16.3	15.3	17.1	17.8	14.6
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	0.52	0.53	NS	0.54	NS		NS	1.7	2.3	2.4	2.5	2.6	

Appendix 40 Effect of treatments on morphological characters of arecanut palm in garden land (Contd…)

Treatment	Dry kernel length (cm)							Dry kernel breadth (cm)							Recovery percentage (%)			
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	2004	2005	2006	Mean
T_1	1.81	1.59	1.79	1.89	1.93	1.92	1.82	1.97	2.17	2.15	2.13	2.26	2.23	2.15	19.27	18.49	19.57	19.11
T_2	1.85	1.91	2.27	2.54	2.38	2.48	2.24	1.95	2.60	2.78	2.76	2.93	2.90	2.65	19.52	16.41	17.30	17.74
T_3	1.73	1.61	1.83	1.94	1.88	1.86	1.81	2.04	2.17	2.12	2.19	2.21	2.28	2.17	18.65	18.94	19.74	19.11
T_4	1.79	1.94	2.34	2.42	2.60	2.37	2.24	2.03	2.71	2.80	2.93	2.87	2.87	2.70	20.72	18.91	18.60	19.41
T_5	1.82	1.92	2.31	2.50	2.61	2.59	2.29	2.07	2.60	2.86	2.89	2.86	2.89	2.70	18.98	17.16	17.52	17.89
T_6	1.77	1.95	2.26	2.43	2.33	2.56	2.22	2.03	2.77	2.72	2.80	2.84	2.81	2.66	21.07	18.20	18.75	19.34
T_7	1.85	1.99	2.30	2.64	2.56	2.64	2.33	1.99	2.81	2.87	2.72	2.98	2.78	2.69	20.79	18.05	18.74	19.19
T_8	1.89	2.04	2.43	2.41	2.48	2.42	2.28	2.02	2.95	2.84	2.81	2.90	2.80	2.72	21.31	18.72	19.09	19.71
T_9	1.78	1.99	2.39	2.61	2.42	2.35	2.26	2.01	2.84	2.81	2.90	2.78	2.97	2.72	20.78	17.83	18.53	19.05
T_{10}	1.87	2.02	2.25	2.35	2.53	2.50	2.25	2.05	2.88	2.74	2.86	2.81	2.93	2.71	20.96	18.61	18.72	19.43
T_{11}	1.77	1.93	2.37	2.46	2.37	2.33	2.20	1.92	2.64	2.83	2.83	2.89	2.84	2.66	19.03	16.80	17.16	17.66
T_{12}	1.78	1.93	2.35	2.59	2.45	2.43	2.25	1.94	2.68	2.76	2.73	2.83	2.83	2.63	19.09	16.96	16.93	17.66
CD(0.05)	NS	0.29	0.34	0.37	0.37	0.37		NS	0.41	0.42	0.42	0.43	0.43		NS	NS	NS	

Appendix 41 Effect of treatments on morphological characters of arecanut palm in garden land (Contd…)

Treatment	Fresh husk thickness (cm)							Fresh husk weight (g)							Dry husk weight (g)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	0.50	0.57	0.58	0.55	0.53	0.55	0.55	18.5	19.1	20.6	19.6	19.7	19.0	19.4	4.72	3.60	6.03	5.86	6.06	6.09	5.39
T_2	0.51	0.53	0.58	0.57	0.53	0.56	0.55	18.0	19.1	27.8	25.1	25.6	27.0	23.8	4.84	4.33	8.01	7.55	7.96	8.67	6.89
T_3	0.48	0.54	0.55	0.52	0.55	0.59	0.54	19.3	19.1	19.8	20.2	20.1	20.1	19.8	4.50	3.63	5.78	6.08	6.21	6.42	5.44
T_4	0.50	0.50	0.58	0.58	0.60	0.52	0.55	19.3	19.3	23.9	23.3	26.0	26.2	23.0	4.68	4.63	6.98	6.95	7.92	8.26	6.57
T_5	0.50	0.52	0.52	0.55	0.52	0.54	0.53	19.4	19.2	25.6	25.8	27.5	25.1	23.8	4.76	4.40	7.42	7.81	8.48	7.95	6.80
T_6	0.49	0.50	0.59	0.60	0.57	0.52	0.54	19.7	19.5	24.7	26.1	24.2	26.7	23.5	4.62	4.65	7.04	7.90	7.52	8.62	6.72
T_7	0.51	0.50	0.59	0.52	0.55	0.55	0.53	19.2	19.6	24.7	26.3	27.2	24.1	23.5	4.83	4.75	7.14	7.84	8.45	7.60	6.77
T_8	0.52	0.45	0.58	0.58	0.58	0.52	0.54	18.5	19.9	25.1	24.1	24.9	26.7	23.2	4.94	4.97	7.17	7.25	7.78	8.65	6.79
T_9	0.49	0.49	0.60	0.56	0.54	0.57	0.54	19.3	19.6	26.2	26.7	26.0	27.4	24.2	4.64	4.79	7.69	8.16	8.15	8.72	7.02
T_{10}	0.52	0.48	0.59	0.58	0.51	0.52	0.53	19.1	19.8	25.2	25.0	26.9	25.6	23.6	4.88	4.82	7.31	7.61	8.32	8.08	6.84
T_{11}	0.49	0.51	0.59	0.54	0.58	0.56	0.55	18.2	19.2	26.3	23.9	25.6	26.0	23.2	4.61	4.37	7.62	7.27	7.88	8.33	6.68
T_{12}	0.49	0.51	0.54	0.57	0.58	0.56	0.54	18.6	19.3	26.5	22.8	26.7	26.4	23.4	4.65	4.44	7.85	6.72	8.30	8.56	6.76
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	NS	3.8	3.7	3.9	3.9		NS	0.684	1.105	1.124	1.192	1.124	

Appendix 42 Effect of treatments on available nitrogen in soil and nitrogen content of arecanut palm in terraced upland

Treatment	Available nitrogen in 25-50 cm soil (kg ha^{-1})							Nitrogen content of kernel (%)							Nitrogen content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	224	213	198	215	221	228	216	0.85	0.54	0.78	0.79	0.82	0.84	0.77	0.90	0.61	0.86	0.88	0.85	0.84	0.82
T_2	229	271	275	314	289	298	279	0.79	0.76	0.85	0.87	0.84	0.86	0.83	0.91	0.85	0.86	0.84	0.87	0.83	0.86
T_3	223	226	238	223	229	315	242	0.80	0.60	0.77	0.79	0.83	0.85	0.77	0.89	0.67	0.83	0.85	0.79	0.86	0.82
T_4	224	284	260	280	309	234	265	0.84	0.88	0.81	0.77	0.81	0.83	0.82	0.90	0.99	0.87	0.84	0.86	0.84	0.88
T_5	213	278	265	303	315	306	280	0.76	0.82	0.84	0.78	0.82	0.86	0.81	0.85	0.92	0.81	0.83	0.86	0.83	0.85
T_6	217	287	270	298	298	287	276	0.83	0.88	0.81	0.79	0.82	0.85	0.83	0.87	0.99	0.87	0.82	0.85	0.83	0.87
T_7	213	294	250	286	303	322	278	0.83	0.91	0.79	0.82	0.78	0.81	0.82	0.85	1.03	0.88	0.82	0.84	0.81	0.87
T_8	223	328	248	275	323	290	281	0.81	1.04	0.90	0.78	0.86	0.79	0.86	0.89	1.17	0.86	0.88	0.82	0.85	0.91
T_9	230	300	257	308	293	295	281	0.73	0.95	0.85	0.80	0.85	0.81	0.83	0.92	1.06	0.88	0.83	0.85	0.83	0.90
T_{10}	218	304	252	292	283	303	275	0.84	1.01	0.79	0.81	0.83	0.81	0.85	0.87	1.13	0.85	0.82	0.86	0.82	0.89
T_{11}	223	281	241	318	286	324	279	0.75	0.85	0.79	0.82	0.79	0.82	0.80	0.89	0.96	0.81	0.85	0.82	0.85	0.86
T_{12}	223	284	250	281	292	309	273	0.81	0.85	0.78	0.82	0.79	0.81	0.81	0.89	0.96	0.90	0.83	0.82	0.87	0.88
CD(0.05)	NS	44	39	44	45	46	17.94	NS	0.129	NS	NS	NS	NS		NS	0.145	NS	NS	NS	NS	

Appendix 43 Effect of treatments on available phosphorus in soil and phosphorus content of arecanut palm in terraced upland

Treatment	Available phosphorus in 25-50 cm soil (kg ha^{-1})							Phosphorus content of kernel (%)							Phosphorus content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	27	28	14	12	16	18	19	0.156	0.086	0.124	0.127	0.131	0.135	0.127	0.160	0.092	0.125	0.128	0.123	0.126	0.126
T_2	28	31	56	53	56	55	47	0.144	0.122	0.120	0.128	0.124	0.137	0.129	0.164	0.131	0.121	0.128	0.124	0.130	0.133
T_3	24	28	16	19	23	24	22	0.147	0.093	0.119	0.127	0.130	0.136	0.125	0.159	0.099	0.135	0.127	0.130	0.124	0.129
T_4	27	31	24	25	24	23	26	0.154	0.146	0.130	0.124	0.127	0.135	0.136	0.160	0.156	0.128	0.124	0.130	0.122	0.137
T_5	26	19	22	23	28	27	24	0.140	0.122	0.123	0.125	0.117	0.132	0.127	0.152	0.131	0.130	0.127	0.129	0.133	0.134
T_6	26	30	24	22	28	25	26	0.151	0.148	0.130	0.123	0.127	0.134	0.135	0.156	0.158	0.124	0.128	0.126	0.132	0.137
T_7	26	30	23	21	25	27	25	0.151	0.149	0.123	0.128	0.124	0.135	0.135	0.152	0.159	0.131	0.127	0.124	0.130	0.137
T_8	27	30	56	58	56	60	48	0.148	0.158	0.132	0.128	0.133	0.126	0.138	0.160	0.169	0.129	0.126	0.131	0.127	0.140
T_9	28	31	57	55	57	55	47	0.134	0.149	0.128	0.131	0.126	0.130	0.133	0.165	0.159	0.135	0.128	0.131	0.127	0.141
T_{10}	26	29	57	54	52	52	45	0.154	0.151	0.136	0.130	0.125	0.134	0.138	0.156	0.162	0.127	0.131	0.129	0.123	0.138
T_{11}	27	30	17	23	24	23	24	0.138	0.122	0.133	0.131	0.126	0.144	0.132	0.159	0.131	0.129	0.131	0.128	0.126	0.134
T_{12}	27	29	25	24	29	28	27	0.149	0.124	0.130	0.127	0.129	0.122	0.130	0.160	0.132	0.129	0.128	0.131	0.127	0.135
CD(0.05)	NS	NS	3	6	7	6	3.167	NS	0.020	NS	NS	NS	NS		NS	0.022	NS	NS	NS	NS	

Appendix 44 Effect of treatments on available potassium in soil and potassium content of arecanut palm in terraced upland

Treatment	Available potassium in 25-50 cm soil (kg ha^{-1})							Potassium content of kernel (%)							Potassium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	267	144	113	116	118	110	145	0.53	0.41	0.53	0.36	0.36	0.33	0.42	1.01	0.95	0.83	0.80	0.76	0.83	0.86
T_2	273	195	391	243	258	267	271	0.49	0.52	0.50	0.41	0.36	0.37	0.44	1.03	1.21	0.91	0.79	0.84	0.78	0.92
T_3	266	144	123	124	130	120	151	0.50	0.41	0.47	0.51	0.40	0.39	0.45	1.00	0.96	0.91	0.79	0.80	0.80	0.88
T_4	267	200	290	228	288	259	255	0.52	0.56	0.52	0.42	0.40	0.35	0.46	1.01	1.30	0.86	0.83	0.84	0.80	0.94
T_5	254	195	253	256	253	213	237	0.48	0.52	0.51	0.42	0.38	0.31	0.44	0.96	1.21	0.89	0.79	0.75	0.76	0.89
T_6	259	246	269	234	278	246	255	0.51	0.59	0.49	0.45	0.36	0.36	0.46	0.98	1.37	0.86	0.81	0.78	0.80	0.93
T_7	254	292	314	252	244	237	265	0.51	0.60	0.46	0.46	0.36	0.32	0.45	0.96	1.39	0.88	0.86	0.76	0.77	0.94
T_8	266	300	238	243	262	211	253	0.50	0.64	0.48	0.49	0.40	0.37	0.48	1.01	1.48	1.00	0.84	0.73	0.82	0.98
T_9	274	292	280	279	265	275	278	0.45	0.61	0.47	0.47	0.39	0.32	0.45	1.04	1.43	0.90	0.87	0.74	0.77	0.96
T_{10}	260	293	334	258	293	293	288	0.52	0.61	0.54	0.45	0.37	0.32	0.47	0.98	1.43	0.88	0.80	0.80	0.81	0.95
T_{11}	266	246	356	237	233	283	270	0.47	0.58	0.50	0.36	0.37	0.36	0.44	1.00	1.35	0.92	0.81	0.75	0.80	0.94
T_{12}	266	291	375	273	264	225	282	0.51	0.55	0.46	0.52	0.41	0.31	0.46	1.01	1.28	0.91	0.86	0.72	0.77	0.92
CD(0.05)	NS	39	44	37	39	37	22.71	NS	0.084	NS	NS	NS	0.050		NS	0.196	NS	NS	NS	NS	

Appendix 45 Effect of treatments on available calcium in soil and calcium content of arecanut palm in terraced upland

Treatment	Available calcium in 25-50 cm soil (kg ha^{-1})							Calcium content of kernel (%)							Calcium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	810	1110	910	890	791	840	892	0.172	0.124	0.191	0.178	0.166	0.161	0.165	0.210	0.158	0.234	0.212	0.213	0.208	0.206
T_2	805	2400	1774	1319	1344	1559	1533	0.159	0.158	0.166	0.190	0.165	0.159	0.166	0.214	0.202	0.206	0.237	0.237	0.232	0.221
T_3	842	1120	960	820	840	870	909	0.162	0.128	0.200	0.167	0.178	0.157	0.165	0.209	0.163	0.204	0.209	0.224	0.215	0.204
T_4	836	1514	2230	1274	1074	1341	1378	0.169	0.176	0.184	0.194	0.200	0.181	0.184	0.210	0.226	0.237	0.222	0.234	0.211	0.223
T_5	855	1465	2090	1505	1613	1655	1530	0.154	0.158	0.173	0.184	0.193	0.171	0.172	0.199	0.202	0.216	0.207	0.229	0.221	0.212
T_6	838	1700	2140	1870	1299	1296	1524	0.166	0.176	0.178	0.160	0.175	0.167	0.170	0.204	0.226	0.213	0.239	0.200	0.229	0.218
T_7	821	1950	1980	1776	1523	1857	1651	0.166	0.176	0.195	0.180	0.186	0.176	0.180	0.199	0.226	0.224	0.231	0.217	0.225	0.220
T_8	833	2100	1667	1419	1227	1516	1460	0.163	0.229	0.192	0.204	0.172	0.170	0.188	0.209	0.293	0.231	0.232	0.226	0.218	0.235
T_9	827	2002	1660	1646	1267	1900	1550	0.147	0.195	0.183	0.200	0.160	0.193	0.180	0.216	0.250	0.229	0.208	0.222	0.228	0.225
T_{10}	843	2100	1730	1240	1138	1801	1475	0.170	0.210	0.193	0.172	0.182	0.161	0.181	0.204	0.269	0.227	0.240	0.219	0.209	0.228
T_{11}	793	1465	1590	1360	1195	1617	1337	0.152	0.158	0.160	0.193	0.170	0.187	0.170	0.209	0.202	0.221	0.235	0.240	0.222	0.221
T_{12}	798	1465	1510	1587	1493	1360	1369	0.164	0.176	0.188	0.195	0.188	0.173	0.181	0.209	0.226	0.200	0.229	0.208	0.217	0.215
CD(0.05)	NS	263	271	226	199	239	133.63	NS	0.026	NS	NS	NS	NS		NS	0.034	NS	NS	NS	NS	

Appendix 46 Effect of treatments on available magnesium in soil and magnesium content of arecanut palm in terraced upland

Treatment	Available magnesium in 25-50 cm soil (kg ha^{-1})							Magnesium content of kernel (%)							Magnesium content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	242	270	285	211	257	277	257	0.184	0.106	0.185	0.185	0.178	0.183	0.170	0.261	0.162	0.216	0.273	0.284	0.250	0.241
T_2	248	294	262	207	249	244	251	0.169	0.156	0.175	0.161	0.177	0.185	0.171	0.267	0.238	0.207	0.293	0.280	0.261	0.258
T_3	231	267	267	280	234	207	248	0.173	0.113	0.177	0.170	0.204	0.177	0.169	0.260	0.172	0.221	0.256	0.257	0.267	0.239
T_4	240	280	305	237	280	270	269	0.181	0.194	0.173	0.188	0.188	0.192	0.186	0.261	0.295	0.205	0.306	0.278	0.278	0.271
T_5	244	286	270	274	286	232	265	0.165	0.156	0.180	0.193	0.185	0.188	0.178	0.248	0.238	0.218	0.245	0.276	0.245	0.245
T_6	237	286	280	262	273	287	271	0.178	0.213	0.168	0.159	0.173	0.174	0.177	0.254	0.324	0.203	0.269	0.273	0.253	0.262
T_7	248	280	255	242	275	212	252	0.178	0.213	0.202	0.183	0.191	0.171	0.190	0.248	0.324	0.192	0.287	0.295	0.274	0.270
T_8	253	364	371	326	328	343	331	0.174	0.250	0.178	0.190	0.200	0.180	0.195	0.261	0.381	0.220	0.280	0.290	0.290	0.287
T_9	238	279	276	277	268	244	264	0.157	0.213	0.196	0.178	0.175	0.187	0.184	0.268	0.324	0.201	0.265	0.270	0.234	0.260
T_{10}	250	283	253	252	236	258	255	0.181	0.220	0.192	0.165	0.194	0.168	0.187	0.254	0.334	0.183	0.262	0.268	0.240	0.257
T_{11}	237	276	294	226	242	239	252	0.162	0.163	0.188	0.177	0.169	0.169	0.171	0.260	0.248	0.178	0.300	0.265	0.286	0.256
T_{12}	239	284	289	240	223	271	258	0.175	0.163	0.187	0.173	0.182	0.167	0.174	0.261	0.248	0.194	0.283	0.260	0.256	0.250
CD(0.05)	NS	45	44	40	42	41	17.25	NS	0.028	NS	NS	NS	NS		NS	0.042	NS	NS	NS	NS	

Appendix 47 Effect of treatments on available sulphur in soil and sulphur content of arecanut palm in terraced upland

Treatment	Available sulphur in 25-50 cm soil (kg ha^{-1})							Sulphur content of kernel (%)							Sulphur content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	8	9	26	34	29	31	23	0.021	0.007	0.184	0.170	0.209	0.183	0.129	0.164	0.062	0.182	0.186	0.165	0.155	0.152
T_2	7	10	25	32	29	31	22	0.020	0.014	0.223	0.177	0.191	0.211	0.139	0.168	0.123	0.166	0.203	0.180	0.166	0.168
T_3	7	10	21	33	27	34	22	0.020	0.008	0.198	0.155	0.174	0.205	0.127	0.163	0.071	0.160	0.179	0.168	0.178	0.153
T_4	7	15	41	42	38	42	31	0.021	0.029	0.217	0.179	0.172	0.191	0.135	0.164	0.256	0.178	0.190	0.198	0.159	0.191
T_5	7	11	22	35	28	33	23	0.019	0.016	0.187	0.160	0.172	0.206	0.127	0.156	0.137	0.156	0.185	0.210	0.179	0.171
T_6	6	16	33	45	37	44	30	0.021	0.030	0.195	0.187	0.177	0.179	0.131	0.160	0.261	0.173	0.212	0.187	0.172	0.194
T_7	8	17	43	41	35	45	31	0.021	0.030	0.209	0.165	0.196	0.172	0.132	0.156	0.265	0.157	0.193	0.177	0.161	0.185
T_8	8	19	40	44	35	41	31	0.020	0.037	0.191	0.162	0.185	0.203	0.133	0.164	0.327	0.187	0.199	0.191	0.170	0.206
T_9	8	18	34	43	37	42	30	0.018	0.037	0.211	0.183	0.183	0.190	0.137	0.169	0.322	0.192	0.184	0.176	0.175	0.203
T_{10}	8	18	37	42	36	44	31	0.021	0.031	0.220	0.154	0.186	0.176	0.131	0.160	0.275	0.163	0.207	0.172	0.152	0.188
T_{11}	7	12	27	29	28	32	22	0.019	0.018	0.202	0.157	0.170	0.193	0.127	0.163	0.161	0.169	0.195	0.174	0.157	0.170
T_{12}	7	12	23	30	26	33	22	0.020	0.020	0.215	0.157	0.178	0.207	0.133	0.164	0.175	0.185	0.205	0.183	0.164	0.179
CD(0.05)	NS	2	5	6	5	6	1.71	NS	0.004	NS	NS	NS	NS		NS	0.033	NS	NS	NS	NS	

Appendix 48 Effect of treatments on available iron in soil and iron content of arecanut palm in terraced upland

Treatment	Available iron in 25-50 cm soil (kg ha^{-1})							Iron content of kernel (ppm)							Iron content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	91	75	81	82	99	91	86	213	234	242	209	207	237	224	219	258	239	240	220	223	233
T_2	85	75	79	81	83	92	83	218	214	246	243	223	240	231	229	282	227	225	240	210	236
T_3	81	73	81	92	97	79	84	230	244	230	233	217	230	231	233	287	219	212	222	237	235
T_4	84	71	80	93	89	87	84	225	216	225	211	226	204	218	225	262	210	243	214	213	228
T_5	89	77	82	85	96	83	85	204	248	222	226	219	219	223	239	251	220	205	226	242	230
T_6	77	70	79	83	80	82	78	222	238	238	236	228	245	234	227	289	224	236	218	202	233
T_7	96	80	85	88	85	76	85	231	236	222	215	244	233	230	231	254	217	208	224	214	225
T_8	92	78	85	97	90	79	87	237	223	226	223	220	213	224	235	216	231	217	203	226	221
T_9	92	79	83	89	86	84	85	208	239	231	230	215	234	226	212	294	242	237	230	233	241
T_{10}	91	77	84	84	93	85	86	239	218	227	219	236	224	227	243	231	235	219	235	216	230
T_{11}	85	73	78	86	88	88	83	234	247	237	238	214	238	235	232	216	223	234	211	229	224
T_{12}	86	72	78	95	91	77	83	243	212	234	240	210	232	229	223	282	208	229	209	221	229
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	40.770	NS	NS	NS	NS	

Appendix 49 Effect of treatments on available manganese in soil and manganese content of arecanut palm in terraced upland

Treatment	Available manganese in 25-50 cm soil (kg ha^{-1})							Manganese content of kernel (ppm)							Manganese content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	21	69	79	87	86	86	71	28.5	30.4	30.9	32.3	29.8	31.2	30.5	30.3	33.0	29.8	30.4	28.6	32.0	30.7
T_2	21	67	75	89	96	84	72	33.0	28.5	31.5	31.2	28.7	33.4	31.1	32.5	32.5	32.8	29.3	31.0	29.2	31.2
T_3	22	73	74	88	87	96	73	27.6	27.4	29.2	29.6	29.3	29.8	28.8	27.0	32.0	28.2	28.9	27.6	30.9	29.1
T_4	22	68	82	95	91	98	76	31.0	26.9	28.9	28.5	30.4	32.8	29.8	31.4	31.2	28.7	31.2	29.2	31.7	30.6
T_5	23	75	78	90	89	90	74	29.2	33.0	32.5	28.2	28.0	29.0	30.0	34.0	30.8	27.0	26.7	31.4	27.0	29.5
T_6	22	66	72	96	100	87	74	32.3	28.0	28.3	29.4	32.8	30.5	30.2	29.8	30.0	31.5	32.5	26.5	28.7	29.8
T_7	22	74	83	99	92	92	77	34.0	32.3	30.3	27.6	30.9	28.0	30.5	33.2	29.5	27.6	25.7	29.5	33.0	29.8
T_8	22	76	80	104	98	102	80	30.5	29.0	26.9	27.0	28.3	27.4	28.2	31.7	28.7	29.2	27.6	25.7	31.2	29.0
T_9	22	71	76	100	102	94	77	29.8	31.0	27.8	31.7	27.5	27.0	29.1	28.3	28.1	32.0	31.7	30.4	28.2	29.8
T_{10}	22	70	81	102	94	89	76	26.9	26.5	33.2	30.7	32.1	32.1	30.3	29.0	27.6	30.3	28.4	32.2	33.7	30.2
T_{11}	21	69	79	92	105	91	76	32.5	30.0	29.7	33.0	31.7	28.3	30.9	28.0	27.2	26.4	30.9	30.0	30.0	28.8
T_{12}	21	72	77	93	90	100	75	32.0	31.7	26.2	33.5	27.0	31.6	30.3	30.7	26.5	31.0	29.8	28.1	32.5	29.8
CD(0.05)	NS	NS	NS	NS	NS	NS	#	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

- pooling not possible as errors homogenous and interaction absent.

Appendix 50 Effect of treatments on available zinc in soil and zinc content of arecanut palm in terraced upland

Treatment	Available zinc in 25-50 cm soil (kg ha^{-1})							Zinc content of kernel (ppm)							Zinc content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	15.7	18.9	22.0	20.5	22.3	25.9	20.9	8.56	8.80	9.18	8.72	9.04	8.72	8.84	8.54	8.50	9.20	8.80	8.99	9.31	8.89
T_2	16.1	18.8	23.9	19.0	23.3	24.3	20.9	8.64	8.99	9.70	8.80	8.56	8.03	8.79	8.28	8.61	8.29	8.77	9.36	9.42	8.79
T_3	15.6	19.8	22.4	20.9	20.9	25.1	20.8	9.10	9.31	8.45	9.60	9.47	9.09	9.17	8.89	9.63	8.66	8.66	8.56	8.88	8.88
T_4	15.7	18.4	23.0	21.5	22.7	22.6	20.7	8.06	9.47	9.54	8.48	9.36	8.50	8.90	8.43	9.97	9.93	9.04	8.72	9.52	9.27
T_5	14.9	20.5	21.7	19.8	21.8	23.7	20.4	8.72	8.50	9.92	9.15	8.04	9.52	8.98	8.03	8.40	8.93	8.56	9.09	9.20	8.70
T_6	15.3	19.3	23.3	23.6	23.0	23.0	21.2	8.91	8.34	8.80	9.04	9.20	8.80	8.85	8.36	9.36	8.50	8.93	8.66	9.74	8.93
T_7	14.9	19.5	21.5	20.1	21.4	22.3	20.0	8.84	9.42	8.91	9.42	8.88	8.40	8.98	8.73	8.23	9.40	8.50	9.79	9.09	8.96
T_8	15.7	18.3	21.1	22.1	21.3	24.8	20.5	8.43	9.15	8.61	8.04	8.72	8.66	8.60	8.19	8.88	8.80	9.86	8.13	9.60	8.91
T_9	16.2	25.8	29.2	28.1	30.1	30.8	26.7	8.35	9.69	8.71	8.66	9.92	9.95	9.21	8.34	9.09	9.10	9.15	9.26	9.97	9.15
T_{10}	15.3	20.4	20.9	18.5	20.6	23.0	19.8	8.29	8.61	9.39	9.17	9.67	8.88	9.00	9.08	8.06	9.04	9.60	9.48	8.02	8.88
T_{11}	15.6	18.0	20.5	19.4	21.0	22.0	19.4	9.01	8.04	9.01	9.87	9.15	8.99	9.01	8.60	9.20	9.60	9.36	8.34	8.72	8.97
T_{12}	15.7	20.9	22.8	23.1	22.2	23.9	21.4	8.53	9.92	8.29	8.99	8.34	9.20	8.88	8.11	8.66	8.07	8.18	8.88	9.31	8.54
CD(0.05)	NS	3.1	3.5	3.4	3.6	3.8	1.322	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 51 Effect of treatments on available copper in soil and copper content of arecanut palm in terraced upland

Treatment	Available copper in 25-50 cm soil (kg ha^{-1})							Copper content of kernel (ppm)							Copper content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	18.7	19.2	17.0	19.3	17.0	17.8	18.2	18.4	19.1	17.3	17.0	17.6	18.6	18.0	19.4	15.7	17.3	18.1	19.4	17.4	17.9
T_2	17.5	20.3	16.4	17.3	15.9	18.2	17.6	15.9	17.8	15.8	18.3	18.3	18.4	17.4	16.8	16.5	16.0	18.8	17.5	16.0	16.9
T_3	16.8	19.7	16.1	18.8	18.4	17.4	17.9	16.1	15.9	16.9	16.8	16.9	18.2	16.8	18.1	15.1	16.3	17.5	17.4	18.2	17.1
T_4	17.3	19.9	15.8	16.7	16.6	19.0	17.5	15.6	16.3	19.4	18.1	18.8	19.0	17.9	17.9	16.7	15.2	15.8	15.9	16.7	16.4
T_5	18.3	18.6	18.5	17.5	15.3	16.9	17.5	16.4	17.4	15.4	16.1	17.9	17.9	16.9	16.3	19.1	15.8	16.8	17.9	18.4	17.4
T_6	15.9	20.7	19.5	19.7	16.3	16.0	18.0	16.7	19.5	16.8	17.3	16.5	19.6	17.7	17.0	17.5	16.6	19.4	16.8	19.0	17.7
T_7	19.7	20.5	19.0	16.3	18.0	16.1	18.3	19.1	17.0	18.0	17.7	17.3	16.0	17.5	17.3	17.0	18.7	17.0	17.8	16.4	17.4
T_8	19.2	18.9	17.5	18.5	17.7	19.5	18.5	17.5	16.8	17.8	18.8	17.2	16.5	17.4	15.2	17.3	17.8	16.4	16.5	15.7	16.5
T_9	19.0	20.1	18.1	17.0	14.9	18.6	17.9	17.3	18.7	17.7	16.5	16.0	16.8	17.2	18.6	16.1	16.9	17.8	18.7	17.8	17.7
T_{10}	18.6	19.5	17.6	17.9	15.1	16.4	17.5	15.1	18.3	18.7	15.7	19.4	17.0	17.4	16.6	17.8	18.3	16.7	18.4	15.2	17.2
T_{11}	17.4	18.3	18.0	16.4	17.3	17.2	17.4	16.5	16.7	17.4	15.4	16.7	17.4	16.7	15.9	18.7	19.2	16.1	18.2	18.6	17.8
T_{12}	17.8	18.0	16.6	18.2	15.6	15.6	16.9	16.9	16.1	16.5	19.0	17.8	17.7	17.3	16.1	18.0	17.5	17.6	17.0	16.9	17.2
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 52 Effect of treatments on available boron in soil and boron content of arecanut palm in terraced upland

Treatment	Available boron in 25-50 cm soil (kg ha^{-1})							Boron content of kernel (ppm)							Boron content of husk (ppm)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	9.42	8.31	8.50	8.70	9.04	9.69	8.94	27.1	16.9	29.6	33.0	28.6	34.3	28.2	39.2	23.7	32.6	28.2	32.0	31.9	31.3
T_2	9.04	9.04	8.34	9.54	8.54	9.11	8.94	25.0	22.5	28.7	33.5	31.7	28.2	28.3	40.1	31.7	30.0	32.0	28.5	28.1	31.7
T_3	8.88	8.07	8.18	8.30	8.16	8.97	8.43	25.6	17.9	31.0	27.4	28.0	32.5	27.1	39.0	25.3	30.5	27.0	27.4	30.8	30.0
T_4	8.57	9.10	8.80	9.04	9.42	8.41	8.89	26.7	28.4	27.0	29.9	30.9	30.7	28.9	39.2	40.0	28.3	33.6	34.2	29.3	34.1
T_5	9.20	8.88	9.20	9.00	9.48	9.33	9.18	24.3	22.6	28.3	29.4	27.0	33.1	27.4	37.2	31.8	30.9	30.0	33.6	27.6	31.8
T_6	8.45	9.26	9.15	8.12	9.29	8.40	8.78	26.2	28.4	28.9	32.6	30.1	33.8	30.0	38.1	40.0	27.3	32.6	31.7	32.1	33.6
T_7	8.28	8.77	8.72	9.20	8.73	8.32	8.67	26.2	31.5	27.3	30.7	29.4	32.5	29.6	37.2	44.3	32.0	33.0	28.2	33.1	34.6
T_8	8.07	9.60	9.47	8.50	8.35	8.18	8.70	25.7	35.4	31.8	31.6	32.5	28.7	31.0	39.1	49.8	29.2	31.4	32.6	32.8	35.8
T_9	9.60	8.56	8.99	8.90	9.17	9.47	9.12	23.2	32.1	32.3	28.9	27.8	33.3	29.6	40.3	45.1	33.2	29.6	29.0	29.7	34.5
T_{10}	9.33	11.80	11.53	11.43	11.57	11.22	11.15	26.8	41.1	32.8	28.3	27.4	29.2	30.9	38.2	57.8	27.8	30.5	30.5	28.4	35.5
T_{11}	9.12	9.47	9.31	9.80	9.73	9.20	9.44	24.0	23.5	27.8	28.0	26.9	30.2	26.7	39.0	33.1	28.5	28.7	29.6	32.6	31.9
T_{12}	8.72	8.72	9.74	9.35	8.91	8.60	9.01	25.8	23.8	30.5	32.0	26.4	32.0	28.4	39.1	33.5	27.0	27.6	31.2	28.9	31.2
CD(0.05)	NS	1.44	1.41	1.44	1.45	1.43	0.555	NS	4.149	NS	NS	NS	NS		NS	5.836	NS	NS	NS	NS	

Appendix 53 Effect of treatments on total silicon in soil and silicon content of arecanut palm in terraced upland

Treatment	Total silicon in 25-50 cm soil (t ha^{-1})							Silicon content of kernel (%)							Silicon content of husk (%)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	296	309	325	292	314	277	302	0.066	0.074	0.069	0.066	0.075	0.069	0.070	0.075	0.071	0.065	0.068	0.067	0.070	0.070
T_2	312	334	328	283	307	244	301	0.077	0.076	0.063	0.078	0.071	0.071	0.073	0.073	0.077	0.068	0.073	0.065	0.079	0.072
T_3	325	344	343	340	352	207	318	0.070	0.072	0.078	0.065	0.067	0.078	0.072	0.076	0.075	0.076	0.065	0.070	0.072	0.073
T_4	316	301	320	296	334	270	306	0.064	0.073	0.076	0.070	0.066	0.066	0.069	0.068	0.073	0.064	0.069	0.069	0.077	0.070
T_5	337	347	301	321	340	232	313	0.073	0.069	0.068	0.075	0.073	0.076	0.072	0.077	0.076	0.069	0.074	0.073	0.071	0.073
T_6	332	355	285	316	320	297	318	0.074	0.078	0.074	0.071	0.064	0.074	0.073	0.063	0.065	0.078	0.075	0.072	0.069	0.070
T_7	290	321	314	305	325	212	295	0.080	0.078	0.075	0.076	0.072	0.067	0.075	0.066	0.071	0.067	0.067	0.074	0.075	0.070
T_8	307	316	355	294	292	239	300	0.071	0.071	0.066	0.074	0.070	0.080	0.072	0.074	0.074	0.074	0.066	0.077	0.074	0.073
T_9	305	312	335	334	316	244	308	0.069	0.067	0.070	0.073	0.062	0.069	0.068	0.071	0.063	0.073	0.070	0.062	0.065	0.067
T_{10}	283	291	307	310	298	258	291	0.076	0.079	0.065	0.064	0.076	0.075	0.072	0.071	0.072	0.075	0.063	0.074	0.067	0.071
T_{11}	348	339	294	353	303	299	323	0.078	0.066	0.073	0.067	0.078	0.073	0.072	0.072	0.068	0.072	0.071	0.073	0.071	0.071
T_{12}	321	326	310	300	285	271	302	0.068	0.065	0.071	0.068	0.068	0.064	0.067	0.069	0.067	0.071	0.078	0.075	0.067	0.071
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 54 Effect of treatments on available aluminium in soil and aluminium content of arecanut palm in terraced upland

Treatment	**Available aluminium in 25-50 cm soil (kg ha^{-1})**							**Aluminium content of kernel (ppm)**							**Aluminium content of husk (ppm)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	93	94	92	98	98	95	95	371	230	219	227	244	222	252	273	254	235	218	241	210	239
T_2	97	95	99	90	92	93	94	343	220	254	220	217	204	243	279	297	218	242	231	222	248
T_3	90	87	82	85	95	99	90	350	209	229	203	223	242	243	271	270	225	209	230	218	237
T_4	95	99	91	94	86	87	92	366	246	200	225	246	214	250	273	249	246	227	211	196	234
T_5	83	83	87	95	90	82	87	333	202	213	214	233	231	238	259	276	227	214	199	215	232
T_6	87	92	96	84	83	86	88	359	240	234	233	250	237	259	265	260	214	246	235	241	243
T_7	85	88	89	96	91	95	91	359	244	226	243	225	209	251	259	257	242	223	227	233	240
T_8	92	89	95	83	85	90	89	353	209	240	236	213	218	245	272	283	207	231	215	214	237
T_9	99	90	85	92	88	88	90	318	211	223	230	204	194	230	281	272	254	237	190	226	243
T_{10}	87	85	91	82	89	97	89	366	204	248	196	211	223	241	266	265	229	202	225	237	237
T_{11}	89	91	94	87	93	92	91	328	237	207	210	240	229	242	271	267	231	234	219	230	242
T_{12}	91	97	93	89	82	84	89	354	235	217	217	209	199	238	272	290	220	240	204	204	238
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	

Appendix 55 Effect of treatments on soil pH and organic carbon content of soil in terraced upland

Treatment	**Soil pH in 25-50 cm soil**							**Organic carbon content of 25-50 cm soil (%)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	5.28	4.80	4.68	4.68	4.60	4.58	4.77	0.32	0.73	0.79	0.71	0.66	0.66	0.64
T_2	5.06	6.38	6.28	6.18	6.07	6.15	6.02	0.32	0.83	0.75	0.69	0.64	0.75	0.66
T_3	5.08	4.74	4.58	4.65	4.52	4.49	4.68	0.33	1.01	1.02	0.98	1.03	0.97	0.89
T_4	5.26	6.07	6.20	6.24	5.96	6.26	6.00	0.33	0.80	0.80	0.77	0.76	0.67	0.69
T_5	5.13	5.93	6.31	6.04	5.84	5.78	5.84	0.34	0.79	0.83	0.74	0.69	0.72	0.69
T_6	5.20	6.13	6.18	5.93	6.16	5.62	5.87	0.33	0.80	0.77	0.64	0.71	0.71	0.66
T_7	5.16	6.18	6.12	6.12	6.23	6.09	5.98	0.32	0.85	0.78	0.65	0.74	0.78	0.69
T_8	5.05	6.29	6.15	6.20	6.19	6.12	6.00	0.33	0.82	0.82	0.80	0.62	0.68	0.68
T_9	5.29	6.18	6.03	6.09	5.93	5.96	5.91	0.33	0.75	0.76	0.73	0.68	0.67	0.65
T_{10}	5.27	6.23	6.06	6.10	5.70	5.87	5.87	0.33	0.82	0.76	0.76	0.67	0.72	0.68
T_{11}	5.19	5.96	5.90	5.87	6.13	6.20	5.88	0.31	0.77	0.73	0.67	0.71	0.81	0.67
T_{12}	5.30	6.03	6.40	6.31	6.10	6.00	6.02	0.32	0.76	0.74	0.78	0.82	0.69	0.69
CD(0.05)	NS	0.92	0.91	0.92	0.91	0.90	0.150	NS	0.13	0.12	0.12	0.12	0.12	0.030

Appendix 56 Effect of treatments on leaf sap pH of arecanut palm in terraced upland

Treatment	Leaf sap pH						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Pooled mean
T_1	3.71	3.23	3.35	3.08	3.37	3.23	3.33
T_2	3.79	4.18	3.01	3.23	3.14	3.36	3.45
T_3	3.69	3.27	3.26	3.33	3.38	3.12	3.34
T_4	3.71	4.26	3.16	3.28	3.37	3.22	3.50
T_5	3.52	4.20	3.12	3.52	3.42	3.40	3.53
T_6	3.60	4.28	3.08	3.15	3.24	3.19	3.42
T_7	3.52	4.30	3.17	3.19	3.33	3.47	3.50
T_8	3.70	4.48	3.46	3.73	3.35	3.79	3.75
T_9	3.81	4.36	3.09	3.22	3.44	3.65	3.60
T_{10}	3.61	4.42	3.24	3.24	3.22	3.72	3.58
T_{11}	3.69	4.22	3.41	3.36	3.32	3.31	3.55
T_{12}	3.70	4.24	3.40	3.14	3.13	3.18	3.47
CD(0.05)	NS	0.634	NS	NS	NS	NS	#

- pooling not possible as errors homogenous and interaction absent.

Appendix 57 Effect of treatments on morphological characters of arecanut in terraced upland

Treatment	Fresh nut length (cm)							Fresh nut breadth (cm)							Fresh nut weight (g)			
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	2004	2005	2006	Mean
T_1	5.84	5.07	5.46	5.05	5.40	5.93	5.46	3.83	3.57	3.84	3.88	4.10	3.61	3.80	29.60	33.35	32.00	31.65
T_2	5.39	5.21	5.27	5.71	5.34	5.46	5.40	3.92	3.75	3.90	3.60	3.99	3.97	3.85	31.40	37.65	41.20	36.75
T_3	5.50	5.08	5.15	5.42	4.88	5.61	5.27	3.81	3.65	4.03	3.91	3.82	4.09	3.89	29.70	34.10	32.45	32.08
T_4	5.75	5.58	5.95	5.88	5.09	5.07	5.55	3.83	3.93	3.71	3.96	3.62	3.90	3.83	31.15	36.90	40.85	36.30
T_5	5.23	5.22	5.40	5.35	5.66	5.64	5.42	3.64	3.76	3.81	4.23	3.94	3.64	3.84	30.50	38.60	42.00	37.03
T_6	5.65	5.75	5.78	5.20	5.77	5.74	5.65	3.72	3.97	3.70	3.55	3.87	3.91	3.79	31.20	36.80	41.15	36.38
T_7	5.64	5.82	4.83	5.54	5.20	5.27	5.38	3.64	4.10	4.16	3.84	4.20	4.21	4.02	30.85	35.35	41.50	35.90
T_8	5.54	5.96	5.24	5.29	5.60	5.19	5.47	3.82	4.35	3.53	4.08	4.07	3.53	3.90	31.60	39.25	40.45	37.10
T_9	5.00	5.86	5.65	5.78	5.49	5.54	5.55	3.94	4.19	3.97	4.02	3.92	3.73	3.96	31.55	35.90	40.60	36.02
T_{10}	5.76	5.93	5.56	5.95	5.00	5.84	5.67	3.73	4.32	3.61	4.12	3.53	3.81	3.85	31.65	36.15	41.30	36.37
T_{11}	5.16	5.32	5.34	5.62	5.90	4.97	5.39	3.81	3.89	4.07	3.64	3.68	4.02	3.85	30.70	37.95	41.25	36.63
T_{12}	5.56	5.50	5.05	5.66	5.27	5.36	5.40	3.82	3.93	4.24	3.97	4.14	3.58	3.95	31.40	39.15	41.40	37.32
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS		NS	NS	6.128	

Appendix 58 Effect of treatments on morphological characters of arecanut palm in terraced upland (Contd…)

Treatment	**Fresh kernel length (cm)**							**Fresh kernel breadth (cm)**							**Fresh kernel weight (g)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	2.87	2.03	2.14	2.17	2.16	2.13	2.25	2.52	1.79	2.60	2.55	2.55	2.57	2.43	9.6	8.7	10.2	11.1	11.3	11.3	10.4
T_2	2.64	2.51	2.70	2.90	2.83	2.73	2.72	2.58	2.22	3.37	3.40	3.35	3.32	3.04	9.7	10.7	13.6	14.4	14.5	14.5	12.9
T_3	2.70	2.09	2.08	2.20	2.11	2.21	2.23	2.51	1.80	2.57	2.60	2.64	2.64	2.46	9.6	8.8	10.2	11.3	11.2	11.3	10.4
T_4	2.82	2.57	2.81	2.84	2.80	2.97	2.80	2.52	2.45	3.39	3.44	3.30	3.25	3.06	9.8	11.5	13.4	14.3	14.4	14.6	13.0
T_5	2.57	2.51	2.87	2.81	2.68	2.72	2.69	2.39	2.26	3.43	3.28	3.45	3.28	3.02	9.3	11.0	13.7	14.6	14.6	14.7	13.0
T_6	2.77	2.64	2.62	2.75	2.80	2.76	2.72	2.45	2.65	3.21	3.32	3.21	3.34	3.03	9.3	11.6	13.3	14.3	14.5	14.9	13.0
T_7	2.77	2.67	2.65	2.78	2.89	2.80	2.76	2.39	2.71	3.23	3.17	3.32	3.44	3.04	9.4	11.7	13.4	14.4	14.7	14.9	13.1
T_8	2.72	2.96	2.90	2.81	2.75	2.84	2.83	2.52	2.93	3.37	3.30	3.40	3.35	3.14	9.1	12.1	13.6	14.4	14.4	14.6	13.0
T_9	2.46	2.78	2.93	2.75	2.84	2.86	2.77	2.59	2.73	3.35	3.35	3.37	3.30	3.11	9.0	11.8	13.5	14.4	15.0	14.4	13.0
T_{10}	2.83	2.79	2.73	2.72	2.73	2.89	2.78	2.45	2.89	3.28	3.23	3.26	3.37	3.08	9.1	12.0	13.4	14.5	14.5	15.0	13.1
T_{11}	2.53	2.56	2.76	2.93	2.72	2.81	2.72	2.51	2.28	3.26	3.20	3.34	3.40	3.00	9.1	11.0	13.8	14.8	14.7	14.6	13.0
T_{12}	2.73	2.57	2.68	2.86	2.66	2.92	2.74	2.52	2.40	3.32	3.25	3.28	3.23	3.00	9.6	11.4	13.3	14.8	14.4	14.3	13.0
CD(0.05)	NS	0.39	0.41	0.42	0.41	0.42		NS	0.37	0.49	0.49	0.49	0.50		NS	1.7	2.0	2.1	2.2	2.2	

Appendix 59 Effect of treatments on morphological characters of arecanut palm in terraced upland (Contd…)

Treatment	**Dry nut length (cm)**							**Dry nut breadth (cm)**							**Dry nut weight (g)**						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	5.73	5.24	5.18	5.15	5.22	5.37	5.32	2.93	2.76	3.04	3.07	3.16	3.25	3.03	10.5	8.4	14.1	12.6	13.3	13.9	12.1
T_2	5.29	5.37	5.73	5.74	5.85	5.77	5.62	2.99	2.78	3.53	3.73	3.48	3.71	3.37	10.2	10.3	13.6	16.5	17.5	17.5	14.3
T_3	5.40	5.26	5.22	5.02	5.29	5.33	5.25	2.91	2.76	3.14	3.10	3.12	3.19	3.04	10.1	8.4	14.2	13.0	13.7	13.8	12.2
T_4	5.65	5.59	5.79	6.03	6.13	6.18	5.89	2.93	2.98	3.17	3.48	3.68	3.81	3.34	10.4	11.6	13.5	16.1	17.0	17.7	14.4
T_5	5.13	5.45	5.66	5.84	6.05	6.14	5.71	2.78	2.87	3.33	3.37	3.62	3.57	3.26	9.6	10.3	14.8	15.9	17.3	18.1	14.4
T_6	5.55	5.65	5.97	6.23	6.18	6.00	5.93	2.84	3.05	3.44	3.66	3.37	3.67	3.34	10.1	11.7	12.8	16.5	17.8	17.3	14.4
T_7	5.54	5.91	5.87	6.17	5.80	5.95	5.87	2.78	3.22	3.71	3.58	3.77	3.41	3.41	10.0	11.7	12.6	16.0	17.0	18.5	14.3
T_8	5.44	6.04	6.01	5.62	5.94	5.83	5.81	2.92	3.39	3.62	3.13	3.26	3.33	3.28	10.2	11.9	14.5	16.8	17.4	17.0	14.6
T_9	4.91	5.97	6.07	5.91	5.47	5.85	5.70	3.01	3.26	3.77	3.18	3.57	3.27	3.34	9.9	11.8	13.1	15.8	17.6	17.0	14.2
T_{10}	5.65	5.98	5.58	5.81	6.10	5.73	5.81	2.85	3.32	3.50	3.30	3.20	3.77	3.32	10.2	11.8	12.6	16.2	17.6	17.5	14.3
T_{11}	5.06	5.55	5.91	5.65	5.54	5.90	5.60	2.91	2.87	3.39	3.11	3.71	3.87	3.31	9.8	10.5	13.9	16.4	17.0	18.0	14.3
T_{12}	5.46	5.58	5.60	5.52	5.64	6.12	5.65	2.92	2.93	3.59	3.25	3.49	3.73	3.32	10.2	10.6	15.3	15.9	17.4	17.7	14.5
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	0.46	NS	NS	NS	NS		NS	1.7	NS	2.4	2.6	2.6	

Appendix 60 Effect of treatments on morphological characters of arecanut palm in terraced upland (Contd…)

Treatment	Dry kernel length (cm)							Dry kernel breadth (cm)							Recovery percentage (%)			
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	2004	2005	2006	Mean
T_1	2.04	1.57	1.73	1.90	1.86	1.87	1.83	1.92	2.06	2.19	2.23	2.13	2.17	2.12	19.53	18.05	19.59	19.06
T_2	1.88	1.88	2.21	2.37	2.54	2.61	2.25	1.96	2.49	2.83	2.76	2.97	2.83	2.64	19.46	18.22	17.86	18.51
T_3	1.92	1.58	1.67	1.93	1.91	1.80	1.80	1.91	2.06	2.14	2.18	2.18	2.22	2.11	20.07	18.24	19.82	19.37
T_4	2.01	1.93	2.33	2.45	2.53	2.54	2.30	1.92	2.58	2.76	2.87	2.84	2.97	2.66	22.05	20.24	19.56	20.62
T_5	1.83	1.89	2.30	2.57	2.48	2.46	2.25	1.82	2.52	2.89	2.92	2.83	2.84	2.64	20.66	17.82	18.02	18.83
T_6	1.97	1.93	2.38	2.49	2.40	2.37	2.26	1.86	2.64	2.80	2.84	2.92	2.81	2.65	22.12	20.92	19.90	20.98
T_7	1.97	1.94	2.26	2.60	2.58	2.49	2.31	1.82	2.65	2.73	2.81	2.89	2.93	2.64	22.20	21.10	19.64	20.98
T_8	1.93	1.99	2.35	2.56	2.41	2.42	2.28	1.91	2.81	2.81	2.86	2.86	2.86	2.68	22.18	19.52	19.88	20.53
T_9	1.75	1.97	2.23	2.48	2.45	2.65	2.25	1.97	2.73	2.90	2.89	2.87	2.87	2.70	21.90	20.81	19.88	20.86
T_{10}	2.01	1.98	2.28	2.53	2.43	2.34	2.26	1.87	2.75	2.86	2.83	2.76	2.78	2.64	22.15	21.02	19.83	21.00
T_{11}	1.80	1.91	2.20	2.42	2.35	2.40	2.18	1.91	2.54	2.78	2.90	2.80	2.90	2.64	19.74	18.05	17.70	18.50
T_{12}	1.94	1.93	2.32	2.40	2.38	2.58	2.26	1.91	2.56	2.87	2.80	2.90	2.89	2.66	19.36	17.52	17.56	18.15
CD(0.05)	NS	0.29	0.34	0.37	0.36	0.37		NS	0.39	0.42	0.42	0.42	0.43		NS	NS	NS	

Appendix 61 Effect of treatments on morphological characters of arecanut palm in terraced upland (Contd…)

Treatment	Fresh husk thickness (cm)							Fresh husk weight (g)							Dry husk weight (g)						
	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean	Feb 2004	Sep 2004	Feb 2005	Sep 2005	Feb 2006	Sep 2006	Mean
T_1	0.64	0.63	0.59	0.60	0.56	0.59	0.60	20.7	20.3	25.8	19.6	20.6	20.8	21.3	5.23	3.90	7.43	5.74	6.16	6.46	5.82
T_2	0.59	0.62	0.52	0.59	0.59	0.57	0.58	21.8	20.6	21.5	25.8	26.7	26.7	23.8	4.83	4.80	5.72	7.57	8.08	8.12	6.52
T_3	0.60	0.63	0.55	0.51	0.54	0.56	0.56	20.7	20.4	26.6	20.2	21.5	20.9	21.7	4.93	3.93	7.54	5.89	6.46	6.43	5.86
T_4	0.63	0.60	0.55	0.54	0.53	0.53	0.56	20.1	20.9	21.1	25.0	26.3	26.4	23.3	5.16	4.99	5.67	7.28	7.76	8.18	6.51
T_5	0.57	0.62	0.54	0.56	0.52	0.55	0.56	20.0	20.7	24.4	24.5	27.0	27.7	24.0	4.69	4.85	6.75	7.05	8.08	8.44	6.64
T_6	0.62	0.60	0.56	0.56	0.52	0.52	0.56	20.6	20.9	19.7	26.3	27.6	25.3	23.4	5.06	5.06	5.28	7.67	8.31	7.64	6.50
T_7	0.62	0.60	0.54	0.58	0.56	0.53	0.57	19.6	21.1	18.5	24.3	25.7	27.7	22.8	5.06	5.06	5.00	7.05	7.63	8.59	6.40
T_8	0.60	0.55	0.52	0.51	0.57	0.54	0.55	20.8	21.3	23.7	26.8	27.4	24.5	24.1	4.97	5.16	6.51	7.73	8.13	7.54	6.67
T_9	0.55	0.57	0.56	0.58	0.52	0.59	0.56	21.1	21.1	20.2	23.8	26.4	25.4	23.0	4.48	5.16	5.42	6.90	7.91	7.69	6.26
T_{10}	0.63	0.55	0.52	0.60	0.52	0.55	0.56	20.9	21.2	18.9	25.5	27.5	25.6	23.3	5.16	5.16	5.05	7.26	8.28	7.91	6.47
T_{11}	0.56	0.61	0.57	0.53	0.55	0.57	0.57	20.6	20.8	21.7	25.6	26.0	27.2	23.6	4.62	4.93	5.83	7.34	7.66	8.41	6.47
T_{12}	0.61	0.60	0.51	0.57	0.55	0.56	0.57	20.9	20.9	25.9	24.4	26.8	27.3	24.3	4.99	4.97	7.22	6.88	8.13	8.35	6.76
CD(0.05)	NS	NS	NS	NS	NS	NS		NS	NS	3.5	3.8	4.0	3.9		NS	0.744	0.958	1.089	1.193	1.206	

NUTRITIONAL MANAGEMENT OF YELLOWING IN ARECANUT

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Yellowing of arecanut is the most serious problem affecting arecanut cultivation. The incidence of yellowing is noticed in isolated patches without any definite pattern. The diagnostic symptoms first appear as yellowing of leaflets in two to three leaves of outermost whorl, with abrupt demarcation between yellow and green regions. Yield in affected palms gets reduced by 30-40 per cent every year and in 3-4 years the entire garden becomes most uneconomical when left without proper management.

Experiments of the research project entitled “Nutritional management of yellowing in arecanut” were conducted for three years from October 2003 to September 2006. Three hundred palms, hundred each in toposequences viz. converted paddy field, garden land and terraced upland of Thrissur, Palakkad and Malappuram districts were studied to develop an yellowing index to quantify yellowing in arecanut. The incidence of yellowing among various toposequences and popular cultivated arecanut varieties were recorded. To develop a management strategy to contain the yellowing, field experiments were laid out in three toposequences viz. converted paddy field, garden land and terraced upland respectively in the farmers’ fields of Thrissur district in RBD using single plant plot with five replications. Treatments involved provision of deep drainage, application of organic manure, lime, sand, sodium silicate, magnesium sulphate, zinc sulphate, borax, ammonium sulphate, urea and three levels of potassium.

The index earlier developed by George *et al.* (1980) was modified as Yellowing index (I) = {(Y+N)/L + R} x 10, where Y is the total score for yellowing, N is the total score for necrosis, R is the score for reduction in crown size and L is half the number of leaves in crown. The modified yellowing index utilizes 13 classes in place of earlier 8 classes to score yellowing, 5 classes in place of earlier 3 classes to score necrosis and 5 classes in place of earlier 3 classes to score reduction in crown size, thus enabling precise quantification of yellowing. The highly significant negative correlation of the leaf elemental composition, growth and yield parameters with the yellowing index of experimental arecanut palm in all the three toposequences viz. converted paddy field, garden land and terraced upland clearly validated the reliability of the index.

The survey done in Thrissur, Palakkad and Malappuram district showed that highest percentage of healthy palms are existing in garden land situations. Among the three toposequences, garden land was found to be inherently more productive and supportive to arecanut cultivation than converted paddy field and terraced upland due to its physiograhic layout. The severity of the yellowing incidence was more in terraced uplands followed by converted paddy field possibly due to the imbalanced availability and uptake of nutrient elements aggravated by excessive leaching of nutrient elements in terraced uplands, and due to impeded drainage in converted paddy field. Survey also showed that local cultivars remained healthier than any of the high yielding varieties such as Kasargode local, Mangala, Mohitnagar and Sumangala as local cultivars recorded the lowest incidence of yellowing. The local cultivars being comparatively healthy could be selected and used as elite mother palms for replanting in severely yellowing affected areas.

Incidence of root rotting was found mainly confined to 16 percent of yellowing affected palms grown in converted paddy field alone. Presence of well drained soils in garden land and terraced upland might have resulted in absence of root rotting in arecanut palms grown under these toposequences. Incidence of both root xylem blockage and presence of phytoplasma in root phloem were found to occur simultaneously in the same yellowing affected palms. However these two phenomena were also found to occur independently of each other in yellowing affected palms irrespective of the toposequences under which the palms were cultivated.

In the converted paddy situation, provision of deep drainage and additional lime application have created a condition congenial for balanced uptake of nutrients as shown by enhanced calcium, magnesium and sulphur contents and reduced phosphorus contents in leaf. The deep drainage treatment increased the nut weight and kernel weight by 3.5g to 1.5g respectively. This increase has helped to maintain the yield even with a reduction in number of nuts palms^{-1} occurred over the years in unfertilized treatments. Application of fertilizers at 100:40:140g palm^{-1} in conjunction with deep drainage and additional lime application increased the *chali* yield by 1001 to 1138 kg ha^{-1}. Sulphur application along with this has further increased the yield to the level of 1289 to 1412 kg ha^{-1} under converted paddy field. Changing the N:K ratio to supply nutrients at 100:40:200 g NPK palm^{-1} increased the yield by 1138 to 1344 kg ha^{-1}. S application together with this enhanced rate further increased the yield by 1385 to 1590 kg ha^{-1} under converted paddy field. Enhanced rate of potassium, combined with magnesium and sulphur application resulted in the highest *chali* yield of 3.22 kg palm^{-1} (4415 kg ha^{-1}). This treatment resulted in the least yellowing index and highest content of chlorophyll, nitrogen, sulphur and magnesium in the plant under converted paddy field.

Under garden land situation, additional application of organic manure by 5 kg ha^{-1} alone has not reflected in the yield increase but has improved the leaf elemental composition particularly that of nitrogen, phosphorus, sulphur and magnesium. Additional quantity of lime over farmers' practise has helped to increase the soil pH and thereby availability and content of calcium in plants. Under garden land situation, fertilizer application at 100:40:140 g ha^{-1} increased the yield by 1069 kg ha^{-1}. Additional organic matter @5 kg palm^{-1} increased the yield by 1316 kg ha^{-1} over pre experiment yield. Enhancement of N:K ratio to 1:2 or 1:2.5 without sulphur application did not increase the yield. However together with sulphur application, notable yield increase by 1289 kg h^{-1} at 1:2 and by 1412 kg ha^{-1} at 1:2.5 ratio was resulted under garden land. Highest yield of 3.99 kg palm^{-1} (5470 kg ha^{-1}) which was 1604 kg more than pre application of treatments was resulted from the treatment which received 100:40:250 g NPK combined with 60 g of magnesium sulphate. Nitrogen application through ammonium sulphate was better than urea since it contained sulphur. Boron application as 20 g borax has also increased yield by 0.97 kg palm^{-1} resulting in 5265 kg ha^{-1} which was 1330 kg more than pre application of treatments under garden land.

Under terraced upland, nutrient application through sulphur containing fertilizers have found to increase the yield considerably. Fertilizer application at 100:40:250 g NPK palm^{-1} with 20 g borax was found to give 3.44 kg palm^{-1} (4716 kg ha^{-1}) and with 20 g zinc sulphate gave 3.38 kg palm^{-1} (4634 kg ha^{-1}). Application of magnesium sulphate has significantly reduced the yellowing index and increased the nitrogen, phosphorus, potassium, calcium, magnesium, chlorophyll-a, chlorophyll-b and total chlorophyll which in turn resulted in high dry matter production.