EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM NUTRITION ON INCIDENCE AND INTENSITY OF GREY BLIGHT OF COCONUT *(Cocos nucifera.* L.)

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DECLARATION

I hereby declare that this thesis entitled "**Effect of nitrogen phosphorus and potassium nutrition on incidence and intensity of grey blight of coconut (*Cocos nucifera* L.)**" 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, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Effect of nitrogen phosphorus and potassium nutrition on incidence and intensity of grey blight of coconut (*Cocos nucifera* L.)**" is a record of research work done independently by Mr. Subramanyan, K. (2000-11-31) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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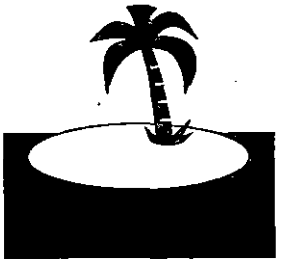

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INTRODUCTION

1. INTRODUCTION

The coconut palm (*Cocos nucifera* L.) which for many centuries past had the distinction of being styled "Kalpavriksha" (Tree of heaven), still continuous to dominate the tropical scene. The palm is primarily a small holders crop with a recorded history of cultivation dating back to more than 3000 years. Its cultivation extends over most of the islands and coasts of the tropics.

The palm has been referred to as the man's most useful tree, "King of tropical flora", "tree of abundance" and "tree of life" because it provides many raw materials of immense utilities and industrial application. Coconut leaves are used for roofing and mats, the trunk provides wood for furniture, the coconut meat is used as food and feed, nut is used in culinary, the oil for cooking and in soap and cosmetic industries, husks are used to produce coir, charcoal and even the roots are used in dyes and traditional medicines.

India is one of the largest coconut producing countries in the world with an estimated area of 1.78 million ha and a production of 12.3 billion nuts (Singh, 2002). The coconut crop sustains nearly 10 million families. Kerala, Karnataka, Andhra Pradesh and Tamil Nadu account for the major area and production of coconut in the country. The contribution of Kerala to the total area is 42.17 per cent and that of Andhra Pradesh and Karnataka being 8.6 and 13.6 per cent respectively. Among the major coconut growing states of India, the share of Kerala in production is 41.17 per cent with a productivity of 5747 nuts/ha (Singh, 2002).

With the increase in area and intensification of coconut cultivation the management problems are also on the increase, involving extensive loss due to diseases, some lethal, while others merely debilitating and reducing yield but not killing the palm. The major diseases affecting coconut palm in Kerala are root (wilt), bud rot, basal stem rot, stem bleeding, leaf rot and grey leaf spot or grey leaf blight.

Among the diseases, grey leaf blight is of common occurrence in all coconut growing areas throughout the world. The disease cause serious damage in nursery plants and adult palms. The grey blight disease reduces height, leaf production and girth at collar by 10.4, 20.1 and 12.5 per cent respectively, in coconut seedlings. The disease also decreased the nut yield of palms by 10.0 – 23.6 per cent (Karthikeyan *et al.*, 2002).

Grey leaf blight caused by *Pestalotiopsis palmarum* (Cooke)Stey. has gained substantial importance in Kerala due to significant damage in young and adult palms. Earlier, this disease was considered to be of minor importance, but its continuous and regular occurrence in the last few years has necessitated a detailed study in its management. Systematic studies on the effect of nutrients and weather parameters on the incidence and intensity of grey blight disease of coconut in Kerala were not available. Hence the investigation was undertaken with the following objectives.

1. Isolation and purification of *P. palmarum* from infected coconut leaves and proving the pathogenicity.
2. Symptomatology.
3. Assessment of the incidence and intensity of grey blight.
4. Estimation of
   a. N, P and K
   b. Ca, Mg and S.
   c. Fe, Mn, Zn, Cu, B, Mo and chlorine
   c. Total sugars, phenols, amino acids and chlorophyll from healthy and diseased leaf tissues
5. Correlation of weather with grey blight occurrence.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The grey blight also known as leaf blight or grey leaf spot was considered as a minor disease of coconut in the early 1980's. But with injudicious fertilizer application and other cultural practices, this disease has emerged as a major problem in coconut cultivation. The disease is seen both in mature palms as well as in seedling causing reduction in vigour of the seedling stunted growth and poor nut yield in adult palms.

2.1 THE PATHOGENS

The genus *Pestalotia* was coined by De Notaris (1839). The word is latinized form of *Pestaloziza*, the Italian botanist after whom the genus was named. Guba (1932) made a monographic study of the genus *Pestalotia*. Steyaert (1949) suggested an amended description of the genus *Pestalotia* in which he included only a single representative *viz.*, *Pestalotia pezoides*. He created the new genera namely *Truncatella* and *Pestalotiopsis* for accommodating the remaining species. Servazzi (1954) however rejected the proposal and preferred to retain the generic name *Pestolatia*. Ramakrishnan and Subramanian (1952) reported *Pestalotia palmarum* Cooke on coconut in Travancore, Kerala.

Dube and Bilgrami (1966) studied 57 isolates of the genera *Pestalotiopsis* and *Pestalotia* causing leaf spot on a variety of plant species and they concluded that all those isolates could be included in the original genus *Pestalotia*. An Xianshu and Han Lianjian (1994) reported that coconut leaf spot (*Pestalotiopsis palmarum*) caused yield loss of 22,40,000 fruits in a growing area of 34800 mu (1 mu = 0.067 ha) in Hainan, China.

Karthikeyan and Bhaskaran (1999) reported that leaf blight disease caused by *Pestalotiopsis palmarum* was found both in seedlings and adult

palms, in Tamil Nadu. Adult palms of 20 to 40 year of age were highly susceptible to the disease.

2.2 OCCURRENCE, DISTRIBUTION OF THE PATHOGEN AND GREY BLIGHT INCIDENCE OF COCONUT

Cooke (1875) first reported *Pestalotia palmarum* on decaying leaves of coconut from Demerara and Bengal. Burkill (1902) reported *P. palmarum* on the leaves of *Phoenix sylvestris* (L.) Roxb. from Bombay. Wright (1925) recorded *P. palmarum* on the leaves of rubber in the nursery. Chowdhury (1946) conducted inoculation experiments with *Pestalotia palmarum* and found that the fungus could infect the leaves of *Borassus flabellifer*, *Areca catechu*, *Cocos nucifera* and *Phoenix sylvestris*. The inoculation was successful only through wounds. Leaf blight disease of coconut was first reported from British Guyana and later from Malaysia, New Hebrides, Sri Lanka, India and Trinidad (Menon and Pandalai, 1958).

Brown (1975) isolated *P. palmarum* from coconut leaf spots. Alonzo and Palomer (1980) reported the incidence of grey leaf spot and blight disease in coconut in the Philippines. In Kerala, leaf blight of Palmyra palm caused by *Pestalotiopsis palmarum* (Cooke.) Stey. was reported by Balakrishnan *et al.* (1982). Obazee and Ikozun (1985) reported the occurrence of a leaf spot of coconut and isolated *P. palmarum*, from the palms in Nigeria. Utomo (1987) found the association of *Pestalotiopsis palmarum* with leaf disease of oil palm. Ram (1989) during his investigation on mycoflora associated with leaf blight of coconut palms reported *P. palmarum* as the most prevalent fungus. Incidence of leaf blight disease was also reported in Indonesia by Warwick *et al.* (1991). Fungi isolated from leaf spot of oil palm collected from Palode plantation of Kerala were *Pestalotiopsis palmarum*, *Pestalotiopsis glandicola* Cost. Steyaert and *P. monochoetioides* Speg. (Kochubabu *et al.*, 1990). Grey blight of *Cinnamomum verum* Bercht. and Press caused

by *Pestalotiopsis palmarum* was reported by Karunakaran *et al.* (1993). Naseema and Sulochana (1993) isolated *P. palmarum* from the infected leaves of nutmeg.

In India, the disease prevalent in all the coconut growing states *viz.*, Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Orissa, Maharashtra and Andaman and Nicobar islands (Papa Rao *et al.*, 1975; Bhaskaran and Ramanathan, 1983; Das *et al.*, 1985; Kudalkar *et al.*, 1991). Hyde and Frohlich (1995) in their study, discussed the association of *Pestalotiopsis palmarum* with leaf spots of *Cocos nucifera*. Anupama (1997) isolated *Pestalotiopsis palmarum* from coconut leaf blight endemic areas of Kerala. Anjos *et al.* (2000) reported a leaf spot of *Cocos nucifera* caused by *Pestalotiopsis guepinii* (Desm)Stey in Brazil during 1998 and 1999.

2.3 SYMPTOMATOLOGY

Menon and Pandalai (1958) described the symptoms of this disease as appearance of minute yellow spots with a grey brown margin on the outer whorl of leaves. The spots may be oval in shape measuring up to 5.0 cm in length. The center of the spots become greyish white while, the brown colour of margin deepens. Many spots coalesce to form larger irregular necrotic patches. On the upper surface of the leaf the fruiting body of the fungus "acervulus" appear as black minute specks. The leaves in advanced stage of infection present a blighted appearance and hence the name leaf blight. Obazee and Ikozun (1985) reported that the pathogen *Pestalotiopsis palmarum* in coconut caused large brown spot surrounded by chlorotic halo, which turned into grey resulting in 'shot holes' symptom. The affected leaflets were shed prematurely. Consequently the number of leaves of the crown is reduced and pre bearing age of young palm is prolonged. Almost the same symptom description was made by Francis (1977), Anupama (1997) and Praveena (1999).

2.4 INFECTION BY *P. palmarum*

Bertus (1927) made cross inoculation studies with *P. theae* (Swada) Stey. and *P. palmarum* and reported that the former species could attack injured leaves of tea and coconut while the latter could infect injured coconut leaves only.

Brown (1975) reported that *P. palmarum* could not infect the uninjured leaves and colonized spots caused by *Dreshchera incurvata* Ito. Jimenez and Reyes (1977) observed that *Colletotrichum*, *Pestalotiopsis* and *Helminthosporium* developed on leaf wounds caused by insects. Lingaraju *et al.* (1987) recorded that germ tubes of conidia of *P. palmarum* penetrated coconut leaves directly. In majority of cases of *Pestalotia* infection symptoms were developed very slowly in older leaves without injury but leaves with injury showed symptoms easily (Anupama, 1997). Praveena (1999) reported that the fungus *Pestalotia* was found to infect older leaves easily and the injured leaves showed symptom development earlier than uninjured leaves.

2.5 NUTRITIONAL STUDIES OF THE PATHOGEN

The growth and size of the spores of certain fungi are influenced by the substrate. Chowdhury (1946) reported that maximum spore size of *Pestalotia palmarum* was obtained when produced on artificial cultural media. Patel *et al.* (1950) noticed that the conidial size of *Pestalotia psidii* Pat. varied according to the substrate on which they are produced. Large conidia were produced in lima bean meal and Richard's agar as compared to those produced on gram meal and oat meal. Agarwal and Ganguli (1959) reported that the spores of *P. vesicolor* Speg produced on its host plant, *Anogeissus latifolia* were smaller than those produced on artificial media.

Das *et al.* (1985) studied the carbon and nitrogen sources on the growth and sporulation of *P. palmarum*. The results revealed that the carbon source tried were significantly superior to control in promoting the

growth of the fungus. The fungi would neither grow nor sporulate in the absence of any carbon source. Sucrose was significantly superior followed by Mannitol, glucose and lactose. They also observed that the fungi failed to sporulate in the absence of nitrogen. Peptone was the best source followed by ammonium oxalate.

Mishra and Choudhary (1989) studied the effect of temperature and pH on the growth and sporulation of *P. mangiferae* and found that the growth and sporulation on Richards medium were best at 25 – 30^{0}C and at pH 5. Bhat *et al.* (1991) reported that mycelial growth and sporulation were improved by addition of vitamins either singly or in combination to the basal medium. Bhat *et al.* (1992) reported that sucrose and potassium nitrate were the best carbon and nitrogen source for pathogen.

2.6 INCIDENCE OF GREY BLIGHT DISEASE AND NUTRIENT STATUS

Leaves with sub optimal level of potassium were very susceptible to the attack by *P. palmarum* (Menon *et al.*, 1950). Potassium fertilizer increases the resistance of the palm against leaf rot disease of coconut (Menon and Nair, 1951). The relationship between leaf magnesium levels and occurrence of *Pestatiopsis* leaf spot in oil palm (*Elaeis quineensis*) has been, recognized for many years (Bull, 1954).

Biddappa and Cecil (1984) analysed the chemical composition of the leaves of healthy and diseased coconut palms affected by root (wilt) disease. He reported that the leaf tissue of healthy palm contained higher Al, Mn, Cu and Co. A higher concentration of more metals were observed in roots system of healthy palms also. The results indicate that impeded translocation of these metals from root to leaf tissue is associated with root (wilt) disease.

More concentration of nitrogen phosphorus, potash and silica were reported in the leaf tissue of root (wilt) affected palm. Values of Ca and Mg were not consistent in the diseased palms, in the state of unbalanced

nutrition. There was relatively more nitrogen also (Varghese *et al.*, 1959). Davis and Pillai (1966) found that the leaves of root (wilt) affected palms contained significantly more of B, Cu, Mo and Zn than those of healthy trees.

Mg level decreased with increase in the level of NPK manuring. K-Mg antagonism was pronounced when the leaf K concentration was above 0.55 per cent. This trend points out that regular K fertilization on soil having low cation exchange capacity (5.5 me/100 mg) may soon bring out the antagonism between the K and Mg which may have negative effect on number of bunches (Ziller and Prevot, 1962). Lilly and Ramadasan (1972) reported that the severity of leaf rot were minimum in seedlings which received NPK Ca and Mg as compared to seedlings under the NPK treatments which produced severe rotting. Lower status of Ca and Mg and higher NPK contents in the leaf tissues of root (wilt) affected coconut palms were reported by Cecil (1975). In a nutritional study of high yielding coconut genotypes, it was reported that among the trace elements, the leaf content of Mn, Cu, Zn and Fe increased with NPK fertilization. The leaf status of B and Mo remained unchanged (Kamaladevi *et al.*, 1976).

Francis (1977) reported that an increase in potassium content caused a decrease in the magnesium and manganese content in leaf tissue. This decrease in magnesium and manganese content resulted in an increase in severity of grey blight of coconut. Mathew and Thomas (1977) found that the status of Ca and Mg of the soil and leaf was not correlated with the incidence of root (wilt) disease in coconut. Karthikeyan and Bhaskaran (1998) detected higher levels of calcium, magnesium, zinc, iron and copper and less of manganese in younger leaves, which are resistant to grey blight. He also suggested that all the secondary and micronutrient except manganese suppressed the growth and sporulation of *Pestalotiopsis palmarum*.

2.7 EFFECT OF SOIL NUTRIENT STATUS IN RELATION TO DISEASES IN COCONUT

The reports on the effect of nutrients and grey blight incidence are meagre. Child (1950) found that omission of potassium from soil led in causing foliage yellowing due to the fungus *Pestalotia*. Menon and Pandalai (1958) and Briton-Jones (1940) reported that the application of balanced fertilizer, adequate shade and spraying with Bordeaux mixture would reduce the disease intensity of leaf blight of coconut. George and Samraj (1966) reported that one of the main causes of high incidence of leaf spot disease of coconut is due the deficiency of boron. Sahasranaman *et al.* (1964) opined that heavier dose of NPK fertilizer aggravated the root (wilt) disease condition and the reduced the yield, where as lower levels helped to maintain an economic yield. Ca had a beneficial effect on yield on the healthy palms where as Mg has a beneficial effects on diseased palms. Robertson *et al.* (1968) recorded many species of *Pestalotiopsis* from oil palm throughout the world and the invasion appears to be associated with magnesium deficiency.

Pillai *et al.* (1976) reported that the root (wilt) disease affected tracts showed a significant reduction in the levels of micronutrient such as Fe; Mn and Zn, in laterite, reclaimed marshy and coastal sandy soils, Zn in alluvial soils and Mn and Zn in sandy and loam soils. The variation in Cu, B and Mo content in the different soil types between healthy and disease affected tract was negligible. Diagnostic studies on the decline in yield in coconut palm in different soils revealed that in the case of the nutrient status *viz.*, N/P, K/Na, P/Mn and P/Zn of palm leaf in red soils, the N content decreased from healthy condition (1.78 %) to unhealthy condition (1.18 %), for P and K the corresponding values were 0.16 per cent to 0.12 per cent and 1.16 per cent to 0.87 per cent respectively. There was a greater reduction in Fe, Zn and Mn content with acuteness of sickness. Healthy leaf contained 254 ppm Fe, while in unhealthy it was 112 ppm. Zn content varied from 20 ppm in healthy leaves to 8 ppm in unhealthy

leaf. In black soils, the leaves of healthy and unhealthy palms contained 1.8 to 1.0 per cent N respectively. The K content was 0.92 and 0.58 per cent in healthy and affected palms. The corresponding value to micronutrient was 226 and 183 ppm for Fe, 18 and 10 ppm for Zn and 163 and 59 ppm for Mn (Pandurangaiah *et al.*, 1978).

Stem bleeding disease of coconut is increased in the absence of nitrogen. The incidence of disease increased with higher doses of phosphorus while the interaction effect of potassium and nitrogen reduces the incidence of diseases (Potty and Radhakrishnan, 1978). Bhaskaran *et al.* (1978) found that in soils of coconut palms affected by pencil point disease, a low level of nitrogen and phosphorus at all depth in the affected zone were observed. Among the micronutrients Fe and Mg contents were low while there was no significant difference of Zn and Cu compared to healthy zone. However, the application of micronutrients along with fertilizer increased the general health of the palms.

Increased incidence of Thanjavur wilt of coconut with heavy dose of nitrogen and potassium was observed by Bhaskaran *et al.* (1978). But phosphorus showed lesser degree in the intensity. Coconut palms deficient in potash prone to incidence of leaf blight (Bhaskaran and Ramanathan, 1983).

Kamalaskhi Amma *et al.* (1982) reported that the application of NPK Ca and Mg was not found to be effective in preventing the incidence of root (wilt) disease in D x T hybrid palm in the disease affected areas. Heavy doses of N P K fertilization increase the incidence of wilt disease of coconut (Narayanaswamy, 1983). The deficiency of calcium, magnesium and zinc predisposes the palm to infection by root (wilt) pathogen (Mathai *et al.*, 1984). Thanjavur wilt of coconut is decreased with application of 0.35, 0.25 and 0.45 kg N, P_2O_5 and K_2O/ palm / year (Rathinam, 1984). He also reported that the disease intensity was highest in palms that received molybdenum.

Uexkull (1990) reported that coconuts that take low chlorine (below 0.25 % Cl) in dry matter, have exhibited reduced growth rate, reduced leaf and nut number, low N concentration, severe signs of moisture stress, stem cracking and stem bleeding due to *Ceratostomella paradoxa* and a high incidence of leaf diseases, especially grey leaf blight *Pestalotia palmarum* and *Helminothosporium incurvatum*. Anupama (1997) reported that palms with wider spacing and receiving higher dose of fertilizer have minimum grey blight intensity. Karthikeyan and Bhaskaran (1997a) found that the severity of grey blight disease of coconut increased with the nitrogen dose.

2.8 EFFECT OF FERTILIZERS IN RELATION TO DISEASES IN COCONUT

Briton-Jones (1940) reported that the disease could be kept under control by improving the growing condition of the diseased palms by balanced fertilizer application. Regular application of potassium chloride reduced the disease incidence of coconut (Abad *et al.*, 1978). Alonzo and Palomar (1980) reported that potassium deficiency in the soils and application of nitrogen and phosphorus increase the leaf blight incidence of coconut. It is generally presumed that the disease incidence also indicated the poor nutritional status of the affected palms (Nambiar, 1994).

Francis (1977) reported that highest degree of infection was noticed in the month of June and lowest in September. Higher disease intensity was noted in the palms which were treated with 680 gm nitrogen 450 g of phosphorus and 900 g of potassium than in those that were treated without nitrogen and potassium, 225 g of phosphorus.

Vijayan and Natarajan (1975) found that doubling the normal NPK application increased the incidence and intensity of wilt disease in both healthy and diseased coconut palms. Bhaskaran *et al.* (1978) reported that in the Thanjavur wilt affected palms, application of heavy dose of nitrogen

(1.05 kg/ palm) and potash (1.35 kg/palm) increased the severity of the disease. Whereas phosphorus (0.50 and 0.75 kg/palm) showed less degree of increase in disease intensity. Control palms (without fertilizers) recorded the lowest rate of increase in disease index when compared to the fertilized palms.

Bhaskaran and Ramanathan (1982) reported that increasing the fertilizer dose above $N_1P_1K_1$ (0.35, 0.25, 0.45 kg/palm/year) level increased the disease intensity of Thanjavur wilt. Very high disease index was observed in $N_1P_1K_3$ (0.35, 0.25, 1.35 kg/palm/year) followed by $N_3P_1K_1$ (1.05, 0.25, 0.45 kg/palm/year). The disease index was low in $N_1P_1K_1$ (0.35, 0.25, 0.45 kg/palm/year) on the Thanjavur wilt of coconut. Anupama (1997) reported that higher dose of nitrogenous fertilizer increased the leaf nitrogen content. In case of phosphorus and potassium, it was not influenced by spacing or its interaction with manuring. The calcium content of leaf was high in palms receiving lowest level of fertilizer and various levels of N P and K did not affect the Ca and Mg content of the leaves.

2.9 CHANGES IN CERTAIN BIOCHEMICAL CONSTITUENTS OF COCONUT PALMS AFFECTED BY DIFFERENT DISEASE

Studies on the biochemical changes due to grey blight of coconut is meagre. Hence a scan was made on the study of biochemical changes related to other coconut diseases. Pillai and Shantha (1965) observed the accumulation of amino acid in tender leaves of root (wilt) affected palms.

There was no significant difference in the levels of amino nitrogen ascorbic acid, total phenols and sugar between leaves of healthy and leaf rot affected coconut palms. However, the contents were found to be increased slightly in diseased leaves (Anonymous, 1976). Lilly and Ramadasan (1979) found significant increase in the total phenol content in leaf rot foliage of coconut. Joseph and Jayasankar (1973) found that in root (wilt) disease coconut palms in the diseased tract contained less total

phenols in the roots as compared to the palms of healthy tract. Ramanujam (1983) found that the pathogen *P. palmarum* induced synthesis of phenolics and phytotoxin of low molecular weight in coconut leaves during infection. Karthikeyan and Bhaskaran (1997b) found that in grey blight (*P. palmarum*) of coconut there was decreased rate of photosynthesis. Starch and cellulose contents were found to decline with infection. The higher concentration of amino acids in the younger leaf tissues plays an important role in disease resistance on grey blight of coconut.

2.10 EPIDEMIOLOGY AND GREY BLIGHT INCIDENCE

An Xianshu and Han Lianjian (1994) reported that grey leaf spot disease of coconut occurred throughout the year and disease incidence increased with rainfall, relative humidity and low atmospheric temperature in August – December. According to them high humidity and monthly mean temperature of 17 – 24^{0}C were found to be favourable for disease epidemics. High seedling density triggered rapid disease spread and continuous cloud, rainy weather and heavy dew resulted in high diseases incidence. Praveena (1999) reported that the grey blight disease was found to occur throughout the year. The disease mainly manifests during cool and dry winter months and intensive blighting occurred in summer months. Per cent disease index was found to be negatively correlated with weather parameter *viz.*, maximum and minimum temperature, rainfall and relative humidity.

Karthikeyan *et al.* (2002) reported that the leaf blight incidence of coconut occurred throughout the year but the disease intensity is severe during rainy season (August to December) in Tamil Nadu. The maximum disease intensity coupled with low temperature and high RH, poor soil nutritional status increased the disease incidence in coconut palms. The disease spread through wind borne conidia.

Leaf rot of coconut was found to be correlated with high humidity and low temperature prevalent during the monsoon period (Radha *et al.*, 1961). The favourable factors for bud rot of coconut were high relative humidity, and low temperature (Radha and Thomas, 1974). Number of 'favourable days' determined the incidence and severity of the disease, which in turn was dependent on the monsoon rains. Palms aged 3 – 20 years exposed to suitable microclimate were the most susceptible.

Radha and Thomas (1974) reported that the occurrence of bud rot disease of coconut was directly related to the microclimate of the palm, RH and temperature in the leaf axis. An infection cycle of coconut tissue was completed in six days under favourable conditions of temperature (22-24^{0}C) and RH (98-100 %). Rao *et al.* (1976) recorded highest incidence of *P. palmarum* occurred in August, moderate during September and October, again become severe during November. But during December there were very few fresh leaf spots and none at all in January. They presumed that the disease manifests mostly during the cool and humid months and extensive blights during summer in only a secondary effect.

Ramapandu *et al.* (1981) reported that spread of Ganoderma wilt of coconut was very much influenced by the range of difference in minimum and maximum humidity and rainfall. Higher range of difference in relative humidity and lesser rainfall more will be the spread of disease. Linear spread was more during December to May and less during June to November. Linear spread of the disease is favoured by low rainfall and low relative humidity during daytime while temperature does not appear to have much influence. The lesser linear spread of the disease during rainy season may be due to the adverse effect of high soil moisture on the causative fungus.

The intensity of *Pestalotiopsis versicolor* was most severe in the late rainy season *ie.*, September and decreased until leaf fall (Harsh *et al.*, 1987). Intensity of grey leaf spot on coconut was maximum in December (40.5 %) and minimum in June (23.9 %) (Suriachandraselvan *et al.*, 1991).

Highly significant negative correlation between disease intensity, relative humidity and rainfall were observed by them. The number of rainy days had no significant relationship with disease intensity.

The leaf rot disease (LRD) of coconut occurred severe in Kerala during the monsoon, a time of high rainfall and relative humidity and low maximum temperature (Srinivasan and Gunasekaran, 1996).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study was conducted during April 2001 to April 2002 to find out the NPK nutrition on the incidence and intensity of grey blight disease and to investigate the potential changes of nutrient contents and biochemical changes in each treatment combination of diseased and healthy areas of the foliage.

3.1 LOCATION OF THE EXPERIMENTAL FIELD

The experiment was conducted at the Coconut Research Station, Balaramapuram. This research station lies at 8^0 – 29`N latitude and $75^0$.57`E longitude and at 64 m above MSL. The station has an average slope ranging from 1 to 3 per cent (Plate 1).

3.2 CLIMATE

The experimental area has a humid tropical climate with a mean annual rainfall of 2600 mm. The average maximum temperature is 30.7^0C while minimum temperature is 23.4^0C.

3.3 SOIL

The soil is red loam belongs to Alfisol. The taxonomic name assigned to soil is loamy skeletal kaolinitic isohyperthermic rhodic haplustalts.

3.4 DETAILS OF MANURIAL EXPERIMENT

The study forms a part of the ongoing long-term experiment at the Coconut Research Station, Balaramapuram. The treatments of this experiment comprised all the possible combination of three levels of N, P and K (O level, lower level and higher level).

The details of experiment:

Nitrogen as 0, 340, 680 g N per palm per year as urea (0, 0.756, 1.510 kg)

Plate 1. View of the Experimental Plot (Coconut Research Station, Balaramapuram)

Phosphorus as 0, 225, 450 g P_2O_5 per palm per year as rock phosphate (0, 1.25, 2.50 kg).

Potassium 0, 450, 900 g K_2O per palm per year as Muriate of potash (0, 0.75, 1.50 kg).

Number of treatment combinations	: 27
Number of replications	: 2
Number of palms per plot	: 4
Total number of palms under treatment	: 216
Total number of palms forming border	: 347

Design

3^3 confounded, factorial experiment confounding NPK^2 in replication – I and NP^2K^2 in replication-II (Fig.I).

3.5 ISOLATION OF PATHOGEN

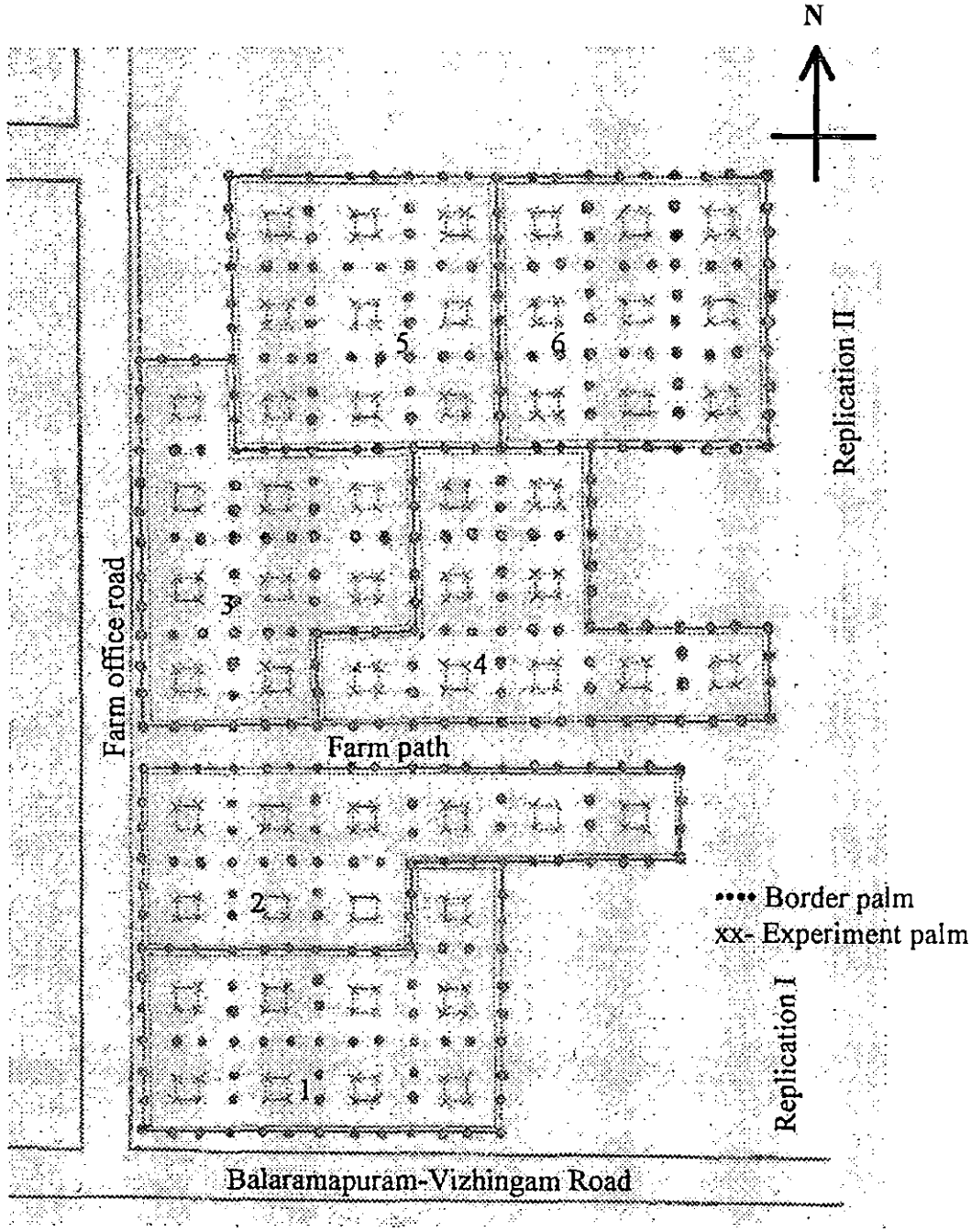
The pathogen causing grey blight of coconut was isolated from infected coconut leaf using standard tissue isolation technique on Potato Dextrose Agar. The mycelium grown was sub cultured on PDA slants. The cultures were periodically sub cultured for further studies.

3.6 SYMPTOMATOLOGY OF THE DISEASE

Symptoms of the disease was studied in detail and are described in the chapter on results.

3.7 IDENTIFICATION OF THE PATHOGEN

The pathogen was identified by studying the cultural and conidial morphology. Slide culture technique (Riddel, 1974) was followed for identification.



Layout : 3^3 Confounded factorial design
Date of started on the permanent manurial trial : 17.02.1964
Total experimental area : 3.643 ha

Fig. 1. Experimental plot at coconut research station, Balaramapuram

3.8 PATHOGENICITY STUDIES

Artificial inoculations were done with and without injury on the plant parts *in vitro*. Injury was made by scraping the surface and also by pinpricks. Inoculations were done with mycelial bits containing conidia of an eight day old culture of the pathogen and were then covered with moist cotton. After inoculation the plant parts were kept in moist chamber and observations were recorded.

3.9 GROWTH AND SPORULATION OF THE PATHOGEN ON DIFFERENT MEDIA

Colony morphology and sporulation of pathogen were studied by growing the pathogen on different solid media *viz*., Potato Dextrose Agar, Potato Sucrose Agar, Richard's Agar, Host Leaf Extract Agar, Czapeks dox Agar and Sabouraud's Agar. The host leaf extract agar medium was prepared as follows:

Fresh host leaf	– 200 g
Dextrose	– 20 g
Agar agar	– 20 g
Distilled water	– 1000 ml

The fresh healthy coconut leaves were collected from the coconut plantation in the early morning hours. The leaves were washed in tap water and chopped after removing the mid rib. Two hundred grams of chopped leaves were boiled with 500 ml of water for 30 minutes to get a decction. The boiled leaves were filtered through ordinary filter paper, 20 g of agar was melted in 500 ml of water. The leaf extract was added to the boiled agar by stirring and by adding dextrose. The volume is made upto 1000 ml. This was sterilized at 121^0C and, 1.04 kg cm^{-2} pressure for 20 minutes.

Culture disc of five mm diameter were cut out from the outer edges of a five-day-old culture of the pathogen by means of sterile cork borer. These were transferred into sterile petri dish containing 10 to 15 ml of different media, and were incubated at room temperature. Observations were taken after a period of eight days for each media. Three replications were maintained. The colony colour and growth morphology were recorded in different media.

3.10 SPORE COUNTS

Five millimeter diameter culture discs were cut out from three different areas of a week old culture grown on different media. The discs were put in 100 ml conical flask containing 50 ml of sterile water. The flask was agitated thoroughly for 15 minutes by hand shaking. One drop of this spore suspension was placed on a clean glass slide under a cover slip. The number of spores in five different microscopic fields under low power magnification was counted (100 X).

The intensity of sporulation was graded as given below.

1. Good : 25 spores and more per microscopic field
2. Moderate : 10 – 24 spores per microscopic field
3. Poor : below 10 spores per microscopic field

3.11 CONIDIAL MORPHOLOGY

Conidial characters were studied both from the infected host plant as well as from seven-day-old culture on different media. Water mounts were used for this study. The coconut leaves with diseased area were cut into bits of 5 cm long and were kept in the moist chamber and incubated for 48 hours.

The conidia were then scraped from the spots/blighted areas using a sterile blade and placed in sterile water. The length, breadth and length of appendages (setae), number of septa and colour of 25 spores were

observed. Similar observations of the fungus grown on six different culture media were also made.

3.12 DISEASE INCIDENCE AND INTENSITY AT VARIOUS NPK COMBINATIONS

In the field experiment, disease intensity was assessed by the method described by Jayaraj *et al.* (1986) with slight modification. Twenty-five leaflets were selected from the middle of the five leaves from lowest whorl from each coconut tree and were graded from 0 – 9 (Plate 2). The details of the score chart is given below :

Disease grade	Description
0	No spot
1	1-10 per cent of the leaf area affected
3	11 to 25 % of the leaf area affected
5	26 to 50 % of the leaf area affected
7	51 to 75 % of the leaf area affected
9	More than 75 % of the leaf area affected

Observations were taken from one tree from each treatment combination. The assessment of the incidence and intensity of grey blight were carried out once in two months from April 2001 to April 2002.

From the initial studies it was observed that each palm had about 30 to 40 leaves and out of these, the oldest 10 to 15 leaves were severely affected by the disease. Hence 5th leaf from the base of the crown was taken as the representative sample.

The per cent disease index was worked out as described by Horsfall and Heuberger (1942).

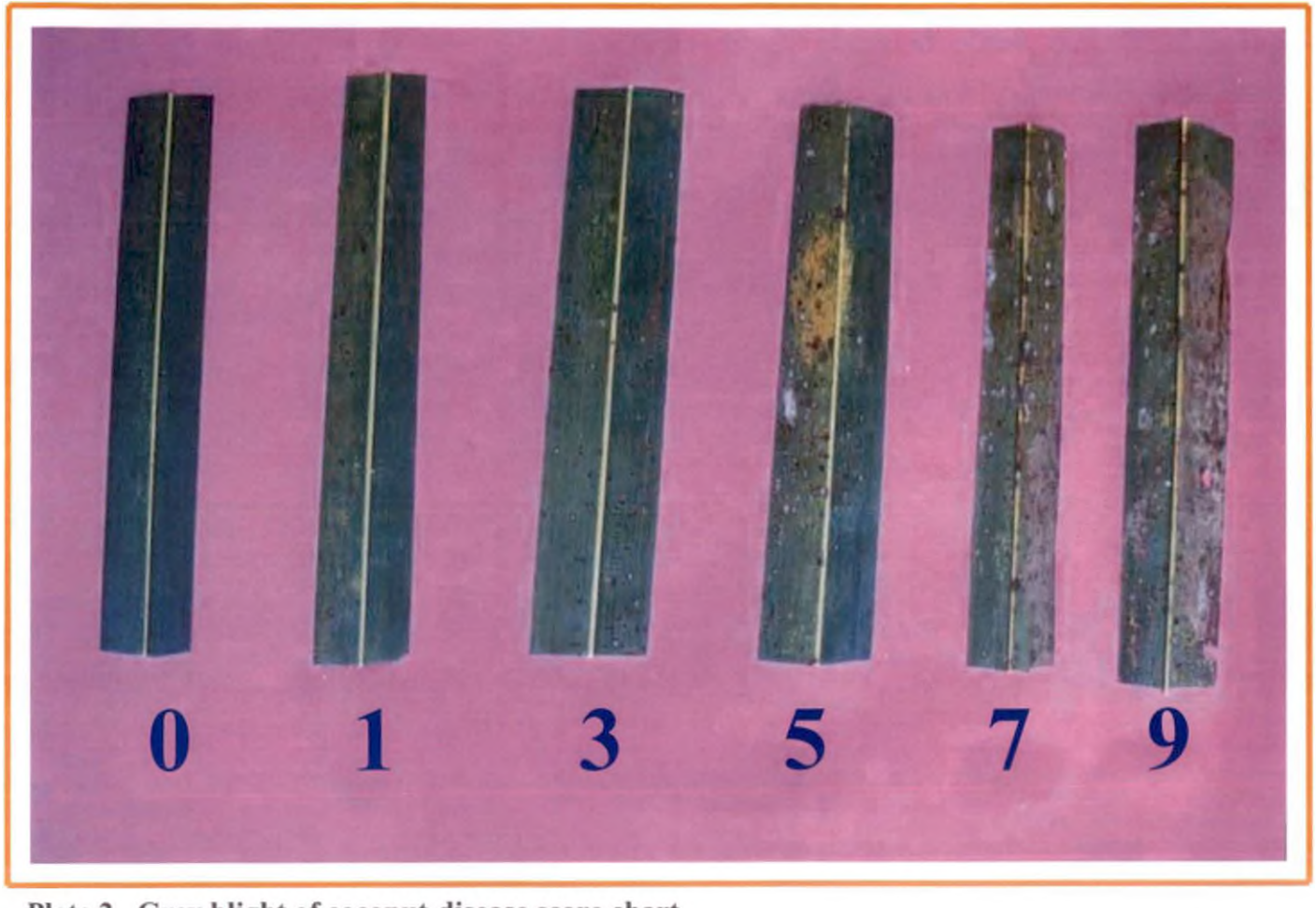


Plate 2. Grey blight of coconut-disease score chart

$$\text{Percent disease index (PDI)} = \frac{\Sigma \text{ of Numerical ratings} \times 100}{\text{Number of leaves observed} \times \text{maximum disease grade}}$$

$$\text{Disease incidence (DI)} = \frac{\text{Number of affected leaves}}{\text{Total number of leaves}} \times 100$$

3.13 DISEASE INCIDENCE / INTENSITY AND WEATHER PARAMETERS

The weather parameters *viz*., maximum, minimum temperature, relative humidity, rainfall and wind speed were recorded for one year starting from April 2001 to April 2002. The data were collected at bimonthly intervals. Diseases incidence and intensity at this period were also recorded using standard score chart.

3.14 PLANT NUTRIENT ANALYSIS

Chemical analysis of the diseased and healthy leaves of the palms for major , secondary, minor elements and other biochemical constituents under different levels of fertilizer application were carried out to assess the changes in the nutrient composition.

3.14.1 Preparation of Plant Samples

Leaf samples were collected between 7 am to 11 am in brown paper covers from the experiment field. The leaf samples were collected from the diseased and healthy portion of the leaves of the palms receiving different formulation of the fertilizer. The leaf samples were cleaned with moist cotton to remove the dust and cut into small pieces and dried in oven at 60 ± 5^0C for 48 hours. Both samples were powdered and composite samples were kept in brown paper packet for further analysis.

3.14.2 Leaf Analysis

The healthy and diseased leaf samples were analysed for NPK, Ca, Mg, S, Fe, Mn, Cu, Mo, B and Cl. The samples were also analysed for chlorophyll, phenol, total sugar and amino acid contents.

The methods adopted for analysis were as follows:

Sl. No.	Elements / component	Methods	References
1	Nitrogen	Modified kjeldahl method	Jackson (1973)
2	Phosphorus	Vanado molybdate Yellow colour method	Jackson (1973)
3.	Potassium	Flame photometry	Stanford and English (1949)
4.	Ca and Mg	Versanate method	Jackson (1973)
5.	Fe, Mn, Zn, Cu	Atomic Absorption Spectrophotometer	Lindsay and Norwell (1978)
6.	S	Turbidimetry	Jackson (1973)
7.	Cl	Titrimetry	Humphries (1979)
8.	Mo, Bo	Colorimetry	Jackson (1973)
9.	Chlorophyll	Spectrophotometry	Smith and Benitenz (1955)
10.	Total phenol	Spectrophotometry	Bray and Thorpe (1954)
11.	Total sugars	Spectrophotometry	Sadasivam and Manikam (1992)
12.	Amino acid	Spectrophotometry	Sadasivam and Manikam (1992)

RESULTS

4. RESULTS

4.1 ISOLATION OF THE PATHOGEN

The pathogen was isolated on Potato Dextrose Agar medium. Initial growth of the pathogen was observed on the second day of plating as whitish mycelial growth. On the fifth day the mycelial growth of the pathogen was transferred to PDA slants. This culture was used for further studies.

4.2 SYMPTOMATOLOGY OF THE DISEASE

The initial symptoms of grey blight of palms were manifested on the leaflets of the outer whorl of leaves as minute yellowish specks. These specks later turned greyish within a period of seven days. These greyish specks later developed into spots of 1-3.5 mm diameter surrounded by yellow halo. At advanced stage these lesions coalesced together, causing blighting of the leaves. On the upper surface of the blighted areas black pycnidia of the fungus was seen.. In some of the susceptible palms, drying up of the leaflets from tip downwards were also observed. The dried up leaves presented symptoms resembling severe drought. In certain cases the symptoms appeared on the middle of the rachis also (Plate 3 a & b).

4.3 PATHOGENICITY STUDY

Artificial inoculation studies showed that the pathogen could infect older leaves more easily than the younger ones. The injured leaves expressed the disease symptoms earlier than the uninjured leaves. Initial symptom of the disease appeared 6-7 days after inoculation. The typical symptoms of the disease after artificial inoculation were observed after 12-14 days.

Plate 3a. Grey blight at advanced stage of coconut leaf

Plate 3b. Close up view of grey blight affected leaflets

Table 1. Growth and sporulation of *P. palmarum* on different solid media

Sl. No.	Medium	Growth characters	Mean colony diameter, mm	Spore count per microscopic field, (100 x)	Sporulation
1.	Potato Dextrose Agar (PDA)	Mycelium cottony white and turned pale yellow as it becomes older with distinct zonations. Sporulation started on fifth day.	87.7	38.33	Good
2.	Potato Sucrose Agar (PSA)	Mycelium thick white at first and turned cream in colour as it becomes older. Sporulation started on sixth day	86.7	35.33	Good
3.	Richards's Agar (RA)	Mycelium cottony white and turned yellow. Zonation faintly seen.	82.7	21.33	Moderate
4..	Czapeks dox Agar (CA)	Mycelium cottony light in colour. Sporulation starts from eleventh day	81.3	23.33	Moderate
5.	Host leaf extract Agar (HLEA)	Growth scanty, Mycelium light yellow, no zonation	79.5	18.54	Moderate
6.	Sabourauds Agar (SA)	Mycelium white turning light yellow, zonation faintly seen, sporulation starts from thirteenth day	73.6	8.33	Poor
		CD	3.14	4.58	

Good – Spore count 25 and above
Moderate – 10-25 spores
Poor – Less than 10 spores

4.4 GROWTH ON DIFFERENT SOLID MEDIA

The mean radial growth and the growth characters of the pathogen on different solid media are presented in Table 1 and Plate 4.

Statistical analysis of the data showed that there was significant difference in the growth of the fungus on different media. The growth of the pathogen on PDA (87.7 mm) and Potato Sucrose Agar (PSA) was on par and were significantly better than the other media tested. The growth of the fungus on the Richards agar, Czapeks dox agar, and Host leaf extract agar was on par and they in turn was inferior to PDA and PSA and superior to Sabouraud's agar.

4.5 SPORULATION ON DIFFERENT MEDIA

The fungus grown on PDA and PSA supported the maximum spores (Table 1) and least spore count was recorded on Sabouraud's agar.

4.6 CONIDIAL MORPHOLOGY OF THE PATHOGEN

The length, breadth and appendage size of the conidia were studied in different media and the data are presented in Table 2 and Plate 5.

The conidia of the pathogen were five celled, the intermediate cells constricted at the dividing septa. The upper and lower cells were hyaline, while the middle cells were olive green colour. The upper cell had three long slender colourless simple appendages.

The length of the conidia of the pathogen did not differ significantly when grown on PDA and PSA (29.21 µm and 29.13 µm respectively). The length of the conidia collected from the host leaves were also on par with the conidia in the above media (29.05 µm). The length of the conidia grown on Richard's agar, Czapeks dox agar, host leaf extract agar and Sabouraud's agar did not differ significantly.

Maximum breadth of the conidia were observed in PDA (7.56 µm). The host leaf extract agar and Sabouraud's agar showed the conidia with smallest breadth (6.85 µm and 6.93 µm respectively).

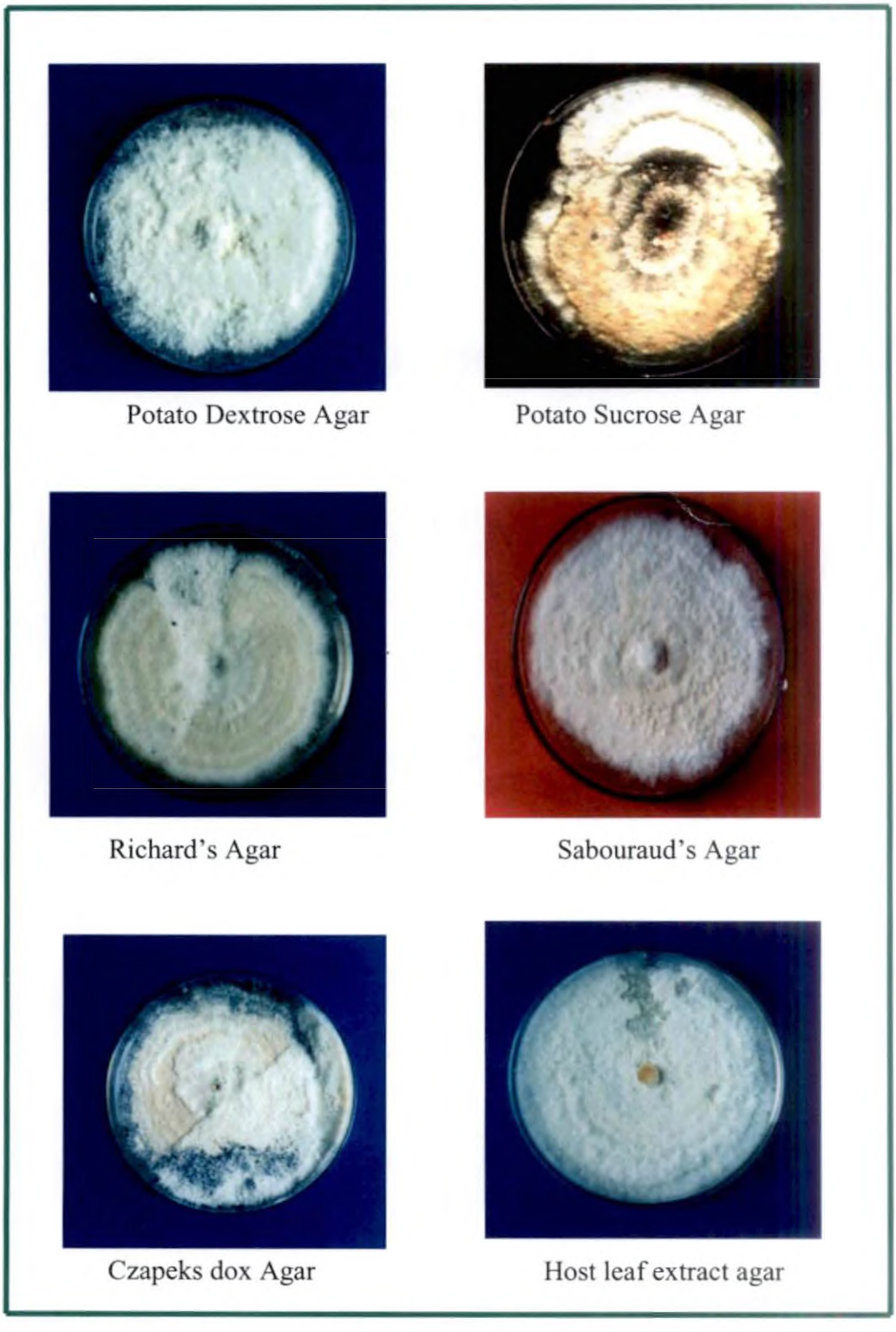
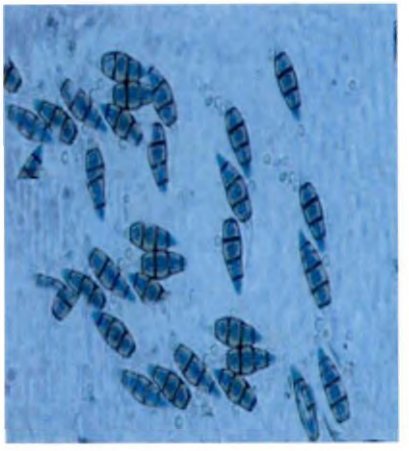
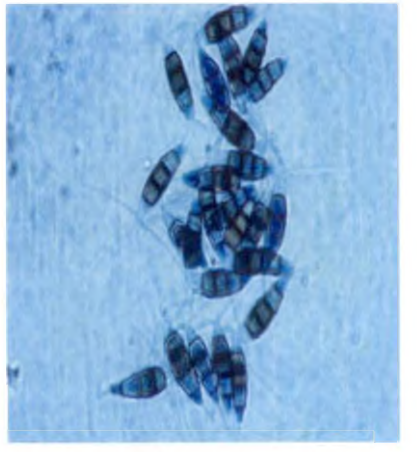


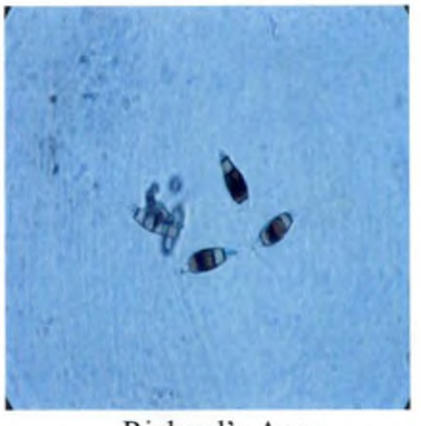
Plate 4. Growth of *Pestalotiopsis palmarum* on different solid media



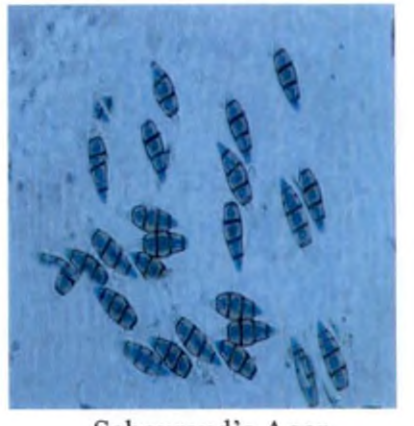
Potato Dextrose Agar



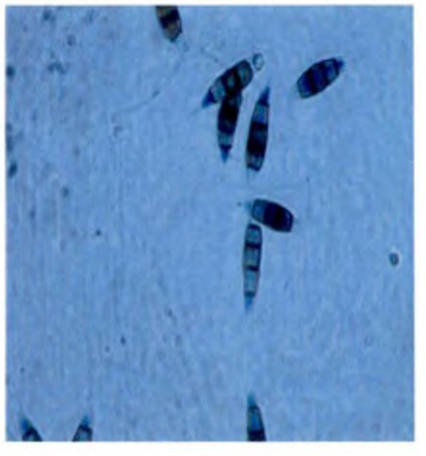
Potato Sucrose Agar



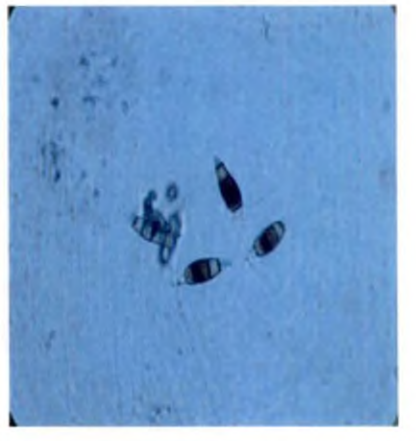
Richard's Agar



Sabouraud's Agar



Czapeks dox Agar



Host leaf extract Agar

Plate 5. Conidia of *Pestalotiopsis palmarum* on different solid media

Table 2 . Conidial measurement of *Pestatiopsis palmarum* on different solid media (mean of 25 spores)

Sl. No.	Culture medium	Spore length			Spore breadth			Appendage length		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
1.	Host	29.94	28.37	29.05	7.94	6.57	7.26	12.47	10.67	11.46
2.	Potato Dextrose Agar (PDA)	30.14	28.44	29.21	8.17	7.17	7.56	12.97	10.87	11.81
3.	Potato Sucrose Agar (PSA)	30.08	28.42	29.13	8.14	6.64	7.40	12.82	10.77	11.69
4.	Richards's Agar (RA)	29.44	28.04	28.66	7.82	6.81	7.21	12.62	10.72	11.54
5.	Czapeks dox Agar (CA)	29.51	27.74	28.53	7.71	6.71	7.11	12.42	10.55	11.37
6.	Sabourauds Agar (SA)	29.44	27.21	28.33	7.54	6.31	6.93	12.54	10.13	11.33
7.	Host Leaf Extract Agrar (HLEA)	29.65	27.43	28.45	7.64	6.43	6.85	12.46	10.68	11.43
	CD			0.33			0.22			0.25

Maximum length of the appendages was observed when the pathogen was grown on PDA and PSA (11.81µm and 11.69 µm respectively). The size of the appendages did not differ significantly when grown on Czapek's dox agar, Richard's agar, Sabouraud's agar and host leaf extract agar.

4.7 IDENTIFICATION OF THE PATHOGEN

Based on the above cultural and conidial morphology the pathogen associated with the grey blight of coconut was identified as *Pestalotiopsis palmarum* (Cooke)Stey.

4.8 EFFECT OF NPK ON DISEASE INCIDENCE (MAIN EFFECTS)

Disease incidence of coconut palms showed an increasing trend with increasing quantity of nitrogen fertilizer application (Table 3). The maximum mean disease incidence was seen in palms which received double the dose of recommended nitrogen (44.45). A similar trend was absorbed with varying dose of potassium application. While phosphorus recorded the maximum disease incidence at P_1 level (44.13).

4.8.1. Effect of NPK on Disease Incidence (Two way Interactions)

Since the different combinations of NPK had no significant effect on disease incidence this study was not undertaken.

4.9 EFFECT OF NPK ON DISEASE INCIDENCE (THREE WAY INTERACTIONS)

Different levels of fertilizer application had significant effect on disease incidence (Table 4). The incidence of grey blight in coconut palm showed a negative trend with potash application in six out of seven observations made. Minimum incidence was noticed in palms, which received no potash. The least disease incidence of 34.70 was noticed in palms, which were applied with $N_0P_2K_0$. The maximum disease incidence was noticed in palms, which received higher doses of

Table 3. Effect of NPK fertilizer on disease incidence (main effects)

Sl. No.	Treatment	Disease incidence							
		April 2001	June 2001	August 2001	October 2001	December 2001	February 2002	April 2002	Mean
1.	N_0	42.45	45.24	52.63	45.44	41.51	37.10	40.51	43.55
2.	N_1	43.03	45.52	53.06	44.73	41.27	37.67	40.73	43.72
3.	N_2	45.11	48.11	53.51	45.91	40.82	37.63	40.08	44.45
	CD	1.23	1.04	0.893	0.56	0.67	0.57	1.29	0.53
4.	P_0	42.23	46.85	52.58	44.76	41.71	37.04	40.53	43.67
5.	P_1	42.02	46.60	54.03	46.26	41.17	37.73	41.08	44.13
6.	P_2	44.34	45.43	52.57	45.05	40.73	37.62	40.69	43.78
	CD	1.23	1.04	0.893	0.56	0.67	0.57	1.29	0.53
7.	K_0	40.79	45.52	52.05	45.45	41.17	36.91	40.34	43.18
8.	K_1	43.16	46.53	53.34	46.48	41.64	37.55	41.04	44.25
9.	K_2	44.64	47.83	53.79	46.13	40.80	37.94	40.94	44.58
	CD	1.23	1.04	0.893	0.56	0.67	0.57	1.29	0.53

Table 4. Effect of NPK fertilizer on per cent disease incidence (three way interactions)

Sl. No.	Treatment	Disease incidence							
		Apr 2001	Jun 2001	Aug 2001	Oct 2001	Dec 2001	Feb 2002	Apr 2002	Mean
1.	$N_0P_0K_0$	40.65	44.90	52.50	43.80	41.95	37.10	38.50	42.77
2.	$N_0P_0K_1$	41.80	47.00	52.05	46.00	46.00	38.15	39.30	44.33
3.	$N_0P_0K_2$	41.00	49.05	52.95	47.00	41.20	37.95	41.00	44.31
4.	$N_0P_1K_0$	42.00	42.00	52.60	43.55	42.00	37.00	41.00	42.88
5.	$N_0P_1K_1$	39.15	46.00	53.65	48.00	40.60	37.85	40.95	43.74
6.	$N_0P_1K_2$	43.45	47.00	54.50	46.05	40.00	37.20	41.30	44.21
7.	$N_0P_2K_0$	41.50	40.75	52.15	42.50	40.95	34.70	41.00	41.94
8.	$N_0P_2K_1$	45.50	43.90	52.35	44.15	40.95	37.55	40.65	43.58
9.	$N_0P_2K_2$	46.20	46.60	50.90	47.90	39.95	36.40	40.85	44.11
10.	$N_1P_0K_0$	41.00	42.65	50.50	42.10	42.05	35.20	40.85	42.05
11.	$N_1P_0K_1$	43..00	44.05	52.75	46.95	42.00	36.00	41.20	42.83
12.	$N_1P_0K_2$	43.25	46.70	53.15	43.95	40.30	35.35	41.80	43.50
13.	$N_1P_1K_0$	40.30	42.15	53.10	43.00	41.15	36:05	38.95	42.10
14.	$N_1P_1K_1$	42.50	46.95	56.45	48.05	41.90	36.95	41.50	44.90
15.	$N_1P_1K_2$	44.05	47.50	56.45	45.80	42.10	41.35	41.20	45.50
16.	$N_1P_2K_0$	39.85	45.55	51.00	41.10	41.05	40.75	41.30	42.94
17.	$N_1P_2K_1$	46.00	46.90	52.55	45.50	40.50	39.00	39.70	44.31
18.	$N_1P_2K_2$	47.30	47.05	51.55	46.10	40.40	38.35	40.05	44.40
19.	$N_2P_0K_0$	40.35	51.00	52.20	44.65	40.25	37.60	41.00	43.86
20.	$N_2P_0K_1$	43.50	46.85	53.25	44.75	40.95	37.00	41.20	43.93
21.	$N_2P_0K_2$	45.50	49.45	53.95	43.60	40.70	39.00	40.00	44.60
22.	$N_2P_1K_0$	39.50	48.45	51.10	46.60	40.15	37.01	40.00	43.26
23.	$N_2P_1K_1$	42.00	49.30	53.25	48.00	41.00	37.80	44.00	45.05
24.	$N_2P_1K_2$	44.40	49.85	54.20	47.30	41.60	38.30	40.85	45.21
25.	$N_2P_2K_0$	42.00	43.20	52.30	43.80	40.95	36.65	40.45	42.76
26.	$N_2P_2K_1$	44.15	47.85	53.8	47.00	40.85	37.65	40.85	44.59
27.	$N_2P_2K_2$	46.60	47.05	56.50	47.45	40.95	37.55	41.40	45.36
	Mean	43.20	47.24	53.43	55.42	40.93	37.90	40.90.	
	CD	2.60	2.2	1.9	1.2	1.4	1.2	2.7	

potash. The maximum disease incidence of 56.50 per cent was observed in palms, which received $N_2P_2K_2$ level.

4.10 EFFECT OF NPK ON DISEASE INTENSITY (MAIN EFFECTS)

Irrespective of nutrients and its levels, the highest incidence by grey blight of coconut was observed during the month of August (Table 5). Similarly as nutrient level increased from zero to two times the recommended dose (N_2, P_2 and K_2) there was a corresponding increase in the disease intensity. At N_0 level the highest disease intensity was noticed during the month of August and during subsequent month there was a decrease in trend in the intensity till February. During that month the disease intensity was only 31.50. Subsequently the disease increased gradually and reached the highest during August.

A similar trend was noticed in N_1 and N_2. The average intensity of disease for N_0, N_1 and N_2 was 35.74, 36.55 and 36.10 respectively.

A similar trend was observed with three level of P application. The average of the disease intensity for P_0, P_1 and P_2 where 35.44, 36.66 and 37.16 respectively.

Trend in the disease intensity with different levels of potash application where similar to that of N and P. Mean disease intensity for K_0, K_1 and K_2 for the period of observation were 35.0, 36.6 and 37.88 respectively.

4.11 EFFECT OF NPK ON DISEASE INTENSITY (TWO WAY INTERACTIONS)

In the two-way interaction with nitrogen and phosphorus, it was seen that when the nitrogen level was increased from zero to two times the normal dose, a corresponding increase in the intensity of disease was observed (Table 6). This was more pronounced when the quantity of nitrogen was increased with the quantity phosphorus. The highest mean disease intensity of 37.77 per cent was observed at N_2P_1 and was almost

Table 5. Effect of NPK fertilizer on disease intensity (main effects)

Sl. No.	Treatment	Disease intensity							
		April 2001	June 2001	August 2001	October 2001	December 2001	February 2002	April 2002	Mean
1.	N_0	32.44	38.50	40.90	39.78	32.73	31.51	34.32	35.74
2.	N_1	32.19	41.13	44.23	41.14	32.26	30.95	33.96	36.55
3.	N_2	33.49	40.93	45.76	41.77	33.04	30.32	34.21	37.10
	CD	0.602	0.588	0.533	0.472	0.683	0.761	0.970	0.57
4.	P_0	31.09	39.26	42.38	40.32	31.85	30.59	33.30	35.44
5.	P_1	33.22	40.26	43.82	40.90	32.84	31.35	34.24	36.66
6.	P_2	33.80	41.05	44.69	41.47	33.33	30.84	34.96	37.16
	CD	0.602	0.588	0.533	0.472	0.683	0.761	0.970	0.57
7.	K_0	31.99	37.17	41.44	39.84	31.62	30.49	32.93	35.10
8.	K_1	32.68	40.97	43.92	40.78	32.96	30.92	34.01	36.60
9.	K_2	34.45	42.43	45.83	42.07	33.44	31.38	35.56	37.88
	CD	0.602	0.588	0.533	0.472	0.683	0.761	0.970	0.57

Table 6. Effect of NPK fertilizer on disease intensity (two way interactions)

Sl. No.	Treatment	Disease intensity							
		April 2001	June 2001	August 2001	October 2001	December 2001	February 2002	April 2002	Mean
1.	N_0P_0	30.83	39.62	40.43	38.83	32.50	30.42	33.62	35.18
2.	N_0P_1	32.37	38.25	39.90	39.45	31.38	31.82	33.17	35.19
3.	N_0P_2	34.13	37.63	42.36	41.05	34.33	32.80	36.18	36.84
4.	N_1P_0	29.50	39.48	41.83	40.56	31.38	30.18	32.82	35.12
5.	N_1P_1	30.02	41.17	45.31	41.28	31.17	31.17	34.40	36.50
6.	N_1P_2	34.05	42.75	45.55	41.57	32.22	31.50	34.67	37.47
7.	N_2P_0	32.95	38.68	44.87	41.57	31.67	31.17	33.47	36.90
8.	N_2P_1	34.30	41.35	46.25	41.97	33.98	31.07	35.15	37.73
9.	N_2P_2	33.22	42.77	46.15	41.78	33.46	28.72	34.02	37.21
	Mean	32.39	40.19	43.63	40.91	32.45	30.92	34.14	36.44
10.	N_0K_0	30.17	35.38	38.02	38.62	31.13	30.78	32.82	33.85
11.	N_0K_1	32.18	39.48	41.47	39.52	33.10	31.88	34.38	36.00
12.	N_0K_2	34.98	40.63	43.22	41.20	33.95	31.87	35.77	37.40
13.	N_1K_0	30.52	38.75	41.02	39.92	31.57	30.63	32.82	35.04
14.	N_1K_1	32.58	41.08	44.52	41.00	32.48	30.52	33.50	36.53
15.	N_1K_2	33.57	43.57	47.17	42.50	32.72	31.70	35.56	38.14
16.	N_2K_0	32.30	37.38	44.40	40.98	32.17	30.50	33.15	35.88
17.	N_2K_1	33.27	42.33	45.77	41.82	33.28	30.37	34.15	37.29
18.	N_2K_2	34.90	43.08	47.10	42.52	33.67	30.53	35.33	38.15
	Mean	32.71	40.10	43.63	0.818	32.68	30.92	34.17	36.47
19.	P_0K_0	29.85	35.68	39.87	39.33	31.58	29.85	32.18	30.04
20.	P_0K_1	31.70	40.17	42.57	40.13	32.62	30.67	33.60	35.93
21.	P_0K_2	31.73	41.93	44.70	41.50	31.35	30.25	34.12	36.94
22.	P_1K_0	31.45	37.20	40.97	39.70	31.75	31.18	33.57	35.12
23.	P_1K_1	33.55	41.30	44.30	40.63	32.62	31.43	34.38	42.75
24.	P_1K_2	34.88	42.27	46.20	42.37	34.17	31.43	34.77	38.01
25.	P_2K_0	31.68	38.63	46.20	40.48	31.53	30.43	33.03	36.00
26.	P_2K_1	32.98	41.43	44.88	41.57	33.62	30.67	34.05	37.17
27.	P_2K_2	36.73	43.08	45.58	42.35	33.82	31.42	33.78	38.26
	Mean	33.33	40.18	43.95	40.88	32.56	30.81	33.72	36.69
	CD	1.04	1.02	0.818	0.818	1.18	1.32	1.68	

the same at N_2P_2 (37.21). During the month of August the highest mean disease intensity of (43.63) was observed for NP interaction.

In case of nitrogen and potassium combination also, the disease intensity showed an increasing trend. With increasing levels of potash, the maximum mean disease intensity of 38.15 per cent and 38.14 per cent was observed in the combination of N_2K_2 and N_1K_2 levels respectively. In this combination also the mean intensity was highest in the month of August (43.63 %).

The intensity of disease showed an increasing trend when the quantity of phosphorus applied was increased, with increasing the quantity of potash. This is evident from the result where an increase in phosphorus from zero to double the dose, along with potash there was increase in the disease intensity. In this combination also the high mean disease intensity was noted in the month of August (43.95 %) and minimum during month of February (30.81).

4.12 EFFECT OF NPK ON DISEASE INTENSITY (THREE WAY INTERACTIONS)

When three levels of N, P and K were applied the disease intensity of 49.00 was observed during the month of August in the treatment combination $N_1P_2K_2$ (Table 7). This was followed by treatment combinations $N_2P_1K_2$ (47.65), $N_2P_1K_1$ (47.00) during the month of August. The lowest disease intensity during the month was in treatment combination $N_0P_1K_0$ (34.9). The variation in the disease intensity during this month was to tune of 14.10 per cent (34.9 to 49.0).

As was observed in the two way interaction, here also the lowest disease intensity was observed during the month of February. During this period treatment combination $N_2P_2K_0$, $N_2P_2K_1$, $N_1P_0K_0$ and $N_0P_0K_0$ did not differ significantly from one another. These combinations recorded the lowest disease intensity.

Table 7. Effect of NPK fertilizer on Disease intensity (three way interactions)

Sl. No.	Treatment	Disease intensity							
		Apr 2001	Jun 2001	Aug 2001	Oct 2001	Dec 2001	Feb 2002	Apr 2002	Mean
1.	$N_0P_0K_0$	29.00	36.00	39.00	37.50	31.65	29.10	32.50	33.54
2.	$N_0P_0K_1$	30.55	40.85	40.55	38.65	32.40	31.00	33.60	35.37
3.	$N_0P_0K_2$	32.95	42.00	41.75	40.35	33.45	31.15	34.75	36.63
4.	$N_0P_1K_0$	30.60	36.00	34.90	38.05	29.80	31.10	33.00	33.35
5.	$N_0P_1K_1$	32.50	39.50	40.85	39.00	31.95	32.15	33.50	35.64
6.	$N_0P_1K_2$	34.00	39.25	43.95	41.30	32.40	32.20	33.30	36.62
7.	$N_0P_2K_0$	30.90	34.15	40.15	40.30	31.95	32.15	32.95	34.65
8.	$N_0P_2K_1$	33.50	38.10	43.00	40.90	34.95	32.50	36.05	37.00
9.	$N_0P_2K_2$	38.00	40.65	43.95	41.95	36.00	32.25	39.55	38.90
10.	$N_1P_0K_0$	29.35	37.50	37.00	39.45	32.10	28.95	31.45	33.69
11.	$N_1P_0K_1$	31.95	39.15	43.00	40.25	32.45	30.00	33.50	35.76
12.	$N_1P_0K_2$	27.80	41.80	45.50	42.00	29.60	31.60	33.50	37.31
13.	$N_1P_1K_0$	31.15	37.60	43.90	40.20	31.95	31.45	33.50	35.68
14.	$N_1P_1K_1$	32.75	41.85	45.05	40.95	32.95	30.55	34.50	36.90
15.	$N_1P_1K_2$	35.15	44.05	47.00	42.70	34.60	31.55	35.20	38.70
16.	$N_1P_2K_0$	31.05	41.15	42.15	40.10	30.65	31.50	33.50	35.70
17.	$N_1P_2K_1$	33.05	42.25	45.50	41.80	32.05	31.00	32.50	36.87
18.	$N_1P_2K_2$	38.05	44.85	49.00	42.80	33.95	32.00	38.00	39.80
19.	$N_2P_0K_0$	31.20	33.55	43.60	41.05	31.00	31.55	32.60	34.90
20.	$N_2P_0K_1$	32.60	40.50	44.15	41.50	33.00	31.00	33.70	36.64
21.	$N_2P_0K_2$	35.05	42.00	46.85	42.15	31.00	31.00	34.10	37.50
22.	$N_2P_1K_0$	32.60	38.00	44.10	40.85	33.55	31.00	34.20	36.30
23.	$N_2P_1K_1$	34.80	42.55	47.00	41.95	32.95	31.60	35.15	38.00
24.	$N_2P_1K_2$	35.50	43.50	47.65	43.10	35.50	30.60	36.10	38.85
25.	$N_2P_2K_0$	33.10	40.60	45.50	41.05	32.00	27.65	32.65	36.10
26.	$N_2P_2K_1$	32.40	43.95	46.15	42.00	33.90	28.50	33.60	37.30
27.	$N_2P_2K_2$	34.15	43.75	46.80	42.30	34.50	30.00	35.8	38.20
	Mean	32.70	33.72	43.60	40.78	32.67	30.93	35.41	
	CD	1.28	1.25	1.25	1.00	1.45	1.62	2.06	

Variation in the disease intensity during the month of February was 4.80 per cent and it ranged from 27.65 ($N_2P_2K_0$) to 32.50 ($N_0P_2K_1$).

As the potash level in the fertilizer combination decreased the intensity of disease also showed a decreasing trend. The disease intensity was least in five out of seven observations, when the potash was not applied with N and P. Disease intensity was least during the month of June (33.55 %) / $N_2P_0K_0$), August (34.90 % / $N_0P_1K_0$), October (37.50 % / $N_0P_0K_0$), February (27.65 % / $N_2P_2K_0$) and April (31.45 % / $N_1P_0K_0$).

4.13 EFFECT OF WEATHER ON INCIDENCE AND INTENSITY OF GREY BLIGHT

4.13.1 Disease Incidence (DI)

The average DI during April 2001 – April 2002 ranged from 37.90 per cent (February) to 53.43 per cent (August). The high PDI was observed when the maximum (29.7^{0}C) and minimum (20.7^{0}C) temperature were least (Table 8 and Fig.2). The DI gradually increased from February and reached maximum during August and subsequently showed a declining trend. The maximum temperature similarly showed an increasing trend from during August to April and then it started reducing. The relative humidity during April 2001 to April 2002 ranged from 76.42 – 83.7 per cent. The highest incidence of the disease (53.43) was observed when the RH was high (more than 83 %) while the DI was least (37.90) when the RH was low (less than 78%).

Rainfall had a positive relationship with DI. The lowest incidence of grey blight was noticed when the palms received least rainfall (15 mm during February). However, the maximum disease was not noticed when the rainfall was higher (407.6 mm). No relationship between wind speed and DI could be arrived at.

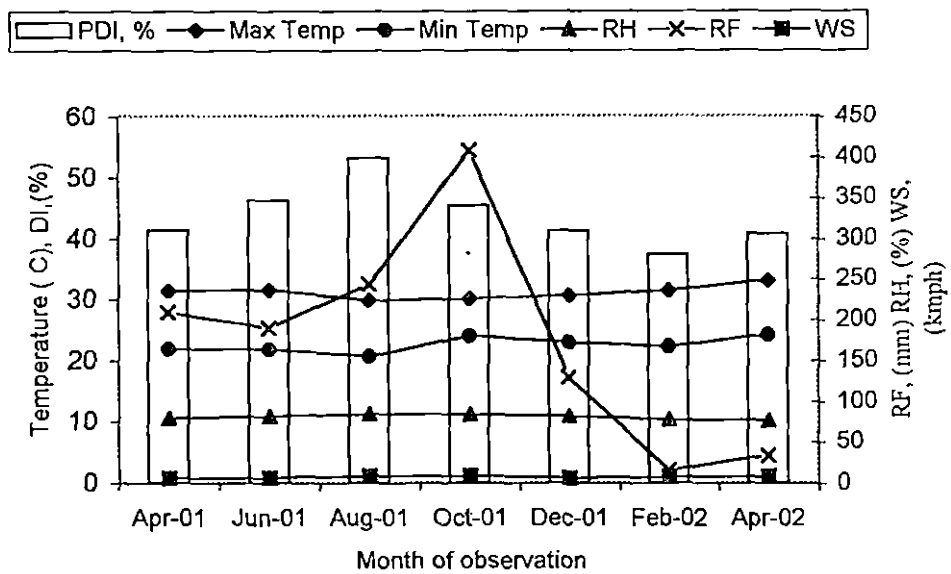


Fig. 2. Grey leaf blight incidence of coconut in relation to weather variables during April 2001- April 2002 (bimonthly interval)

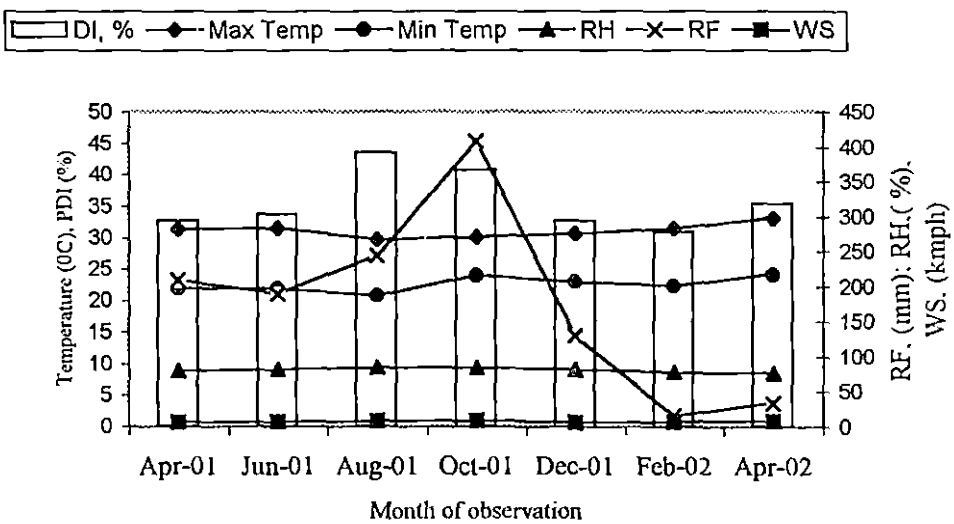


Fig. 3. Grey leaf blight intensity of coconut in relation to weather variables during April 2001-April 2002 (bimonthly interval)

4.13.2 Disease Intensity (PDI)

The disease intensity during April 2001 to April 2002 ranged from 30.93 per cent to 43.60 per cent (Table 8 and Fig. 3). The relationship of disease intensity with weather parameter was similar to that observed with disease incidence.

4.14 CORRELATION OF WEATHER WITH DISEASE INCIDENCE AND INENSITY

A correlation study was conducted with the different weather parameters, the disease incidence and intensity. The data are presented in Table 9. It was observed that the maximum and minimum temperature had a negative correlation with the disease intensity and incidence where as there was a positive correlation for relative humidity, rainfall and wind speed with disease intensity and incidence.

4.15 NUTRIENT COMPOSITION OF HEALTHY LEAF TISSUES

4.15.1 Main Effect of N on Major Elements

Among the major elements, except P, the contents of N and K elements were found to be significant (Table 10). The highest N and K contents were observed at N_2 level (1.66 and 1.31 % respectively). The lowest content of N was observed at N_0 level (1.31 %). No significant difference in the K content of leaf tissue was noticed at N_0 and N_1 levels.

4.15.2 Effect of N on Secondary Elements

The highest content of Ca and Mg were observed at N_2 level (0.343, 0.322 % respectively) and the lowest contents of Ca and S were observed at N_0 level (0.241 and 0.105 % respectively). There was no significant difference in the levels of Mg between N_0 and N_1 levels.

4.15.3 Effect of N on Minor Elements

Contents of all the minor elements except Zn and Mo were found to be statistically significant at different levels of 'N' application and they

Table 8 . Weather factors in relation to disease incidence (DI) and disease intensity (PDI) on grey leaf blight of coconut for the period of April 2001 – April 2002

Sl. No.	Period	DI			PDI			Temperature, ^{0}C		Relative humidity, %	Rainfall, mm	Wind speed, kmph
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum			
1.	Apr 2001	47.30 ($N_1P_2K_2$)	39.50 ($N_2P_1K_0$)	43.20	38.05 ($N_1P_2K_2$)	27.80 ($N_1P_0K_2$)	32.70	31.3	21.9	79.5	209.0	5.6
2.	Jun 2001	51.00 ($N_2P_0K_0$)	40.75 ($N_0P_2K_0$)	47.24	44.85 ($N_1P_2K_2$)	33.55 ($N_2P_0K_0$)	33.72	31.5	21.9	81.5	189.1	6.6
3.	Aug 2001	56.50 ($N_2P_2K_2$)	50.50 ($N_1P_0K_0$)	53.43	49.00 ($N_1P_2K_2$)	34.90 ($N_0P_1K_0$)	43.60	29.7	20.7	83.6	243.3	7.8
4.	Oct 2001	48.05 ($N_1P_1K_1$)	41.10 ($N_1P_2K_0$)	45.42	43.10 ($N_2P_1K_2$)	37.50 ($N_0P_0K_0$)	40.78	30.1	24.0	83.7	407.6	8.5
5.	Dec 2001	46.00 ($N_0P_0K_1$)	39.95 ($N_0P_2K_2$)	40.93	36.00 ($N_0P_2K_2$)	29.60 ($N_1P_0K_2$)	32.67	30.6	22.9	81.2	129.4	5.7
6.	Feb 2002	41.35 ($N_1P_1K_2$)	34.70 ($N_0P_2K_0$)	37.90	32.50 ($N_0P_2K_1$)	27.65 ($N_2P_2K_0$)	30.93	31.4	22.3	77.2	15.0	7.0
7.	Apr 2002	44.00 ($N_2P_1K_1$)	38.50 ($N_0P_0K_0$)	40.90	39.55 ($N_0P_2K_2$)	31.45 ($N_1P_0K_0$)	35.41	33.1	24.2	76.4	33.7	8.3

Table 9. Correlation between per cent disease incidence and disease intensity with weather parameters

Sl. No.	Weather parameters	PDI (r value)	DI (r value)
1.	Maximum temperature (^{0}C)	-0.607	-0.544
2.	Minimum temperature (^{0}C)	-0.376	-0.109
3.	Relative humidity (%)	0.481	0.267
4.	Rain fall (mm)	0.644	0.697
5.	Wind speed (kmph)	0.265	0.519

Table 10. Nutrient composition of healthy leaf tissues on coconut (main effects)

Sl. No.	Treatment	N %	P %	K%	Ca %	Mg %	S %	Cl %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	B (ppm)
1.	N_0	1.13	0.116	1.19	0.241	0.306	0.105	0.679	133.11	461.51	17.41	3.86	0.275	11.10
2.	N_1	1.36	0.119	1.19	0.275	0.306	0.109	0.677	134.60	457.40	20.92	4.18	0.477	11.40
3.	N_2	1.66	0.125	1.31	0.343	0.322	0.112	0.688	138.59	495.47	20.23	4.83	0.269	13.64
	CD	0.027	NS	0.011	0.003	0.012	0.006	0.005	0.962	1.343	0.676	0.039	0.008	0.554
4.	P_0	1.31	0.112	1.19	0.277	0.298	0.108	0.667	135.23	472.86	20.25	4.45	0.309	13.13
5.	P_1	1.40	0.112	1.25	0.288	0.311	0.108	0.679	132.55	468.71	19.22	4.19	0.434	12.22
6.	P_2	1.45	0.129	1.26	0.295	0.323	0.109	0.699	138.51	472.81	19.10	4.23	0.277	11.68
	CD	0.027	0.003	0.011	0.003	0.012	NS	0.005	0.962	1.343	0.676	0.039	0.008	0.554
7.	K_0	1.36	0.119	0.946	0.275	0.330	0.109	0.633	133.02	455.35	19.33	3.88	0.292	11.36
8.	K_1	1.39	0.120	1.27	0.278	0.325	0.108	0.687	138.06	471.16	19.57	4.35	0.317	12.55
9.	K_2	1.40	0.121	1.48	0.306	0.278	0.108	0.724	135.21	487.86	19.67	4.64	0.411	13.12
	CD	0.027	NS	0.011	0.003	0.012	NS	0.005	0.962	1.343	NS	0.039	0.008	0.554

were highest at N_2 level (Cl-0.688%, Fe – 138.59 ppm, Mn –495.47 ppm Cu-4.83 ppm, B – 13.64 ppm) Zn and Mo were highest at N_1 level (20.92 and 0.477 ppm respectively). The lowest contents of Fe, Zn, Cu were observed at N_0 level. 'Cl and 'B' did not differ significantly at N_0 and N_1 levels.

4.15.4 Effect of P on Major Elements

The different levels of P resulted in significant difference on the major elements. The highest content of N and P were observed at P_2 level (1.45 and 0.129 % respectively). In case of K no significant difference was observed with P_1 and P_2 levels. The lowest content of N and K were observed at P_0 level (0.131 and 1.19 % respectively).

4.15.5 Effect of P on Secondary Elements

Among the secondary elements contents of Ca and Mg were significant at different levels of P application. The highest contents of Ca and Mg were observed at P_2 level (0.245%) and the lowest was observed at P_0 level.

4.15.6. Effect of P on Minor Elements

The contents of all the minor elements were significantly different at different levels of P application. The highest contents of Cl and Fe were observed at P_2 level (0.699 % and 138.51 ppm respectively). While the highest contents of Zn, Cu and B were observed at P_0 level (Fig. 4). (20.25, 4.45 and 13.13 ppm respectively) and lowest content was observed at P_2 level.

4.15.7. Effect of K on Major Elements

The contents of N and K were significantly different at different levels of K. The highest content of K was observed at K_2 level (1.48%). The lowest content of N and K were observed at K_0 level (1.36 and 0.946% respectively). The content of N observed at K_1 and K_2 levels were not significant.

4.15.8 *Effect of K on Secondary Elements*

The contents of Ca and Mg were significantly different at different levels of K. The Ca content was highest at K_2 level (0.306 %) and lowest at K_0, which was on par with K_1. The highest Mg content was observed at K_0 and was on par with K_1. The lowest content of Mg was observed at K_2 level (Fig.6).

4.15.9 Effect of K on Minor Elements

Analysis of the data showed that the different levels K had a significant influence on all the minor elements except Zn. The contents of Cl, Mn, Cu, Mo and B were highest at K_2 level while maximum Fe was noticed at K_1. The lowest content of all the minor elements were observed at K_0 level.

4.16 NUTRIENT COMPOSITION OF DISEASED LEAF TISSUES (MAIN EFFECTS)

4.16.1 Effect of N on Major Elements

The contents of all the major elements were significant at different levels of N application (Table 11). The highest content of P was observed at N_2 level (0.103 %). The lowest content of N and P were observed at N_0 level (0.855 and 0.082 % respectively). The content of K observed at N_0 level was on par with N_2.

4.16.2 Effect of N on Secondary Elements

The contents of the secondary elements were significantly different at the different levels of N application. The highest content of Ca and Mg were obtained at N_2 level (0.253 and 0.350 % respectively). The lowest content of secondary elements were observed at N_0 level (0.210, 0.328 and 0.097%)

Table 11. Nutrient composition on diseased leaf tissues of coconut (main effects)

Sl. No.	Treatment	N %	P %	K%	Ca %	Mg %	S %	Cl %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	B (ppm)
1.	N_0	0.855	0.082	0.645	0.210	0.328	0.097	0.655	131.73	458.84	16.78	3.75	0.244	11.29
2.	N_1	0.935	0.095	0.620	0.241	0.334	0.105	0.660	133.52	453.37	19.32	4.10	0.407	10.53
3.	N_2	0.938	0.103	0.634	0.253	0.350	0.106	0.670	138.32	492.86	19.04	4.68	0.244	12.31
	CD	0.003	0.002	0.014	0.002	0.003	0.006	0.009	0.833	0.276	0.57	0.096	0.011	0.286
4.	P_0	0.894	0.085	0.601	0.222	0.334	0.103	0.653	134.13	469.89	18.92	4.32	0.288	12.30
5.	P_1	0.923	0.094	0.663	0.240	0.338	0.101	0.656	131.53	465.66	18.18	4.13	0.350	11.27
6.	P_2	0.915	0.102	0.634	0.244	0.340	0.104	0.676	137.90	469.53	18.04	4.08	0.261	11.68
	CD	NS	0.002	0.014	0.002	0.003	NS	0.009	0.833	0.276	0.57	0.096	0.011	0.286
7.	K_0	0.907	0.093	0.468	0.222	0.352	0.105	0.612	131.53	452.30	17.39	3.79	0.256	11.36
8.	K_1	0.905	0.092	0.647	0.238	0.344	0.101	0.663	137.43	467.74	18.60	4.23	0.333	12.55
9.	K_2	0.920	0.095	0.785	0.246	0.315	0.103	0.709	134.60	485.03	19.16	4.53	0.309	13.12
	CD	NS	0.002	0.014	0.002	0.003	NS	0.009	0.833	0.276	0.57	0.096	0.011	0.286

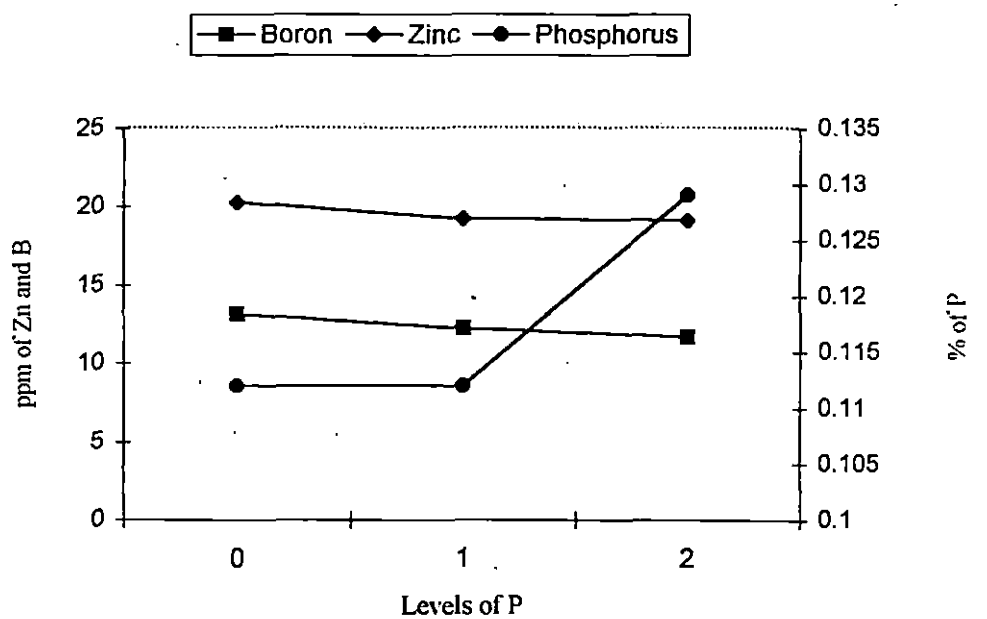


Fig. 4. Effect of P on P, Zn and B contents of healthy leaf tissues of coconut

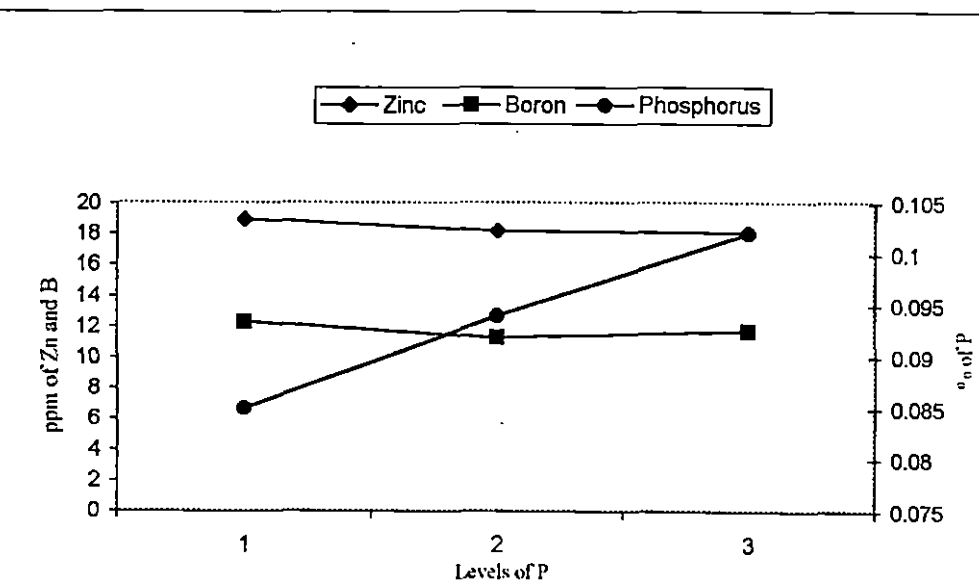


Fig. 5. Effect of P on P, Zn and B contents of diseased leaf tissues of coconut

4.16.3 Effect of N on Minor Elements

The highest content of all the minor elements except Zn and Mo were observed at N_2 level. The highest content of Mo was observed at N_1 level. The lowest content of Mn, Mo and B were observed at N_0 level.

4.16.4 Effect of P on Major Elements

The N content in leaf samples, with different levels of P was not significant. The lowest content of P and K were observed at P_0 level. (0.085 and 0.601% respectively). The K content was highest at P_1 level (0.663%).

4.16.5 Effect of P on Secondary Elements

The amount of Ca and Mg significantly altered with different levels of P. The highest content of Ca was observed at P_2 level. The lowest content of Ca and Mg were noticed at P_0 (0.222, 0.334 % respectively).

4.16.6 Effect of P on Minor Element

Zn, Cu and B were found to be highest at P_0 level. The highest content of Cl and Fe were observed at P_2 level (0.676 %, 137.90 ppm). The highest and lowest content of Mo was observed at P_1 and P_2 level (0.350, 0.261 respectively). The levels of Zn, Cu and B were found to be on par at P_1 and P_2 levels (Table 11 and Fig.5).

4.16.7 Effect of K on Major Elements

The content of N was not significant at different levels of K. In case of P, K_1 was on par with K_0 and K_2 while K_0 was significantly different from K_2.

4.16.8 Effect of K on Secondary Elements

The levels of Ca and Mg were significant at different levels of K application. The highest content of Ca was observed at K_2 level (0.246%) and Mg at K_0 (0.352%). The increase in the level of K resulted in a

Table 12. Nutrient composition on the healthy leaf tissues of coconut (two way interactions)

Sl. No.	Treatment	N %	P %	K%	Ca %	Mg %	S %	Cl %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	B (ppm)
1.	N_0P_0	1.05	0.107	1.12	0.246	0.302	0.100	0.653	130.73	451.47	17.95	3.98	0.203	14.17
2.	N_0P_1	1.15	0.113	1.17	0.236	0.306	0.107	0.675	129.70	463.93	17.35	3.83	0.340	11.02
3.	N_0P_2	1.19	0.128	1.22	0.240	0.310	0.108	0.708	138.88	469.12	16.93	3.78	0.282	10.78
4.	N_1P_0	1.32	0.118	1.09	0.240	0.284	0.114	0.667	135.20	462.87	22.38	4.28	0.547	12.08
5.	N_1P_1	1.36	0.120	1.24	0.289	0.306	0.106	0.668	133.92	459.72	20.73	4.20	0.644	11.21
6.	N_1P_2	1.41	0.120	1.26	0.296	0.329	0.108	0.698	134.67	449.60	19.65	4.06	0.239	10.91
7.	N_2P_0	1.56	0.110	1.29	0.345	0.310	0.111	0.680	139.75	504.25	20.43	5.10	0.178	13.15
8.	N_2P_1	1.69	0.127	1.34	0.338	0.322	0.109	0.693	134.03	482.47	19.57	4.55	0.318	14.44
9.	N_2P_2	1.74	0.139	1.31	0.350	0.332	0.112	0.692	141.98	499.70	20.70	4.86	0.310	13.33
	CD	NS	NS	0.020	0.004	NS	NS	0.009	1.667	2.325	1.171	0.068	0.013	0.960
10.	N_0K_0	1.12	0.117	0.88	0.235	0.327	0.106	0.633	132.75	445.45	16.80	3.55	0.275	11.09
11.	N_0K_1	1.13	0.114	1.27	0.232	0.318	0.102	0.683	133.20	462.98	17.98	3.86	0.235	11.98
12.	N_0K_2	1.14	0.117	1.42	0.254	0.274	0.107	0.720	133.27	476.08	17.48	4.17	0.315	12.90
13.	N_1K_0	1.34	0.119	0.95	0.277	0.315	0.107	0.622	130.05	439.28	21.00	4.00	0.336	10.52
14.	N_1K_1	1.36	0.122	1.19	0.260	0.319	0.107	0.686	139.75	458.95	20.57	4.19	0.560	11.83
15.	N_1K_2	1.39	0.118	1.44	0.289	0.286	0.114	0.724	133.98	473.95	21.20	4.35	0.535	11.85
16.	N_2K_0	1.64	0.121	1.00	0.313	0.348	0.114	0.643	136.25	481.32	20.20	4.09	0.266	12.46
17.	N_2K_1	1.68	0.126	1.34	0.343	0.341	0.114	0.693	141.11	491.55	20.15	4.95	0.158	13.85
18.	N_2K_2	1.68	0.129	1.59	0.376	0.276	0.104	0.729	138.28	513.55	20.35	5.42	0.383	14.62
	CD	NS	NS	0.02	0.004	NS	0.01	0.009	1.667	2.325	NS	0.068	0.013	NS
19.	P_0K_0	1.27	0.103	0.937	0.263	0.313	0.107	0.617	132.98	451.75	19.93	3.92	0.164	11.98
20.	P_0K_1	1.32	0.114	1.19	0.269	0.315	0.108	0.671	138.28	473.92	20.43	4.55	0.355	13.15
21.	P_0K_2	1.34	0.118	1.43	0.298	0.267	0.109	0.713	134.41	492.92	20.42	4.89	0.409	14.25
22.	P_1K_0	1.38	0.133	0.939	0.269	0.335	0.108	0.630	128.68	454.95	18.88	3.95	0.344	11.68
23.	P_1K_1	1.41	0.118	1.29	0.280	0.324	0.105	0.683	135.75	470.57	19.03	4.13	0.398	12.58
24.	P_1K_2	1.41	0.108	1.52	0.314	0.274	0.110	0.723	133.18	480.60	19.73	4.49	0.559	12.40
25.	P_2K_0	1.44	0.121	0.963	0.293	0.342	0.112	0.652	137.38	459.35	19.18	3.77	0.368	10.40
26.	P_2K_1	1.44	0.129	1.33	0.286	0.337	0.110	0.708	140.11	469.00	19.25	4.37	0.198	11.91
27.	P_2K_2	1.46	0.137	1.49	0.307	0.293	0.106	0.738	138.03	490.07	18.85	4.55	0.264	12.70
	CD	NS	0.017	0.02	0.004	NS	NS	NS	1.667	2.325	NS	0.068	0.013	NS

decrease in Mg content in the leaf. The lowest content of Ca was observed at K_0 while Mg was lowest at K_2 level (Table 11,Fig.6).

4.16.9 Effect of K on Minor Elements

The levels of Cl, Mn, Cu and B were highest at K_2 level while contents of Fe and Mo were maximum at K_1 level (137.43 and 0.333 ppm). The lowest content of all these minor elements were registered at K_0 level.

4.17 INTERACTION EFFECT OF NPK ON THE NUTRIENT CONTENTS OF HEALTHY LEAF TISSUES (TWO WAY INTERACTIONS)

4.17.1 N x P Interaction

4.17.1.1 Major Elements

The results of the study were presented in Table 12. N and P were not significant at NP interaction. Highest content of K was observed in palms receiving N_2P_1 (1.34%) and the lowest in those palms exposed to treatments N_1P_0 (1.09%).

4.17.1.2 Secondary Elements

Among the secondary elements the content of Ca was highest at N_2P_2 level and lowest at N_0P_1, N_0P_2 and N_1P_0 levels. No significant difference in the contents of Mg and S was noticed with NP interaction.

4.17.1.3 Minor Elements

The NP interaction influenced the contents of minor elements in the leaf tissue. The highest Cl content was observed at N_0P_2 (0.708 %) and the lowest at N_0P_0 (0.653). The highest Fe content was observed at N_2P_2 and lowest at $N_0P_1$and N_0P_0. The highest content of Mn was observed at N_2P_0 (504.25 ppm) and lowest were at N_1P_2 and N_0P_0. The highest content of Zn was noticed at N_1P_0 (28.3ppm) and lowest were at N_0P_2, N_0P_1 and N_0P_0. The highest content of Cu was recorded at N_2P_0 (5.10 ppm) and lowest with N_0P_2 (3.78 ppm). The highest content of Mo was noticed at N_1P_1 (0.644 ppm) and the lowest was noticed at N_0P_0. The highest content

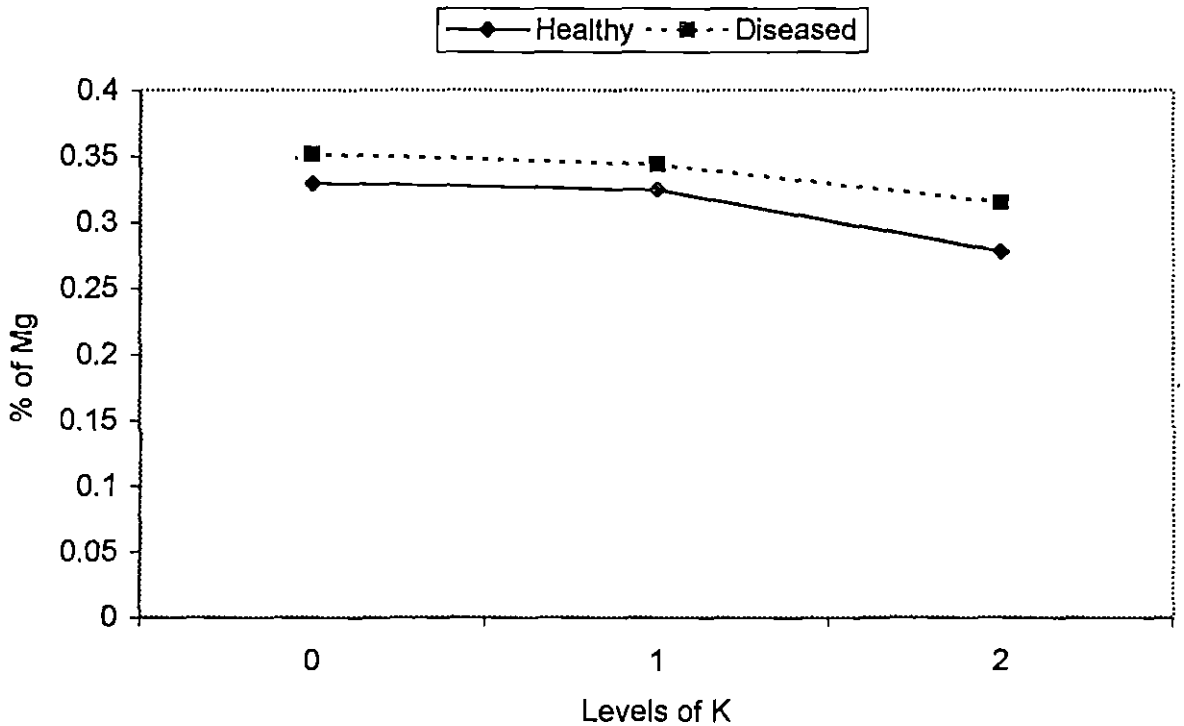


Fig.6. Effect of K on the Mg content of healthy and diseased leaf tissue of coconut

of B was noticed with N_2P_1 (14.44 ppm) and N_0P_0 (14.17 ppm). The lowest contents were noticed with N_0P_2, N_1P_1 and N_1P_2.

4.17.2 N x K Interaction

4.17.2.1 Major Elements

Among the major elements, only K content was significant. The highest content of K was observed at N_2K_2 level (1.59 %) and lowest content was observed at N_0K_0 level (0.88 %).

4.17.2.2 Secondary Elements

Among the secondary elements, contents of Ca and S were found to be significant. The highest content of Ca was noticed at N_2K_2 (0.376 %) and lowest was noticed at N_0K_1 (0.232 %) and N_0K_0 levels. The highest content of S was observed with N_2K_1, N_2K_0, N_1K_2. The lowest content were found with N_0K_1, N_1K_1, N_1K_0, N_0K_2, N_0K_0 and N_2K_2.

4.17.2.3 Minor Elements

The contents of all the minor elements except Zn and B were found to be significant at NK interaction. The Cl content was highest with N_2K_2 and N_1K_2 and N_0K_2. The highest content of Mn was noticed at N_2K_2 (513.55 ppm). The highest content of Fe was noticed with N_0K_1 and N_1K_1 (141.11 and 139.75 ppm) respectively the lowest content of Cl, Fe and Mn were registered at N_1K_0 (0.622%, 130.05, 439.28 ppm respectively). The highest content of Cu was observed at N_2K_2 (5.42 ppm) and lowest at N_0P_0 (3.55 ppm). The Mo content was highest at N_1K_2 (0.560 ppm) and lowest at N_2K_1 (0.158 ppm).

4.17.3 PK interaction

4.17.3.1 Major Elements

The highest content of P was recorded with P_2K_2, P_1K_0, P_2K_1 and P_2K_0. The lowest content were noticed with P_0K_0, P_1K_1, P_0K_2, P_0K_1 and P_1K_2. The K content was highest at P_1K_2 (1.52%) and lowest was recorded with P_0K_0 and P_1K_0.

4.17.3.2 Secondary Elements

With PK interaction only Ca was found to be significant. The highest content of Ca was observed at P_1K_2 level (0.314 %) and lowest was observed at P_0K_0 (0.263%).

4.17.3.3 Minor Elements

Except Cl, Zn and B, all the other minor elements were found to be significant at different levels of P and K. The highest Fe content was observed at P_2K_1 (140.11 ppm) and lowest at P_1K_0 (128.68 ppm). The Mn content was highest at P_0K_2 (492.92 ppm) and lowest (451.75 ppm.). The Cu content was highest at P_0K_2 (4.89 ppm) and lowest at P_2K_0 (3.77 ppm). The Mo content was highest at P_1K_2 (0.559 ppm) and lowest at P_0K_0 (0.164 ppm).

4.18 INTERACTION ON THE NUTRIENT CONTENT OF DISEASED LEAF TISSUES (TWO WAY INTERACTIONS)

4.18.1 Interaction Effect of N x P

4.18.1.1 Major Elements

A scan through the data on NP interaction effect showed that, except K, the contents of other major elements were significant (Table 13). The highest content was noticed with N_1P_2, N_2P_0, N_2P_1 and N_1P_1. The lowest N content was noticed with N_0P_0 and N_0P_2 (0.812 and 0.859 % respectively). The highest P content was observed at N_2P_2 (0.112 %) and lowest was at N_0P_0 (0.072 %)respectively.

4.18.1.2 Secondary Elements

The Ca and Mg contents were found to be significant at different levels of N x P interaction. The Ca and Mg content were highest at N_2P_2 (0.261 and 0.355 % respectively) and the lowest were observed at N_0P_0 (0.195 and 3.22 % respectively).

Table 13. Nutrient composition on the diseased leaf tissues of coconut (two way interactions)

Sl. No.	Treatment	N %	P %	K%	Ca %	Mg %	S %	Cl %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	B (ppm)
1.	N_0P_0	0.812	0.072	0.608	0.195	0.322	0.096	0.640	129.62	448.82	17.15	3.88	0.189	13.66
2.	N_0P_1	0.896	0.085	0.688	0.216	0.333	0.095	0.645	128.22	461.57	16.95	3.71	0.289	10.20
3.	N_0P_2	0.859	0.091	0.638	0.222	0.329	0.102	0.680	137.33	466.13	16.23	3.67	0.259	10.01
4.	N_1P_0	0.910	0.089	0.583	0.227	0.332	0.108	0.660	134.62	459.13	20.77	3.16	0.510	11.73
5.	N_1P_1	0.924	0.094	0.650	0.248	0.335	0.103	0.645	132.67	455.38	19.28	4.27	0.480	10.01
6.	N_1P_2	0.980	0.102	0.627	0.249	0.337	0.104	0.675	133.25	445.60	17.93	3.87	0.237	9.86
7.	N_2P_0	0.960	0.095	0.612	0.243	0.349	0.106	0.660	138.13	501.72	18.85	4.94	0.168	11.50
8.	N_2P_1	0.950	0.102	0.653	0.255	0.346	0.109	0.677	133.70	480.02	18.30	4.41	0.283	13.60
9.	N_2P_2	0.905	0.112	0.638	0.261	0.355	0.106	0.673	143.12	496.85	19.97	4.70	0.291	11.82
	CD	0.053	0.004	NS	0.004	0.005	NS	0.016	1.442	0.478	0.987	0.166	0.020	0.496
10.	N_0K_0	0.831	0.084	0.527	0.202	0.338	0.102	0.598	131.25	443.62	16.45	3.47	0.233	10.78
11.	N_0K_1	0.863	0.078	0.645	0.211	0.332	0.097	0.655	131.38	459.88	17.13	3.75	0.240	11.18
12.	N_0K_2	0.873	0.085	0.763	0.220	0.313	0.093	0.712	132.53	473.02	16.75	4.04	0.258	11.91
13.	N_1K_0	0.947	0.092	0.412	0.224	0.352	0.106	0.613	128.52	434.78	16.28	4.00	0.314	9.68
14.	N_1K_1	0.915	0.097	0.655	0.244	0.345	0.102	0.662	138.95	454.48	19.47	4.06	0.454	10.91
15.	N_1K_2	0.952	0.097	0.793	0.257	0.306	0.108	0.705	133.07	470.85	20.23	4.25	0.453	11.01
16.	N_2K_0	0.943	0.104	0.465	0.241	0.367	0.108	0.625	134.82	478.48	17.43	3.90	0.222	10.94
17.	N_2K_1	0.938	0.102	0.640	0.259	0.357	0.104	0.673	141.95	488.87	19.20	4.87	0.305	12.14
18.	N_2K_2	0.935	0.103	0.798	0.261	0.326	0.106	0.712	138.18	511.23	20.48	5.27	0.215	13.83
	CD	NS	0.004	0.024	0.004	0.005	NS	NS	1.442	0.478	0.987	0.166	0.020	0.496
19.	P_0K_0	0.905	0.085	0.448	0.211	0.349	0.102	0.607	131.45	448.45	18.13	3.76	0.162	11.16
20.	P_0K_1	0.905	0.086	0.620	0.223	0.343	0.100	0.643	137.18	470.28	19.40	4.43	0.315	12.52
21.	P_0K_2	0.873	0.084	0.723	0.231	0.311	0.107	0.710	133.73	490.93	19.18	4.79	0.352	13.20
22.	P_1K_0	0.905	0.093	0.477	0.230	0.354	0.107	0.608	127.30	451.77	16.61	3.97	0.311	10.81
23.	P_1K_1	0.901	0.092	0.675	0.239	0.345	0.101	0.655	134.50	467.62	18.28	4.03	0.387	10.94
24.	P_1K_2	0.963	0.096	0.839	0.250	0.315	0.097	0.703	132.78	477.58	19.63	4.40	0.351	12.06
25.	P_2K_0	0.910	0.102	0.478	0.226	0.355	0.107	0.622	135.83	456.67	17.36	3.64	0.297	9.42
26.	P_2K_1	0.910	0.098	0.645	0.251	0.346	0.103	0.692	140.60	465.33	18.11	4.22	0.262	10.78
27.	P_2K_2	0.924	0.104	0.780	0.256	0.318	0.102	0.715	137.27	486.58	18.65	4.37	0.233	11.49
	CD	NS	0.004	0.024	0.004	NS	NS	0.016	1.442	0.478	0.987	0.166	0.020	0.496

4.18.1.3 Minor Elements

The contents of all the minor elements were significant at N x P interactions. The highest content of Cl was noticed with N_0P_2, N_2P_1, N_1P_2 and N_2P_2 and lowest content were noticed with N_0P_0, N_1P_1 and N_0P_1. The Fe content was highest at N_2P_2 (143.12 ppm) and lowest contents were observed with N_0P_1 and N_0P_0 (128.22 and 129.62 ppm respectively). The Mn and Cu content were highest at N_2P_0 (501.72, 4.94 ppm respectively). The Cu content was lowest at N_1P_0 (3.16 ppm). The Zn content was highest with N_1P_0 and N_2P_2 (20.77, 19.77 ppm respectively). The lowest content of Zn was observed with N_0P_2, N_0P_1 and N_0P_0. The Mo content was highest at N_1P_0 (0.510 ppm) and lowest at N_2P_0 (0.168 ppm). The B content was highest with N_0P_0 and N_2P_1 (13.66 and 13.60 ppm respectively), and the lowest were observed with N_1P_2, N_1P_1, N_0P_2 and N_0P_1.

4.18.2 N x K Interaction

4.18.2.1 Major Elements

The contents of P and K were influenced by N x K interaction. The highest content of P was observed with N_2K_0, N_2K_2 and N_2K_1 and lowest content at N_0K_1 (0.078%). The highest content of K was observed with N_2K_2 and N_1K_2 (0.798 and 0.792% respectively and the lowest content at N_1K_0 (0.412%).

4.18.2.2 Secondary Elements

The Ca and Mg contents were significant at different levels of N x K interaction. The Ca content was highest with N_2K_2, N_2K_1 and N_1K_2 and lowest content at N_0K_0 (0.202%). The Mg content was highest at N_2K_0 (0.367%) and lowest content at N_2K_2 (0.306 %).

4.18.2.3. Minor Elements

The contents of all the minor elements except Cl were significant at N x K level of interaction. The Fe content was highest at N_2K_1

(141.95ppm) and lowest at N_1K_0 (128.52 ppm). The Mn, Cu and B content were highest at N_2K_2 (511.23, 5.27 and 13.87 ppm respectively). The lowest content of Mn and B were observed at N_1K_0 level (434.78 and 9.68 ppm respectively). The lowest content of Cu was observed at N_0K_0 (3.47 ppm). The Mo content was highest at N_1K_1 (0.560 pm) and lowest at N_2K_1 (0.158 ppm). The Zn content was highest with N_2K_2 and N_1K_2 (20.48 and 20.23 ppm respectively) and lowest with N_1K_0, N_0K_0, N_0K_2 and N_0K_1.

4.18.3 P x K Interaction

4.18.3.1. Major Elements

The P and K contents was significant. The highest content of P was observed with P_2K_2 and P_2K_0 (0.104 and 0.102 % respectively) and lowest content was observed with P_0K_2, P_0K_2, P_0K_0 and P_0K_1. The K content was highest at P_1K_2 (0.839 %) and lowest at P_0K_0 (0.448 %).

4.18.3.2 Secondary Elements

Only Ca content was significant at P x K interaction with highest and lowest content at P_2K_2 (0.256%) and P_0K_0 (0.211 %) levels respectively.

4.18.3.3. Minor Elements

The contents of all the minor elements were significantly different at P x K interactions. The highest Cl content observed at P_2K_2, P_0K_2 and P_1K_2. The Fe content was highest at P_2K_1 (140.60 ppm) and lowest at P_1K_0 (127.30 ppm). The Mn content was highest at P_0K_2 (490.93 pm) and lowest at P_0K_0 (448.45 ppm). The Zn content was highest with P_1K_2, P_0K_1, P_0K_2 and P_2K_2. The lowest content were found to be with P_1K_0 and P_2K_0. The Cu and B content were highest at P_0K_2 (4.79 and 13.20 ppm respectively). The Cu content was lowest at P_2K_0 and P_0K_0 (3.64 and 3.76 respectively). The B content was lowest at P_0K_0 (9.42 ppm). The Mo content was highest at P_1K_1 (0.387 ppm) and lowest P_0K_0 (0.162 ppm).

4.19 NUTRIENT CONTENT OF HEALTHY LEAF TISSUES (THREE WAY INTERACTIONS)

4.19.1 NPK Effect on Major Elements

Except K, other two major elements were non significant at various 3 way of interaction (Table 14). The highest content of K was noticed with $N_2K_1P_2$ and $N_2P_0K_2$ (1.63 and 1.61% respectively). The low content of K was noticed with $N_0P_2K_0$, $N_1P_1K_0$ and $N_0P_1K_0$.

4.19.2 NPK effect on Secondary Elements

Among the secondary elements except S, Ca and Mg were significant. The highest content of Ca was observed at $N_2P_1K_2$ (0.386 %) and the lowest with $N_1P_0K_0$ and $N_0P_1K_0$ (0.209 and 0.214 % respectively). The highest content of Mg was observed with $N_2P_2K_0$ and $N_2P_2K_1$ (0.356 and 0.355 % respectively). The lowest content of Mg was observed with $N_1P_0K_2$, $N_2P_0K_2$, $N_0K_2P_2$, $N_1P_1K_2$, $N_0P_1K_2$, $N_2P_1K_2$, $N_0P_0K_2$ and $N_0P_0K_0$.

4.19.3 NPK Effects on Minor Elements

Contents of the minor elements except Zn were statistically significant at 3 way interactions. The highest content of Cl was observed a $N_0P_2K_2$ (0.75%). The lowest content was noticed at $N_0P_0K_0$ (0.605%).

The highest content of Fe was observed with $N_2P_2K_1$ (142.90 ppm) $N_2P_2K_0$ and $N_2P_0K_1$ (142.20 and 142.0 ppm respectively). The lowest content was recorded with $N_2P_1K_0$ (128.05ppm) and with $N_0P_1K_0$, $N_1P_1K_0$, $N_1P_1K_0$, $N_0P_0K_0$ and $N_0P_1K_1$. The highest content of Mn was recorded at $N_2P_0K_2$ (526.05 ppm) and lowest was recorded at $N_0P_0K_0$ (428.50 ppm). The highest content of Cu was observed at $N_2P_0K_2$ (5.75 ppm) and lowest was observed at $N_0P_2K_2$ (3.45 ppm). The highest content of Mo was observed with $N_1P_1K_1$ (0760 ppm) $N_1P_0K_1$ (0.743 ppm). The lowest content was recorded at $N_2P_0K_1$ (0.130 ppm). The highest content of B was recorded at $N_0P_0K_2$ (16.45 ppm) and lowest content was recorded with $N_1P_2K_0$ (9.55 ppm) with $N_0P_2K_0$, $N_1P_1K_0$ and $N_0P_1K_2$.

Table 14. Nutrient composition on the healthy leaf tissues of the coconut (three way interactions)

Sl. No.	Treatment	N %	P %	K%	Ca %	Mg %	S %	Cl %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	B (ppm)
1.	$N_0P_0K_0$	1.02	0.105	0.90	0.267	0.321	0.101	0.605	129.75	428.50	17.90	3.55	0.180	12.50
2.	$N_0P_0K_1$	1.05	0.107	1.27	0.218	0.304	0.096	0.650	131.95	458.00	18.50	3.93	0.193	13.35
3.	$N_0P_0K_2$	1.06	0.110	1.37	0.253	0.281	0.102	0.705	130.50	467.90	17.45	4.47	0.238	16.45
4.	$N_0P_1K_0$	1.11	0.123	0.88	0.214	0.327	0.106	0.645	128.80	452.75	16.00	3.66	0.308	11.18
5.	$N_0P_1K_1$	1.16	0.108	1.27	0.244	0.318	0.106	0.675	129.90	463.95	17.95	3.87	0.255	11.33
6.	$N_0P_1K_2$	1.18	0.108	1.36	0.251	0.275	0.110	0.705	130.40	475.10	18.10	3.96	0.458	10.55
7.	$N_0P_2K_0$	1.22	0.123	0.873	0.224	0.333	0.111	0.650	139.70	455.10	16.50	3.45	0.338	9.60
8.	$N_0P_2K_1$	1.18	0.126	1.27	0.236	0.332	0.104	0.725	137.73	467.00	17.50	3.80	0.258	11.05
9.	$N_0P_2K_2$	1.18	0.133	1.53	0.260	0.265	0.108	0.750	139.20	485.28	16.80	4.09	0.250	11.70
10.	$N_1P_0K_0$	1.26	0.110	0.93	0.209	0.282	0.106	0.620	130.70	438.85	21.75	4.14	0.165	12.08
11.	$N_1P_0K_1$	1.34	0.123	1.03	0.237	0.313	0.113	0.675	140.90	464.95	22.30	4.24	0.743	12.48
12.	$N_1P_0K_2$	1.34	0.123	1.31	0.276	0.257	0.123	0.705	133.98	484.80	23.10	4.47	0.734	11.68
13.	$N_1P_1K_0$	1.36	0.140	0.875	0.285	0.327	0.106	0.610	129.20	437.85	21.20	4.08	0.495	9.93
14.	$N_1P_1K_1$	1.34	0.123	1.26	0.276	0.318	0.098	0.663	138.65	465.15	20.35	4.22	0.760	11.65
15.	$N_1P_1K_2$	1.37	0.097	1.57	0.307	0.273	0.116	0.730	133.90	476.15	20.65	4.30	0.678	12.05
16.	$N_1P_2K_0$	1.39	0.108	1.05	0.336	0.338	0.110	0.635	130.25	441.15	20.05	3.78	0.348	9.55
17.	$N_1P_2K_1$	1.40	0.120	1.28	0.266	0.323	0.110	0.720	139.70	446.75	19.05	4.11	0.175	11.35
18.	$N_1P_2K_2$	1.46	0.133	1.43	0.285	0.327	0.103	0.738	134.05	460.90	19.85	4.28	0.195	11.83
19.	$N_2P_0K_0$	1.53	0.095	0.98	0.315	0.338	0.114	0.625	138.50	487.90	20.15	4.07	0.148	11.38
20.	$N_2P_0K_1$	1.57	0.113	1.27	0.353	0.330	0.116	0.688	142.00	498.80	20.45	5.48	0.130	13.43
21.	$N_2P_0K_2$	1.60	0.123	1.61	0.366	0.265	0.103	0.728	138.75	526.05	20.70	5.75	0.258	14.65
22.	$N_2P_1K_0$	1.67	0.135	1.06	0.307	0.352	0.114	0.635	128.05	474.25	19.45	4.11	0.230	13.95
23.	$N_2P_1K_1$	1.71	0.125	1.32	0.320	0.338	0.110	0.710	138.80	482.60	18.80	4.32	0.180	14.78
24.	$N_2P_1K_2$	1.68	0.120	1.63	0.386	0.278	0.104	0.735	135.25	490.55	20.45	5.22	0.543	14.60
25.	$N_2P_2K_0$	1.72	0.133	0.96	0.318	0.356	0.114	0.670	142.20	481.80	21.00	4.09	0.420	12.05
26.	$N_2P_2K_1$	1.75	0.141	1.43	0.357	0.355	0.116	0.680	142.90	493.25	21.20	5.20	0.163	13.35
27.	$N_2P_2K_2$	1.75	0.145	1.53	0.376	0.286	0.106	0.725	140.85	524.05	19.90	5.28	0.348	14.60
	CD	NS	NS	0.024	0.005	0.026	NS	0.011	2.041	2.849	NS	0.084	0.016	1.176

4.20 NUTRIENT CONTENT OF DISEASED LEAF TISSUES (3 WAY INTERACTIONS)

4.20.1 NPK Effects on Major Elements

The analysis of the data for the NPK interaction revealed that only the P content was significant (Table 15). The highest content of P was recorded at $N_2P_2K_0$ (0.116) and lowest content was observed at $N_0P_0K_1$ (0.068%).

4.20.2 NPK Effects on Secondary Elements

All the contents of all the secondary elements were found to be non significant at NPK interactions.

4.20.3 NPK Effects on Minor Elements

Contents of all the minor elements except Zn were statistically significant at three way interactions. The highest content of Cl was noticed with $N_0P_2K_2$ (0.725 %) with $N_1P_2K_2$, $N_2P_0K_2$, $N_2P_1K_2$, $N_0P_0K_2$, $N_0P_2K_1$, $N_1P_0K_2$, $N_1P_2K_1$ and $N_2P_2K_2$. The lowest content was noticed with $N_0P_0K_0$ (0.585%) with $N_0P_1K_0$, $N_1P_2K_0$, $N_1P_1K_0$ and $N_2P_0K_0$.

The highest content of Fe was observed at $N_2P_2K_1$ (146.25 ppm) and lowest content was observed with $N_2P_1K_0$ (127.05 ppm) with $N_0P_1K_1$, $N_1P_1K_0$ and $N_1P_2K_0$. The highest content of Mn was registered at $N_2P_0K_2$ (524.95 ppm) and lowest content was observed at $N_0P_0K_0$ (425.10 ppm). The highest content of Cu was observed at $N_2P_0K_2$ (5.61 ppm) and lowest content was observed with $N_0P_2K_0$ (3.40 ppm) with $N_0P_0K_1$, $N_0P_1K_0$, $N_1P_2K_0$ and $N_0P_2K_1$. The highest content of Mo was registered at $N_1P_0K_1$ (0.73.03 ppm) and lowest content was registered with $N_2P_0K_1$ (0.125 ppm) $N_2P_1K_2$ and $N_2P_0K_0$ (0.133 and 0.138 ppm respectively). The highest content of B was noticed at $N_0P_0K_2$ (15.60 ppm) and was on par with $N_2P_1K_2$ (15.00 ppm). The lowest content was noticed at $N_1P_2K_0$ (8.25 ppm) and was on par with $N_1P_1K_0$ (8.85 pm).

Table 15. Nutrient composition on the diseased leaf tissues of the coconut (three way interactions)

Sl. No.	Treatment	N %	P %	K%	Ca %	Mg %	S %	Cl %	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Mo (ppm)	B (ppm)
1.	$N_0P_0K_0$	0.770	0.075	0.500	0.185	0.335	0.098	0.585	128.80	425.10	17.00	3.45	0.175	11.88
2.	$N_0P_0K_1$	0.854	0.068	0.620	0.194	0.323	0.095	0.625	130.20	455.10	17.50	3.85	0.195	13.50
3.	$N_0P_0K_2$	0.812	0.073	0.705	0.205	0.308	0.095	0.710	129.85	466.25	16.95	4.35	0.188	15.60
4.	$N_0P_1K_0$	0.854	0.084	0.565	0.218	0.374	0.106	0.600	127.10	452.05	16.35	3.55	0.243	10.90
5.	$N_0P_1K_1$	0.868	0.084	0.675	0.207	0.337	0.098	0.635	127.70	461.00	17.25	3.74	0.248	10.05
6.	$N_0P_1K_2$	0.966	0.086	0.823	0.225	0.318	0.080	0.700	129.85	471.65	17.25	3.85	0.368	9.65
7.	$N_0P_2K_0$	0.867	0.094	0.550	0.203	0.337	0.102	0.610	137.85	453.70	16.00	3.40	0.283	9.55
8.	$N_0P_2K_1$	0.868	0.083	0.640	0.232	0.337	0.100	0.705	136.25	463.55	16.65	3.68	0.278	10.00
9.	$N_0P_2K_2$	0.840	0.095	0.760	0.230	0.313	0.104	0.725	137.90	481.55	16.05	3.93	0.218	10.48
10.	$N_1P_0K_0$	0.980	0.088	0.370	0.217	0.345	0.105	0.630	129.90	435.05	20.05	3.93	0.173	11.93
11.	$N_1P_0K_1$	0.882	0.094	0.630	0.229	0.347	0.105	0.645	140.55	460.75	21.20	4.13	0.733	12.75
12.	$N_1P_0K_2$	0.868	0.086	0.750	0.235	0.303	0.113	0.705	133.40	481.60	21.05	4.41	0.625	10.50
13.	$N_1P_1K_0$	0.882	0.093	0.405	0.228	0.354	0.104	0.605	127.75	432.05	17.30	4.44	0.425	8.85
14.	$N_1P_1K_1$	0.896	0.095	0.695	0.256	0.343	0.099	0.635	137.00	461.00	20.10	4.14	0.463	9.65
15.	$N_1P_1K_2$	0.994	0.095	0.850	0.261	0.308	0.107	0.695	133.25	473.10	20.45	4.25	0.553	11.53
16.	$N_1P_2K_0$	0.980	0.095	0.460	0.228	0.356	0.109	0.605	127.90	437.25	17.50	3.62	0.345	8.25
17.	$N_1P_2K_1$	0.966	0.101	0.640	0.246	0.347	0.100	0.705	139.30	441.70	17.10	3.91	0.168	10.33
18.	$N_1P_2K_2$	0.994	0.110	0.780	0.274	0.308	0.104	0.715	132.55	457.85	19.20	4.09	0.183	11.00
19.	$N_2P_0K_0$	0.966	0.094	0.470	0.232	0.366	0.104	0.605	135.65	485.20	17.50	3.89	0.138	9.70
20.	$N_2P_0K_1$	0.980	0.097	0.610	0.247	0.359	0.100	0.660	140.80	495.00	19.50	5.31	0.125	11.30
21.	$N_2P_0K_2$	0.938	0.095	0.750	0.253	0.324	0.115	0.715	137.95	524.95	19.55	5.61	0.243	13.50
22.	$N_2P_1K_0$	0.980	0.103	0.460	0.244	0.364	0.110	0.620	127.05	471.20	16.20	3.91	0.265	12.68
23.	$N_2P_1K_1$	0.938	0.097	0.655	0.256	0.356	0.104	0.695	138.80	480.85	17.50	4.22	0.450	13.13
24.	$N_2P_1K_2$	0.930	0.106	0.845	0.265	0.319	0.103	0.715	135.25	488.00	21.20	5.11	0.133	15.00
25.	$N_2P_2K_0$	0.882	0.116	0.460	0.247	0.373	0.111	0.650	141.75	479.02	18.60	3.91	0.263	10.45
26.	$N_2P_2K_1$	0.895	0.110	0.655	0.276	0.357	0.108	0.665	146.25	490.75	20.60	5.09	0.340	12.00
27.	$N_2P_2K_2$	0.938	0.109	0.800	0.265	0.335	0.099	0.705	141.35	520.75	20.70	5.09	0.270	13.00
	CD	NS	0.004	NS	NS	NS	NS	0.02	1.767	0.585	NS	0.203	0.024	0.608

4.21 BIOCHEMICAL COMPOSITION OF HEALTHY LEAF TISSUES (MAIN EFFECTS)

4.21.1 Effect of N on Biochemical Composition

Except phenol, contents of all the other constituents were found to be significant (Table 16 and Fig. 7, 8, 9 and 10). The highest contents of amino acids, chlorophyll and total sugars were noticed at N_2 level of nitrogen application (0.556, 2.27, 6.77 mg/g respectively and lowest contents of these constituents were observed at N_0 level (0.518,1.32 and 6.42 mg/g respectively).

4.21.2 Effect of P

The highest contents of amino acids, chlorophyll, phenol and total sugars were observed at P_2 levels of P application (0.539 mg/g, 1.90 mg/g, 2514.89 µg/g and 6.63 mg/g respectively) and lowest contents of these constituents were observed at P_0 level. Phenol content was observed at P_1 level (2426.44 mg/g).

4.21.3 Effect of K

Chlorophyll and phenol contents were significant different levels of K application. The highest content of chlorophyll and phenol were observed at K_2 level (1.83 mg/g, 2532.39 µg/g respectively). The lowest content of chlorophyll was noticed with K_0 level (1.75 mg/g) with K_1 (1.76 mg/g). The lowest content of phenol was noticed with K_1 and K_0 level (2438.67, 2473.61 µg/g). The values of amino acids and total sugars did not differ with K levels.

4.22 BIOCHEMICAL COMPOSITION OF DISEASED LEAF TISSUES (MAIN EFFECTS)

4.22.1 Effect of N on Biochemical Composition

All the biochemical constituents were found to be significant at different levels of N application (Table 17). The highest content of amino acid, chlorophyll and phenol were observed at N_2 level (0.587 mg/g,

0.576 mg/g, 3506.67 µg/g respectively). The highest content of total sugar was observed with N_2 level (7.93 mg/g) with N_1 level (7.88 mg/g) and lowest content of these constituents were observed at N_0 level (0.545 mg/g, 0.479 mg/g, 3036.94 µg/g, 7.47 mg/g respectively).

4.22.2 Effect of P on Biochemical Composition

All the biochemical constituents were significant at different levels of P application. The highest content of amino acids was observed P_0 level (0.568 mg/g) and lowest at P_2 (0.564 mg/g). But P_1 was on par with P_0 and P_2. The high content of chlorophyll was observed with P_2 and P_1 (0.571 mg/g) and lowest at P_0 (0.494 mg/g) and 0.529 mg/g).

The highest content of phenol was noticed at P_2 levels (3376.94 µg/g) and lowest at P_0 (3274 µg/g). But P_1 was on par with P_0 and P_2. The highest content of total sugar was observed at P_2 and P_1 (7.90 and 7.85 mg/g respectively) and lowest at P_0 (7.53 mg/g).

4.22.3 Effect of K on Biochemical Composition

Among the biochemical constituents only the total sugar was found to be significant. The highest content of total sugar was noticed at K_2 level (7.81 mg/g) and lowest at K_0 level (7.69 mg/g). But K_1 was on par with K_0 and K_2.

Table 16. Biochemical composition of healthy leaf tissues (main effects)

Sl. No.	Treatment	Amino acids (mg/g)	Chlorophyll (mg/g)	Phenol (µg/g)	Total sugar (mg/g)
1	N_0	0.518	1.32	2473.72	6.42
2	N_1	0.537	1.75	2473.69	6.53
3	N_2	0.556	2.27	2497.25	6.77
	CD	0.021	0.034	NS	0.056
4	P_0	0.535	1.62	2503.33	6.56
5	P_1	0.536	1.82	2426.44	6.54
6	P_2	0.539	1.90	2514.89	6.55
	CD	NS	0.034	46.93	0.056
7	K_0	0.536	1.75	2473.61	6.55
8	K_1	0.537	1.76	2438.67	6.59
9	K_2	0.537	1.83	2532.39	6.59
	CD	NS	0.034	46.93	NS

Table 17. Biochemical composition of diseased leaf tissues (main effects)

Sl. No.	Treatment	Amino acids (mg/g)	Chlorophyll (mg/g)	Phenol (µg/g)	Total sugar (mg/g)
1	N_0	0.545	0.479	3036.94	7.47
2	N_1	0.567	0.539	3417.50	7.88
3	N_2	0.587	0.576	3506.67	7.93
	CD	0.023	0.034	84.83	0.091
4	P_0	0.568	0.494	3279.17	7.53
5	P_1	0.567	0.529	3305.00	7.85
6	P_2	0.564	0.571	3376.94	7.90
	CD	0.023	0.034	84.83	0.091
7	K_0	0.565	0.516	3313.33	7.69
8	K_1	0.567	0.535	3295.28	7.78
9	K_2	0.567	0.542	3352.50	7.81
	CD	NS	NS	NS	0.091

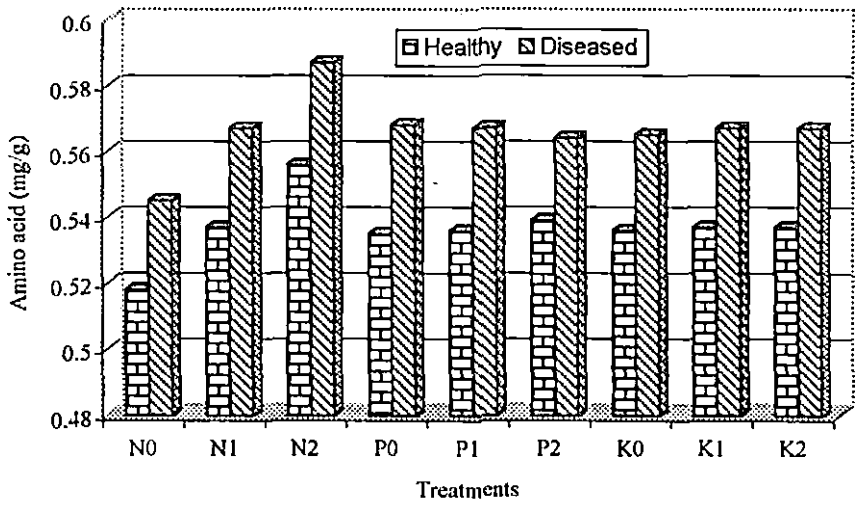


Fig. 7. Effect of different levels of NPK on amino acid content of healthy and diseased leaf tissues of grey blight of coconut (main effect)

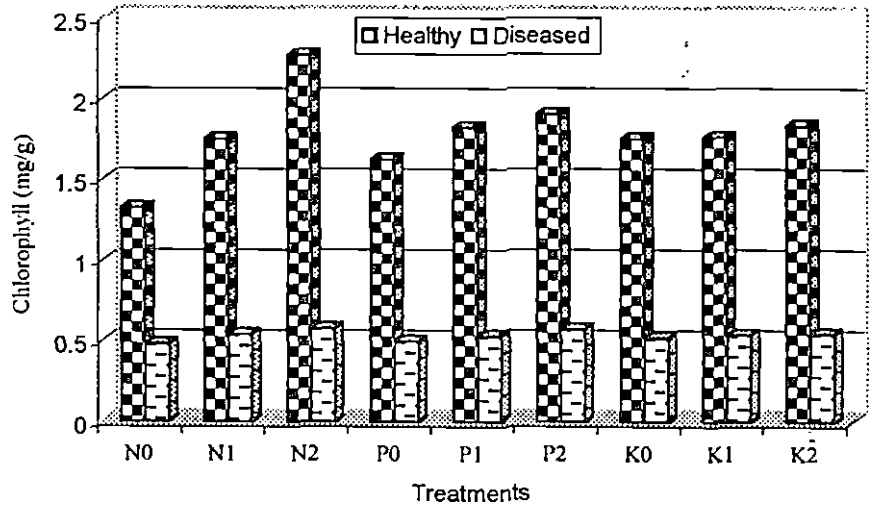


Fig. 8. Effect of different levels of NPK on chlorophyll content of healthy and diseased leaf tissues of grey blight of coconut (main effect)

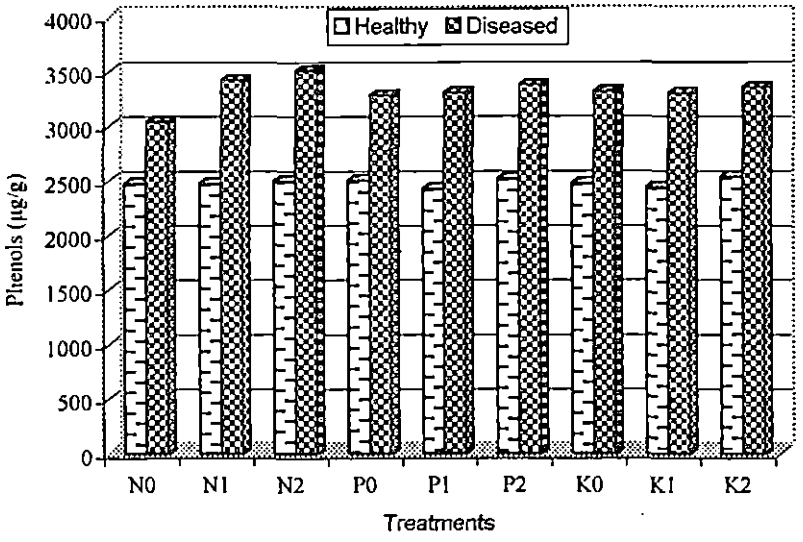


Fig. 9. Effect of different levels of NPK on phenol content of healthy and diseased leaf tissues of grey blight of coconut (main effect)

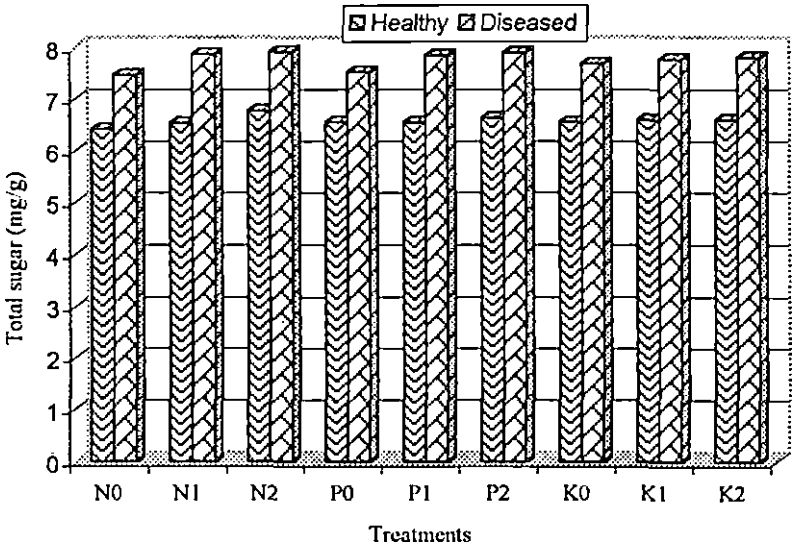


Fig. 10. Effect of different levels of NPK on Total sugar content of healthy and diseased leaf tissue of grey blight of coconut (main effects)

DISCUSSION

5. DISCUSSION

The information on the continuous application of NPK fertilizers on the yield and biomass production of information is available in coconut. But the information on the incidence and intensity of diseases in continuously manured trees are not available so far. Hence, a study was undertaken on the effect of continuous application of NPK fertilization on the incidence and intensity of grey blight of coconut and the nutrient status of healthy and diseased leaf tissues in a thirty seven year old Permanent Manurial Trial (PMT) at the Coconut Research Station, Balaramapuram 2001-2002.

Several fungi have been reported to cause leaf blight of coconut in different parts of the world. *P. palmarum* (Cooke) Stey. was found to be the predominant one in the affected leaves (Papa Rao *et al.*, 1975; Bhaskaran and Ramanathan, 1983).

In the studies conducted at the Coconut Research Station, Balaramapuram only *Pestalotiopsis palmarum* was found to be associated with leaf blight disease of coconut. Further, studies on the morphology of the pathogen confirmed the identity of the pathogen as *Pestalotiopsis palmarum* (Cooke) Stey.

The symptamatology of the disease was described earlier by several workers (Menon and Pandalai, 1958; Francis 1977; Obazee and Ikozun, 1985; Anupama, 1997 and Praveena, 1999).

Symptoms similar to those observed by earlier workers were observed in the present study also. Symptoms were noticed mainly on the injured leaves. In the pathogenicity study using *Pestalotiopsis palmarum*, it was found that pathogen infect very easily if wounds are present on the leaf lets. Similar results were recorded by earlier workers (Bertus, 1927 and Chowdhury, 1946). In the present study it was observed that older

leaves with injury developed symptoms quickly but leaves without injury developed the symptoms very slowly.

The pathogen was unable to infect the young leaves without injury. In some cases fungus developed symptom on the leaf lets when artificial wounding was not made. This might be due to the presence of wounds already made by insects. It can be concluded from the study that *P.palmarum* is a weak pathogen. Brown (1975), based on the studies on phytopathogenicity of *Pestatiopsis mangiferae*, observed that the organism is a weak pathogen capable of infecting only injured leaves.

The growth and sporulation of the fungus was influenced by different media. PDA, PSA and Richards agar were found to be ideal for supporting the growth and sporulation of the fungus. Verma (1967) reported that the variations in the growth and spore size of certain fungi were influenced by different substrates. Rangaswamy and Sambadan (1962) noticed that the conidial size of *Pestalotia psidii* varied according to the substrate on which they were grown. *P. palmarum* was found to grow well in media containing certain carbon sources like dextrose and starch.

Das *et al.* (1985) reported that sucrose was the best carbohydrate for growth of *P. palmarum* while lactose and glucose, gave maximum sporulation. Peptone was the best nitrogen source followed by ammonium oxalate. In the present study also sucrose and dextrose supported the best growth and sporulation of the pathogen.

The disease intensity was high at N_2, P_2 and K_2 levels of fertilizer applications. In two-way interaction also, it was observed that N_2P_1 and N_2P_2 combinations showed maximum disease intensity. In PK combinations P_2K_2 showed the maximum disease intensity.

In three way interaction maximum disease intensity was noticed with $N_1P_2K_2$ and $N_2P_1K_2$ levels. It is inferred that in main and interaction combinations higher levels of nutrients has a significant role in disease intensity.

When the different levels of nitrogen and phosphorus fertilizer were given, there was not much variation in disease intensity, while an increasing trend in the disease intensity was observed when potash fertilizer was applied at double the dose (K_2 level). Even though potash has an important role in disease resistance, higher dose of K in combination with higher levels of N and P might have made the palms more susceptible to grey blight incidence. Karthikeyan and Bhaskaran (1997a) reported that severity of grey blight with increased levels of nitrogen. Application of nitrogen and phosphorus in soils deficient in potash increased the incidence of grey blight in coconut (Alonzo and Palomar, 1980). Increased incidence of Thanjavur wilt of coconut with increased dose of nitrogen and potassium were reported by Bhaskaran *et al.* (1978). A similar observation was made in the present study also. Higher dose NPK application resulted in the increased occurrence of grey blight.

Irrespective of the levels and combinations of nutrients, the disease occurrence was high in the month of August. The higher levels of nutrient application favoured increased development of cell sap which might have favoured the disease occurrence along with favourable weather conditions in the month of August. Francis (1977) recorded high intensity of grey blight with palms treated with the recommended dose of nitrogen and double the recommended dose of P and K. The present findings were also in agreement with above report. The present study was conducted in a field where permanent manurial trial is being conducted for the past 37 years. Hence, the increased levels of K applied to the field for such a long period might have influenced the content of other nutrients.

The disease intensity was high in palms, which received $N_1P_2K_2$ level of fertilizers in the month of August followed by the same level in the month of June. The high dose of fertilizers coupled with favourable weather parameters might have aggravated the disease intensity. Wilt incidence in coconut palms were increased with double the dose of normal

NPK application (Vijayan and Natarajan 1975). Francis (1977) concluded that an increase in potassium content caused a decrease in the magnesium and manganese content in the leaf tissues. This decrease in magnesium and manganese contents resulted in an increase in severity of grey blight. The same observation was noticed in the present study.

Tisdale and Nelson (1970) pointed out that the continuous application of potassic fertilizers to the soil could bring about a wide ratio of exchangeable potassium to exchangeable magnesium. High levels of potash fertilizers where the magnesium level of the soil is too low will further aggravate the situation. Andre-voision (1965) stated that potassium has got antagonistic effect on elements like magnesium, calcium and sodium. Hence, it may also be assumed that the low contents of Mg, Mn, Mo and secondary elements in the leaf may be due to this high K levels. A similar trend was seen in the case of diseased leaf tissue also. At the highest level of phosphorus and potash fertilizers, maximum disease incidence was observed. In palms, which received $N_0P_2K_0$, level of fertilizer the minimum disease incidence was observed.

Eventhough grey blight incidence was observed throughout the year, it was severe during the rainy season (August-September-October). An Xianshu and Han Lianjian (1994) and Karthikeyan *et al.* (2002) reported the severity of grey blight in the month of August-December. The present findings were also in agreement with the above report. The maximum disease incidence was associated with moderate rainfall, high relative humidity and high wind speed.

Correlation study revealed a positive correlation with the disease incidence and intensity with rainfall, relative humidity and wind speed. A negative correlation was observed with the disease index and temperature. The wind speed favoured the dissemination of the fungal propagules, while the high relative humidity favoured the sporulation and germination. The influence of weather parameters on the foliar disease intensity has been reported by several workers (Bhaskaran and Kandasamy, 1977;

Chandramohan *et al.*, 1987; Suhag and Duhan, 1984). The present finding on the effect of weather parameters on the grey blight disease incidence was in agreement with the reports of Suriachandraselvan *et al.* (1991).

The role of continuous inorganic fertilizer on the nutrient content of coconut leaf tissues was studied (Table 10, 11, 12, 13, 14 and 15) in the main and interaction effects. In general, an increase in nutrient content was observed with increased level of fertilizer application in both healthy and diseased leaf tissues. But the nutrient contents were comparatively more in healthy than diseased leaf tissues probably due to reduced translocation of nutrients in diseased leaf tissue. The content of K observed in N_2 level (680 g palm^{-1} year^{-1}) in healthy tissues (1.31 %) was almost double of that observed in diseased tissues (0.634 %).

Highest nitrogen content in healthy and diseased leaf tissues was observed at N_2 level (1.66, 0.938 % respectively). Application of nitrogen fertilizer resulted in increased in an nitrogen content in both healthy and diseased leaf tissues but the foliage N content was far below the critical limit of 1.8 to 2.0 per cent prescribed by Mitra (1988). The loamy nature of the soil and continuous non-application of organic manure in the experimental site might have resulted in the leaching loss of nitrogen fertilizer, which in turn resulted in low uptake of nitrogen.

Phosphorus content was high in healthy and diseased leaf tissues at N_2 level (0.103 %), in interaction effects also similar observation was noticed in diseased leaf tissues with N_2P_2 (0.112 %) and $N_2P_2K_0$ (0.116 %). There was variation in the contents of P and K in the healthy and the diseased tissues. Both P and K elements were comparatively very low in the diseased tissues. Relation with P and K nutrients with various diseases of coconut was reported by several workers. Low contents of P and K were observed in the leaves of unhealthy coconut palms of red and black soils (Pandurangaiah *et al.*, 1978). Bhaskaran *et al.* (1978) observed low levels of N and P in the leaves of pencil point disease affected coconut palms. Aggravation of root (wilt) disease of coconut by increased

NPK fertilization was reported by Sahasranaman *et al.* (1964). The dead or necrotic tissues that were unable to translocate these nutrients from the healthy to diseased areas may attribute the accumulation of very low content of these elements. So far no information is available on the status of nitrogen in the grey blight affected tissues of coconut.

The effect of phosphorus was significant in both healthy and diseased coconut leaves. In healthy leaf tissues high content of phosphorus was observed at P_2 level, with main, two way and three way interactions. At the NP interactions, only N and P effects were non-significant in healthy leaf tissues. The contents of phosphorus at the different interactions were very low in the diseased coconut leaf tissues though the same level of phosphorus (P_2 level -450 g) was applied. The low content of phosphorus may be due to impeded translocation of this element from healthy to diseased areas. It may also be attributed to the hindrance offered by the toxins produced by the pathogen. Higher content of NPK and Si in the diseased leaf tissues of coconut root (wilt) affected palms was observed by Varghese *et al.* (1959). In the present study also a low content of phosphorus was observed in the grey blight affected leaf tissue in coconut. The nutrient content of healthy and diseased leaf tissues were highly influenced by application of nitrogen and phosphorus fertilizer. In general N_2, P_2 level gave the highest nutrient contents in the healthy tissue. This may be due to fact that phosphorus stimulates the root growth thereby enhancing the nutrient uptake significantly. Phosphorus deficiency resulted in poor root development and discolouration of the leaves. Francis (1977) reported an increase of K in coconut leaf tissue with increased levels of potash application. In case of K, the highest content of K was noticed in the healthy tissue at the K_2 level (900 g palm^{-1} year^{-1}) in the main, two way and three way interactions (K-1.48 %, N_2K_2-1.59 %, P_2K_2-1.49 % and $N_2P_1K_2$-1.63 % respectively).

In diseased leaf tissues, highest value for K was observed at K_2 level, in all the interactions, except three ways. But the K content was

low compared to healthy leaf tissue (0.785, 0.798, 0.839 % respectively). The low content of K accumulation in the diseased leaf tissues at the same level of potash application may be due to interrupted transport of this element from healthy to the diseased tissues. No studies are available so far on the content of K in grey blight diseased leaf tissues of coconut.

Low content of K was observed by Pandurangaiah *et al.* (1978) in the unhealthy coconut palms in red soils. But high content of NPK was reported in the leaves of root (wilt) affected palms (Robert *et al.*, 1975). It is imperative that application of higher dose of fertilizers favoured the excessive development of plant sap, which in turn favour the occurrence of diseases (Child, 1964).

Calcium and Magnesium content were high at N_2 level of fertilizer application in healthy leaf tissue in the main and two-way interactions (Ca-0.343 and Mg-0.322 % respectively). The same effect was noticed at P_2 level of phosphorus fertilizer application. But it was observed that there was not much variation in magnesium content at P_2 level.

Highest Mg content was observed at K_0 level while Ca was highest at K_2 level. So at higher doses of N and P and at low levels of K, the higher contents of secondary elements were accumulated in the leaves, almost similar effect was observed at the two-way interaction also. At N_2P_2 and $N_2P_1K_2$ levels higher Ca was observed. Sulphur was significant at $N_1P_0K_2$ and was on par with various levels whereas magnesium was highest $N_2P_2K_0$, which was on par at $N_2P_2K_1$. At the higher level of potash application only the content of Mg was found to be lower. This shows the antagonistic effect of K on Mg. The decrease in Mg content with increase in the levels of K was reported by Francis (1977) and Prabhakumari (1992). The regular application of K in soil having low cation exchange capacity (5.5 me /100 g) may soon bring about the

antagonistic effect between K and Mg, which may have on influence on the disease development.

In the diseased leaf tissues also, the highest content of Ca and Mg were observed at N_2 and P_2 level fertilizer application. In case of potassium except Mg, the other two secondary elements were found to be highest at K_2 level though the S content was non-significant. Mg content was highest at K_0 level and lowest at K_2 level. The same observation was noticed in two-way interaction at K_2 level. At the three way interaction, the effect of secondary elements were non significant. Studies were available on the contents of Ca and Mg in the index leaf of coconut but no studies were available on the nutrient content of grey blight affected leaf tissues.

Minor elements recorded the same trend in healthy and diseased leaf tissues. In the case of main effect except, the content of Zn and Mo, all the other minor elements were found to be highest at N_2 level of fertilizer application. At N_1 level the highest contents of Zn and Mo were observed.

In both healthy and diseased leaf tissues Fe and Cl contents were high at P_2 level of phosphorus application though the contents were comparatively very low in diseased tissues. The contents of other elements were different at different levels of phosphorus application.

With respect to potassium, all the minor elements were high in the healthy leaf tissue. Fe and Mo were highest at K_1 level, in diseased leaf tissue.

At the two-way interactions it was observed that in both healthy and diseased leaf tissues, the contents of Mn and Cu were high at N_2 level of fertilizer application. Fe content was observed to be high at P_2K_1 level of fertilizer application though the contents were high in diseased tissues.

Though a high content of Fe was observed in the diseased leaf tissues at $N_2P_2K_1$ level, the same trend was found in healthy, leaf tissues also. In both cases except Zn, all other elements were found to be non-

significant. High contents of Mn and Cu were observed in diseased leaf tissues at $N_2P_0K_2$ level. A high content of Al, Mn, Cu and Cl were recorded in the healthy leaves of root (wilt) affected coconut (Biddappa and Cecil, 1984). Mathew and Thomas (1977) reported that there was no correlation in the status of Ca and Mg in the leaf and soils of root (wilt) affected palms. Davis and Pillai (1966) reported that the leaves of root (wilt) affected palms contained more of B, Cu, Mn and Zn. In a nutritional study with NPK fertilizers in coconut palms, Kamaladevi *et al* (1976) reported increased contents of Zn, Mn, Cu and Fe. The leaf status of B and Mo remained unchanged. No studies are available so far on the contents of minor elements on the grey blight infected leaf tissues of coconut.

The different levels of N, P and K had a significant effect on the contents of the different biochemical constituents.

In the present study it was observed that the chlorophyll content was high at N_2 level in both healthy and diseased leaf tissue. In the diseased leaf tissue, the chlorophyll content was very low compared to the healthy tissues (0.576 mg g^{-1}). Though the quantity of nitrogen applied was 680 g^{-1} $palm^{-1}year^{-1}$ (N_2 level) the content of chlorophyll was low in the diseased leaf tissue.

In general with increase in disease intensity the photosynthetic pigments were decreased. Karthikeyan (1997b) in his study on the post infectional changes in grey blight of coconut reported that there was decline in the chlorophyll contents in coconut palms. The P and K fertilizers had no effect on the chlorophyll content in diseased leaf tissue. Shanta *et al.* (1959) recorded partial or complete disappearance of chlorophyll in the leaves of root (wilt) coconut palms and attributed that the disintegration and degeneration of the chloroplasts resulted in the destruction of chlorophyll in the affected areas, which in turn reduce the photophospharation.

But the high contents of chlorophyll were observed in the healthy tissues at P_2 and K_2 level (450, 900 $g^{-1}palm^{-1}year^{-1}$). The low contents of chlorophyll in the infected tissues at this level of fertilizer application may be due to fact that the dead tissues were unable to assimilate the nutrient elements, which in turn assist in the production of chlorophyll.

Das (1994) observed reduction in chlorophyll content in diseased leaves of rice plants infected by *Gerlachia oryzae*. The low content of chlorophyll in the diseased tissues may be due to fact that there is decrease in the synthesis of pigments in infected tissues. Destruction of chloroplast through protolysis by the pathogens were also reported (Mayer *et al.*, 1969). However, no reports are available so far on the decrease in the content of chlorophyll in the grey blight diseased plant tissue at the different levels of NPK fertilizer application in the coconut palm.

Phenol content was observed to be significant at P_2 and K_2 level in healthy tissues (2514.89 and 2532.39 µg/g).

At K level, the content of phenols were non significant in diseased tissues. The phenol production is significant with fertilizer application in healthy tissues. Susceptibility or resistance of host to pathogens is correlated with the phenolic contents of the host tissues. In the present study, in general a high content of phenolics was observed in the diseased leaf tissues. Increased content of phenolics in coconut being infected by *P. palmarum* was reported by Karthikeyan (1997b). Ramanujam (1983) isolated a phytoalexin which is phenolic in nature from the culture of *P. palmarum*. Increased content of total and O.D phenols was reported in the mango leaves infected by *Pestalotiopsis mangiferae* compared to healthy leaves. In case of guava, increased phenol accumulation was observed in both resistant and susceptible cultivars infected by *Pestalotiopsis versicolor*. Accumulation of phenolics in the diseased tissue was reported by Bhaskaran *et al.* (1978). However, no reports are available on the increased content of phenolic production in the diseased leaf samples affected by grey blight of coconut with different levels of NPK fertilizers.

The phenols produced in the infected host tissues may be incompatible for the pathogen. Hence there was an accumulation of increased phenolic levels in the diseased leaf tissues. Sugars are the precursors of phenolics and the accumulation of sugars in the infected tissues also result in the increased levels of phenolics. In the present study an increased levels of sugars was observed in the diseased leaves. This increased sugar content might have enhanced the synthesis of phenolics which inturn increased the disease intensity. Moreover *in vitro* studies revealed that *P. palmarum* was a sugar loving pathogen.

Content of total sugars was significant at the different levels of NPK in both healthy and diseased tissues. At the two levels of N, P and K significant increase in the content of total sugar were observed in both the healthy and diseased tissues. But high content of total sugar was observed in the diseased tissues at two levels of NPK application (N_2-7.93 mg/g, P_2-7.90 mg/g, K_2-7.81 mg/g). Higher quantity of sugars in susceptible leaves of coconut infected by grey blight was reported by Karthikeyan and Bhaskaran (1997b). A similar finding was observed in the present study also.

In the cultural studies also, the pathogen favoured dextrose and sucrose amended solid media for growth and sporulation. These findings indicate that the *P. palmarum* is a sugar loving pathogen and the grey blight disease is a high sugar disease. Soluble sugar constitutes the readily oxidisable substrate for the host as well as for the pathogen (Karthikeyan, 1997b). Increase in sugar content in the diseased leaf tissues were observed by several workers (Narayanaswamy, 1983; Sakthi and Joshi, 1973). However, no reports are available in the increased contents of total sugars in the grey blight infected coconut with the different levels of NPK fertilizers.

Contents of amino acids were found to be significant in healthy and diseased leaf tissues at the different levels of NPK. Maximum amino acid quantity was observed at N_2P_2 level of fertilizer application (0.556 mg/g,

0.539 mg/g respectively). At different levels of K no significant effect was observed. The increased amino acid accumulation in the diseased tissues may be due to deranged cell metabolic activity due to infection, by which, proteins synthesis might have been blocked. However, no studies are available on the contents of total amino acids in the healthy and diseased leaf tissues with different levels of NPK fertilizers in coconut palms.

The results of the present investigation clearly shows the influence of fertilizer application on the incidence of grey blight of coconut. The recommended dose of NPK fertilizer (340, 225,450 $g^{-1}palm^{-1}year^{-1}$) is the ideal dose of nutrient for the palms from disease point of view.

The study also revealed the contents of major, secondary, minor elements and biochemical constituents in the diseased and healthy tissues. Further, it gives certain indications regarding the effect of weather parameters on the disease incidence. This may help in forecasting the disease well in advance thereby helping the farmers in adopting suitable and timely plant protection measures.

SUMMARY

6. SUMMARY

The investigation on "Effect of nitrogen, phosphorus and potassium on incidence and intensity of grey blight of coconut" was conducted during 2001-2002 was conducted for a period of one year in a Permanent Manurial Trial (PMT) at Coconut Research Station, Balaramapuram. The experiment was laid out in a 3^3 confounded factorial design with two replications.

The pathogen associated with grey blight of coconut was isolated from the infected leaf tissues on PDA. Based on the cultural and conidial morphology the pathogen associated with the disease was identified as *Pestalotiopsis palmarum* Cooke (Stey). The pathogenicity studies also confirmed the pathogen. Among the different solid media tested for the growth and sporulation of the pathogen, potato dextrose and potato sucrose agar were found to be the best for growth and sporulation. Sabouraud's agar recorded the least growth and sporulation.

The largest conidia in the culture were observed on potato dextrose agar, potato sucrose agar and conidia collected from the host where as the smallest was observed on Sabouraud's agar.

The occurrence of the grey blight was correlated with NPK fertilizer application. It was observed that the disease incidence and the intensity increased with the increased levels of fertilizer application. The disease intensity was maximum in palms applied with $N_1P_2K_2$ level of fertilizer in the month of August. The minimum intensity was observed at $N_2P_2K_0$ during the month of February.

The disease occurred throughout the year, while the incidence and intensity was maximum in the month of August and declined till February and then gradually increased.

The highest disease incidence and intensity were observed when the relative humidity was above 83 per cent. The maximum temperature at this period was 29.7^{0}C and the minimum temperature 20.7^{0}C. The rainfall

during this period was 243.3 mm. These weather parameters were observed during the month of August.

The lowest disease incidence and intensity was observed when the relative humidity was 77.2 per cent. The maximum temperature was 31.4^{0}C and minimum temperature 22.3^{0}C. Rainfall during this period was 15 mm. These weather parameters were recorded during the month of February.

The study on the effect of weather parameter on the grey blight occurrence revealed that there was a positive correlation with rainfall, relative humidity and wind speed whereas a negative correlation with temperature. This is the first study in Kerala on the effect of different NPK levels and weather parameters on the grey blight disease of coconut.

The nutrient studies of major, secondary and minor elements both in healthy and diseased leaf tissue of coconut was studied. It revealed that in general there was an increased on the major, secondary and minor elements in both healthy and diseased leaf samples. But the content of Mg was decreased at higher levels of K application in both healthy and diseased leaf tissue. In case of Zn and B, there was decrease in the content at higher levels of P application in both healthy and diseased leaf tissue. This trend shows the antagonistic effect of K on Mg and P on Zn and B.

In healthy leaf tissue amino acid, phenol and total sugar contents were found be high with higher levels of fertilizer applications. The same trend was observed in diseased leaf tissue except chlorophyll. This is the first study on the nutrient status of grey blight diseased and healthy leaf tissue of coconut palms in India.

From this study, it is recommended that the level of $N_1P_1K_1$ (340, 225, 450 g per palm per year) is the ideal recommendation for coconut palms from disease point of view.

Since Mg is available only in the soil, other sources of Mg has to be supplied in order to overcome the antagonistic effect of potassium.

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7. REFERENCES

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EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM NUTRITION ON INCIDENCE AND INTENSITY OF GREY BLIGHT OF COCONUT *(Cocos nucifera.* L.)

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8. ABSTRACT

The investigation on the "Effect of nitrogen, phosphorus and potassium on incidence and intensity of grey blight of coconut" was conducted during 2001-2002 at the Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala. The coconut palms cultivated in the Permanent Manurial Trial experimental plot of the station was used for the studies.

The pathogen was isolated from the infected leaf tissue by the standard tissue isolation technique. Cultural and morphological studies confirmed the identify of the pathogen as *Pestalotiopsis palmarum* (Cooke) Stey. Among the different artificial media tried potato dextrose and sucrose were the best for growth and sporulation of the pathogen.

Conidial morphology of fungus was studied on six media. The fungus produced largest conidia and appendages on PDA and PSA, while those produced on PDA had the maximum breadth.

The maximum incidence and intensity of grey blight was observed in the month of August. During the subsequent months it declined and the least was observed in February.

The incidence and intensity of the disease was correlated with different levels of NPK fertilizer application and nutrition status of palms.

Higher rate of nitrogen, phosphorus and potash application in soil resulted in higher rate of these nutrients in the leaf samples and higher rate of the disease.

The disease intensity was maximum in palms supplied with the treatment combination $N_1P_2K_2$ and minimum in $N_2P_2K_0$.

The highest disease incidence and intensity were observed when the relative humidity was above 83 per cent. The maximum temperature at this period was 29.7^{0}C and the minimum temperature 20.7^{0}C. The rainfall

during this period was 243.3 mm. These weather parameters were observed during the month of August.

The lowest disease incidence and intensity was observed when the relative humidity was 77.2 per cent. The maximum temperature was 31.4^{0}C and minimum temperature 22.3^{0}C. Rainfall during this period was 15 mm. These weather parameters were recorded during the month of February.

There was a positive correlation on the incidence and intensity of grey blight with rainfall, relative humidity and wind speed where as a negative correlation was observed with temperature.

Nutrient composition of the healthy leaf tissue indicated that with an increase in the nitrogen level, there was a corresponding increase in the nutrient status of major, secondary and micronutrients. A similar trend was noticed with phosphorus and potassium also. However, with increase in potassium level there was a corresponding decrease in the magnesium content. Similarly with an increase in phosphorus a decrease in zinc and boron content was observed both in healthy and diseased leaf tissues.

Both in two way and three way interactions, involving NP, NK, PK and NPK the composition of nutrients of healthy as well as in diseased leaves increased with increase in the levels of nitrogen, phosphorus and potassium.

Chlorophyll, total sugar, amino acid and phenol contents in healthy tissues were found to be high with higher levels of fertilizer application. The same trend was observed in diseased leaf tissues except chlorophyll.

APPENDIX

APPENDIX I

Meteorological data (April 2001 – April 2002) (Mean of 14 values)

Sl. No.	Period	Temperature, ^{0}C			Relative humidity, %	Rainfall (mm)	Wind speed (kmph)
		Maximum	Minimum	Average			
1	April 2001	31.3	21.9	26.6	79.5	209.0	5.6
2.	June 2001	31.5	21.9	26.7	81.5	189.1	6.6
3.	August 2001	29.7	20.7	25.2	83.6	243.3	7.8
4.	October 2001	30.1	24.0	27.1	83.7	407.6	8.5
5.	December 2001	30.6	22.9	26.8	81.2	129.4	5.7
6.	February 2002	31.4	22.3	26.9	77.2	15.0	7.0
7.	April 2002	33.1	24.2	28.7	76.4	33.7	8.3