CHARACTERISATION OF BORON DEFICIENT COCONUT PALMS (*Cocos nucifera* L.)

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2017

DECLARATION

I, hereby declare that this thesis entitled **"CHARACTERISATION OF BORON DEFICIENT COCONUT PALMS (*Cocos nucifera L*)"** is a bonafide record of research work done by me during the course of research and 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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ABBREVIATIONS

%	:	Per cent
Al	:	Aluminium
AOAC	:	The Association Official Agricultural Chemists
B	:	Boron
B(OH)4	:	Orthoboric acid
C	:	Carbon
CD	:	Critical Difference
CDB	:	Coconut Development Board
cm	:	Centimeter
CPCRI	:	Central Plantation Crops Research Institute
CRD	:	Completely Randomized Design
Cu	:	Copper
dm	:	desimeter
et . al	:	et alia
Fe	:	Iron
Fig.	:	Figure
g	:	gram
ha	:	Hectare
HCl	:	Hydrochloric acid

K	:	Pottassium
kg	:	Kilogram
mg	:	Milligram
MIS	:	Mean Intensity Score
ml	:	milli litre
mm	:	milli meter
Mn	:	Manganese
MSL	:	Mean Sea Level
N	:	Nitrogen
ppm	:	Parts per million
PS II	:	Photosystem two
t	:	tonne
TNAU	:	Tamil Nadu Agricultural University
WCT	:	West Coast Tall
Zn	:	Zinc
ZREAC	:	Zonal Research and Extension Advisory Council

INTRODUCTION

1. INTRODUCTION

The coconut palm is referred to as 'Kalpavriksha' - the 'tree of heaven' as each and every part of the palm is useful to mankind in one way or other. It provides food, drink, fuel and timber. Millions of families in India depend on coconut for their livelihood either directly or indirectly. In the world statistics of coconut, India ranks third in area occupying 2.141 million ha with a production of 21665 million nuts (CDB,2014). The four southern states viz Kerala, Tamil Nadu, Karnataka and Andhra Pradesh are the major coconut producing states in India accounting for more than 90 per cent of area and production. Coconut production in Kerala plays an important role in the state economy and culture of Kerala .

Coconut palm remains in the same soil for nearly 100 years and requires sufficient nutrition for substantial yield since the crop produces nuts throughout the year. State Planning Board in a recent assessment of the fertility status of the soils of Kerala reported that 65% of the soils are deficient in boron. In Kerala 6.5 lakh ha area is under coconut cultivation. As the 65% of the soils is deficient in boron majority of the coconut growing areas will express one or the other symptoms of the deficiency. During the XXX1st ZREAC workshop of southern zone of Kerala, boron deficiency has been identified as an emerging problem in coconut. Boron deficiency is reported to be a common and widespread disorder of palms throughout the world also (Corrado *et al*., 1992; Kamalakshiamma and Shanavas,2002; Elliott *et al*., 2004; Broschat, 2007a) .

Boron is a micronutrient needed by plants in very small quantities but must be available to satisfy the requirements of major functions in plants. B deficiency is becoming a serious problem in the commercial production of coconut, Kamalakshiamma *et al.* (2001) listed forty four boron deficiency symptoms in coconut. Fused leaf, accordion leaf, floral necrosis and premature nut drop are associated with B deficiency in *Cocos nucifera.* Fruits of B deficient *Cocos nucifera* were often cracked, had blackened husks, or lacked a shell. A strong correlation was found between copra production and B fertilization rates. (Kamalakshiamma and Shanavas, 2002). The deficiency leads to twists or bends in the stems, failure of apical meristems to fully open and expand. In some cases, necrotic truncation of the leaves may result in an inverted V shape (Broshat, 2011).

Visual deficiency symptoms can thus be a powerful diagnostic tool for evaluating the nutrient status of plants but these do not develop until after there had been a major effect on yield, growth and development (Taiz *et al*., 2010). Thus identification of earlier symptoms assumes importance and the symptoms associated with boron deficiency need to be hence grouped based on severity of damage which may be useful while management practices are undertaken.

The presence of boron deficiency symptoms in palm need not necessarily imply that the soil is deficient in that element. There are other external factors also which interfere with the boron availability. The predisposing factors leading to the development of boron deficiency should be identified and can be recommended for correction prior to the application of any corrective fertilizers. The morphological characterisation of the boron deficient coconut palms will help to understand the extent of damage that occurs due to deficiency. Hence in this context an experiment was undertaken with the objective of identification of boron deficient coconut palms and predisposing factors responsible for deficiency based on the visual diagnosis and to study the morphological characters of boron deficient and healthy coconut palms.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cocos nucifera L. is a perennial tropical species of the Arecaceae family, one of the most important in the Monocotyledoneae class. The coconut palm sustains the livelihood of millions of people in coastal regions of the tropics and subtropics. Though Kerala is known as the land of coconut, the per palm production is much less when compared to that of other coconut growing states of India. This is because of some of the diseases or deficiencies that commonly occur in coconut growing areas in the state.

Though a lot of studies had been conducted on the response of coconut to macronutrient application, investigations on micronutrients in relation to coconut cultivation were quite few. In India except in the case of boron, a general concept is in favour of application of only major and secondary nutrients to coconut. Deficiency of micronutrients is more common in light textured and calcareous soils. The tropical acid soils are in a better position with respect to micronutrients such as Fe, Mn, Zn and Cu since these cations are easily soluble and readily available under acid soil conditions. But introduction of high yielding varieties, intensive cropping systems, use of high analysis fertilizers and accompanied changes in the soil management practices have altered the availability of micronutrients. Utmost care must be taken in the management of micronutrients since the range of deficiency and toxicity is very narrow (Prema,1996).

Among the micronutrient deficiencies, boron deficiency is most widely seen in coconut. Unlike other micronutrients, boron has not been shown to form a part of any enzyme system. Boron (B) is a unique non-metal micronutrient required for normal growth and development of plants. Boron is essential for cell structure of plants (Warington, 1923). Boron is concerned in the water relations in cells and in the translocation of sugars within the plant. It enhances tissue respiration and it has role in germination of pollen. Boron controls the action of calcium in the plant and helps to keep calcium in a soil (Prema, 1996).

Boron is considered as one of the essential micronutrient elements for plant growth. Deficiencies of micronutrients, particularly of boron are being reported in coconut. The problem has further been aggravated by intensive cultivation and use of high inorganic fertilizers, without using organic supplements. Widespread boron deficiency was reported in parts of Assam, West Bengal, Kerala and other parts of the world (Brunin and Coomans, 1973; Cecil and Pillai, 1978;Cecil *et al,* 1991 and Nambiar, 1994). Soils differ widely in their micronutrient supplying capacity regardless of the total content.

In soils, concentration of total B is reported to be in the range of 20 to 200 mg B kg-1 and its available concentrations also vary greatly from soil to soil (Mengel and Kirkby, 1987).

The possible roles of B include sugar transport, cell wall synthesis, lignification, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, and as part of the cell membranes (Parr and Loughman, 1983; Welch, 1995; Ahmad *et al*., 2009).

The boron deficiency symptoms on the mild palms observed were sharply bent(hooked leaf)leaflet tips and transverse transluscent streaking on the leaflets and in the severe palms symptoms observed were rachis tips devoid of leaflets, tightly fused new leaves along entire length, at leaf tip or at the base, new leaves may emerge small in size, with crumpled, corrugated or accordion-like leaflets, premature fruit loss, dead inflorescences and entire crown bent in one direction or twisted leaves (Brown,2007).

2.1. IDENTIFICATION OF BORON DEFICIENT COCONUT PALMS

Hook leaf is common in *Cocos nucifera* and *Elaeis guineensis* and has been attributed to B deficiency by Ollagnier and Valverde (1968); Brunin and Coomans (1973) and Manciot *et al*. (1980). Boron deficiency is expressed in a range of leaf symptoms. However, in all cases the distal end of leaflets at the tip of the frond are most affected. Pinnae are misshapen, stiff and brittle. "Hook leaf" is one typical symptom of B deficiency (Uexkull and Fairhurs, 1999).

According to Kumar 2015, leaf crinkling is one of the earliest symptoms of boron deficiency and manifested as hooked leaf. These hooked leaves are rigid and which is not possible to straighten out without tearing the leaves. And the leaves will have a serrated zig zag appearance. The failure of newly emerging spear leaves to open normally is one of the most common symptoms of boron deficiency. During the chronic stages of deficiency multiple unopened spear leaves may be visible at the apex of the canopy. Corrado *et al*., (1992) reported boron deficiency could also be chronic, affecting a series of successive leaves as they develop. As an immobile element, B deficiency causes leaflet fusion and malformation, truncation, and reduction in the size of newly emerging leaves.

Shorrocks,1(1997) observed that boron deficiency characteristically damages the shoot apical meristem of palms, where the leaf primordia develop within the apical bud. When new growth emerges it is often deformed. According to Caldwell (1997) palms with feather-shaped fronds may be more susceptible to boron deficiency than palms with palmate leaves.

Boron is immobile in plants ; hence , deficiency symptoms appear on younger tissue. Boron is involved in cell division, pollination, and cell wall synthesis in plants. When deficient, the growing point of plants stop developing and will eventually die if the deficiency persists (Kelling,1999). Studies conducted on coconut revealed that deficiency of boron caused malformations of various types and shapes in the leaf as well as the nuts resulting in stunted growth and low productivity in coconut. All the symptoms may not appear on a single palm at any given time. The identification of different types of symptoms of boron deficiency in the field is very important for the coconut cultivators (Kamalakshiamma and Shanavas ,2001).

Kamalakshiamma and Shanavas (2002) reported that floral necrosis and premature nut drop are associated with B deficiency in *Cocos nucifera*. They also noted that fruits of B deficient *Cocos nucifera* were often cracked, had blackened husks, or lacked a shell.

Boron is an essential micronutrient for coconut, which helps in the multiplication of meristematic tissues. It helps the metabolism of protein, synthesis of pectin, maintenance of water relation, translocation of sugars, fruiting process, growth of pollen tube and in the development of flowers and fruits. It was revealed for the first time that many other symptoms, viz., crinkling, whipping, hooking, cracking, bulging in the base of the nut; cracking in the husk, shell and inside the mesocarp; discolouration of mesocrarp; decaying of the kernel resulting in poor quality copra; production of nuts without shell formation; formation of branched inflorescence, inflorescence with blackish colour, etc. hitherto unknown due to nutrient deficiency were also due to boron deficiency (Kamalakshiamma, 2004).

Broschat (2007) viewed that boron deficiency could be extremely transient, affecting developing leaves for as little as a day or 2 before normal growth resumes. Hooked leaves appear to be symptoms of a mild and transient B deficiency. Boron-deficient palms often abort their fruits prematurely and inflorescences may have extensive necrosis near their tips.

Micronutrient elements, iron, manganese, copper and zinc are not generally found limiting in the nutrition of oil palm on acid soil conditions. Boron deficiency is occasionally found on young palms in the field showing a reduction of leaf area in certain leaves producing incipient 'little leaf', advanced 'little leaf' with extreme reduction of leaf area and bunching and reduction in the number of leaflets and 'fish-bone' leaf. The 'fish-bone' leaves are abnormally stiff with leaflets reduced to projections. Leaf malformations including 'hook leaf' and corrugated leaflets are some other associated symptoms. Soil application of 50 - 200 g borax decahydrate per oil palm, depending on age and severity of symptoms is practiced for correcting the malady(TNAU Agriportal, 2013).

Patnude and Nelson (2012) observed that deficiency in boron limits and distorts the foliar growth of many palm species. Deficiency may cause chlorosis (yellowing) in young leaves, shortening of terminal internodes, or "scorched" leaf tips .

Boron nutrient is predominantly found in the cell wall, forming complexes with pectic substances (Hu and Brown, 1994). According to Dannel *et al.*, (2000) the plants with deficiency of boron (−B) began to present the symptoms of deficiency three months after the omission of B from the nutrient solution. The evolution of the symptoms of deficiency was critical after approximately 13 months of the omission of B, which suggests that part of the noncomplexed boron and even the complexed with pectin may have been translocated in the plant.

Boron deficiency causes a wide array of symptoms, not only among species of palms, but also within a single species (i.e. *Cocos nucifera*). A better understanding of the effects of B deficiency in coconut will be important to optimize a rational fertilization management in coconut plants. Thus, modification of PSII photochemistry and gas-exchange in boron deficient green dwarf coconut plants were investigated. The results suggested that a modification of PSII photochemistry (non-stomatic effects) and gas-exchange (stomatic effects) were induced by boron deficiency. Such modifications are manifested by (1) increase in the ratio of total dissipation to the amount of active reaction centres (RCs) [dissipation (DI)/RC] and (2) leaf-to-air vapor pressure difference (VPD leaf-air). These modifications (on PSII photochemistry and gas-exchange) were caused by a decrease in energy absorbed per excited cross-section [absorption flux (ABS)/cross section of the sample (CS0)], density of active reaction centres (RC/CS), maximal trapping rate of an exciton that will lead to QA reduction measured over a cross- section of active and inactive RCs [trapping flux (TR)/CS_0], electron transport per excited cross-section [electron transport flux (ET_0)/CS)], area above curve (proportional to the pool size of the electron acceptors QA on the reducing side of PSII), photosynthesis (A), stomatal conductance (gs), transpiration (E), chlorophyll concentration (SPAD readings), growth parameters (root DW and height plant). The results demonstrated that by analyzing fluorescence (JIP test parameters) derived from the polyphasic fluorescence transients measurements were able to estimate the functional changes of PSII in B deficient coconut plants. The results in this study suggested that fluorescence analysis (JIP test) and instantaneous measurements of gas-exchange can be useful tools in assessing the physiological effects of B deficiency in green dwarf coconut (Pinho, *et.al*, 2010).

Jayasekhara and Lokanathan (1988) reported that the symptoms observed in 12 young coconut palms of age 1-3 years were unsplit, crinkled nature of leaflets; stunted and withered apical leaves; lack of leaflets in some fronds. The symptoms in the untreated affected palms gradually became acute and the palms died after 6-8 months. The critical nutrient concentration range for B in the third leaf was 8-10 ppm and the deficiency could be corrected only at the incipient stages by soil application of sodium tetraborate

The boron deficiency is disturbing the growth of the leaf from initial shape up to the meristem to the final stretching. The symptoms, visible as early as the spear apparition and the opening of the leaflets, induce irreversible deformation and discolouration of the leaf (Corrado, 1992).

Patnude and Nelson (2012) reported that in early stages, boron deficiency appears as subtle leaf wrinkling. In later stages, "accordion leaf" and twisting of petioles or leaf midribs, deformation of leaves or abnormal bending of stem at the stem apex was noticed. The deformations caused by boron deficiency include twists or bends in the stems, failure of apical meristems to fully open and expand and leaf wrinkling or crumpling known as "accordion leaf." Such deformities can range from subtle to gross, the latter associated with severe disease. Chronic boron deficiency will cause spear leaves to emerge unopened at the apex of the canopy. This apical damage can also cause twisting of the petioles and leaves or wrinkles in the leaf tissue.

Boron deficiency symptoms appear due to the role of boron in the growth of cell wall and the plasma membrane (Power and Woods, 1997) and due to its limited mobility or immobility (Hu *et al*, 1997).

In the coconut palms, B deficiency decreases the photosynthetic capacity, since it reduces the electron transportation of photosystem II (–12.5%), photosynthesis (35.7%), sweating (–32.2%) and stomatal conductance (–45.6). Symptoms of B deficiency become visible as soon as the leaf emerges, which occurs two or more months after the occurrence of the deficiency. In coconut palm a transitory boron deficiency can affect leaf development just days before its full growth (Broschat, 2007).

2.2. SOIL AND PLANT BORON STATUS

Boron is an essential element involved in plant metabolism and cannot be replaced by or interchanged with any other element (Patnude and Nelson,2012). The boron deficient plants led leaves and folioles to become deformed. The deficient and sufficient contents of boron varied significantly in the canopy, but(-B) ranged from 9.0 mgkg^{-1} to 11.5 mgkg^{-1} , while in the sufficient palms (+B), the content ranged from 17.2 mgkg^{-1} to 22.9 mgkg^{-1}.

Boron controls the action of Ca in the plant and helps to keep Ca in a soluble form. It is also concerned with N metabolism and oxidation reduction equilibria in cells. In boron deficient situation, the nitrates stored in the roots, leaves and stem may inhibit the formation of amino acids and protein synthesis (Prema, 1996).

In coconut growing tracts of India, available B ranged from traces to 12ppm. The range of available Bis 0.02 to 1.43 ppm in Assam (Chakraborty *et al.*, 1973) and 0.19 to 0.22 ppm in West Bengal (Baranwal *et al.*, 1989). In Kerala,12 percent of soils are having below 0.1 ppm available B.

Ng *et al,* (1968) working with the dura planting materials, reported that B concentration in the oil palm canopy was similar to the stem. They did not find any trend in B concentrations between leaves of different ages and concluded that B may be mobile in the oil palm.

Rajaratnam (1972) by using the tenera planting materials showed increasing B concentrations from the youngest to the oldest leaf suggesting that B is immobile in oil palm. B moves rapidly along the transpiration stream resulting in the accumulation of B at the tips of the oil palm leaf and leaflets.

Boron plays a vital role in transport of carbohydrates, cell wall metabolism ,permeability and stability of cell membranes, and phenol metabolism (Marschner, 1995). Boron one of the essential micronutrient, is responsible for cell wall formation and stabilization and lignification and xylem differentiation and it imparts drought tolerance and plays an important role in pollen germination. Boron deficiency symptoms are conspicuous on terminal buds or youngest leaves which become discolored and may die under acute deficiency. Internodes become shorter and give a bushy rosette appearance. Boron deficiency also induces calcium deficiency.

The total boron content of Kerala soil ranges from 27.5 to 330 mg/kg and the hot water extractable boron ranges from 0.05 to 7.90 mg/kg. About 65 percent soils of Kerala are deficient in boron. The soils of southern and northern coastal planis, low lands of lateritic origin are deficient in boron. Very high levels of boron (>5mg/kg) as well as boron retention are detected Pokkali and Kaipad soils due to sea water inundation and high levels of organic matter(Santhosh, 2013).

The general recommendations for the application of boron to young coconut plants is 30 g of borax applied to the 4th leaf axilla. For mature plants, it is recommended that the micronutrient should be applied directly into the soil - in a dosage of 2 kg ha^{-1} of B as borax (Sobral 1998). When analysis indicates levels lower than 0.2 mg dm^{-3} (hot water) (Teixeira *et al.* 2005). The application of boron directly into the soil is more efficient than foliar techniques due to the low mobility it shows in plant tissues. Boron applied to the soil has a more persistent effect than when it is deposited in leaf axillae (Pinho *et al.*, 2008; Broschat, 2011).

The storehouse of most of the boron in the soil is the soil organic matter. Soils low in organic matter are deficient in boron more often than soils with high organic matter content (Kelling, 1999). Santos *et al.* (2004), in an evaluation of the nutritional status of a coconut palm orchard, reported that boron was one of the most yield limiting factors. According to their findings, the most important elements for coconut production in decreasing importance were K > Ca > B. Under acid soil conditions, boron is more water-soluble and can therefore be leached below the root-zones of plants by rainfall or irrigations. It has also been shown that symptoms of boron deficiency are associated with high soil pH values (alkaline conditions). Reduced boron solubility under alkaline soil conditions can result in less plant uptake and increased potential for boron deficiencies (Muntean, 2007).

The leaf B concentrations did not vary significantly among leaves within the canopy or among leaflets within a single leaf for coconut palm but basal leaflets of paurotis palm had higher B concentrations than central leaflets. Boron concentrations were significantly higher toward the tips of individual leaflets in both species. The boron deficient oil palms in the replanted estates are applied with 100-150 g borate fertilizer two or three times a year from the second year after replanting to manage the deficiency(Ng, 1977). Application of Solubor to the soil significantly increased leaf B concentrations in all leaves of coconut palm after 2 months as well as in new leaves produced up to 6 months later. Application of Solubor as a leaf axil drench was much less effective in increasing foliar B concentrations than soil treatment (Broschat, 2011).

Boron deficiency is widespread because the available boron in the surface soil has been exhausted by the previous oil palm crop, while applications of potash also suppress B uptake by the palm. The boron deficient oil palms in the replanted estates are applied with 100-150 g borate fertilizer two or three times a year from the second year after replanting to manage the deficiency.

Boron deficiency reduces stomatal opening and transpiration (Bejerano and Ltai, 1981), induces plasma membrane solute leakage (Tang and Fuente, 1986), and inhibits meristematic tissue development, resulting in growth inhibition (Marschner, 1995) and maintenance of cell wall integrity (Hu and Brown, 1994).

2.2. IDENTIFICATION OF PREDISPOSING FACTORS

The insufficient amounts of a given nutrient element in the soil can result in a deficiency of that element, most deficiencies are induced by external factors, which either render the element unavailable to the plant or the plant in capable of taking up the element in sufficient quantities. Common causes of nutrient deficiencies in Florida include cool temperatures, poorly aerated soils, root rot diseases, genetic differences among palms, mechanical root injury, planting too deeply, high soil pH and nutrient imbalances (Broschat and Donselman,1985).

The solubility of several soil minerals will be decreased by several factors (Keren and Bingham, 1985) like naturally occurring low fertility levels, removal of nutrients by several successive crops, and the increased use of fertilizers and acidity correctives(Mattiello *et al*.,2009).

The factors affecting B uptake include soil type (texture, alkalinity/calcareousness, pH, organic matter content), B concentration, moisture, and plant species (Welch *et al*., 1991). Brown and Hu (1998) observed that Boron absorption by plant roots is closely related to pH and B concentration in the soil solution and is probably a non-metabolic process. In heavy, clayish soils also boron may be unavailable to plants due to strong adsorption to soil particles (Chaudary and Shukla, 2004).

Silva *et al.* (1995) and Communar and Keren (2006) also pointed out the importance of factors such as sandy soils, low in organic matter and exposed to heavy rains, which drain much of the boron to deeper layers. Chronic B deficiencies caused by soil drying and high soil pH affect multiple leaves and ultimately productivity.

Boron is absorbed from the soil by plants as borate, a negatively charged ion (anion). Since boron is non-mobile in plants, a continuous supply from soil or planting media is required in all plant meristems. In mineral soils, release of boron is usually quite slow. Much of the available soil boron is held rather tightly by soil organic material. As organic matter decomposition occurs boron is released with a portion being absorbed by plants, leached below the root zone area (especially in high rainfall/acid soil areas) or tied up (unavailable) under alkaline soil conditions (Muntean,2007).

The occurrence of B deficiency depends on multiple factors, such as weather conditions (drought, high precipitation, etc.), soil conditions (low pH ,soils B, leaching, calcareous soils B fixation) and the cultivated crop species (Shorrocks , 1997).

When the surface soil dries out plants are unable to feed in the zone where most of the available boron is present. This can lead to boron deficiency. When rain or irrigation moistens the soil, the plant can again feed from the surface soil and the boron deficiency often disappears (Kelling, 1999).

Boron deficiency has been commonly reported in soils which are highly leached and or developed from calcareous, alluvial and loessial deposits (Takkar *et al.*, 1989; Razzaq and Rafiq, 1996; Borkakati and Takkar, 2000).

Several soil factors and conditions render soils deficient in B. Low soil organic matter content, coarse sandy texture, high pH, liming, drought, intensive cultivation , more nutrient uptake than application, and the use of fertilizers poor in micronutrients are considered to be the major factors associated with the occurrence of B deficiency (Dregne and Powers, 1942; Elrashidi and Connor, 1982; Takkar *et al.*, 1989; Goldberg and Forster, 1991; Rahmatullah *et al.*, 1999; Eguchi and Yamada, 1997; Rashid *et al.,* 1997, 2005; Mengel and Kirkby, 2001; Niaz *et al.*, 2002,2007; Rashid and Rayan, 2004).

An experiment was conducted to evaluate the various levels of B on yield of PKM1 tomato. The results revealed that the highest fruit yield of 33 t ha-1 was recorded in treatment that received borax @ 20 kg ha-1 and was found to be significantly superior to rest of the treatments (0, 5, 10, 15 and 25 kg ha-1). The yield increase was about 33.6 per cent over control(Sathya, 2006).

Elrashidi and O'Connor (1982) have shown strong correlations between B and organic carbon contents of soil. Mineralisation of organic matter releases some B. The risk of B deficiency increases when organic matter contents decline (Shorrocks,1997). Somewhat like nitrates, boron is not readily held by the soil particles and moves down through coarse- textured soils, often leaching below the root zones of many plants. Because less leaching occurs on fine textured silts and clays, these soils are not boron deficient as often as sands (Kelling, 1999). When the palms grow near asphalt parking lots or in nutrient-poor soils, characteristic boron deficiency symptoms can develop and become increasingly severe over time (Patnude and Nelson, 2012).

Boron (B) deficiency is one of the most common and widespread of all nutrient deficiencies in palms. It occurs in palms growing in high rainfall areas of the tropics, but is also found in palms growing in desert climates (Elliott *et al.*, 2004).

The availability of boron in soil is affected considerably by soil pH. At low pH, most of the boron compounds are soluble and thus boron remains available to plants as boric acid. In coarse textured soils with low organic matter (sandy and lateritic soils of Kerala) having low pH, boron is lost by leaching as the boron retention capacity of soil is very low. Availability of boron in acid soils decreases with increase in pH. Liming of soil reduces boron availability temporarily due to lime induced boron adsorption and occlusion as $B(OH)_4$ by freshly precipitated Al and Fe hydrous oxides. Organic matter can adsorb and retain both in acidic and alkaline pH. Mineralization of soil organic matter releases boron and makes it available to plants (Rajasekharan *et al.*,2013).

2.2.1. Pest and Disease Incidence

Boron deficiency maintain cell wall integrity (Hu and Brown, 1994) and inhibits meristematic tissue development, resulting in growth inhibition, permeability and stability of cell membranes and phenol metabolism (Marschner, 1995).

Boron is essential for the phenol metabolism (Marschner, 1995). Phenolics including lignin and isoflavones have beneficial effects against diseases when plants are attacked by pathogens (Wang *et al,* 1989, Dixon,1993; Parvez, *et al*, 2004). Phenolics or polyphenols are synthesized through the shikimate phenylpropanoids flavonoids pathways, producing monomeric and polymeric phenols and polyphenols (Lattanzio *et al.*,2006). Phenolics such as benzoquinones (C6), phenolic acid (C6-C1), flavonoids and iso- flavonoids (C6-C3-C6) and lignins (C6)n, (C6-C3-C6)n (Aoki *et al*, 2008; Whiting, 2000) are essential for growth, reproduction and protection of plants against biotic (fungus, bacteria, virus, and insect infection) or abiotic stresses such as drought and temperature.

Lethal yellowing disease (LY) of *Cocos nucifera* is also characterized by inflorescence necrosis and premature fruit drop (Elliott *et al*., 2004). The fruits of lethal yellowing affected palms will usually show blackening of the calyx end, whereas B-deficient fruits will exhibit only random browning, if any, of immature fruits. Other foliar symptoms of either lethal yellowing or B deficiency may be looked into to distinguish between these two disorders (Broschat, 2007).

2.3. MORPHOLOGICAL CHARACTERIZATION

2.3.1. Growth parameters

Kelling (1999) opined that boron is immobile in plants , hence deficiency symptoms appear on younger tissue. Boron is involved in cell division, pollination, and cell wall synthesis in plants. When deficient, the plants growing point stop developing and will eventually die if the deficiency persists. Kamalakshiamma and Shanavas (2001) observed that the length of the petiole and number of leaves reduced due to boron deficiency .

One of the most common symptoms of B deficiency is the failure of newly emerging spear leaves to open normally. They may be tightly fused throughout their entire length, or the fusion can be restricted to basal or distal parts of the spear leaf. In a chronic state, multiple unopened spear leaves may be visible at the apex of the canopy (Broschat, 2007). Patnude and Nelson (2012) noticed that deficiency in boron, limited and distorted the foliar growth of many palm species.

Leaves having abnormally thin leaflets sparsely spaced along the rachis were produced in two of the sand cultured *Syagrus romanzoffiana* without B in a study conducted by Broschat in 2007.

Leaflet fusion was observed in two *Syagrus romanzoffiana* seedlings grown without B in the sand culture experiment (Broschat, 2007). It has been induced in sand culture in *Elaies guineensis* (Rajaratnam 1972, Dufour and Quencez 1979) and *Caryota mitis* (Broschat 1984) and has been attributed to B deficiency in *Cocos nucifera* by , Brunin and Coomans (1973), Manciot *et al.* (1980) and Kamalakshiamma and Shanavas (2002).

The boron deficiency induced premature lignification in the roots of beans(Neales,1960).The absence of boron affects the cells of growing regions and affects the differentiating cells and leads to the death of the growing points (Rajaratnam and Lowry, 1973). Boron deficiency also compromises the coconut palm's radicular system, decreasing the percentage of fine roots, increasing the percentage of thick roots, causing over sprouting, necrosis, darkening and thickening of roots (Power and Woods, 1997). Boron deficiency, in general, reduces root growth (Filho and Malavolta, 1997; Viegas *et al,* 2004) and in the coconut palm tree, production of total roots is reduced by 30% and of thin roots by 48%(Pinho *et al.*2008)

In Southeast Asia, the oil palm is mainly cultivated on the highly weathered Ultisols and Oxisols derived from granite, sandstones and shales. These soils have low soil B contents (Shorrocks, 1997) and therefore, B deficiency symptoms on the oil palm in various types of malformed, younger leaves are common particularly during drought.

Boron deficiency causes premature lignification of the cell walls in the oil palm(Rajaratnam and Lowry,1974) and under severe conditions, at the little leaf stage, yield may decline by about 83%. Thus water soluble B fertilizer such as Fertibor (15% B) is regularly applied at the rate of 1 to 3 kg B ha^{-1} yr^{-1} in the first six years after planting to prevent B deficiency in the oil palm(Rajaratnam,1973).

2.3.2.Yield

Nutritional equilibrium is essential for high and sustainable productivity of the coconut palm tree (Reddy *et al.,* 2002). The most important observations indicate that mineral nutrient deficiencies, mainly micronutrients, cause reductions in the number of feminine flowers per spathe and the fruits, which eventually succeed easily drop off the plant, a condition generally referred to as "abortion of immature fruits"(Siqueira *et al.*,1997;Holanda *et al*,2007).

The study conducted in CPCRI on coconut palms revealed that borax application improved all the yield attributes significantly. In seedlings the leaf emerging after six months of boron application was found to be free from any malformation. But an adult palm would normally take about 8 to 10 months to express the improvement. In seedlings below five years of age, application of borax was found to be effective in reducing the symptoms of leaf rot disease. The number of female flowers per bunch showed a significant increase when the quantity of the boron applied increased. The palms treated with boron showed an increase in the number of bunches in the palm(Kamalakshiamma,2001).

Boron also plays a vital role in pollination and seed production (Gupta *et al.*,1985).The photosynthetic and enzyme activity was improved by B fertilization and it also plays a significant role in protein and nucleic acid metabolism (Satya *et al.*, 2009).Boron deficiency may also cause a functional failure in pollen tubes, the effects of which are evident in the flowers or fruits. Fruits may abort prematurely as a result of severe boron deficiency (Broschat, 2012).

The effect of boron on the nutritional status of the dwarf coconut palm and its productivity when artificially applied to the culture soil was carried out in a four year old, artificially irrigated, orchard in Brazil, between January, 2005 and October, 2006. The soil was a red yellow latosol (B: 0.18 mg dm^{-3}) and the treatments consisted of application of five boron dosages especially zero, 1, 2, 4, and 6 kg ha^{-1}. Boron (borax) dosages were applied in equal halves directly into the soil in the months of January and February of 2005. The higher palm tree production was associated to levels of 0.6mg dm^{-3} of B in the soil and 23.5mg kg^{-1} in leaves. In ninety five percent of palm trees, maximum production was obtained with the use of a boron dosage of 2 and 1kg ha^{-1}. (Moura *et.al.,* 2013).

Boron is important in pollen germination and pollen tube growth, which is likely to increase fruit set. Therefore, boron fertilization may increase yield, particularly when plants are grown on sandy soil with a low content of available boron, as shown by (Wojcik *et al.*,2001 and Nyomora *et al.*2007). The severe boron deficiency has a strong effect on the crop production that could reduce the yield by 84 per cent. This drop is probably caused by the drastic reduction of the leaf area and by metabolic changes (Rajaratnam, 1973).

Kamalakshiamma and Shanavas (2002) found a strong correlation between copra production and B fertilization rates. Boron application in the boron deficient soils increased oil yields in sunflower cultivars (Sumathi *et al*., 2005).

The application of boron fertilizer to a coconut palm orchard increased boron soil and leaf levels and affected fruit production (Moura.*et.al*,2013)

A study was conducted to investigate the effects of five boron (B) doses; 0, 2.5, 5.0, 7.5 and 10.0 kg B ha-1 in B-deficient calcareous soils on yield and some yield components of four sunflower genotypes. Genotypes have shown variations with respect to their responses to B applications. AS-615 and Coban had the highest seed yield (3.75 and 3.23 t ha-1, respectively) at 7.5 kg B ha-1, whereas S-288 and TR- 4098 yielded 4.17 and 3.28 t ha-1, respectively, at 0 kg B ha-1. Therefore, S-288 and TR-4098 can be indicator genotypes for B toxicity. The other genotypes appeared to have high sensitivity to B deficiency. For AS-615 and Coban, application at 7.5 kg B ha-1 level was found to be sufficient for adequate grain yield, whereas further B levels might have detrimental effects on grain yield (Ceyhan *et al.,* 2008).

A study conducted by Harmankaya *et al* (2008) in the common bean (*Phaseolus vulgaris* L.) revealed that the yield losses in this crop may occur due to boron (B) deficiency when the susceptible cultivars are grown in calcareous boron deficient soils. The study was therefore aimed at investigating the effects of three B doses: control (0.0 kg ha^{-1}), soil application (3.0 kg ha^{-1}) and foliar fertilization (0.3 kg ha^{-1}) on yield and some yield components of six common bean genotypes in the B deficient soil (with available 0.19 mg B kg^{-1}). Plant height, pods per plant, seeds per pod, seed yield, protein content, 100-seed weight and B concentration in leaf were studied. Higher yield was obtained from higher

B applied genotypes than those of check. Applications both of soil and foliar B increased yield average of 10 and 20%, respectively. Genotypes had the highest seed yield when B was foliar applied indicating that soil factors affected available B. The highest seed yield was obtained from Karaca_ehir-90 with 4078.2 kg ha-1. Yunus-90 was found to be B tolerant, while the other genotypes appeared to be highly B sensitive. The result showed that B deficiency in common bean might lead to significant yield losses and foliar application should be advised.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled "Characterisation of boron deficient coconut palms (*Cocos nucifera* L.)" was conducted during the period from April 2015 to March 2016. This chapter reveals the methods followed in the identification of boron deficient coconut palms, predisposing factors leading to boron deficiency and the methods and materials used for the morphological characterization of the selected palms.

3.1. IDENTIFICATION OF BORON DEFICIENT COCONUT PALMS

3.1.1. Location of the Study

The study was conducted in Kalliyoor panchayat of Thiruvananthapuram district.

3.1.2. Selection of Respondents

A list of coconut farmers from the krishi bhavan was collected and 160 coconut farmers were selected by simple random sampling. A field visit was conducted in the selected farmer's field to see whether the coconut palms were showing boron deficiency based on the symptoms (Kamalakshiamma and Shanavas, 2002). Hundred coconut fields showing boron deficiency were selected and the number of respondents were 100.

Coconut palms from different farmers field were selected based on the visual symptoms of leaf, inflorescence, nut and crown (Appendix 1). The leaf symptoms were unopened crinkled leaf, crinkled leaf lamina, palms with short petioles, palms with reduced number of leaves, hooked leaf ,fan like or fused leaf ,fish bone appearance ,asymmetric arrangement of leaf with wider space between leaflets, single sided leaf and cracking of petiole. The inflorescence symptoms were necrotic inflorescence, inflorescence with very few female flowers and aborted inflorescence.

The nut symptoms included bunches showing hen and chicken symptom, nut showing cavity, nuts with uneven kernel development, nuts without any kernel, bulging at distal end of nut, cracking of the shell, cracking on the husk, black patches on the surface of the husk and discolouration of the mesocarp. The crown symptoms were crowded crown, crown choking and fully necrotic terminal bud.

3.1.3. Development of Score for Categorizing the Boron Deficient Coconut Palms

A procedure was developed for scoring the coconut palms showing boron deficiency into three groups based on the intensity of deficiency. The group one included palms with mild intensity while group two included palms with moderate intensity and group three included palms with severe intensity. The symptoms identified by Kamalakshiamma and Shanavas (2002) was listed and for developing a score. A pilot study was conducted in the sample area to identify the symptoms which come under the mild, moderate and severe intensity.

Based on symptoms listed by Kamalakshiamma and Shanavas (2002) , and the pilot study conducted, a ten scale score was developed to categorize the boron deficient hundred palms surveyed into three groups based on the intensity of deficiency. Based on the scores developed the mild category palms were given a score which ranged from one to three, the score of the moderate intensity palms ranged from four to six and the score of the palms with severe intensity ranged from seven to ten.

The symptoms of boron deficiency and the ten scale score developed for scoring of palms are presented in Table 1.

Table 1.Symptoms used for developing the score for boron deficiency in coconut palms

Scores	Symptoms	Intensity
I	Hooked leaf + Fused leaf+ Black patches on the surface of the husk	Mild
II	Hooked leaf + Fused leaf+ Black patches on the surface of the husk + Palm with crowed crown	
III	Palms with reduced number of leaves + Hooked leaf + Fused leaf+ Black patches on the surface of the husk + Palm with crowed crown	
IV	Palms with reduced number of leaves + Hooked leaf + Fused leaf+ Black patches on the surface of the husk + Palm with crowed crown + Inflorescence with very few female flowers	Moderate
V	Palms with reduced number of leaves + Hooked leaf + Fused leaf + Black patches on the surface of the husk + Palm with crowed crown + Inflorescence with very few female flowers + Aborted inflorescence + Bunch showing hen and chicken symptom	
VI	Palms with reduced number of leaves + Hooked leaf + Fused leaf + Black patches on the surface of the husk + Palm with crowed crown + Inflorescence with very few female flowers + Aborted inflorescence + Bunch showing hen and chicken symptom + Necrotic inflorescence + Fish bone appearance + Nuts with uneven kernel development+Asymmetric arrangement of leaf with wider space between leaflets	
VII	Palms with reduced number of leaves + Hooked leaf + fused leaf+ Black patches on the surface of the husk + Palm with crowed crown+ Inflorescence with very few female flowers + Aborted inflorescence + Bunch showing hen and chicken symptom + Necrotic inflorescence + Fish bone appearance + Nuts with uneven kernel development + Asymmetric arrangement of leaf with wider space between leaflets + Discolouration of the mesocarp + Nuts without any kernel	Severe

VIII	Palms with reduced number of leaves + Hooked leaf + fused leaf+ Black patches on the surface of the husk + Palm with crowed crown + Inflorescence with very few female flowers + Aborted inflorescence + Bunch showing hen and chicken symptom + Necrotic inflorescence + Fish bone appearance + Nuts with uneven kernel development + Asymmetric arrangement of leaf with wider space between leaflets + Discolouration of the mesocarp + Nuts without any kernel + with high leaflet internodal length	Severe
IX	Palms with reduced number of leaves + Hooked leaf + fused leaf+ Black patches on the surface of the husk + Palm with crowed crown + Inflorescence with very few female flowers+Aborted inflorescence + Bunch showing hen and chicken symptom + Necrotic inflorescence + Fish bone appearance + Nuts with uneven kernel development + Asymmetric arrangement of leaf with wider space between leaflets + Discolouration of the mesocarp + Nuts without any kernel + with high leaflet internodal length + no nut formation	
X	Palms with reduced number of leaves + Hooked leaf + fused leaf+ Black patches on the surface of the husk + Palm with crowed crown + Inflorescence with very few female flowers + Aborted inflorescence + Bunch showing hen and chicken symptom + Necrotic inflorescence + Fish bone appearance + Nuts with uneven kernel development + Asymmetric arrangement of leaf with wider space between leaflets + Discolouration of the mesocarp + Nuts without any kernel + with high leaflet internodal length + no nut formation +Crown choking + Fully necrotic terminal bud	

Each palm showing deficiency symptom was given a score based on the symptom observed in the palm and categorized into palms showing mild, moderate and severe intensity of boron deficiency based on the score obtained. The percentage of symptoms in each category of boron deficient palm based on score was also worked out. From the selected and categorized coconut palms, five palms each from mild, moderate and severe intensity of boron deficiency and five nearby healthy palms were selected for further morphological characterization.

3.2. BORON STATUS OF SOIL AND PLANT

The soil boron status of coconut palms showing deficiency symptoms which were categorized into mild, moderate and severe intensity of boron deficiency were analysed by hot extraction method(Gupta,1967).

The plant boron status of the coconut palm was also analysed from the index leaf of coconut palms showing mild, moderate and severe intensity of boron deficiency. The soil and plant boron status of selected palms were compared with the soil and boron status of the healthy palms. The boron status of soil and plant of selected categorized palms were then compared with the scores developed to see whether the scores developed were correct.

3.2.1. Soil Analysis

3.2.1.1. Preparation of Soil Sample for Boron analysis

Soil samples were collected from the selected coconut fields for analyzing the nutrient status of the soil. Soil samples were taken at 30- 45 cm depth. Soil from five palms of each group and composite samples were prepared by quartering method. The samples were air dried, ground, passed through 2mm sieve and stored air tight. The processed samples were analysed for soil available boron.

3.2.1.2. Estimation of Boron in Soil Samples

Hot water extraction method by Gupta (1967) was adopted for the estimation of B in the soil samples. Air dried and sieved soil sample (20g) was taken in a 250ml conical flask and boiled on a hot plate for 5 minutes after adding 0.5g activated charcoal and 40 ml distilled water. This was filtered immediately through a Whatmann number 42 filter paper and cooled to room temperature. The aliquot (1 ml) was transferred to 10 ml polypropylene tube and 2 ml each of buffer and Azomethine – H reagent were added. After 30 minutes, the absorbance was read on a spectrometer (104) at 420 nm after standardization using B solutions (0.1,0.2,0.4,0.8, and 1 ppm) with the above procedure.

3.2.2. Plant Analysis

Plant samples were collected from the 14th leaf of coconut from the bottom of the crown for analysis (Pushparajah,1998). All the plant samples were dried in oven at 70°C, ground and used for analysis. The Azomethine-H colorimetric method (Wolf, 1971) is the standard procedure used for the analysis of boron.

3.2.2. 1. Estimation of Boron in Plant Samples

Dried plant sample (0.5g) was mixed well with 0.1g calcium oxide powder and transferred to a porcelain crucible placed in a muffle furnace. The furnace temperature was raised gradually to a maximum of 550°C and the sample was ignited completely, and then cooled with water. Three millilitre of dilute HCl (1:1) was added and heated for 20 minutes on a water bath. The content was transferred to a 25 ml standard flask and volume was made up with diluted water.

The made up digest (1 ml) was transferred in to polypropylene tube to which were added 2ml each of buffer and Azomethine – H reagent. Absorbance was read at

420 nm on a spectrometer (104) after 30 minutes. Standard B solutions (0.1, 0.2, 0.4,0..6,0.8 and 1 ppm) were also read using the same procedure.

3.3. IDENTIFICATION OF PREDISPOSING FACTORS

The predisposing factors responsible for the B deficiency was identified from coconut fields showing boron deficiency based on questionnaire survey. The information on field, soil, plant characteristics and management aspects were collected from the hundred fields surveyed. The number of palms in the field ranged from ten to three hundred and twenty. The field characteristics included drainage of the field and elevation of the area. The soil characteristics of the field included soil type and soil organic matter. The plant characteristics and management aspects of the field included the age of the palm, fertilizer and organic matter application, irrigation, disease and pest incidence. Based on the questionnaire the details about the field, soil, plant characteristics and management aspects of the coconut field showing boron deficiency were collected and statistically analysed.

3.4.CHARACTERISATION OF BORON DEFICIENT COCONUT PALMS

Five palms from selected grouped coconut palms were observed for one year for the morphological characters.

3.4. 1. Morphological Characterization

The palms of almost similar age, genotype and class of soil coming under four groups were taken for the study. Group one included palms with mild intensity, group two included palms with moderate intensity, group three included palms with severe intensity and group four included healthy palms which were taken as control. Five palms from each group were selected and morphological characters like growth and yield parameters were recorded for a period of one year at forty five days interval.

Design of experiment – CRD

Groups - 4

Number of palms in each group – 5

Total number of palms- 20

Groups

1. Group 1 - Mild intensity
2. Group 2 - Moderate intensity
3. Group 3 - Severe intensity
4. Group 4 - Healthy palms (Control)

3.4. 1.1. Growth Parameters

The growth parameters like number of leaves, number of fused leaves, leaflet internodal length and root anatomy of the selected twenty palms were recorded at forty five days interval for a period of one year.

3.4. 1.1.1. Number of leaves

The number of fully opened leaves on the crown of each palm were counted and mean expressed at forty five days interval upto one year.

3.4. 1.1.2. Number of fused leaves

The total number of fused leaves in each palm was counted and mean expressed at forty five days interval upto one year

3.4.1.1.3. Leaflet internodal length

The internodal length between each leaflet of leaves in each palm was measured and mean obtained (Manju,1992)

3.4.1.1.4. Root anatomy

The newly sprouted fresh roots from the coconut palms of mild, moderate, severe intensity of boron deficiency and healthy palms were collected. The thin section of the root was taken and the section was stained with safranin. The section was observed under microscope. Recorded the characters observed in the roots of different groups of palms.

3.4. 1.2.Yield Characters

The yield characters like number of female flowers per bunch of unfertilised inflorescence, number of unopened spadices, number of spadices, number of bunches, number of nuts set per bunch, number of malformed nuts ,number of nuts/palm/year, polar diameter of nut, equatorial diameter of nut, thickness of husk, weight of husked nut, weight of unhusked nut, weight of opened nut, volume of nut water, thickness of meat, weight of embryo, weight of shell, weight of kernel, weight of copra, oil content of the selected twenty palms were recorded for a period of one year.

3.4. 1.2.1. Number of female flowers per bunch of unfertilised inflorescence

The number of female flowers on the opened unfertilized inflorescence were counted and mean expressed at 45 days interval for one year

3.4. 1.2.2. Number of unopened spadices

The number of all spadices which were unopened but fully or partially emerged in each palm was counted and the mean expressed at 45 days interval for one year.

3.4. 1.2.3. Number of spadices

The number of opened spadices till the button stage in each palm was counted and mean expressed at 45 days interval for one year

3.4. 1.2.4. Number of bunches

The number of bunches with nuts were counted in each palm and mean expressed at 45 days interval for one year

3.4. 1.2.5. Number of nuts set per bunch

The number of nuts were counted on all bunches up to button stage of each coconut palm and mean number of nuts per bunch obtained was expressed at 45 days interval for one year .

3.4. 1.2.6. Number of malformed nuts

The total numbers of malformed nuts produced in each bunch of each palm was counted and the mean was expressed at 45 days interval for one year

3.4. 1.2.7. Number of nuts/palm/year

The total number of nuts in a palm at each harvest at 45 days interval was counted for an year and the mean expressed.

3.4. 1.2.8. Polar diameter of nut

The length of the nut from one pole to the other was measured by set square blocking of the nut of each palm and the distance was measured using a meter scale and the mean was expressed at 45 days interval in millimeters (Manju,1992)

3.4. 1.2.9. Equatorial diameter of nut

The breadth of the nut at the middle portion of each palm was measured by setsquare blocking of the nut and the distance was measured using a meter scale and the mean expressed at 45 days interval as equatorial diameter of the nut in millimeters (Manju,1992)

3.4. 1.2.10.Thickness of husk

Thickness of husk of each matured nut from each palm was recorded by piercing the husk with a poker till it reached the shell and mean length of the needle from the shell to the outer surface of the husk pierced at the flat surfaces of the nut gave the thickness of husk .in cm (Manju,1992). The measurements were recorded at 45 days interval for a period of one year.

3.4. 1.2.11.Weight of husked nut

The weight of husked nuts from each harvest of each palm at 45 days interval was taken using a pan balance and the mean value at each harvest is expressed in gram (Paul,2001).

3.4. 2.12.Weight of unhusked nut

The weight of nuts with husk of each nut at each harvest of each palm was taken using a pan balance and the mean was calculated at 45 days interval for one year and expressed in gram (Paul,2001).

3.4. 1.2.13.Weight of opened nut

The husked nut at each harvest of each coconut palm was split into two halves, coconut water drained and weighed (Paul,2001) and mean expressed in gram at 45 days interval for one year.

3.4. 1.2.14.Volume of nut water

The nut at each harvest from each palm was taken, coconut water was drained into a measuring cylinder after splitting the dehusked nut and the volume of nut water was measured and mean expressed in millilitre at 45 days interval for one year (Paul, 2001).

3.4. 1.2.15.Thickness of meat

Thickness of meat was measured using Vernier Calipers at three different places on the opened nut of each palm and mean thickness expressed in centimeter (Paul, 2001).

3.4. 1.2.16.Weight of embryo

The embryo with a portion of endosperm from the soft eye of the nut was scooped out using a cork borer from dehusked and split opened mature coconut of each palm. The embryo was extracted from the endosperm with the help of a scalpel, weighed and mean weight was expressed in gram.

3.4. 1.2.17. Weight of shell

The kernel was removed from shell of dehusked and split opened mature coconut of each palm and the weight of the each shell was recorded and mean value expressed in gram.

3.4. 1.2.18.Weight of kernel

The kernel from the shell of dehusked and split opened mature coconut was excised out of the shell of each palm and weighed and mean value expressed in gram.

3.4. 1.2.19.Weight of copra

The kernel was excised out of the shell of dehusked and split opened mature nut of each palm and sun dried for eight consecutive days. The moisture content was measured and brought down from 50 to 55 per cent of fresh kernel to six percent on drying and drying was continued till constant weight was obtained and the mean weight was expressed in gram.

3.4.1.2.20. Oil content

The oil was extracted from copra of nuts of each palm coming under 4 groups using soxhlet extraction procedure of AOAC(1996) and mean value expressed in percentage.

3.4.2. SCORING FOR PEST

3.4.2.1.Scoring of Coried Bug

The scoring of coried bug was done in the selected 20 coconut palms. The third numch of the palms was selected and the total number of nuts in the bunch and the number of nuts damaged by pest were recorded. The percentage of infestation was calculated as follows (Paul,2006) (Appendix3),

$$\text{percentage of damage} = \frac{\text{Number of nuts in the bunch}}{\text{Total number of nuts in the bunch}} \times 100$$

3.4.2.2.Scoring of Mite

The scoring of mite was done in the selected 20 coconut palms. The harvested nuts were divided in to five damage categories and classified according to visible surface damage(Paul,2001) (Appendix 4).

Category 1- Nuts with no mite damage(0%)

Category 2- Nuts with superficial mite damage(1-10%)

Category 3- Nuts with significant mite damage but not much smaller (11-25%).

Category 4- Nuts with significant mite damage, smaller and with some distortion (26-50%).

Category 5- Nuts very heavily attacked, very much reduced in size and often greatly distorted(51-100%).

Statistical Analysis

Data related to the survey part of the study was analysed by frequency distribution method and the data relating to the morphological characters were analysed by applying the analysis of variance technique as applied to CRD described by Cohran and Cox(1965) and the significance was tested by F test (Snedecor and Cohran, 1967). In cases were the effects were found to be significant, critical difference (CD) values were calculated by using standard technique.

RESULTS

4. RESULTS

The study entitled "Characterisation of boron deficient coconut palms *(Cocos nucifera L.)*" was carried out during April 2015 to March 2016 in the farmer's field at Kalliyoor panchayat and the results are presented in this chapter.

4.1. IDENTIFICATION OF BORON DEFICIENT COCONUT PALMS

Hundred coconut palms from different farmers' fields in Kalliyoor panchayat showing boron deficiency were identified based on the visual symptoms of leaf, inflorescence, nut and crown. The results on the categorization of boron deficient coconut palms is given in Table 2.

Among the hundred coconut palms surveyed 14 palms came under mild group (14 %) with the score coming between 1-3. Eighty palms were under moderate group (80%) which received a score ranging from 4-6 and six came under severe intensity palms (6 %) which had a score ranging from 7-10.

The percentage distribution of deficiency symptoms in each category of boron deficient palms based on score is given in Table 3. Based on the score obtained, out of the fourteen palms of mild intensity 15 percentage were having hooked leaves. The percentage of hooked leaves in moderate intensity was 23 and 12 for severe intensity. Ninety two percent of palms showing mild intensity had fused leaves. Similarly 73.75 per cent of moderate and 86 of severe intensity palms showed fused leaves (Plate 1). Thirty seven percentage of the total number of leaves present in the severe intensity palms were fused. Out of the total leaves, the number of fused leaves in the mild intensity palms were 7, 23.33 per cent for moderate and 37 per cent for palms with severe intensity. High leaflet internodal length was noticed in 24, 15 and 11 of the palms with mild, moderate and severe intensity of boron deficiency. Twenty palms under the mild intensity had inflorescence with few female flowers. The palms under moderate and severe intensity showed 70 and 85.91 of inflorescence with few female flowers respectively. The palms under mild intensity showed reduced number of leaves was 7.14 percent while it was 15 and 28. 7 per cent for palms with moderate and severe intensity respectively. The aborted inflorescence, bunches showing hen and chicken symptoms (Plate 2) and necrotic inflorescence (Plate 3) were 72, 71.11 and 71.52 per cent respectively in palms showing severe intensity. Symptoms on inflorescence, nut and crown were absent on palms with mild intensity. In moderate palms 40.12 per cent showed aborted inflorescence while bunches showing hen and chicken symptoms were noticed in 55. Crowded crown (Plate 4) was noticed in 57.14 per cent of the palm with severe intensity while it was 25 per cent in the palm with moderate intensity. The percentage of fish bone appearance, discoloration of mesocarp (Plate 5), nuts with uneven kernel development and nuts without any kernel was 71.42, 22, 28.78 and 28.47 per cent respectively in palms with severe intensity of boron deficiency. Fish bone appearance was observed in 22.50 per cent of moderate palms while the discoloration of mesocarp was noticed in 4 per cent of the palms with moderate intensity.

Plate 1. Fused leaves

Plate 2. Hen and Chicken symptom

Plate 3. Crowded crown

Plate 4. Necrotic inflorescence

Table 2. Results of categorization of hundred boron deficient palms

Groups	Number of palms	Percentage affected
Mild intensity	14	14
Moderate intensity	80	80
Severe intensity	6	6

Table 3.Percentage of symptoms in each category of boron deficient palms based on score

Sl no.	Symptoms	Mild (14/100)	Moderate (80/100)	Severe (6/100)
1	Hooked leaves	15%	23%	12%
2	Presence of fused leaves	92 %	73.75%	86%
3	Number of fused leaves	7%	23.33%	37%
4	High leaflet internodal length	24%	15%	11%
5	Inflorescence with few female flowers	20%	70%	85.71%
6	Palms with reduced number of leaves	7.14%	15 %	28.7%
7	Aborted inflorescence	0%	40.12%	72%
8	Bunch showing hen and chicken symptom	0%	55%	71.11%
9	Palm with crowed crown	0 %	25%	57.14%
10	Necrotic inflorescence	0%	47.50%	71.52%
11	Fish bone appearance	0%	22.50%	71.42%
12	Discolouration of the mesocarp	0%	4%	22%
13	Nuts with uneven kernel development	0%	0%	28.78%
14	Nuts without any kernel	0%	0%	28.47%

4.2. BORON STATUS OF SOIL AND PLANT

The boron status of soil and plant (mg/kg) is given in the Table 4. Soil and plant boron was analysed for the selected palms of four groups and mean soil boron status ranged from 0.122 – 0.358 mg/kg of soil for boron deficient palms and 0.529 mg/kg of soil for the healthy palms. Plant boron status ranged from 1.18 - 3.68 mg/kg of soil for boron deficient palms and 13.88 for the healthy palms. Soil B content around healthy palms is within the critical level of B in soil.

Table 4.Boron status of soil and plant (mg/kg of soil)

Groups	Soil	Plant
Mild intensity	0.358	3.68
Moderate intensity	0.256	2.50
Severe intensity	0.122	1.18
Healthy	0.529	13.88
CD(0.05)	0.048	2.806

4.3. IDENTIFICATION OF PRE-DISPOSING FACTORS

The predisposing factors responsible for the boron deficiency was identified from 100 coconut fields showing boron deficiency of Kalliyoor panchayat based on questionnaire survey.

The results of the survey on field characteristics of coconut fields deficient in boron is given in Table 5.

Field characteristics had shown 100 per cent drainage in the selected fields and 96 of the fields showed an elevation of 28 to 30 meter above mean sea level and four had an elevation of twenty five meter above mean sea level.

The soil characteristics of coconut fields deficient in boron is shown in Table 6.

The soil type of the fields surveyed was red loam and the soil pH ranged between 6 to 7.5. Fifty seven per cent of fields were having a pH range of 6 to 6.5. Thirty nine per cent were having a pH range of 6.6 to 7.0. Four per cent of fields were having a pH range of 7.1-7.5. Thirty of the fields having medium organic matter ranged from 0.86 to 2.1 and 70 of the fields surveyed were having low organic matter ranging from 0.32 to 0.74 per cent.

The plant characteristics of boron deficient coconut field is shown in Table 7. The age of the palms surveyed ranged between 20 to 40. Fifty three per cent of the palms were between the age group 20 to 25. Sixteen per cent of the palms fell in the age group of 26 to 30 and 25 per cent of the palms were between the age group of 31 to 35. Six per cent of the palms were between the age group of 36 to 40.

The management characteristics of the field is given in Table 8. Boron deficiency was noticed in the fields where intercropping was practiced which contributed 63 per cent of the fields surveyed even though the field was applied with organic manure and fertilizer. Similarly 37 per cent of the fields without intercrop and poor agronomic practices also showed boron deficiency. Out of 63 per cent of fields with intercrop, 24 per cent were applied with organic matter alone. Thirty one per cent of fields with intercrop were practicing both organic matter and fertilizer application.

Twenty two per cent of fields were given proper irrigation and 78 per cent of fields were rainfed. Twenty six per cent of the fields showed disease incidence and among the 26 per cent, leaf rot was the main disease noticed which contributed to 88.46 per cent and 11.54 per cent was due to bud rot.

The hundred per cent of the palms showing boron deficiency showed pest incidence. Mite and coreid bug were the major pests found over there. Eighty nine per cent of the fields were having the mite attack and 50 per cent of the fields were having a combined infestation of mite and coreid bug.

The deficiency percentage of coconut fields having boron deficiencyis given in table 9. Out of the hundred palms showing boron deficiency 52 per cent of the boron deficient coconut fields showed boron deficiency between zero to 25 per cent, 26 per cent of the boron deficient fields showed boron deficiency between 26 to 50 per cent, 22 per cent of boron deficient fields showed boron deficiency ranging from 51-75 percentage.

Table 5. Field characteristics of coconut fields deficient in boron

Field characteristics	Remarks
Drainage characteristics of the field	Well drained (100%)
Elevation of the area	96% of the area 28-30m above MSL 4% of the area 25m above MSL

Table 6. Soil characteristics of coconut fields deficient in boron

Soil characteristics	Observation	Percentage
Soil type	Red loam	100
Soil pH	6.0-6.5	57
	6.6-7.0	39
	7.1 – 7.5	4
Soil organic matter	0.32- 0.74 0.86- 2.1	70 30

Table 7. Plant characteristics of boron deficient coconut field

Age of the palm	Percentage
20-25	53
26-30	16
31-35	25
36-40	6

Table 8.Management characteristics of boron deficient coconut fields

Management characteristics	No of fields (%)	
	With	Without
Fields with intercrops	63	37
Field with application of organic manure alone (with intercrops)	24	08
Field with application of organic manure and fertilisers (with intercrops)	31	
Fields without intercrops but with organic matter and fertilizer application	0	
Irrigation of the field	22	78
Disease incidence	26	74
a)Leaf rot	88.46 (23 fields)	
b)Bud rot	11.54 (3 fields)	
Pest incidence	100	0
a)Mite	89	
b)coreid bug	53	

Table 9. Deficiency percentage of coconut fields having boron deficiency

Deficiency percentage	Fields(%)
0-25	52
26-50	26
51-75	22
>75	0

4.4. MORPHOLOGICAL CHARACTERISATION

From the hundred selected boron deficient coconut palms five palms each from mild, moderate and severe intensity of boron deficiency were observed for morphological characters and were compared with five healthy palms for one year.

4.4.1. Growth Parameters

4.4.1.1. Number of leaves

The number of leaves in the palms coming under the four groups observed for one year at 45 days interval is given in Table 10. During the first day of observation, the number of leaves in the palms with mild and moderate intensity were found to be on par and the healthy palms were significantly different from the other three groups. The number of leaves in the mild, moderate and healthy palms were on par during the 45th day of observation while the severe palms were significantly different from the other three groups. The number of leaves on the mild and moderate intensity palms were on par and was significantly different from severe intensity palms at 90 days of observation. The number of leaves in the healthy, mild and moderate palms were on par during the 135th day of observation and it was significantly different from that of the severe palms. The number of leaves in the mild and moderate palms during the 180th day of observation were found to be on par and it was significantly different to that of the healthy and severe palms. The number of leaves in healthy, mild and moderate palms were on par during the 225th and 315th day of observation and it was significantly different to that of the severe palms. The number of leaves in the .mild, moderate and severe palms were on par during the 360th day of observation and it was significantly different from that of the healthy palms. The mean number of leaves over the year in the healthy, mild, moderate and severe palms were significantly different from each other.

4.4.1.2 Number of fused leaves

The number of fused leaves in the palms are given in Table 11.

The numbers of fused leaves in the severe intensity palms were found to be higher compared to that of healthy, mild and moderate palms. There were no fused leaves in the healthy palms in all periods of observation. The number of fused leaves in the mild, moderate and severe palms were significantly different from each other during all periods of observation except at 180th and 225th day of observation wherein the mild and moderate intensity palms were on par . The yearly mean number of fused leaves in the severe palms was 11.75. The number of fused leaves in the severe intensity palms ranged between 10.40 to 13.80 throughout the period of observation. The yearly mean number of fused leaves in the three groups of palms were significantly different from each other.

Table 10.Number of leaves

Number of leaves at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	30.6	30.8	30.8	31.0	31.2	30.0	30.8	30.2	31.2	30.75
Moderate intensity	30.0	30.4	29.8	30.2	29.4	30.0	30.0	30.2	30.2	30.03
Severe intensity	27.6	28.0	27.2	27.6	27.2	27.0	28.0	27.2	27.6	27.48
Healthy	32.0	31.6	31.4	32.2	31.2	32.0	31.6	31.2	31.2	31.55
CD (0.05)	1.354	1.615	1.324	2.033	1.324	1.499	1.709	1.748	1.552	0.390

Table 11. Number of fused leaves

Number of fused leaves at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	1.69	1.20	1.40	1.80	1.80	1.80	1.80	1.80	2.00	1.70
Moderate intensity	5.33	4.60	5.60	5.20	4.00	4.20	6.00	7.00	6.80	5.42
Severe intensity	11.64	12.40	11.20	13.80	12.40	10.60	11.60	11.60	10.40	11.75
Healthy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD (0.05)	0.748	2.707	4.011	4.401	2.553	3.087	2.417	2.011	1.836	0.821

4.3.1.3. Leaflet internodal length

The leaflet internodal length of the four groups of palms are given in Table 12.

The leaflet internodal length in the severe(2.88) and moderate(2.72) palms were on par during the first day of observation and it was significantly different from the healthy(2.06) and mild palms (2.40). The leaflet internodal length of the mild(2.26) and moderate(2.52) palms were on par during the 45th day of observation. The leaflet internodal length of the healthy (2.06), mild (2.30), moderate(2.54) and severe palms (2.88) were significantly different from each other during the 90th day of observation. The leaflet internodal length of the healthy (2.04), mild (2.30), moderate (2.56) and severe palms (2.92) were significantly different from each other during the 135th, day of observation. The leaflet internodal length of the healthy 2.06), mild (2.30), moderate (2.56) and severe palms (2.84) were significantly different from each other during the 180th day of observation. The leaflet internodal length of the healthy 2.06), mild (2.28), moderate (2.56) and severe palms (2.88) were significantly different from each other during the 225th day of observation. The leaflet internodal length of the healthy(2.04), mild (2.34), moderate (2.57) and severe palms (2.80) were significantly different from each other during the 270th day of observation. The leaflet internodal length of the healthy (2.06), mild (2.34), moderate (2.54) and severe palms (2.88) were significantly different from each other during the 315th day of observation. The leaflet internodal length of the healthy (2.02), mild(2.30), moderate (2.50) and severe palms (2.92) were significantly different from each other during the 360th day of observation. The yearly mean leaflet internodal length of the healthy (2.05), mild (2.31), moderate (2.56) and severe palms (2.88) were significantly different from each other. The leaflet internodal length was the highest for the coconut palms with severe intensity.

4.3.1.4. Root anatomy

The root anatomy of the four groups of palms is shown in plate 7.The root anatomy of palms with severe and moderate intensity of boron deficiency showed the presence of loosely packed cortical cells. While the cortical cells present in the roots of healthy palms were tightly packed and the cortical cells in the palms with mild intensity were less tightly packed.

Table 12.Leaflet internodal length

Leaflet internodal length(cm) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	2.40	2.26	2.30	2.30	2.30	2.28	2.34	2.34	2.30	2.31
Moderate intensity	2.72	2.52	2.54	2.56	2.56	2.56	2.57	2.54	2.50	2.56
Severe intensity	2.88	2.96	2.88	2.92	2.84	2.88	2.80	2.88	2.92	2.88
Healthy	2.06	2.04	2.06	2.04	2.06	2.06	2.04	2.06	2.02	2.05
CD (0.05)	0.223	0.088	0.106	0.106	0.094	0.106	0.066	0.100	0.094	0.040

Healthy

Mild

Moderate

Severe

Plate 5. Root anatomy of palms

4.3.2. Yield characteristics

4.3.2.1. Number of female flowers per bunch of unfertilized inflorescence

The number of female flowers per bunch of unfertilized inflorescence in the healthy, mild, moderate and severe palms are given in Table 13.

The number of female flowers per bunch of unfertilized inflorescence in the palms during the first day of observation was significantly different for healthy, mild and severe intensity of boron deficient palms. The number of female flowers per bunch of unfertilized inflorescence in healthy palms during the first day of observation was 38.00 and that of the severe palms were 22.40. The number of female flowers per bunch of unfertilized inflorescence on the 45th day of observation was on par for healthy and mild intensity while it was significantly different for severe intensity compared to healthy and mild intensity. The number of female flowers per bunch of unfertilized inflorescence for moderate and severe intensity palms were on par on the 90th, 180th and 225th day of observation. The number of female flowers on the 135th day, 180th and 225th of observation were significantly different for healthy, moderate and severe intensity palms. The healthy palms were having the highest number of female flowers (40.20) and the severe palms were having the lowest (23.80) on 225th day. The number of female flowers on the 270th day of observation was significantly different in all the four groups of palms. The healthy palms showed highest number of female flowers (39.60) and the severe palms showed the lowest number of female flowers(23.00). The number of female flowers on the 315th day of observation was significantly different among all the four palms. The healthy palms showed highest number of female flowers(37.00) and the severely affected palms showed the lowest number of female flowers(23.60). The number of female flowers on the 360th day of observation was significantly different from each other in all the four group of palms. The healthy palms showed highest number of female flowers(39.00) while the severely affected palms showed the lowest number of female flowers(23.60). The percentage increase of number of female flowers per bunch of unfertilized inflorescence in the severe palms over the healthy palms were 37.91 per cent.

4.3.2.2. Number of unopened spadices

The number of unopened spadices are given in the Table 14.The numbers of unopened spadices in the mild and moderate palms were on par during the 1st day of observation and that of the healthy and severe palms were significantly different. The number of unopened spadices in the mild, moderate and severe palms were on par on the 45th day of observation and that of the healthy palms(4.20) was significantly different from the other three groups. The number of unopened spadices in the mild and moderate palms on the 90th day of observation was 2.80 and 2.60 respectively and it was on par. The number of unopened spadices on the healthy and severe palms were significantly different. On the 135th and 180th day of observation the number of unopened spadices in the mild and moderate palms found to be on par while that of the healthy and severe palms were significantly different. On the 225th, 270th ,315th and 360th day of observations the mild and moderate palms and moderate and severe palms were on par . The healthy palms were significantly different. The number of unopened spadices in the healthy palms ranged from 4.20 to 4.60. The number of unopened spadices the mild palms ranged from 2.60 to 3.00. The number of unopened spadices in the moderate palms ranged from 2.20 to 2.60. The number of unopened spadices in the severe palms ranged from 1.20 to 2.00. The mean numbers of unopened spadices in the healthy palms were 4.42, mild palm were 2.72, moderate palms were 2.40 and severe palms were 1.52.

Table 13.Number of female flowers per bunch of unfertilised inflorescence

Number of female flowers per bunch of unfertilized inflorescence at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	33.20	34.40	33.80	32.20	32.80	33.20	32.00	33.20	32.80	33.07
Moderate intensity	27.60	26.80	26.80	26.40	27.40	27.40	27.40	28.40	28.20	27.38
Severe intensity	22.40	23.80	24.40	24.00	24.00	23.80	23.00	23.60	23.60	23.62
Healthy	38.00	36.00	38.20	36.40	38.00	40.20	39.60	37.00	39.00	38.04
CD (0.05)	2.570	4.116	4.127	2.351	3.413	3.668	3.456	2.941	3.010	0.876

Table 14. Number of unopened spadices

Number of unopened spadices at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	2.80	2.60	2.80	3.00	2.80	2.60	2.60	2.80	2.60	2.72
Moderate intensity	2.20	2.40	2.60	2.40	2.60	2.20b	2.20	2.40	2.40	2.40
Severe intensity	1.80	2.00	1.40	1.60	1.20	1.60	1.40	1.60	1.40	1.52
Healthy	4.60	4.20	4.40	4.40	4.40	4.60	4.20	4.60	4.60	4.42
CD (0.05)	0.920	0.894	0.848	0.792	0.820	0.701	0.820	0.848	0.733	0.184

4.3.2.3. Number of spadices

The number of spadices are given in the Table 15.

The number of spadices were on the 1^{st} day of observation was found to be on par in the case of mild intensity and moderate intensity palms and it was found to be significantly different from that of healthy and severe intensity palms. The number of spadices on the 45^{th} day of observation was found to be on par for the healthy, mild intensity and moderate intensity palms and was significantly different from the severe intensity palms. The observation on the 90^{th} ,135^{th} and 180^{th} day of observation was on par for mild and moderate intensity palms and differed significantly from healthy and severe intensity palms. The observation on 225^{th} , 270^{th}, 315^{th} and 360^{th} day of observation revealed that the number of spadices for mild and moderate intensity palms and moderate and severe intensity palms were on par and differed significantly from the healthy palms. The yearly mean of the observations taken for one year revealed that the number of spadices for healthy palms were 1.93 and it reduced to 1.47 and 1.20 for mild and moderate intensity palms. The number of spadices were the least for the severe intensity palms (0.58).

4.3.2.4. Number of bunches

The number of bunches in the four groups of palms for a period of one year at 45 days interval are shown in the Table 16.

On the first day of observation the number of bunches in the moderate (6.20) and severe intensity palms (5.80) and that of healthy (7.40) and mild palms (7.20) were found to be on par. On the 45^{th} day of observation the healthy (8.00) and mild intensity palms (6.60) and mild (6.60) and moderate intensity palms (6.00) and moderate (6.00) and severe intensity palms (5.40) were found to be on par. The healthy (7.40) and mild intensity palms (6.60) and mild (6.60) and moderate intensity palms (6.20) and moderate (6.20) and severe intensity palms (5.40) were found to be on par on the 225^{th} day of observation. On the 360^{th} day of observation the healthy (7.40) and mild intensity palms (6.60) and mild (6.60) and moderate intensity palms

(6.40) and moderate (6.40) and severe intensity palms (5.60) were found to be on par. The number of bunches in the mild (6.20), moderate (6.00) and severe intensity palms (5.40) on the 90th day of observation were found to be on par while the number of bunches in the healthy palms found to be significantly different. On the 135th day of observation the number of bunches in the mild (6.60), moderate (6.40) and severe (5.80) intensity palms were found to be on par. On the 180th day of observation the number of bunches in the healthy (7.80) palms found to be significantly different from other 3 groups while the mild (6.80), moderate (6.60) and severe (6.00) intensity palms were found to be on par. On the 270th day of observation, the number of bunches in the mild (7.00) and moderate (6.40) palms found to be on par and differed significantly from the palms with severe (5.40) intensity and healthy(7.40) palms. On 315th day of observation, the number of bunches in the mild (5.20) and moderate (4.80) palms found to be on par and differed significantly from the healthy (7.00) and severe intensity (2.60) palms. The palms with mild (6.60), moderate (6.40) and severe (5.60) intensity palms found to be on par and the healthy (7.40) palms were significantly different on the 360th day of observation. The number of bunches in the healthy palms showed a significant difference than that of severe palms in all periods of observation. The yearly mean revealed that the number of bunches in the mild (6.53) and moderate (6.04) intensity were on par and differed significantly from the severe (5.20) intensity and healthy (7.47) palms.

Table 15. Number of spadices

Number of spadices at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	1.40	1.40	1.60	1.40	1.60	1.40	1.60	1.40	1.40	1.47
Moderate intensity	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Severe intensity	0.60	0.60	0.60	0.40	0.60	0.60	0.60	0.60	0.60	0.58
Healthy	2	1.80	2.20	1.60	2.00	1.80	2.00	2.00	2.00	1.93
CD (0.05)	0.596	0.674	0.674	0.701	0.596	0.674	0.674	0.596	0.596	0.101

Table 16.Number of bunches

Number of bunches at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	7.20	6.60	6.20	6.60	6.80	6.60	7.00	5.20	6.60	6.53
Moderate intensity	6.20	5.40	6.00	6.40	6.60	6.20	6.40	4.80	6.40	6.04
Severe intensity	5.80	4.80	5.40	5.80	6.00	5.40	5.40	2.60	5.60	5.20
Healthy	7.40	8.00	7.40	7.40	7.80	7.40	7.40	7.00	7.40	7.47
CD (0.05)	0.733	1.543	1.017	0.975	0.870	1.183	0.920	0.920	0.993	0.647

4.3.2.5. Number of nuts set per bunch

The nuts set per bunch of the four groups of palms are given in the Table 17. The statistical analysis showed a significant difference between all the four groups of palms during the whole period of observation. The nuts set per bunch on the first day of observation was significantly different in healthy (13.80) palms, palms with mild (9.00), moderate (5.60) and severe (3.60) intensity. On the 45th day of observation the healthy palms showed a mean nuts set per bunch of 13.80, palms with mild intensity showed a mean nut set of 8.40, moderate intensity showed a mean nut set per bunch of 5.60 and that of severe palms showed a mean nut set bunch of 3.00. The mean nuts set per bunch of healthy palms was 13.60, palms with mild intensity was 8.60, moderate intensity was 5.80 and severe intensity was 3.80 and on the 90th day of observation and were significantly different in all four groups. On the 135th day of observation the mean nuts set per bunch of healthy (13.60), mild intensity (8.40), moderate intensity (5.60) and severe intensity (3.20) palms were significantly different from each other in all the four groups of palms. On the 180th day of observation the mean nuts set per bunch in the healthy (13.80), mild intensity (8.80), moderate intensity (5.60) and severe intensity (3.60) palms were significantly different from each other in all four groups of palms. The nuts set per bunch of healthy (13.20), mild intensity (7.60), moderate intensity (5.80) and severe intensity (3.60) palms were significantly different from each other on the 225th day of observation. The nuts set per bunch of healthy palms (13.60), mild intensity (7.60), moderate intensity (5.80) and severe intensity (3.60) palms were significantly different from each other on 270th day of observation. As observed from the yearly mean out of the 38.04 (Table 13) female flowers produced by the inflorescence in healthy palms 13.06 were set in healthy palms, while the nuts set per bunch in severe intensity palms were only 3.44. The setting percentage of healthy palms was 34% while that for the severely affected palms were 13 per cent. The nuts set per bunch of healthy palms ranged from 13.20 to 13.80 and that of mild, moderate and severe palms ranged from 7.60 to 9.2, 5.60 to 6.40 and 3.00 to 3.80 respectively.

4.3.2.6. Nuts per palm per year

The nuts produced per palm per year observed in four groups of palms are given in the table 18. The healthy palms produced 102.8 nuts per palm per year compared to 66 nuts in mild intensity palms and 38 in moderate intensity palms. The nuts produced in severe intensity palms were only 15.6 showing a drastic reduction the yield compared to healthy palms. As the intensity of the deficiency increased the yield showed intensive reduction.

Table 17. Number of nuts set per bunch

Number of nuts set per bunch at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	9.00	8.40	8.60	8.40	8.80	7.60	9.20	8.40	8.60	8.56
Moderate intensity	5.60	5.60	5.80	6.00	5.60	5.80	5.80	6.00	6.40	5.84
Severe intensity	3.60	3.00	3.80	3.20	3.60	3.60	3.20	3.60	3.40	3.44
Healthy	13.80	13.80	13.60	13.60	13.80	13.20	13.60	13.80	13.20	13.60
CD (0.05)	0.596	0.894	1.348	1.391	1.060	1.421	1.146	1.308	1.098	0.32

Table 18. Number of nuts per palm per year

Number of nuts per palm per year	
Groups	Mean
Mild intensity	66
Moderate intensity	38
Severe intensity	15.60
Healthy	102.80
CD (0.05)	6.331

4.3.2.7. Number of malformed nuts

The number of malformed nuts of the four groups of palms are given in the table 19. The healthy palms showed no incidence of malformed nuts during the one year observation period. During all days of observation the healthy palms were not having any malformed nuts. On the first day of observation the mild intensity (0.00) palms were significantly different from the other palms and palms with moderate intensity(0.60) and severe intensity(1.00) were on par on the same day. On the 45th day of observation the palms with severe intensity(1.20) significantly different from the palms with mild intensity(0.00), moderate intensity(0.40) and healthy palms(0.00). on the 90th day of observation the mild intensity palms(0.00) were on par with the palms with moderate intensity(0.40). And the palms with severe intensity(1.00) and moderate intensity(0.40) found to be on par on the same day. The palms with severe intensity found to be significantly different from all the other groups of palms on the 135th day of observation. And the palms with mild(0.00) and moderate intensity(0.40) found to be on par on the same day of observation. On the 180th day of observation the palms with severe intensity(1.20) is significantly different from the palms with mild(0.00) and moderate intensity(0.40). the palms with moderate(0.60) and severe intensity(1.20) is found to be on par on the 225th day of observation. And the palms with mild(0.00) and moderate(0.60) intensity is found to be significant on the 225th day of observation. On the 270th day of observation the palms with severe intensity is found to be significantly different from the palms with mild intensity(0.20) and moderate intensity(0.40). on the 315th day of observation the palms with severe intensity(1.20) found to be significantly different from the palms with mild intensity(0.20) and on par with palms with moderate intensity(0.60). The palms with mild and moderate intensity are on par on the same day of observation. On the 360th day of observation the palms with severe intensity(1.40) is found to be significantly different from the palms with mild(0.00) and moderate intensity(0.80). And the palms with moderate intensity is found to be significantly different from that of the palms with mild intensity on the same day of observation. The yearly mean of the number of malformed nuts reveal that the palms with severe intensity(1.18) is found to be significantly different from that of the palms with mild(0.044) and moderate intensity(0.51). And the palms with mild and moderate intensity is found to be significantly different on the same day of observation.

4.3.2.8. Polar diameter of the nut

The polar diameter of the nut observed from the four groups of palms for one year are given in Table 20. There was significant difference in polar diameter of nuts between mild, moderate, severe and healthy in all periods of observation. The healthy palms showed a highest polar diameter on all days of observation. The mean value for the polar diameter was found to be higher in the healthy palms (257.09mm) compared to the other groups. On the first day of observation the polar diameter of the healthy palms (260.40mm) were found to be significantly different from that of the palms with mild (247.80mm), moderate (234.80mm) and severe intensity (227.80mm). On the 45th day of observation the healthy palms (255.60) found to be significantly different from that of the palms with mild (247.60), moderate (233.20mm) and severe intensity (224.40mm) and the polar diameter of nuts in all groups of palms found to be significantly different. On the 90th day of observation the polar diameter of nuts is significantly different from healthy palms (256.60mm) than that of the palms with mild (243.40mm), moderate (232.00mm) and severe (225.60mm) intensity. The polar diameter of nut on the 135th day of observation found to significantly different in all groups of palms. The nuts from healthy palms (258.20mm) were having the highest polar diameter compared to mild (243.40mm), moderate (232.00mm) and severe intensity palms (226.80mm) on the same day of observation. On the 180th day of observation the healthy palms (254.40mm) found to be significantly different from that of the palms with mild (245.40mm), moderate (232.60mm) and severe intensity (224.00mm) and the polar diameter of nuts in all groups of palms found to be significantly different. The polar diameter of nut on the

225th day of observation in the healthy palms (258.20mm) found to significantly different from mild (245.00mm), moderate (235.60mm) and severe intensity (226.00mm) palms. On the 270th day of observation the healthy palms (256.60mm) found to be significantly different from that of the palms with mild (247.60mm), moderate (235.40mm) and severe intensity (225.20mm). On the 315th day of observation the polar diameter of nuts is significantly different from healthy palms (256.80 mm) than that of the palms with mild (244.40 mm), moderate (232.80 mm) and severe (226.20 mm) intensity. On the 360th day of observation the polar diameter of nuts is significantly different from healthy palms (257.00 mm) than that of the palms with mild (246.40 mm), moderate(232.40 mm) and severe(225.20 mm) intensity. The polar diameter of the nut expressed in millimeter of healthy, mild, moderate and severe palms. The mean polar diameter of the nuts from healthy, mild, moderate and severe palms were 257.09 mm, 245.71 mm, 233.42 mm and 225.69 mm respectively. The mean polar diameter of healthy palms is found to be significantly different from that of mild, moderate and severe intensity palms.

Table 19. Number of malformed nuts

Number of malformed nuts at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.044
Moderate intensity	0.60	0.40	0.40	0.40	0.40	0.60	0.40	0.60	0.80	0.51
Severe intensity	1.00	1.20	1.00	1.20	1.20	1.20	1.20	1.20	1.40	1.18
Healthy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD (0.05)	0.596	0.674	0.596	0.674	0.470	0.674	0.733	0.733	0.568	0.100

Table 20. Polar diameter of nut

Polar diameter of nut at 45 days interval (mm)										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	247.80	247.60	243.40	243.40	245.40	245.00	247.60	244.40	246.80	245.71
Moderate intensity	234.80	233.20	232.00	232.00	232.60	235.60	235.40	232.80	232.40	233.42
Severe intensity	227.80	224.40	225.60	226.80	224.00	226.00	225.20	226.20	225.20	225.69
Healthy	260.40	255.60	256.60	258.20	254.40	258.20	256.60	256.800	257.00	257.09
CD (0.05)	2.958	4.998	4.591	3.051	3.668	4.317	4.402	4.315	4.175	1.489

4.3.2.9. Equatorial diameter of the nut

The equatorial diameter of the nut from the four groups of palms in all days of observation are given in Table 21. The equatorial diameter of the unhusked nut between mild, moderate, severe and healthy palms were significantly different in all periods of observation. The healthy palms showed a highest equatorial diameter on all periods of observation. The equatorial diameter of the nut is expressed in millimeters. On the first day of observation the equatorial diameter of nuts is significantly different from healthy palms (165.80 mm) than that of the palms with mild(151.40 mm), moderate(136.40 mm) and severe(115.20 mm) intensity. On the 45th day of observation the equatorial diameter of nuts is significantly different from healthy palms (166.40 mm) than that of the palms with mild (147.40 mm), moderate (132.80 mm) and severe(114.60 mm) intensity. The equatorial diameter of nuts on the 90th day of observation is significantly different from healthy palms (165.00 mm) than that of the palms with mild (148.80 mm), moderate (135.80 mm) and severe(114.40 mm) intensity. The equatorial diameter of nuts on the 135th day of observation is significantly different in all four groups of palms. The equatorial diameter of nut from healthy palms were 162.00, mild intensity palms were 149.20, moderate intensity palms were 138.00 mm and severe intensity palms were 114.80. The equatorial diameter of nuts on the 180th day of observation is significantly different in all four groups of palms. The equatorial diameter of nut from healthy palms were 164.00 mm, mild intensity palms were 149.00 mm, moderate intensity palms were 134.00 mm and severe intensity palms were 113.80 mm. The equatorial diameter of nuts on the 225th day of observation is significantly different in all four groups of palms with the equatorial diameter of nut from healthy palms were 162.00 mm, mild intensity palms were 149.00 mm, moderate intensity palms were 138.00 mm and severe intensity palms were 112.80 mm. On the 270th day of observation the equatorial diameter of nuts is significantly different in all groups of palms. The equatorial diameter of nuts from healthy palms were 163.60 mm, mild intensity palms were 149.20 mm, moderate intensity palms were 138.00 and severe intensity palms were 113.00 mm. The equatorial diameter of nuts on the 315th day of observation is significantly different in all four groups of palms with the equatorial diameter of nut from healthy palms were 162.20 mm, mild intensity palms were 149.60 mm, moderate intensity palms were 135.00 mm and severe intensity palms were 112.20 mm. On the 360th day of observation the equatorial diameter of nuts is significantly different in all groups of palms. The equatorial diameter of nuts from healthy palms were 163.80 mm, mild intensity palms were 150.00 mm, moderate intensity palms were 135.20 mm and severe intensity palms were 113.00 mm. The mean equatorial diameter of the nuts from healthy, mild, moderate and severe palms were 163.63mm, 149.29mm, 135.20mm and 113.58 mm respectively and the values were significantly different from each other in all four groups of palms.

4.3.2.10. Thickness of husk

The thickness of husk from the four groups of palms are given in Table 22. The husk thickness showed a significant difference between different groups in all periods of observation. The thickness of husk is expressed in millimeters. On the first day of observation the thickness of husk is significantly different from healthy palms (19.20 mm) than that of the palms with mild (16.50 mm), moderate (14.40 mm) and severe(12.30) intensity. On the 45th day of observation the thickness of husk is significantly different from healthy palms (18.80 mm) than that of the palms with mild (16.40 mm), moderate (13.80 mm) and severe(11.60 mm) intensity. The thickness of husk on the 90th day of observation is significantly different from healthy palms (18.60 mm) than that of the palms with mild (16.50 mm), moderate (13.80 mm) and severe(11.90 mm) intensity. The thickness of husk on the 135th day of observation is significantly different in all four groups of palms. The thickness of husk from healthy palms were 19.20 mm, mild intensity palms were 16.40 mm, moderate intensity palms were 14.00 mm and severe intensity palms were 12.20 mm. The thickness of husk on the 180th day of observation is significantly different in all four groups of palms. The equatorial diameter of nut from healthy palms were 18.80 mm, mild intensity palms were 16.40 mm, moderate intensity palms were 14.00 and severe intensity palms were 12.20 mm. The thickness of husk on the 225th day of observation is significantly different in all four groups of palms with the thickness of husk from healthy palms were 19.00 mm, mild intensity palms were 16.30, moderate intensity palms were 13.20 mm and severe intensity palms were 11.70 mm. On the 270th day of observation the thickness of husk is significantly different in all groups of palms. The thickness of husk from healthy palms were 18.80 mm, mild intensity palms were 16.20, moderate intensity palms were 14.30 and severe intensity palms were 11.40. The thickness of husk on the 315th day of observation is significantly different in all four groups of palms with the thickness of husk from healthy palms were 18.80 mm, mild intensity palms were 16.60 mm, moderate intensity palms were 14.20 mm and severe intensity palms were 11.70 mm. On the 360th day of observation the thickness of husk is significantly different in all groups of palms. The thickness of husk from healthy palms were 19.00 mm, mild intensity palms were 16.30 mm, moderate intensity palms were 14.20 mm and severe intensity palms were 13.10 mm. The mean thickness of husk from healthy, mild, moderate and severe palms were 18.90 mm, 16.40 mm, 13.90 mm and 12.00 mm respectively and the values were significantly different from each other in all four groups of palms.

Table 21. Equatorial diameter of nut

Equatorial diameter of nut at 45 days interval (mm)										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	151.40	147.40	148.80	149.20	149.00	149.00	149.20	149.60	150.00	149.29
Moderate intensity	136.40	132.80	135.80	138.00	134.00	138.00	137.60	135.00	135.20	135.20
Severe intensity	115.20	114.60	114.40	114.80	113.80	112.80	113.00	112.20	113.00	113.55
Healthy	165.80	166.40	165.00	162.00	164.00	162.00	163.60	162.20	163.80	163.63
CD (0.05)	2.804	4.609	3.493	1.940	3.396	1.572	2.155	3.157	3.201	1.397

Table 22. Thickness of husk

Thickness of husk at 45 days interval (mm)										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	16.50	16.40	16.50	16.40	16.40	16.30	16.20	16.60	16.30	16.40
Moderate intensity	14.40	13.80	13.80	14.00	14.00	13.20	14.30	14.20	14.20	13.90
Severe intensity	12.30	11.60	11.90	12.00	12.20	11.70	11.40	11.70	13.10	12.00
Healthy	19.20	18.80	18.60	19.20	18.80	19.00	18.80	18.80	19.00	18.90
CD (0.05)	0.900	0.980	0.900	0.850	0.950	0.700	0.730	1.040	1.320	0.320

4.3.2.11.Weight of husked nut(g)

The weight of husked nut are given in Table 23. There was a significant difference in the weight of husked nut between all the four groups in all periods of observation. The husked nuts from the healthy palms showed highest weight among the four groups of palms in all periods of observation. The palms with severe intensity of boron deficiency showed a lowest weight of husked nut comparing with the other palms on all days of observation. On the first day of observation the weight of husked nut is significantly different from healthy palms (740.80g) than that of the palms with mild (594.20 g), moderate (479.80g) and severe (373.60g) intensity. On the 45th day of observation the weight of husked nut is significantly different from healthy palms (725.80g) than that of the palms with mild (573.20g), moderate (476.20g) and severe (370.00g) intensity. The weight of husked nut on the 90th day of observation is significantly different from healthy palms (725.80) than that of the palms with mild (587.20g), moderate (480.00g) and severe (370.20g) intensity. The weight of husked nut on the 135th day of observation is significantly different in all four groups of palms. The weight of husked nut from healthy palms were 724.20g, mild intensity palms were 575.60g, moderate intensity palms were 475.20g and severe intensity palms were 371.80g. The weight of husked nut on the 180th day of observation is significantly different in all four groups of palms. The weight of husked nut from healthy palms were 724.20g, mild intensity palms were 575.40g, moderate intensity palms were 476.80g and severe intensity palms were 369.60g. The weight of husked nut on the 225th day of observation is significantly different in all four groups of palms with the thickness of husk from healthy palms were 724.00g, mild intensity palms were 586.00g, moderate intensity palms were 476.40g and severe intensity palms were 370.00g. On the 270th day of observation the weight of husked nut is significantly different in all groups of palms. The weight of husked nut from healthy palms were 725.80g, mild intensity palms were 584.80g, moderate intensity palms were 476.80g and severe intensity palms were 369.40g. The weight of husked nut on the 315th day of observation is significantly different in all four groups of palms with the weight of husked nut from healthy palms were 724.60g, mild intensity palms were 584.20g, moderate intensity palms were 476.20g and severe intensity palms were 369.60g. On the 360th day of observation the weight of husked nut is significantly different in all groups of palms. The weight of husked nut from healthy palms were 724.20g, mild intensity palms were 586.60g, moderate intensity palms were 474.80g and severe intensity palms were 369.00g. There was a yield reduction of fifty percent in severe palms compared to healthy. The mean nut weight of husked nut from the four groups of palms were 726.67g, 583.02g, 476.91g and 370.36 g for the healthy, mild , moderate and severe palms respectively.

4.3.2.12. Weight of unhusked nut

The weight of unhusked nut in the four groups of palms are given in Table 24. There were significant differences in the weight of unhusked nut between mild, moderate, severe and healthy palms in all periods of observation. The unhusked nuts from the healthy palms showed highest weight among the four groups of palms on all days of observation. And the severe palms showed a lowest weight of unhusked nut compared to other palms on all days of observation. On the first day of observation the weight of unhusked nut is significantly different from healthy palms (1702.50 g) than that of the palms with mild (1206.20g), moderate (900.20 g) and severe (578.80 g) intensity. On the 45th day of observation the weight of unhusked nut is significantly different from healthy palms (1644.20 g) than that of the palms with mild (1150.00 g), moderate (843.00 g) and severe (492.80 g) intensity. The weight of unhusked nut on the 90th day of observation is significantly different from healthy palms (1355.40 g) than that of the palms with mild (1150.20 g), moderate (873.00 g) and severe (651.40 g) intensity. The weight of unhusked nut on the 135th day of observation is significantly different in all four groups of palms. The weight of unhusked nut from healthy palms were 1303.00 g, mild intensity palms were 1114.00 g, moderate intensity palms were 868.20 g and severe intensity palms were 575.00 g. The weight of unhusked nut on the 180^{th} day of observation is significantly different in all four groups of palms. The weight of unhusked nut from healthy palms were 1412.00 g, mild intensity palms were 1133.40 g, moderate intensity palms were 861.80 g and severe intensity palms were 600.20 g. The weight of unhusked nut on the 225^{th} day of observation is significantly different in all four groups of palms with the weight of unhusked nut from healthy palms were 1403.20 g, mild intensity palms were 1170.00 g, moderate intensity palms were 787.20 g and severe intensity palms were 665.00 g. On the 270^{th} day of observation the weight of unhusked nut is significantly different in all groups of palms. The weight of unhusked nut from healthy palms were 1395.80 g, mild intensity palms were 1261.20 g, moderate intensity palms were 874.60 g and severe intensity palms were 738.80 g. The weight of unhusked nut on the 315^{th} day of observation is significantly different in all four groups of palms with the weight of unhusked nut from healthy palms were 1435.60 g, mild intensity palms were 1213.60 g, moderate intensity palms were 821.00 g and severe intensity palms were 672.80 g. On the 360^{th} day of observation the weight of unhusked nut is significantly different in all groups of palms. The weight of unhusked nut from healthy palms were 1396.00 g, mild intensity palms were 1152.60 g, moderate intensity palms were 778.80 g and severe intensity palms were 601.40 g. The mean nut weight of unhusked nut from the four groups of palms were 1449.71 g, 1172.36 g, 845.31 g and 619.58 g for the healthy, mild , moderate and severe intensity palms respectively.

Table 23 Weight of husked nut

Weight of husked nut (g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	594.20	573.20	587.20	575.60	575.40	586.00	584.80	584.20	586.60	583.02
Moderate intensity	479.80	476.20	480.00	475.20	476.80	476.40	476.80	476.20	474.80	476.91
Severe intensity	373.60	370.00	370.20	371.80	369.60	370.00	369.40	369.60	369.00	370.36
Healthy	740.80	725.80	725.80	724.20	724.80	724.00	725.80	724.60	724.20	726.67
CD (0.05)	12.323	25.193	11.47	11.951	12.694	11.307	12.738	12.309	10.982	4.333

Table 24.Weight of unhusked nut

Weight of unhusked nut (g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	1206.20	1150.00	1150.20	1114.00	1133.40	1170.00	1261.20	1213.60	1152.60	1172.36
Moderate intensity	900.20	843.00	873.00	868.20	861.80	787.20	874.60	821.00	778.80	845.31
Severe intensity	578.80	492.80	651.40	575.00	600.20	665.00	738.80	672.80	601.40	619.58
Healthy	1702.50	1644.20	1355.40	1303.00	1412.00	1403.20	1395.80	1435.60	1396.00	1449.71
CD (0.05)	68.331	268.53	187.30	111.15	140.86	107.92	244.23	145.23	139.22	78.343

4.3.2.13. Weight of opened nut

The weight of opened nut among the four groups of palms are given in Table 25. There was a significant difference in the weight of opened nut between all the four groups in all periods of observation. The opened nuts from the healthy palms showed the highest weight among the four groups of palms on all days of observation. The palms of severe intensity recorded the lowest weight of opened nut compared with the other palms on all days of observation. On the first day of observation the weight of opened nut is significantly different from healthy palms (603.40 g) than that of the palms with mild (470.20 g), moderate (365.20 g) and severe (264.40 g) intensity. On the 45th day of observation the weight of opened nut is significantly different from healthy palms (601.20 g) than that of the palms with mild (455.40 g), moderate (362.20 g) and severe (266.40 g) intensity. The weight of opened nut on the 90th day of observation is significantly different from healthy palms (600.80 g) than that of the palms with mild (469.60 g), moderate (365.60 g) and severe (265.00 g) intensity. The weight of opened nut on the 135th day of observation is significantly different in all four groups of palms. The weight of opened nut from healthy palms were 601.40 g, mild intensity palms were 457.20 g, moderate intensity palms were 360.80 g and severe intensity palms were 264.80 g. The weight of opened nut on the 180th day of observation is significantly different in all four groups of palms. The weight of opened nut from healthy palms were 600.80 g, mild intensity palms were 458.00 g, moderate intensity palms were 363.20 g and severe intensity palms were 263.00. The weight of opened nut on the 225th day of observation is significantly different in all four groups of palms with the weight of opened nut from healthy palms were 601.60 g, mild intensity palms were 470.00 g, moderate intensity palms were 363.20 g and severe intensity palms were 264.60. On the 270th day of observation the weight of opened nut is significantly different in all groups of palms. The weight of opened nut from healthy palms were 601.20 g, mild intensity palms were 466.20 g, moderate intensity palms were 364.20 g and severe intensity palms were 263.40 g. The weight of opened nut on the 315th day of observation is significantly different in all four groups of palms with the weight of opened nut from healthy palms were 602.40 g, mild intensity palms were 467.20 g, moderate intensity palms were 363.80 g and severe intensity palms were 263.00 g. On the 360th day of observation the weight of opened nut is significantly different in all groups of palms. The weight of opened nut from healthy palms were 600.40 g, mild intensity palms were 469.00 g, moderate intensity palms were 361.80 g and severe intensity palms were 262.80 g. The mean nut weight of opened nut from the four groups of palms were 601.46 g, 464.76 g, 363.33 g and 264.16 g for the healthy, mild , moderate and severe intensity palms respectively. The mean weight of opened nut 601.46 gram in healthy compared to 264.16 g in severe showed a yield reduction of 56 per cent over the healthy.

4.3.2.14. Volume of nut water

The volume of nut water from the boron deficient and healthy groups of palms are given in Table 26. There was a significant difference in the volume of nut water between all the four groups in all periods of observation. The volume of nut water showed a significant reduction in boron deficient groups compared to healthy palms. The volume of nut water from the healthy palms showed the highest weight among the four groups of palms on all days of observation. The palms of severe intensity recorded the lowest weight of opened nut compared with the other palms on all days of observation. On the first day of observation the volume of nut water is significantly different from healthy palms (124.40ml) than that of the palms with mild (470.20,118.60ml), moderate (116.60ml) and severe (106.60) intensity. On the 45th day of observation the volume of nut water is significantly different from healthy palms (119.20ml) than that of the palms with mild (117.80ml), moderate (114.60ml) and severe (105.20ml) intensity. The volume of nut water on the 90th day of observation is significantly different from healthy palms (125.00ml) than that of the palms with mild (117.60ml), moderate (114.60ml) and severe (105.20ml) intensity. The volume of nut water on the 135th day of observation is significantly different in all four groups of palms. The volume of nut water from healthy palms were 122.80ml, mild intensity palms were 118.20ml, moderate intensity palms were 114.80 and severe intensity palms were 107.00ml. The volume of nut water on the 180th day of observation is significantly different in all four groups of palms. The volume of nut water from healthy palms were 124.00ml, mild intensity palms were 117.40ml, moderate intensity palms were 113.80ml and severe intensity palms were 106.60ml. The volume of nut water on the 225th day of observation is significantly different in all four groups of palms with the volume of nut water from healthy palms were 122.40ml, mild intensity palms were 116.00ml, moderate intensity palms were 112.80ml and severe intensity palms were 105.40ml. On the 270th day of observation the volume of nut water is significantly different in all groups of palms. The volume of nut water from healthy palms were 124.20ml, mild intensity palms were 118.60, moderate intensity palms were 113.00ml and severe intensity palms were 106.00ml. The volume of nut water on the 315th day of observation is significantly different in all four groups of palms with the volume of nut water from healthy palms were 122.20ml, mild intensity palms were 117.00ml, moderate intensity palms were 112.20ml and severe intensity palms were 106.60ml. On the 360th day of observation the volume of nut water is significantly different in all groups of palms. The volume of nut water from healthy palms were 123.80ml, mild intensity palms were 117.80ml, moderate intensity palms were 113.00ml and severe intensity palms were 106.20ml. The mean volume of nut water from the four groups of palms were 123.11ml, 117.67ml, 113.91ml and 106.09 ml for the healthy, mild , moderate and severe intensity palms respectively. The severe palms showed a reduction of thirteen percent over the healthy palms.

Table 25. Weight of opened nut

Weight of opened nut (g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	470.20	455.40	469.60	457.20	458.00	470.00	466.20	467.20	469.00	464.76
Moderate intensity	365.20	362.20	365.6	360.8	363.20	363.20	364.20	363.80	361.80	363.33
Severe intensity	264.40	266.40	265.00	264.80	263.00	264.60	263.40	263.00	262.80	264.16
Healthy	603.40	601.20	600.80	601.40	600.80	601.60	601.20	602.40	600.40	601.46
CD (0.05)	1.161	0.940	1.127	0.792	0.920	0.763	1.017	1.558	0.792	3.107

Table 26. Volume of nut water

Volume of nut water(ml) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	118.60	117.80	117.60	118.20	117.40	116.00	118.60	117.00	117.80	117.67
Moderate intensity	116.60	114.60	114.40	114.80	113.80	112.80	113.00	112.20	113.00	113.91
Severe intensity	106.60	105.20	105.20	107.00	106.60	105.40	106.00	106.60	106.20	106.09
Healthy	124.40	119.20	125.00	122.80	124.00	122.40	124.20	122.20	123.80	123.11
CD (0.05)	1.379	6.561	3.090	2.283	2.395	1.127	2.012	2.034	1.940	1.176

4.3.2.15. Thickness of meat

The meat thickness in all four groups of palm were given in Table 27. The thickness of meat in all four groups of palms were significantly different in all periods of observation. On the first day of observation the meat thickness is significantly different from healthy palms (18.40mm) than that of the palms with mild (15.60mm), moderate (13.60mm) and severe (11.20mm) intensity. On the 45th day of observation the meat thickness is significantly different from healthy palms (18.20mm) than that of the palms with mild (15.40mm), moderate (13.40mm) and severe (11.20mm) intensity. The meat thickness on the 90th day of observation is significantly different from healthy palms (18.00mm) than that of the palms with mild (15.40mm), moderate (13.40mm) and severe (10.60mm) intensity. The meat thickness on the 135th day of observation is significantly different in all four groups of palms. The meat thickness from healthy palms were 17.60mm, mild intensity palms were 15.60mm, moderate intensity palms were 13.60mm and severe intensity palms were 11.00mm. The meat thickness on the 180th day of observation is significantly different in all four groups of palms. The meat thickness from healthy palms were 18.20mm, mild intensity palms were 15.40mm, moderate intensity palms were 13.00mm and severe intensity palms were 11.40mm. The meat thickness on the 225th day of observation is significantly different in all four groups of palms with the meat thickness from healthy palms were 18.80mm, mild intensity palms were 15.60mm, moderate intensity palms were 13.20mm and severe intensity palms were 11.20mm. On the 270th day of observation the meat thickness is significantly different in all groups of palms. The meat thickness from healthy palms were 18.80mm, mild intensity palms were 15.80mm, moderate intensity palms were 13.50mm and severe intensity palms were 11.40mm. The meat thickness on the 315th day of observation is significantly different in all four groups of palms with the meat thickness from healthy palms were 18.00, mild intensity palms were 15.20, moderate intensity palms were 14.00mm and severe intensity palms were 11.40mm. On the 360th day of observation the meat thickness is significantly different in all groups of palms. The meat thickness from healthy palms were 18.40mm, mild intensity palms were 15.40mm, moderate intensity palms were 13.40mm and severe intensity palms were 11.20mm. The mean meat thickness among the healthy, mild, moderate and severe intensity palms were 18.3, 15.5, 13.5 and 11.2mm respectively.

4.3.2.16. Weight of embryo

The weight of embryo of the four groups of palms are given in Table 28.The weight of embryo on the first day of observation for mild and moderate intensity palms were on par and was significantly different from severe intensity and healthy palms. The weight of embryo recorded from mild intensity and moderate intensity were on par on 45th , 135th ,180th 225th , 270th ,315th and 360th day of observation.

The highest embryo weight of 0.098 g was observed in the healthy palms on the 45th, 225th and 315th day of observation. The lowest embryo weight of 0.06 g was observed in the severe palms on the first day of observation. The weight of embryo in gram in the healthy palms ranged from 0.092 to 0.098g, in mild intensity palms 0.082g to 0.088g, for moderate intensity palms from 0.081 to 0.088g and in severe intensity palms ranged from 0.060 to 0.067. The mean embryo weight of the healthy, mild, moderate and severe intensity palms were 0.096, 0.085, 0.084, 0.065 g respectively

Table 27. Thickness of meat

Thickness of meat(mm) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	15.60	15.40	15.40	15.6 0	15.40	15.60	15.80	15.20	15.40	15.50
Moderate intensity	13.60	13.40	13.40	13.6 0	13.00	13.20	13.50	14.00	13.40	13.50
Severe intensity	11.20	11.20	10.60	11.00	11.40	11.20	11.40	11.40	11.20	11.20
Healthy	18.40	18.20	18.00	17.60	18.20	18.80	18.80	18.00	18.40	18.30
CD (0.05)	0.910	0.980	0.940	1.050	1.110	0.730	0.740	0.810	0.880	0.320

Table 28. Weight of embryo

Weight of embryo(g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	0.082	0.086	0.086	0.083	0.083	0.088	0.086	0.088	0.084	0.085
Moderate intensity	0.086	0.088	0.081	0.082	0.084	0.084	0.085	0.085	0.084	0.084
Severe intensity	0.060	0.062	0.062	0.067	0.066	0.065	0.067	0.064	0.064	0.065
Healthy	0.096	0.098	0.096	0.092	0.092	0.098	0.096	0.098	0.094	0.096
CD (0.05)	0.006	0.003	0.003	0.004	0.006	0.002	0.005	0.003	0.005	0.002

4.3.2.17. Weight of shell

The weight of shell of four groups of palms are given in Table 29. The weight of shell was on par for mild and healthy palms on 45th, 90th, 135th, 225th, 270th and 360th day of observation. On the 45th day of observation the weight of shell was on par for the palms coming under mild and moderate intensity group. On the 360 th day of observation the weight of shell on moderate intensity palms were on par with severe intensity palms. The weight of shell in the healthy palms was the highest on first day of observation (166.6 g). The weight of shell ranged from 159.80g to 163.00g in mild intensity palms 155.20g to 158.20g in moderate intensity palms and 155.20g to 158.20g in severe intensity palms. The mean weight of shell for healthy, mild, moderate and severe intensity palms were 163.57g, 161.40g, 156.42g and 152.02 g respectively.

4.3.2.18. Weight of kernel

The weight of kernel of all the four groups of palms are given in Table 30. The weight of kernel of the four groups of palms showed significant difference during all periods of observation. The healthy palms(453.20g) showed highest weight for the fresh kernel on the first day of observation. The severe intensity palms showed the lowest kernel weight of 176.80g on the 225th day of observation. On the first day of observation the weight of kernel is significantly different from healthy palms (453.2060g)) than that of the palms with mild (294.60g), moderate (226.0060g)) and severe (178.00g)) intensity. On the 45th day of observation the weight of kernel is significantly different from healthy palms (452.206g) than that of the palms with mild (291.00g), moderate (224.80g) and severe (177.80g) intensity. The weight of kernel on the 90th day of observation is significantly different from healthy palms (436.20 g) than that of the palms with mild (288.60g), moderate (222.60 g) and severe (178.40 g) intensity. The weight of kernel on the 135th day of observation is significantly different in all four groups of palms. The weight of kernel from healthy palms were

398.20 g, mild intensity palms were 290.00 g, moderate intensity palms were 224.20 g and severe intensity palms were 178.40 g. The weight of kernel on the 180th day of observation is significantly different in all four groups of palms. The weight of kernel from healthy palms were 406.60 g, mild intensity palms were 290.20 g, moderate intensity palms were 227.20 g and severe intensity palms were 177.00. The weight of kernel on the 225th day of observation is significantly different in all four groups of palms with the weight of kernel from healthy palms were 401.60, mild intensity palms were 290.20 g, moderate intensity palms were 223.80 g and severe intensity palms were 176.80 g. On the 270th day of observation the weight of kernel is significantly different in all groups of palms. The weight of kernel from healthy palms were 400.00 g, mild intensity palms were 291.20 g, moderate intensity palms were 222.80 g and severe intensity palms were 179.80 g. The weight of kernel on the 315th day of observation is significantly different in all four groups of palms with the weight of kernel from healthy palms were 401.00 g, mild intensity palms were 291.20 g, moderate intensity palms were 226.40 g and severe intensity palms were 179.60 g. On the 360th day of observation the weight of kernel is significantly different in all groups of palms. The weight of kernel from healthy palms were 399.20 g, mild intensity palms were 289.00, moderate intensity palms were 223.60 g and severe intensity palms were 177.60 g. The mean weight of kernel 416.49 gram in healthy compared to 177.16 g in severe showed a yield reduction of 57 per cent over the healthy.

Table 29. Weight of shell

Weight of shell(g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	163.00	162.40	162.80	161.00	160.20	161.40	162.00	159.80	160.00	161.40
Moderate intensity	158.20	157.40	156.00	155.60	156.20	157.20	155.20	156.00	156.40	156.42
Severe intensity	153.20	153.60	146.00	148.20	148.60	153.80	154.80	155.00	155.40	152.02
Healthy	166.6	166.40	163.20	162.00	164.00	162.00	163.60	162.20	163.80	163.57
CD (0.05)	3.220	5.073	3.964	2.504	3.435	2.381	2.824	3.117	2.376	2.002

Table 30. Weight of kernel

Weight of kernel(g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	294.60	291.00	288.60	290.00	290.20	290.20	291.20	291.20	289.00	290.67
Moderate intensity	226	224.80	222.60	224.20	227.20	223.80	222.80	226.40	223.60	224.60
Severe intensity	178	177.80	178.40	178.40	177.00	176.80	179.80	179.60	177.60	177.16
Healthy	453.20	452.20	436.20	398.20	406.60	401.60	400.00	401.00	399.20	416.49
CD (0.05)	2.372	2.071	1.354	2.140	2.573	2.494	2.600	3.307	2.096	11.435

4.3.2.19. Weight of copra

The weight of copra from all four groups of palms are given in Table 31.The weight of copra showed a significant difference among all the four group. On the first day of observation the weight of copra is significantly different from healthy palms (225.90) than that of the palms with mild (145.70 g), moderate (112.80 g) and severe (89.00 g) intensity. On the 45th day of observation the weight of copra is significantly different from healthy palms (226.10 g) than that of the palms with mild (145.50), moderate (112.40 g) and severe (88.80 g) intensity. The weight of copra on the 90th day of observation is significantly different from healthy palms (218.10 g) than that of the palms with mild (144.50 g), moderate (111.30 g) and severe (89.20 g) intensity. The weight of copra on the 135th day of observation is significantly different in all four groups of palms. The weight of copra from healthy palms were 199.10 g, mild intensity palms were 145.30 g, moderate intensity palms were 112.10 g and severe intensity palms were 89.60 g. The weight of copra on the 180th day of observation is significantly different in all four groups of palms. The weight of copra from healthy palms were 203.30 g, mild intensity palms were 145.10 g, moderate intensity palms were 113.60 g and severe intensity palms were 87.40 g. The weight of copra on the 225th day of observation is significantly different in all four groups of palms with the weight of copra from healthy palms were 200.80 g, mild intensity palms were 145.10 g, moderate intensity palms were 111.90 g and severe intensity palms were 84.40 g. On the 270th day of observation the weight of copra is significantly different in all groups of palms. The weight of copra from healthy palms were 200.00 g, mild intensity palms were 145.10 g, moderate intensity palms were 111.40 g and severe intensity palms were 89.90 g. The weight of copra on the 315th day of observation is significantly different in all four groups of palms with the weight of copra from healthy palms were 200.50 g, mild intensity palms were 145.60 g, moderate intensity palms were 113.20 g and severe intensity palms were 88.80 g. On the 360th day of observation the weight of copra is significantly different in all groups of palms. The weight of copra from healthy palms were 199.50, mild intensity palms were 144.50, moderate intensity palms were 111.80 g and severe intensity palms were 88.80 g. The mean weight of copra 208.14 g in healthy compared to 88.43 g in severe showed a yield reduction of 57 per cent over the healthy.

4.3.2.20. Oil content

The oil content among the four groups of palms in all periods of observation are given in Table 32. The oil content in mild, moderate, severe intensity palms and healthy palms were significantly different in all periods of observation. A mean oil content of sixty five percent of was noticed in healthy while it reduced to 61 per cent in mild , 57 per cent in moderate and 52 per cent in severe. On the first day of observation the oil content is significantly different from healthy palms (65.42 per cent) than that of the palms with mild (61.44 per cent), moderate (57.28 per cent) and severe (51.96 per cent) intensity. On the 45th day of observation the oil content is significantly different from healthy palms (65.38 per cent) than that of the palms with mild (60.94 per cent), moderate (56.84 per cent) and severe (52,16 per cent) intensity. The oil content on the 90th day of observation is significantly different from healthy palms (65.66 per cent) than that of the palms with mild (61.62 per cent), moderate (56.82 per cent) and severe (52.56 per cent) intensity. The oil content on the 135th day of observation is significantly different in all four groups of palms. The oil content from healthy palms were 65.44 per cent, mild intensity palms were 61.22 per cent, moderate intensity palms were 57.02 per cent and severe intensity palms were 52.40 per cent. The oil content on the 180th day of observation is significantly different in all four groups of palms. The oil content from healthy palms were 65.58 per cent, mild intensity palms were 61.48 per cent, moderate intensity palms were 57.02 per cent and severe intensity palms were 52.40 per cent. The oil content on the 225th day of observation is significantly different in all four groups of palms with the oil content from healthy palms were 65.64 per cent, mild intensity palms were 60.92 per cent, moderate intensity palms were 57.02 per cent and severe intensity palms were

52.64 per cent. On the 270th day of observation the oil content is significantly different in all groups of palms. The oil content from healthy palms were 65.34 per cent, mild intensity palms were 61.78 per cent, moderate intensity palms were 57.02 per cent and severe intensity palms were 52.32 per cent. The oil content on the 315th day of observation is significantly different in all four groups of palms with the oil content from healthy palms were 65.48 per cent, mild intensity palms were 61.22 per cent, moderate intensity palms were 57.48 per cent and severe intensity palms were 52.72 per cent. On the 360th day of observation the oil content is significantly different in all groups of palms. The oil content from healthy palms were 65.50 per cent, mild intensity palms were 60.98 per cent, moderate intensity palms were 56.94 per cent and severe intensity palms were 52.48 per cent. The mean oil content 65.49 per cent in healthy compared to 52.48 per cent in severe showed a yield reduction of 19 per cent over the healthy.

Table 31. Weight of copra

Weight of copra(g) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	145.70	145.50	144.30	145.00	145.10	145.10	145.60	145.60	144.50	145.14
Moderate intensity	112.80	112.40	111.30	112.10	113.60	111.90	111.40	113.20	111.80	112.12
Severe intensity	89.00	88.80	89.20	89.60	87.40	84.40	89.90	88.80	88.80	88.43
Healthy	225.90	226.10	218.10	199.10	203.30	200.80	200.00	200.50	199.50	208.14
CD (0.05)	2.068	1.017	0.677	1.062	2.100	2.240	1.305	2.421	1.062	5.690

Table 32. Oil content

Oil content (%) at 45 days interval										
Groups	1st day	45th day	90th day	135th day	180th day	225th day	270th day	315th day	360th day	Mean
Mild intensity	61.44	60.94	61.62	61.22	61.48	60.92	61.78	61.22	60.98	61.29
Moderate intensity	57.28	56.84	56.82	57.02	57.18	57.02	57.02	57.48	56.94	57.07
Severe intensity	51.96	52.16	52.56	52.40	51.62	52.64	52.32	52.72	52.48	52.26
Healthy	65.42	65.38	65.66	65.44	65.58	65.64	65.34	65.48	65.50	65.49
CD (0.05)	1.017	1.084	1.152	1.415	1.438	1.036	0.918	0.629	1.013	0.255

4.3.3.Scoring for coreid bug

The scoring for coreid bug is given in Table 33.The scoring for mite and coreid was done based on the score developed by Paul (2006).

The scoring for the infestation of coreid bug in the selected twenty palms of mild, moderate ,severely intensity of boron deficiency and healthy palms revealed that in the palms with mild and moderate intensity , the percentage of damage ranged between eleven to fifty percent. The percentage of infestation in the palms with severe intensity ranged between twenty six to seventy five percent. The percentage of damage for the healthy palms was the minimum and ranged from 0 to 10 percent with the mean intensity score ranging from 0 to 1.3.

The intensity of attack of coreid bug was found to be more in the palms with severe intensity (3.61) which was significantly different from all other three groups. The palms with moderate and mild intensity showed a mean intensity score of 2.72 and 2.58 respectively and were on par . The healthy palms had a mean intensity score of 0.724 which was the least score noticed and was significantly different from mild, moderate, and severe intensity of boron deficient palms.

4.3.4.Scoring of mite

The scoring for the infestation of mites in the selected twenty mild, moderate, severe intensity and healthy palms is shown in table 34. The results revealed that in the palms with mild intensity, the percentage of damage ranged between one to twenty five percent. The percentage of infestation in the palms with moderate intensity ranged from one to hundred percent and severe intensity ranged between eleven to hundred percent. The healthy palms were having percentage of damage ranged from 0-10.

Table 33.Damage in coconut palms due to coried bug attack

Group	Mean Intensity Score
Mild intensity	2.58
Moderate intensity	2.72
Severe intensity	3.61
Healthy	1.72
CD(0.05)	0.74

Table 34 .Damage in coconut palms due to mite attack

Palm	MIS	Percentage of damage
Mild 1	Category 2	1-10
Mild 2	Category 3	11-25
Mild3	Category 2	1-10
Mild 4	Category 2	1-10
Mild 5	Category 3	11-25
Moderate 1	Category 2	1-10
Moderate 2	Category 3	11-25
Moderate 3	Category 4	26-50
Moderate 4	Category 5	50-100
Moderate 5	Category 5	50-100
Severe 1	Category 4	26-50
Severe 2	Category 5	50-100
Severe 3	Category 4	26-50
Severe 4	Category 3	11-25
Severe 5	Category 4	26-50
Healthy 1	Category 1	0
Healthy2	Category 2	1-10
Healthy3	Category 1	0
Healthy4	Category 1	0
Healthy5	Category 2	1-10

DISCUSSION

5 .DISCUSSION

The study entitled "Characterisation of boron deficient coconut palms (*Cocos nucifera* L.)" identified boron deficient coconut palms, predisposing factors and characterised morphological features and the results of which are discussed here based on the study conducted during the year 2015-2016.

5.1. IDENTIFICATION OF BORON DEFICIENT COCONUT PALMS

The coconut palms showing boron deficiency symptoms were identified from different farmers field in Kalliyoor panchayat based on the visual symptoms of leaf, inflorescence , nut and crown as listed by Kamalakshiamma and Shanavas (2002) . Based on the survey hundred such palms showing boron deficiency symptoms were identified. Each palm was given a score based on the symptoms observed in leaf, inflorescence nut and crown as developed as part of the experiment, the details of which are given in appendix 1. Depending on the total score obtained in each palm , it was categorized into coconut palms having mild intensity of boron deficiency and the score obtained ranged from 1- 3. Similarly those coconut palms which had an overall score of 4 to 6 were catagorised as moderate intensity palms and coconut palms which obtained a score of 7 to 10 were categorised as palms having severe intensity of boron deficiency.

Among the hundred coconut palms thus surveyed 14 palms came under mild intensity group (14 %). Eighty palms (80 %) were under moderate intensity group and six palms (6 %) came under severe intensity group. Boron deficiency has become a common deficiency problem among the coconut palms of Kerala. The study conducted by Santhosh in 2013 reported that total boron content of Kerala soil ranges from 27.5 to 330 mg/kg. The hot water extractable boron ranges from 0.05 to 7.90 mg/kg. About 65 percent soils of Kerala are deficient in boron. Coconut palms of boron deficiency surveyed had showed that most of the affected palms fall in the moderate intensity group.

Visual nutrient deficiency symptoms can be a very powerful diagnostic tool for evaluating the nutrient status of plants. The principle advantage of visual diagnostic symptoms is that they are readily obtained and provide an immediate evaluation of nutrient status. The main drawback is that the visual symptoms do not develop until after there has been a major effect on yield, growth and development (Taiz *et al.*, 2010).

Kamalakshiamma *et al.* (2001) had listed 44 boron deficiency symptoms in coconut. These symptoms were listed down and the symptoms obtained in the coconut palms surveyed were noted. Based on the different symptoms noted it was possible to identify the common symptoms found in different palms. In the mild intensity palms 15 per cent of the mild intensity group has hooked leaves. Fused leaves was also a common symptom found in 92 % of the palms of mild intensity group. However the number of fused leaves were less, only about 7 % while the leaflet internodal length was the highest 24 % in mild intensity group. Among the inflorescence characters, the inflorescence with few number of female flowers were only 20 %. All other inflorescence and nut characteristics were absent in mild intensity group of palms. Ollagnier and Valverde (1968) ; Brunin and Coomans (1973) and Manciot *et al.*(1980) reported that hooked leaf is common in *Cocos nucifera* and *Elaeis guineensis* and has been attributed to B deficiency. Broschat (2007) opined that hooked leaves appear to be symptoms of a mild and transient B deficiency.

In moderate intensity palms, the leaf characteristics such as hooked leaf, presence of fused leaf and number of fused leaf were 23 %, 73.75 % and 23.33 % respectively. Of the 80 % of palms showing moderate intensity of boron deficiency, 15 % of palms showed high leaflet intermodal length and reduced number of leaves. Inflorescence with few female flowers were observed in 70 % of moderate intensity palms. 40.12 % of moderate intensity palms showed aborted inflorescence while 47.5% showed necrotic inflorescence. The bunches with hen and chicken symptoms were noticed in

55% of the moderate intensity palms. 25% of the palms were with crowed crown and 22.5% had fish bone appearance. Discolouration of mesocarp was seen in 4 % of palms with moderate intensity. Corrado *et al.* (1992) reported that that boron deficiency can also be chronic, affecting a series of successive leaves as they develop. As an immobile element, B deficiency causes leaflet fusion and malformation, truncation, and reduction in the size of newly emerging leaves.

Hooked leaves were noted in only 12 % of the severe intensity palms. 86 % of severe intensity palms showed fused leaves while the number of fused leaves was 37%, the highest among the three groups. High leaflet internodal length was noticed in 11% of the severe intensity groups. 28.7% of the palms were with reduced number of leaves while 57.14% had crowed crown. Among the inflorescence characters, inflorescence with few female flowers, aborted and necrotic inflorescences were 85.71 %, 72 % and 71.11 % respectively. Among the nut symptoms, 71.11 % of palms produced bunches with hen and chicken symptom 28.78 % of palms had nuts with uneven kernel development while 28.47 % showed nuts without any kernel. Discolouration of mesocarp was noticed in 22 % of the severe intensity palms. Thus it can be inferred that in mild intensity groups, the symptoms were prominent in leaf characteristics, while the inflorescence and nut characteristics were not much affected. The moderate intensity palms produced leaf and inflorescence symptoms mostly. Nut symptoms were not much prominent in moderate intensity groups though bunches with hen and chicken symptoms were observed. However in severe intensity palms leaf, inflorescence and nut symptoms were present and the intensity of inflorescence and nut symptoms were more prominent in severe intensity palms.

Thus it can be inferred that by looking into the leaf, inflorescence and nut characteristics it is possible to classify the coconut palms showing boron deficiency into mild, moderate and severe intensity groups. The identification of different types of symptoms of boron deficiency in the field is very important for the coconut cultivators. High leaflet internodal length, inflorescence with few female flowers and reduced number of leaves as symptoms of boron deficiency were reported by Kamalakshiamma and Shanavas (2001). Boron-deficient palms often abort their fruits prematurely and inflorescences may have extensive necrosis near their tips (Broschat,2007).

The boron deficiency symptoms on the mild palms observed were sharp bent (hooked leaf) leaflet tips and transverse translucent streaking on the leaflets and in the severe palms where rachis tips devoid of leaflets, tightly fused new leaves along entire length, at leaf tip or at the base, new leaves may emerge small in size, with crumpled, corrugated or accordion-like leaflets, premature fruit loss, dead inflorescences and entire crown bent in one direction or twisted leaves (Brown, 2007).

Boron deficiency is occasionally found on young palms in the field showing a reduction of leaf area in certain leaves producing incipient 'little leaf', advanced 'little leaf' with extreme reduction of leaf area and bunching and reduction in the number of leaflets and 'fish-bone' leaf. The 'fish-bone' leaves are abnormally stiff with leaflets reduced to projections (TNAU Agriportal, 2013).

5.2. BORON STATUS OF SOIL AND PLANT

The visual symptoms though help to identify the deficiency of the particular nutrient; the deficiency can be confirmed only by the analysis of the particular nutrient in soil and plant. Hence the soil and plant boron status of four groups of palms were analysed.

Soil boron status of the selected palms of four groups ranged from 0.122 – 0.358 mg/kg of soil for boron deficient palms and 0.529 mg/kg of soil for the healthy palms (Table 4). The soil boron status recorded for mild intensity group was 0. 358 mg/kg, for moderate intensity group was 0.256 mg/kg and that for severe intensity group was 0.122 mg/kg of soil. Plant boron status analysed revealed that for the mild intensity group plant boron status was 3.68 mg/kg, for moderate intensity group 2.5 mg/kg and for severe intensity group it was 1.18 mg/kg. The plant boron status for healthy palms showed a mean value of 13.88mg/kg. The results of soil and plant boron status of selected palms showed that the grouping of palms based on symptoms were correct and it followed the same trend as soil and plant boron status. The results also showed that when the soil boron status falls below 0.529 mg/kg the symptom will be expressed. When the soil boron level falls to 0.122 mg/kg the inflorescence and nut symptoms became prominent. .Soil B content around healthy palms and plant boron status of healthy palms analyses was within the critical level of B. Similarly when the plant boron status falls to 3.68 mg/kg, the symptoms was expressed (Kelling, 1999).

The soils of southern and northern coastal plains, low lands of lateritic origin are deficient in boron. Very high levels of boron (>5mg/kg) as well as boron retention are detected in Pokkali and Kaipad soils due to sea water inundation and high levels of organic matter (Kamalakshiamma, 2001).

In an evaluation of the nutritional status of a coconut palm orchard by Santos *et al.* (2004) reported that boron was one of the most yield limiting factors. According to their findings, the most important elements for coconut production in decreasing importance were K > Ca > B.

5.3. IDENTIFICATION OF PRE-DISPOSING FACTORS FOR DEFICIENCY

The predisposing factors responsible for the boron deficiency identified from the coconut fields showing deficiency based on questionnaire survey revealed that 100% drainage was noticed in the boron deficient fields. No single field was observed where water was stagnant. Thus it was not possible to identify whether water stagnation was acting as a predisposing factor. Ninety six percent of the fields showed an elevation of 28 to 30 m above mean sea level and four per cent had an elevation of 25m above mean sea level.

The soil type of the fields surveyed was red loam and the soil pH ranged between 6 to 7.5. Fifty seven per cent of fields were having a pH range of 6 to 6.5. Thirty nine per cent were having a pH range of 6.6 to 7.0. Four per cent of fields were having a pH range of 7.1-7.5. Thirty percent of the fields had medium organic matter ranged from 0.86 to 2.1 and 70 % of the fields were having low organic matter ranging from 0.32 to 0.74 percent. The organic matter content of boron deficient fields thus fall in the low and medium organic matter and organic matter has an an effect on the release of boron. Boron deficiency has been commonly reported in soils which are highly leached and or developed from calcareous, alluvial and loessial deposits (Takkar *et al*., 1989; Razzaq and Rafiq, 1996; Borkakati andTakkar, 2000).

Kelling (1999) reported that soil organic matter is the storehouse of most of the boron in the soil. Soils low in organic matter are deficient in boron more often than soils with high organic matter content. In a study conducted by Chaudary and Shukla

(2004) it was found that boron may be unavailable to plants in heavy clayish soils due to strong adsorption to soil particles.

Silva *et al.* (1995) and Communar and Keren (2006) pointed out that sandy soils, low in organic matter and exposed to heavy rains, which drain much of the boron to deeper layers showed boron deficiency. Chronic B deficiencies were also caused by soil drying and high soil pH.

Muntean (2007) reported that boron is absorbed from the soil by plants as borate, a negatively charged ion (anion). Since boron is non-mobile in plants, a continuous supply from soil or planting media is required in all plant meristems. In mineral soils, release of boron is usually quite slow. Much of the available soil boron is held rather tightly by soil organic material. As organic matter decomposition occurs boron is released with a portion being absorbed by plants, leached below the root zone area (especially in high rainfall/acid soil areas) or tied up (unavailable) under alkaline soil conditions.

The study conducted by Welch *et al.* (1991) reported that the factors affecting B uptake include soil type (texture, alkalinity/calcareousness, pH, organic matter content), B concentration, moisture and plant species. According to Shorrocks (1997) the occurrence of B deficiency depends on multiple factors such as weather conditions (drought, high precipitation, etc.), soil conditions (low pH, soil B leaching, calcareous soils, B fixation) and the cultivated crop species. Brown and Hu (1998) revealed that boron absorption by plant roots was closely related to pH and B concentration in the soil solution; and was probably a non-metabolic process.

The age of the palms surveyed ranged between 20 to 40 and fifty three percent of the palms were between the age group 20 to 25. Sixteen percent of palms fell in the age group of 26 to 30 and 25% of the palms were between the age group of 31 to 35. Six percent of the palms were between the age group of 36 to 40.

Boron deficiency was noticed in 63 % of fields where intercropping was practiced and 37 % of the fields where intercropping was not practiced. Out of 63 per cent of fields with intercrop, organic matter application was followed in 24 % of the fields. 31 % of fields with intercrop were practicing both organic matter and fertilizer application. In 8 % of the fields neither organic matter nor fertilizers were applied. This indicates that the fields were generally deficient in boron content whether intercropping was practiced or not. Even though organic matter and fertilizers were applied the nutrient supplied through those was not sufficient enough to improve the boron content in the fields. Proper irrigation was present in 22 % of the fields and 78% of fields were rainfed. Disease incidence was noticed in 26 per cent of boron deficient palms and of this leaf rot was the main disease noticed which contributed to 88.46% followed by bud rot which contributed to 11.54%. Kamalakshiamma (2001) reported that application of borax in seedlings below five years of age was effective in reducing the symptoms of leaf rot disease.

Boron (B) deficiency is one of the most common and widespread of all nutrient deficiencies in palms. It occurs in palms growing in high rainfall areas of the tropics but is also found in palms growing in desert climates (Elliott *et al*., 2004).

Keren and Bingham (1985) reported that substances used for correcting acidity will decrease the solubility of several soil minerals. In a similar study low levels of boron found in tropical soil was attributable to factors like naturally occurring low fertility levels, removal of nutrients by several successive crops, and the increased use of fertilizers.

Several soil factors and conditions render soils deficient in B. Low soil organic matter content, coarse/sandy texture, high pH, liming, drought, intensive cultivation and more nutrient uptake than application, and the use of fertilizers poor in micronutrients are considered to be the major factors associated with the occurrence of B deficiency (Dregne and Powers, 1942; Elrashidi and Connor, 1982;Takkar *et al*., 1989; Goldberg and Forster, 1991; Rahmatullah *et al.*, 1999; Eguchi and Yamada,1997; Rashid *et al.*, 1997, 2005; Mengel and Kirkby, 2001; Niaz *et al.*(2007); Rashid and Rayan, (2004).

The hundred percent of the palms showing boron deficiency showed pest incidence. Mite and coreid bug were the major pests found. Mite attack was noticed in 89 % of the fields and 50 % of the fields were having a combined infestation of mite and coreid bug. In a study conducted by Wang *et al.* (1989) ; Marschner (1995) revealed that boron is essential for the phenol metabolism. Phenolics including lignin and isoflavones have beneficial effects against diseases when plants are attacked by pathogens.

In a similar study conducted by Whiling (2000) and Aoki *et al.* (2008) phenolics such as benzoquinones (C6), phenolic acid (C6-C1), flavonoids and iso-flavonoids (C6-C3-C6), and lignins (C6)n, (C6-C3-C6)n are essential for growth, reproduction and protection of plants against biotic (fungus, bacteria, virus, and insect infection) or abiotic stresses such as drought and temperature.

Out of the hundred palms showing boron deficiency 52 percent of the boron deficient coconut fields showed boron deficiency between zero to 25 per cent, 26 per cent of the boron deficient fields showed boron deficiency between 26 to 50 per cent, 22 per cent of boron deficient fields showed boron deficiency ranging from 51-75 percentage.

5.4.MORPHOLOGICAL CHARACTERISATION

From the 100 selected boron deficient coconut palms five palms each from mild, moderate and severe intensity of boron deficiency were observed for morphological characters and were compared with five healthy palms for one year.

5.4.1.Growth parameters

5.4.*1.1.Number of leaves*

The number of leaves in the palms coming under the four groups observed for one year at 45 days interval is represented in the Fig.1. During the first day of observation, the number of leaves in the palms with mild and moderate intensity were found to be on par and the healthy palms were significantly different from the other three groups. During the 45th, 135th, 225th and 315th day of observation, the number of leaves in the mild intensity, moderate intensity and healthy palms were on par while the severe intensity palms were significantly different from the three groups. The number of leaves on the mild and moderate intensity palms were on par and was significantly different from severe intensity palms at 90 days of observation. The number of leaves in the mild and moderate palms during the 180th day of observation were found to be on par and it was significantly different to that of the healthy and severe palms. The number of leaves in the mild, moderate and severe palms were on par during the 360th day of observation and it was significantly different from that of the healthy palms. The mean number of leaves over the year in the healthy, mild, moderate and severe palms were significantly different from each other.

Thus it was found that the number of leaves in the palms with boron deficiency was noticed had less number of leaves compared to that of the healthy palms.

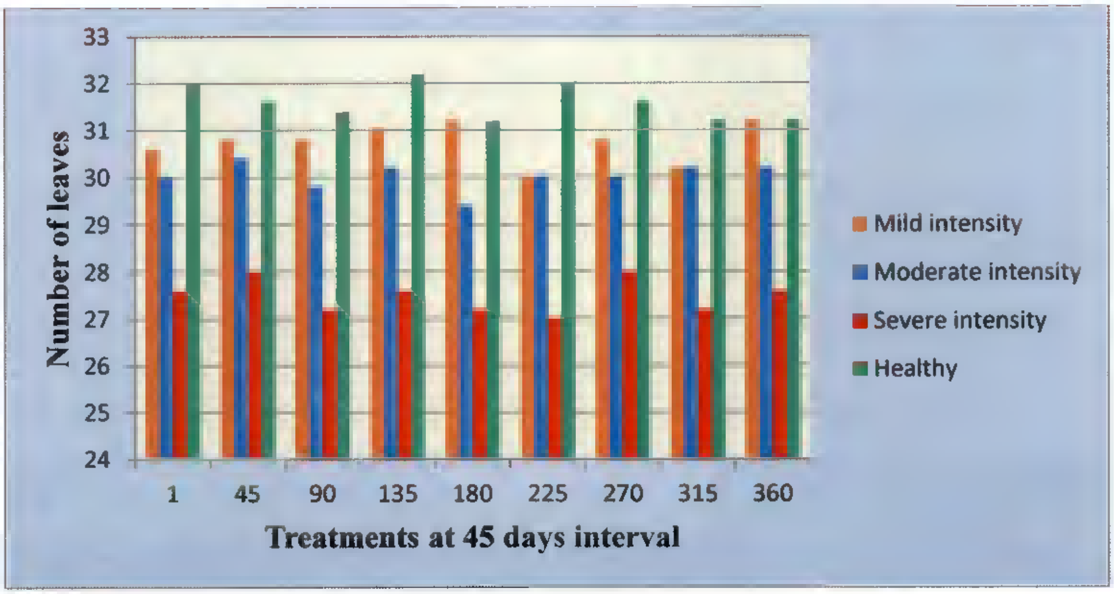

Fig.1. Number of leaves at 45 days interval

In a study conducted by Kamalakshiamma and Shanavas (2001) a similar observation of reduction in the length of the petiole and number of leaves in the coconut palms due to boron deficiency was reported.

5.4.*1.2 Number of fused leaves*

The number of fused leaves in the mild, moderate, severe intensity of boron deficient and healthy coconut palms are given in Fig.2.The numbers of fused leaves in the severe intensity palms were found to be higher compared to that of healthy, mild and moderate palms. There were no fused leaves in the healthy palms in all periods of observation. During all periods of observation the number of fused leaves in the mild, moderate and severe palms were significantly different from each other except at 180thand 225th day of observation wherein the mild and moderate intensity palms were on par. The yearly mean number of fused leaves in the severe intensity palms was 11.75. The number of fused leaves in the severe intensity palms ranged between 10.40 to 13.80 throughout the period of observation. The yearly mean number of fused leaves in the three groups of palms were significantly different from each other. The number of fused leaves increased with the intensity of boron deficiency. The palms with severe intensity had the highest number of fused leaves through out the period of observation.

In 2007, Broschat reported fused leaves as one of the most common symptoms of B deficiency. It is the failure of newly emerging spear leaves to open normally. They may be tightly fused throughout their entire length, or the fusion can be restricted to basal or distal parts of the spear leaf. In a chronic state, multiple unopened spear leaves may be visible at the apex of the canopy.

The study conducted by Brown (2007) reported that the boron deficiency symptoms on the mild palms observed were sharply bent (hooked leaf) leaflet tips and transverse translucent streaking on the leaflets. In the severe palms rachis tips were devoid of leaflets, tightly fused new leaves along entire length or leaf tip or at the base, new leaves may emerge small in size with crumpled, corrugated or

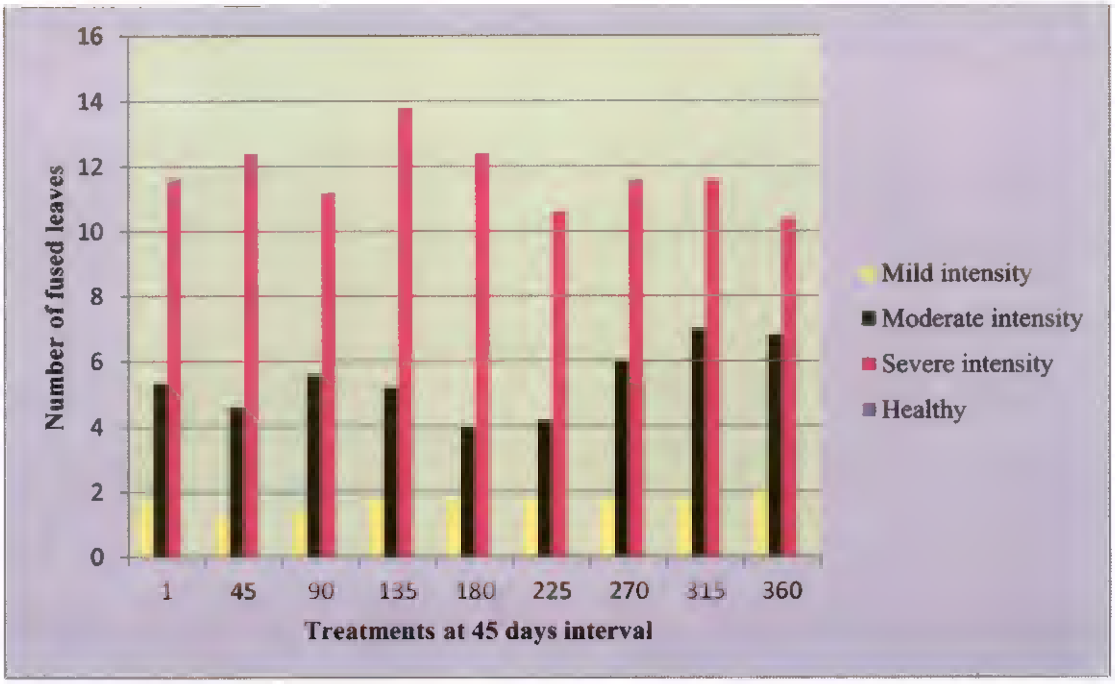

Fig.2. Number of fused leaves at 45 days interval

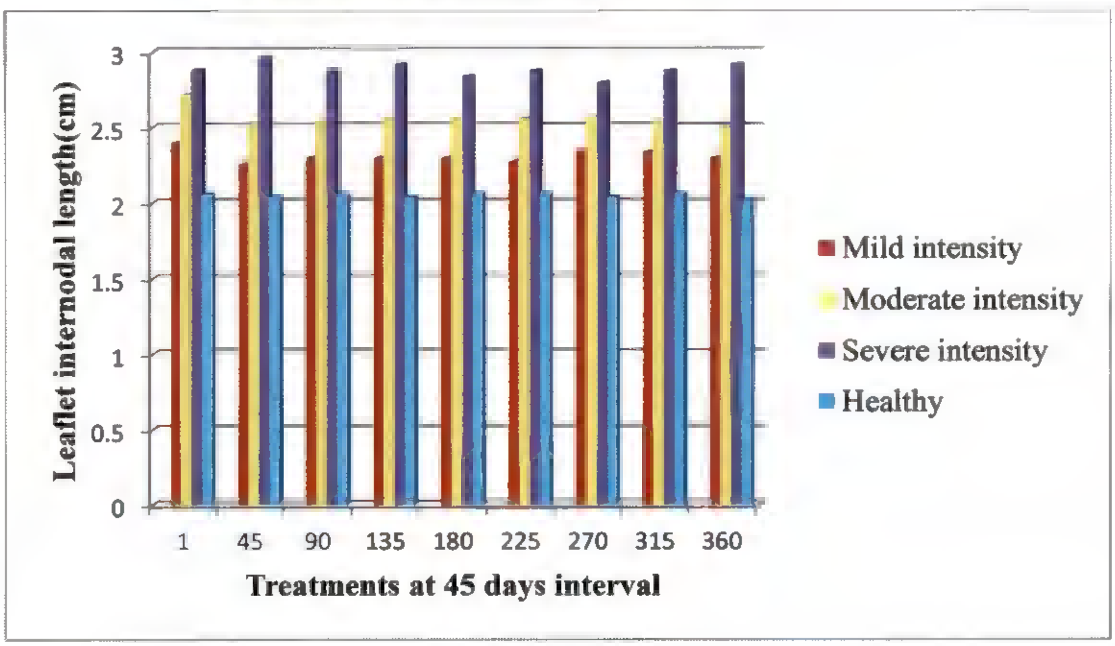

Fig.3. Leaflet internodal length

accordion-like leaflets, premature fruit loss, dead inflorescences and entire crown bent in one direction or with twisted leaves.

5.3.1.3. Leaflet internodal length

The leaflet internodal length of the four groups of palms are given in Fig.3. The leaflet internodal length in the severe and moderate intensity palms were on par during the first day of observation and it was significantly different from the healthy and mild palms. The leaflet internodal length of the mild and moderate intensity palms were on par during the 45th day of observation. The leaflet internodal length of the healthy palms , mild, moderate and severe intensity palms were significantly different from each other during the 90th, 135th, 180th ,225th , 270th ,315th and 360th day of observation. The yearly mean leaflet internodal length of the healthy, mild, moderate and severe intensity palms were significantly different from each other. The leaflet internodal length was the highest for the coconut palms with severe intensity of boron deficiency on all periods of observation.

In a study conducted by Broschat in 2007 reported that the boron deficiency will cause increase in the leaflet internodal space.

5.3.1.4. Root anatomy

The root anatomy of palms with severe and moderate intensity of boron deficiency showed the presence of loosely packed cortical cells (Plate 5). While the cortical cells present in the roots of healthy palms were tightly packed and the cortical cells of roots in the palms with mild intensity were less tightly packed.

Rajaratnam and Lowry (1973) viewed that the absence of boron affects the cells of growing regions and affects the differentiating cells and leads to the death of the growing points. Boron deficiency, in general, reduced root growth (Filho and Malavolta, 1997; Viegas *et al,* 2004) and in the coconut palm tree, production of total roots was reduced by 30% and of thin roots by 48% (Pinho *et al.*2008).

5.3.2. Yield characteristics

5.3.2.1. Number of female flowers per bunch of unfertilized inflorescence

The number of female flowers per bunch of unfertilized inflorescence in the healthy, mild, moderate and severe intensity palms are given in Fig.4.

The number of female flowers per bunch of unfertilized inflorescence in the palms during the first day of observation was significantly different for healthy, mild and severe intensity of boron deficient palms. The number of female flowers per bunch of unfertilized inflorescence in healthy palms during the first day of observation was 38.00 and that of the severe intensity palms were 22.40. The number of female flowers per bunch of unfertilized inflorescence on the 45th day of observation was on par for healthy and mild intensity while it was significantly different for severe intensity compared to healthy and mild intensity. The number of female flowers per bunch of unfertilized inflorescence for moderate and severe intensity palms were on par on the 90th, 180th and 225th day of observation. The number of female flowers on the 135th day, 180th and 225th of observation were significantly different for healthy, moderate and severe intensity palms. The healthy palms were having the highest number of female flowers (40.20) and the severe intensity palms were having the lowest (23.80) on 225th day. The number of female flowers on the 270th day of observation was significantly different in all the four groups of palms. The healthy palms showed highest number of female flowers (39.60) and the severe intensity palms showed the lowest number of female flowers (23.00) on this day. The number of female flowers on the 315th day of observation was significantly different among all the four palms. The healthy palms showed highest number of female flowers (37.00) while the severe intensity palms showed the lowest number of female flowers (23.60)on this day. The number of female flowers on the 360th day of observation was significantly different from each other in all the four group of palms. The healthy palms showed highest number of female flowers (39.00) while the palms of severe intensity showed the lowest number of female flowers (23.60) on this day. The percentage increase in the number of female flowers per bunch of unfertilized inflorescence in the healthy palms over the severe intensity palms were 37.91 per cent.

Mineral nutrient deficiencies mainly micronutrients, cause reductions in the number of feminine flowers per spathe and the fruits, which eventually easily drop off the plant, a condition generally referred to as "abortion of immature fruits" (Siqueira *et al.*, 1997; Holanda *et al,* 2007).

The study conducted in CPCRI on coconut palms revealed that borax application improved all the yield attributes significantly. The number of female flowers per bunch showed a significant increase when the quantity of the boron applied increased (Kamalakshiamma, 2001). Boron deficiency may cause a functional failure in pollen tubes, the effects of which are evident in the flowers or fruits. Fruits may abort prematurely as a result of severe boron deficiency (Broschat, 2012).

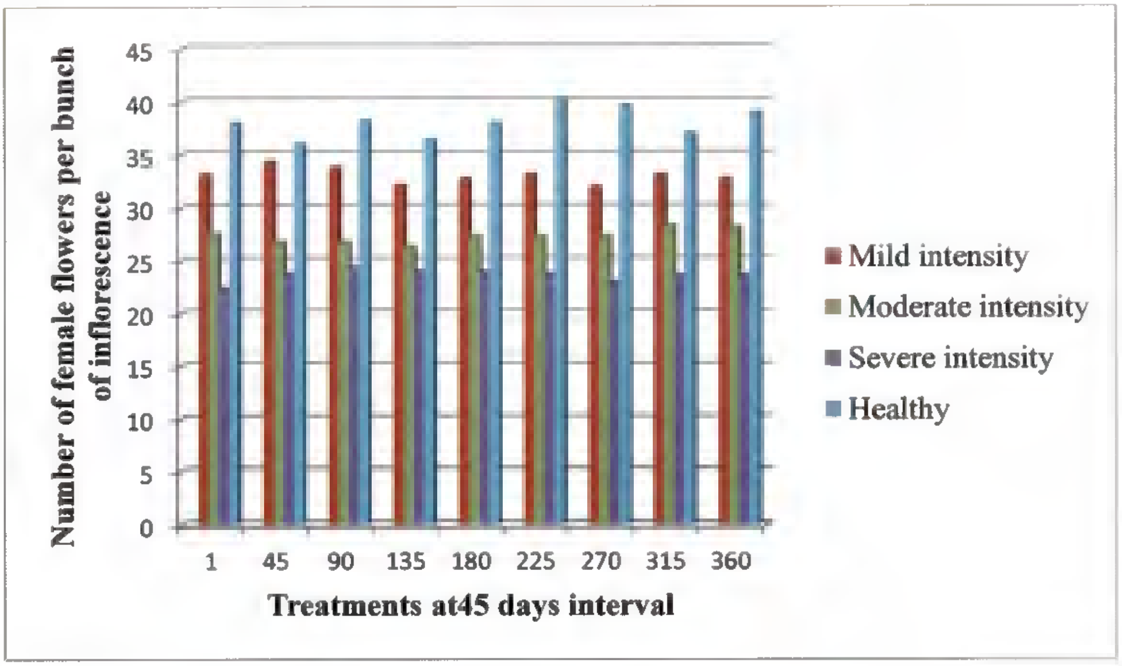

Fig.4. Number of female flowers per bunch of unfertilized inflorescence.

5.3.2.2. Number of unopened spadices

The number of unopened spadices are given in Fig.5. The numbers of unopened spadices in the mild and moderate intensity palms were on par during the 1st day of observation and was significantly different from the healthy palms. The number of unopened spadices in the mild, moderate and severe intensity palms were on par on the 45th day of observation and that of the healthy palms (4.20) was significantly different from the other three groups. The number of unopened spadices in the mild and moderate intensity palms on the 90th day of observation was 2.80 and 2.60 respectively and it was on par. The number of unopened spadices on the healthy and severe intensity palms were significantly different on the 90th day. On the 135th and 180th day of observation the number of unopened spadices in the mild and moderate intensity palms were found to be on par while that of the healthy and severe intensity palms were significantly different. On the 225th, 270th, 315th and 360th days of observation the mild and moderate intensity palms as well as moderate and severe palms were on par with each other. The healthy palms were significantly different from the mild, moderate and severe intensity palms on all these days. The number of unopened spadices in the healthy palms ranged from 4.20 to 4.60 throughout the period of observation. Similarly the number of unopened spadices in the severe intensity palms ranged from 1.20 to 2.00 throughout the period of observation. The mean number of unopened spadices in the healthy palms over the year was 4.42, for mild intensity palms were 2.72, moderate intensity palms were 2.40 and severe intensity palms were 1.52 and were significantly different from each other.

5.3.2.3. Number of spadices

The number of spadices observed in four groups of palms for one year is given in the Fig.6.The number of opened spadices on the 1st day of observation for mild and moderate intensity was found to be on par and was significantly different from that of healthy and severe intensity palms. The number of spadices for the healthy, mild and moderate intensity palms were on par at 45 th day of observation and but was significantly different from the severe intensity palms. The observation on the 90th, 135th and 180th day of observation was on par for mild and moderate intensity palms and differed significantly from healthy and severe intensity palms. The observation on 225th , 270th, 315th and 360th day revealed that the number of opened spadices for mild and moderate intensity palms and moderate and severe intensity palms were on par and differed significantly from the healthy palms. The yearly mean of the observations taken for one year revealed that the number of opened spadices for healthy palms were 1.93 and it reduced to 1.47 and 1.20 for mild and moderate intensity palms respectively. The number of opened spadices were the least for the severe intensity palms (0.58). A study conducted by Kamalakshiamma in 2001 revealed that boron has a significant role in the yield of coconut palms.

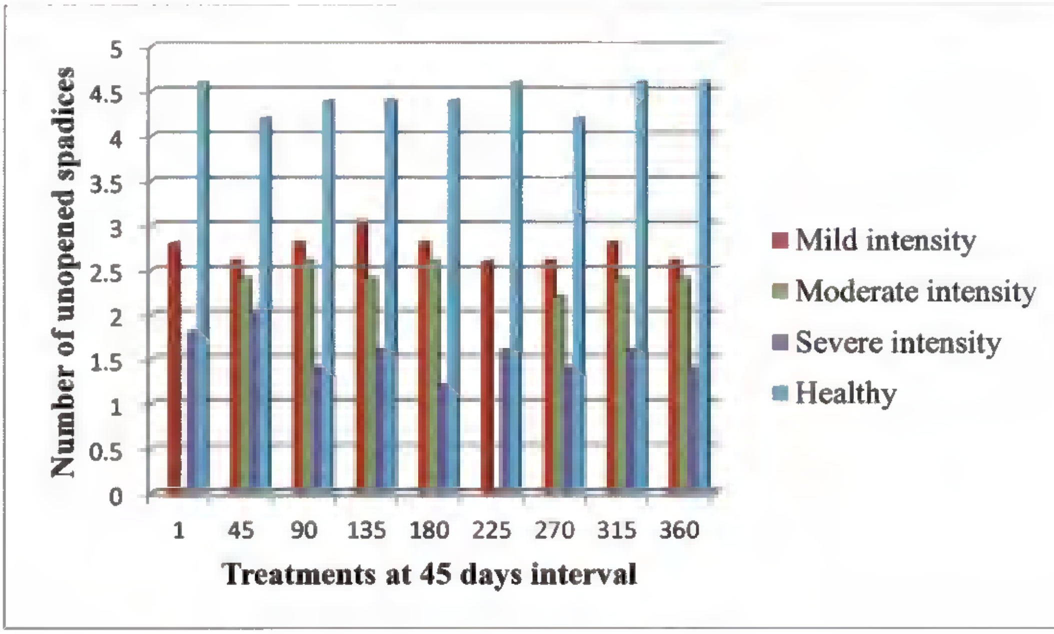

Fig.5. Number of unopened spadices

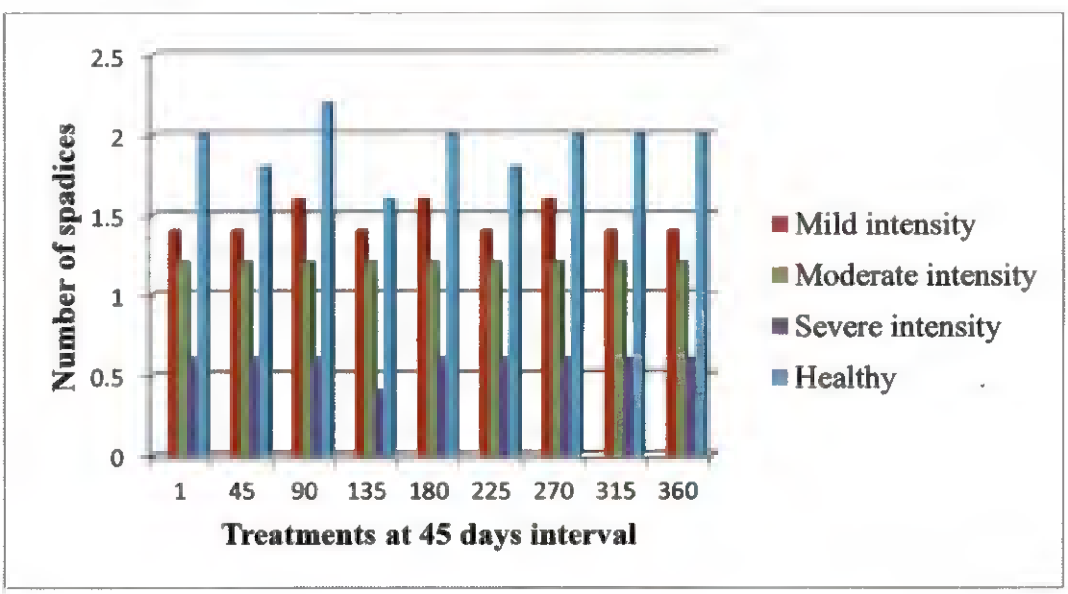

Fig.6.Number of spadices

5.3.2.4. Number of bunches

The number of bunches in the four groups of palms for a period of one year at 45 days interval is shown in the Fig.7.

On the first day of observation the number of bunches in the moderate (6.20) and severe intensity palms (5.80) and that of healthy (7.40) and mild palms (7.20) were found to be on par. On the 45th day of observation the healthy (8.00) and mild intensity palms (6.60) and mild (6.60) and moderate intensity palms (6.00) and moderate (6.00) and severe intensity palms (5.40) were found to be on par. The number of bunches in the mild (6.20), moderate (6.00) and severe intensity palms (5.40) on the 90th day of observation were found to be on par while the number of bunches in the healthy palms found to be significantly different from the other three groups. On the 135th day of observation the number of bunches in the mild (6.60), moderate (6.40) and severe (5.80) intensity palms were found to be on par. On the 180th day of observation the number of bunches in the healthy (7.80) palms were found to be significantly different from other 3 groups while the mild (6.80), moderate (6.60) and severe (6.00) intensity palms were found to be on par. The healthy (7.40) and mild intensity palms (6.60) and mild (6.60) and moderate intensity palms (6.20) and moderate (6.20) and severe intensity palms (5.40) were found to be on par on the 225th day of observation. On the 360th day of observation the healthy (7.40) and mild intensity palms (6.60) and mild (6.60) and moderate intensity palms (6.40) and moderate (6.40) and severe intensity palms (5.60) were found to be on par. On the 270th day of observation, the number of bunches in the mild (7.00) and moderate (6.40) palms found to be on par and differed significantly from the palms with severe (5.40) intensity and healthy(7.40) palms. On 315th day of observation, the number of bunches in the mild (5.20) and moderate (4.80) palms were found to be on par and differed significantly from the healthy (7.00) and severe intensity (2.60) palms. The palms with mild (6.60), moderate (6.40) and severe (5.60) intensity palms were found to be on par and were significantly different from the healthy (7.40) palms on the 360th day of observation. The number of bunches in the healthy palms showed a significant difference from that of severe intensisty palms in all periods of observation. The yearly mean revealed that the number of bunches in the mild (6.53) and moderate (6.04) intensity were on par and differed significantly from the severe (5.20) intensity and healthy (7.47) palms.

The study conducted in the palms treated with boron showed an increase in the number of bunches in the palm (Kamalakshiamma, 2001).

5.3.2.5. Number of nuts set per bunch

The number of nuts set per bunch for four groups of palms are given in the Fig.8. The statistical analysis showed a significant difference between all the four groups of palms during the whole period of observation. The nuts set per bunch on the first day of observation differed significantly between healthy (13.80) , mild intensity (9.00), moderate intensity (5.60) and severe (3.60) intensity palms. On the 45th day of observation the healthy palms showed a mean nuts set per bunch of 13.80, palms with mild intensity showed a mean nut set of 8.40, moderate intensity , 5.60 and that of severe intensity palms showed a mean nut set bunch of 3.00. The mean nuts set per bunch for healthy palms was 13.60, for mild intensity was 8.60, for moderate intensity was 5.80 and for severe intensity was 3.80 on the 90th day of observation and it differed significantly among all four groups. On the 135th day of observation the mean nuts set per bunch of healthy (13.60), mild intensity (8.40), moderate intensity (5.60) and severe intensity (3.20) palms were significantly different from each other in all the four groups of palms. On the 180th day of observation the mean nuts set per bunch in the healthy (13.80), mild intensity (8.80), moderate intensity (5.60) and severe intensity (3.60) palms were significantly different from each other in all four groups of palms. The nuts set per bunch of healthy (13.20), mild intensity (7.60), moderate intensity (5.80) and severe intensity (3.60) palms were significantly different from each other on the 225th day of observation. The nuts set per bunch of healthy palms (13.60), mild intensity (7.60), moderate intensity (5.80) and severe intensity (3.60) palms were significantly different from each other on 270th day of observation. As observed from the yearly mean, out of the 38.04 (Table 13) female flowers produced by the inflorescence in healthy palms 13.06 were set in healthy palms, while the nuts set per bunch in severe intensity palms were only 3.44 out of the 23.62 female flowers produced. The setting percentage of healthy palms was 34.33 % while that for the severely affected palms were 14.56 %. The nuts set per bunch of healthy palms ranged from 13.20 to 13.80 and that of mild, moderate and severe intensity palms ranged from 7.60 to 9.2, 5.60 to 6.40 and 3.00 to 3.80 respectively.

Study conducted by Wojcik *et al*.(2003) and Nyomora *et al.*(2007) reported that boron is important in pollen germination and pollen tube growth, which is likely to increase fruit set. Therefore boron fertilization may increase yield, particularly when plants are grown on sandy soil with a low content of available boron.

The application of boron fertilizer to a coconut palm orchard increased boron soil and leaf levels and affected fruit production (Moura *et.al.*, 2013).

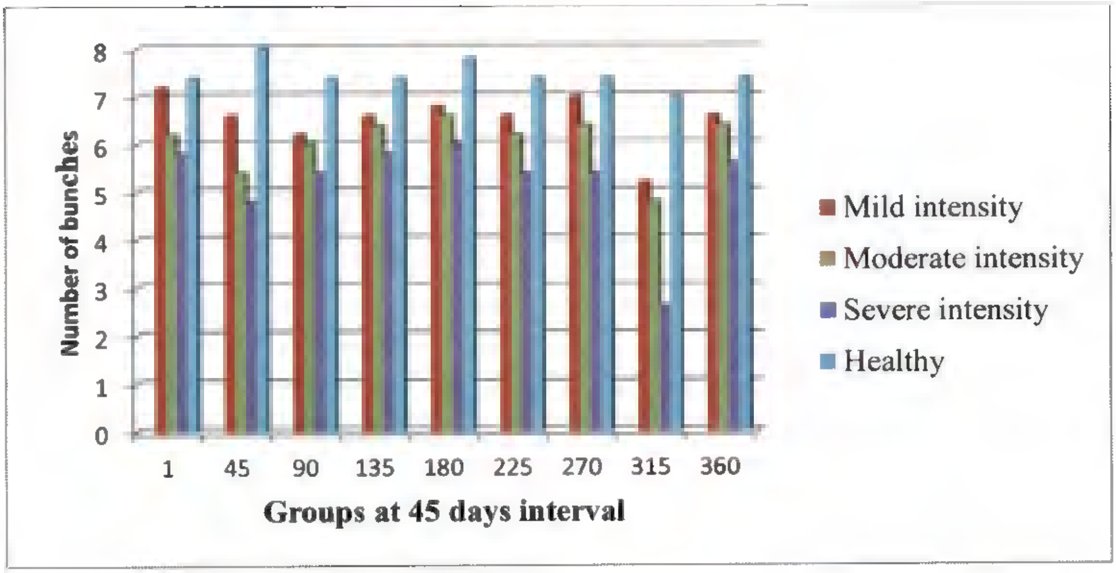

Fig.7.Number of bunches at 45 days interval

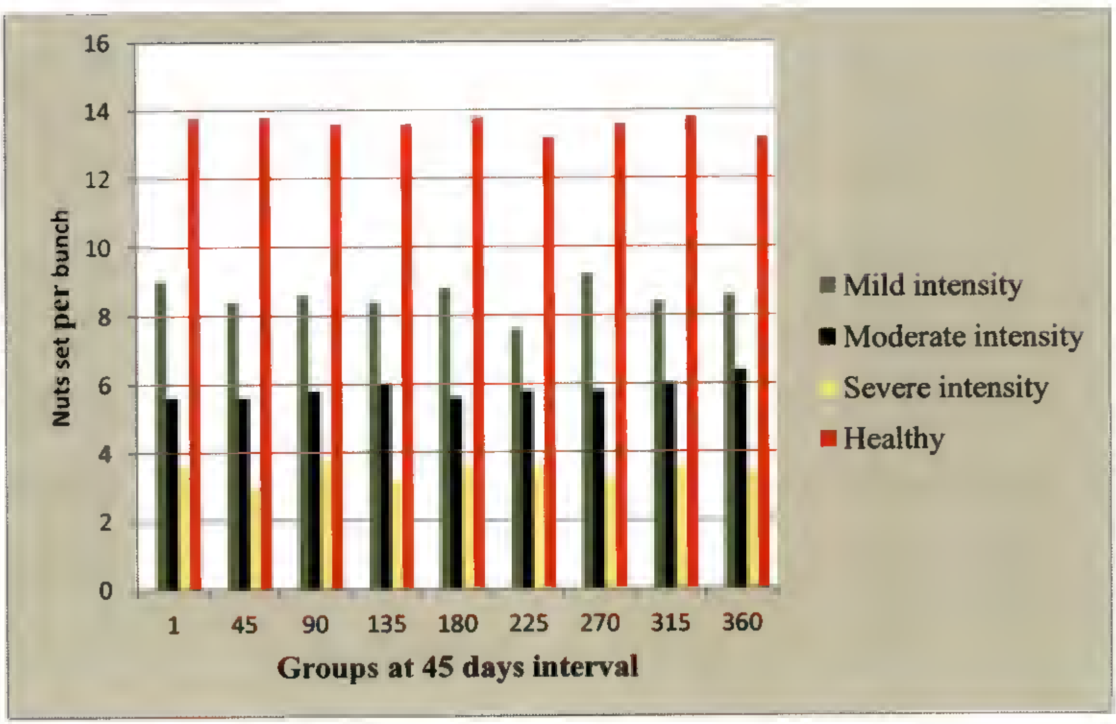

Fig.8.Nuts set per bunch at 45 days interval

5.3.2.7. Number of malformed nuts

The number of malformed nuts of the four groups of palms are given in Fig 9. The healthy palms showed no incidence of malformed nuts during the one year observation period. Malformed nuts were not reported on the mild intensity palms except on 270 th and 315th day of observation. The number of malformed nuts in the mild and moderate palms on the 1st, 45th, 135th, 180th and 270th day of observation were found to on par. The number of malformed nuts among the mild ,moderate and healthy palms were found to be on par during the 45th, 90th, 135th, 180th , 225th , 270th and 315th day of observation. During all the periods of observation the severe intensity palms were found to have highest number of malformed nuts compared to moderate and mild palms. The number of malformed nuts in the mild, moderate and severe intensity palms ranged from 0.00 to 0.20, 0.40 to 0.80 and 1.00 to 1.40 respectively.

Studies conducted by Kamalakshiamma and Shanavas in 2001on coconut palms revealed that deficiency of boron caused malformations of various types and shapes in the leaf as well as the nuts resulting in stunted growth and low productivity.

5.3.2.7. Number of nuts per palm per year

The nuts produced per palm per year observed in four groups of palms is given in Fig.10. The healthy palms produced 102.8 nuts per palm per year compared to 66 nuts in mild intensity palms and 38 in moderate intensity palms. The nuts produced in severe intensity palms were only 15.6 showing a drastic reduction in the yield compared to healthy palms. As the intensity of the deficiency increased the yield showed an intensive reduction.

The severe boron deficiency has a strong effect on the crop production that could reduce the yield by 84 per cent. This drop is probably caused by the drastic reduction of the leaf area and by metabolic changes also (Rajaratnam, 1973).

The study conducted by Kamalashiamma (2001) reported that the application of boron to the coconut palms showed an increase in the yield.

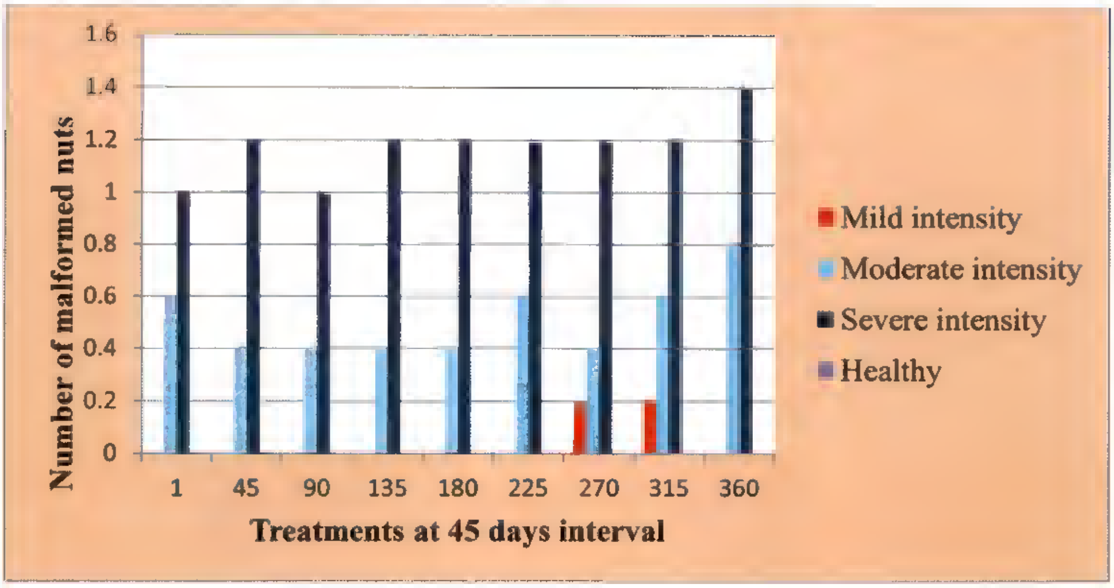

Fig.9. Number of malformed nuts at 45 days interval

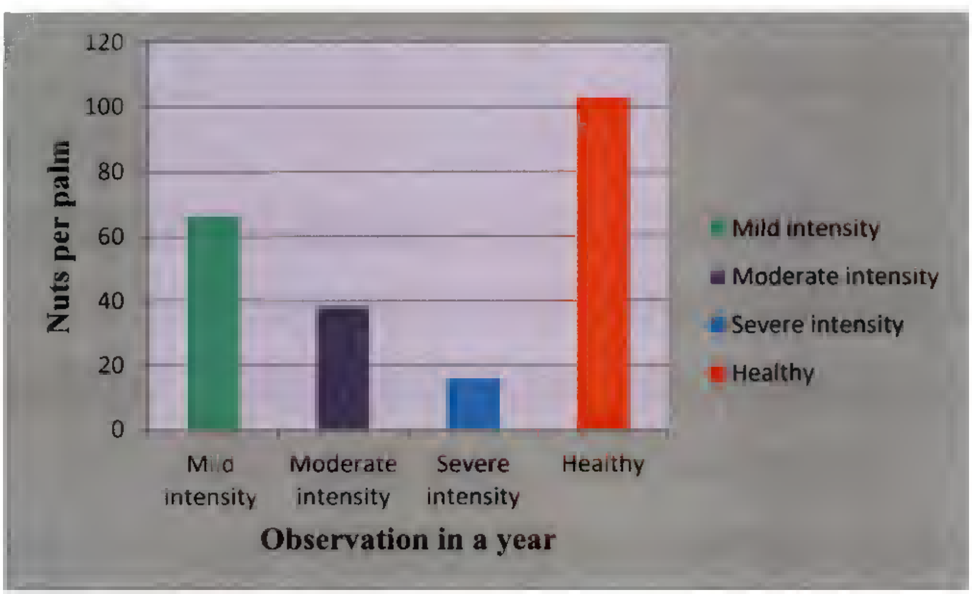

Fig.10.Nuts per palm per year

5.3.2.8. Polar diameter of nut

The polar diameter of the nut observed from the four groups of palms for one year is given in Fig.11. There was significant difference in polar diameter of nuts between mild intensity, moderate intensity, severe intensity and healthy palms in all periods of observation. The healthy palms showed highest polar diameter on all days of observation. On the first day of observation the polar diameter was obtained in the healthy palms (260.40mm). The polar diameter of the nut expressed in millimeter of healthy, mild, moderate and severe palms ranged from 254.40 to 260.40, 243.40 to 247.80, 232 to 235.60 and 224 to 227.80 respectively during different periods of observation. The mean polar diameter of the nuts from healthy, mild, moderate and severe intensity palms were 257.09, 245.71, 233.42 and 225.69 respectively. The results showed that deficiency of boron had effect on the polar diameter of the nut.

5.3.2.9. Equatorial diameter of nut

The equatorial diameter of nut from the four groups of palms in all days of observation is given in Fig.12. The equatorial diameter of the unhusked nut showed significant variation between mild, moderate, severe intensity and healthy palms in all periods of observation. The healthy palms showed highest equatorial diameter on all periods of observation and the equatorial diameter obtained in the healthy palms on the first day of observation was 165.80mm. The mean equatorial diameter of the nut of healthy, mild, moderate and severe intensity palms were 163.63mm, 149.29mm, 135.20mm and 113.58 mm respectively.

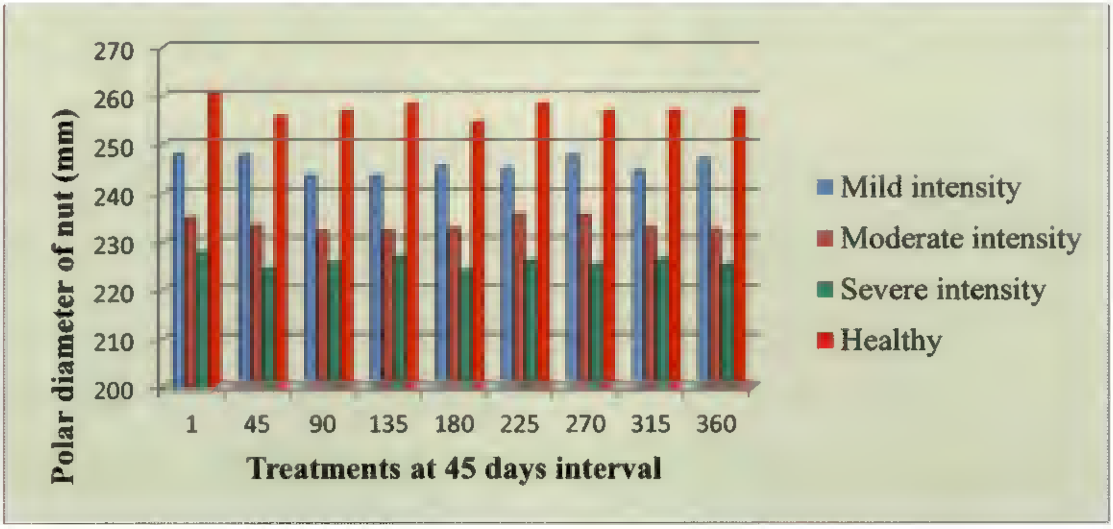

Fig.11.Polar diameter of nut(mm) at 45 days interval

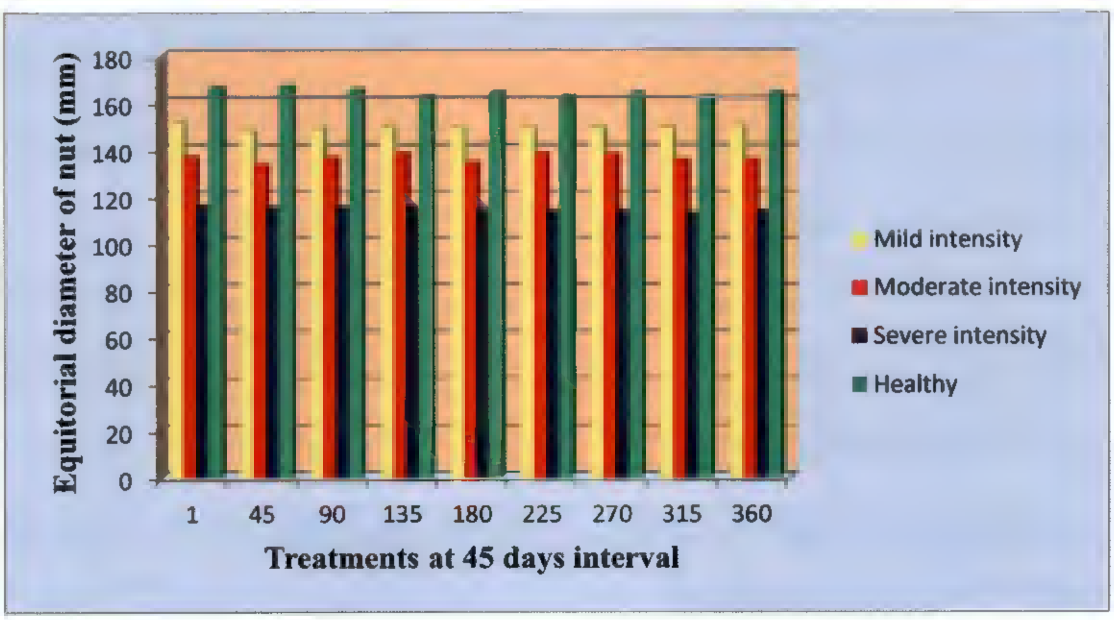

Fig.12.Equatorial diameter(mm) at 45 days interval

5.3.2.10. Thickness of husk

The thickness of husk observed for four groups of palms over the year is given in Fig.13. The husk thickness showed a significant difference between different groups in all periods of observation. The healthy palms showed highest husk thickness of 19.2 at 1st and 135th day of observation compared to that of the other groups of palms. The thickness of husk in centimeter of the healthy palms ranged from 18.6 to 19.2, mild intensity palms ranged from 16.2 to 16.6, moderate intensity palms ranged from 13.2 to 14.4 and severe intensity palms ranged from 11.4 to 13.1. The mean husk thickness of the healthy, mild, moderate and severe intensity palms were 18.9, 16.4, 13.9 and 12.0 cm respectively. The present results revealed that the husk thickness also was reduced due to boron deficiency.

5.3.2.11. Weight of husked nut

The weight of husked nut observed for four groups of coconut is represented in Fig.14. There was a significant difference in the weight of husked nut between all the four groups in all periods of observation. The husked nuts from the healthy palms showed highest weight (740.80g) among the four groups of palms on the first day of observation. The trend was the same for all periods of observation. The palms with severe intensity of boron deficiency showed lowest weight of husked nut when compared with the other group of palms (369.40g) on the 270th day of observation. There was a yield reduction of 49.10 % per cent in severe intensity palms compared to healthy on 270th day of observation. The weight of husked nut during the period of observation in healthy palms ranged from 724.00g to 740.80g, mild intensity palms ranged from 573.20g to 594.20g, moderate intensity palms ranged from 474.80g to 480.00g and severe intensity palms ranged from 369.00g to 373.60g.The yearly mean nut weight of husked nut of the four groups of palms were 726.67g, 583.02g, 476.91g and 370.36 g for the healthy, mild, moderate and severe intensity palms respectively.

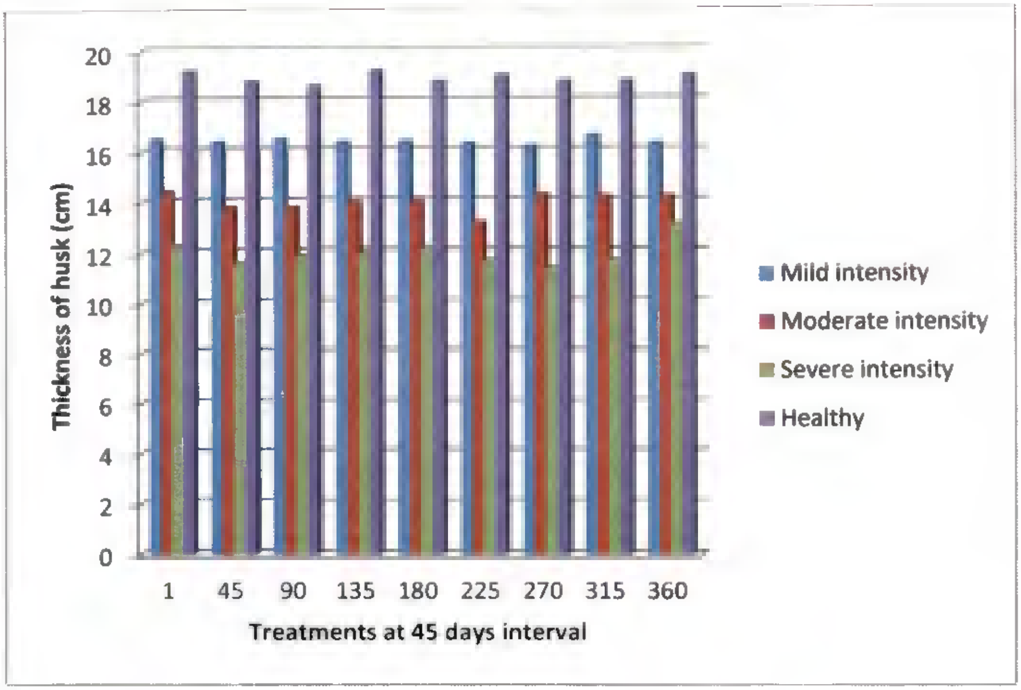

Fig.13.Thickness of husk (cm) at 45 days interval

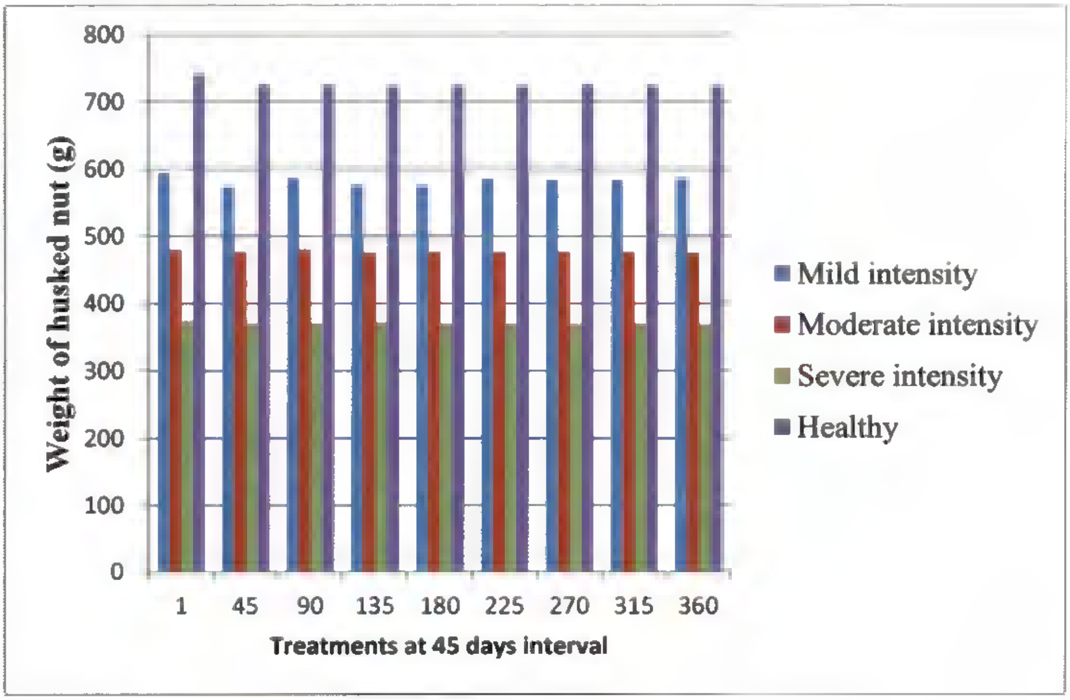

Fig.14.Weight of husked nut (g) at 45 days interval

5.3.2.12. Weight of unhusked nut

The weight of unhusked nut in the four groups of palms is given in Fig.15. There were significant differences in the weight of unhusked nut between mild, moderate, severe intensity palms and healthy palms in all periods of observation. The unhusked nuts from the healthy palms showed highest weight (1702.50g) among the four groups of palms on the first day of observation. And the severe intensity palms showed lowest weight of unhusked nut compared to other palms (578.80g) on the 1st day of observation. The weight of unhusked nut in the healthy, mild intensity , moderate intensity and severe intensity palms during the period of observation ranged from 1303.00g to 1702.50g, 1114.00g to 1261.20g, 778.80g to 900.20g and 492.80g to 738.80g respectively. The mean nut weight of unhusked nut from the four groups of palms were 1449.71, 1172.36, 845.31 and 619.58 g for the healthy, mild , moderate and severe intensity palms respectively.

5.3.2.13. Weight of opened nut

The weight of opened nut among the four groups of palms is given in Fig.16. There was a significant difference in the weight of opened nut between all the four groups in all periods of observation. The opened nuts from the healthy palms showed the highest weight (603.40g) among the four groups of palms on the first day of observation. The palms of severe intensity recorded the lowest weight of opened nut compared with the other palms (262.80g) on the 360th day of observation. The weight of opened nut in healthy palms was 601.20g while that of mild intensity palms was 455.4g, moderate intensity 362.20g and severe intensity was 266.46g during 45th day of observation. The mean nut weight of opened nut from the four groups of palms were 601.46, 464.76, 363.33 and 264.16 g for the healthy, mild , moderate and severe intensity palms respectively. The yearly mean weight of opened nut was 601.46 g in healthy palms compared to 264.16 g in severe intensity palms thus representing an yield reduction of 56 per cent over the healthy.

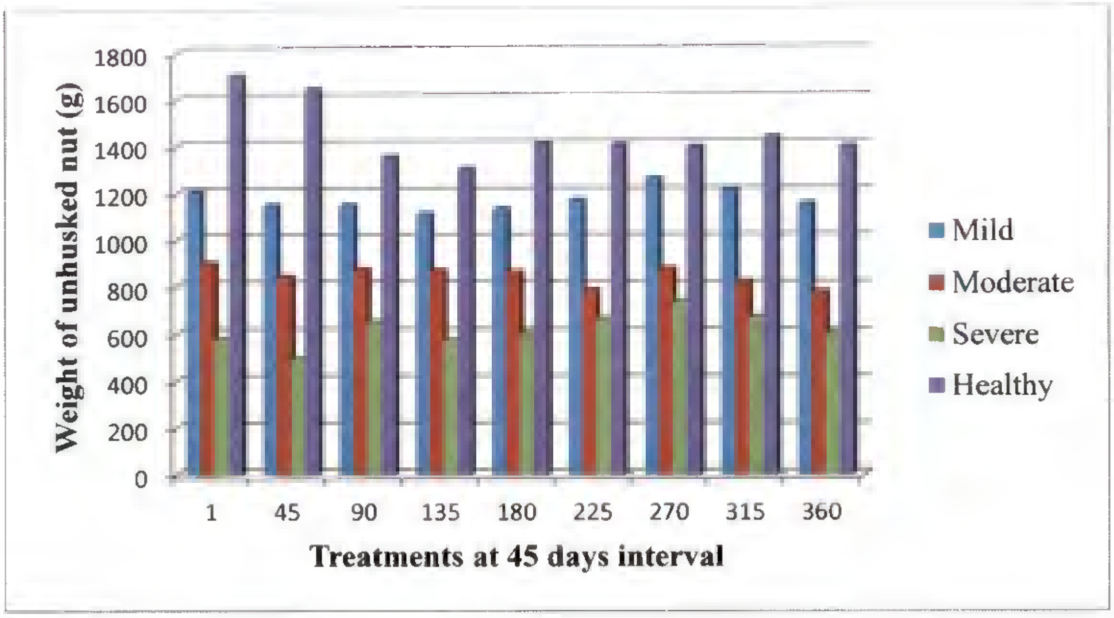

Fig.15.Weight of unhusked nut (g) at 45 days interval

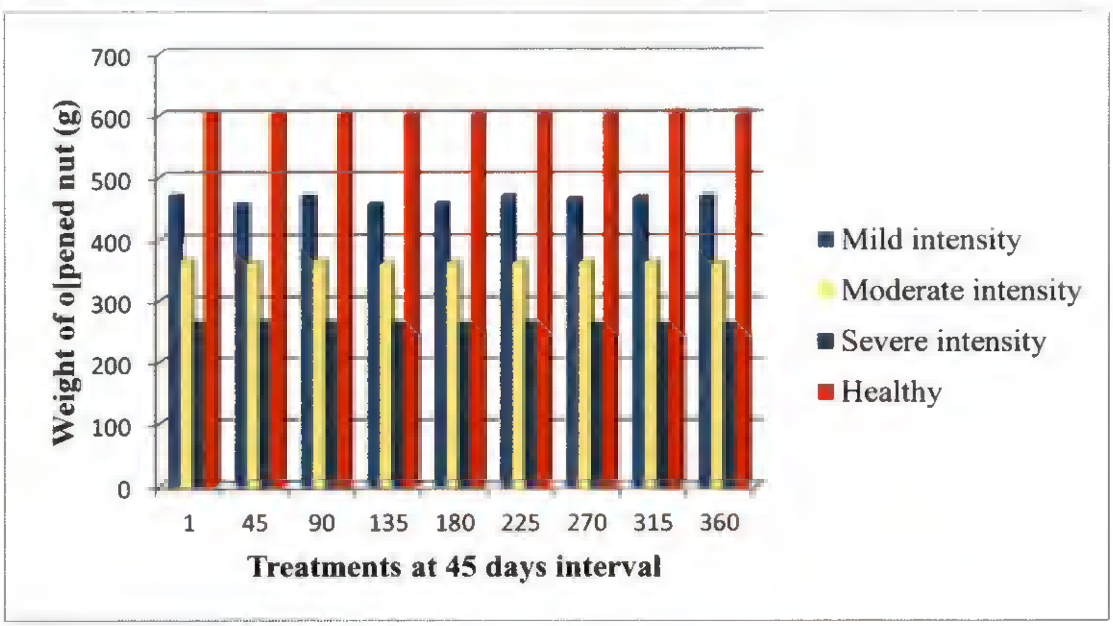

Fig.16.weight of opened nut (g) at 45 days interval

5.3.2.14. Volume of nut water

The volume of nut water from the boron deficient and healthy groups of palms is given in Fig.17. The volume of nut water showed a significant reduction in boron deficient groups compared to healthy palms. On the 45th day of observation the volume of nut water from the healthy, mild and moderate intensity palms were on par. On the 315th day of observation the volume of nut water on the mild and moderate intensity group of palms were 117.00ml and 112.20ml respectively. The healthy palms showed highest nut water volume on 90th day of observation (125 ml). The volume of nut water in healthy palms ranged from119.20 to 125.00 ml, in mild intensity palms ranged from 116.00 to 118.60 ml, moderate intensity palms ranged from 112.20 to 116.60 ml and severe intensity palms ranged from 105.20 to 107.00 ml. The mean volume of nut water obtained from the healthy, mild intensity, moderate intensity and severe intensity palms were 123.11, 117.67, 113.91 and 106.09 ml respectively. The severe palms showed a reduction of 12.22 % over the healthy palms as revealed from the yearly means.

5.3.2.15. Thickness of meat

The meat thickness in all four groups of palm observed over an year is given in the Fig.18. The thickness of meat differed significantly between all four groups of palms in all periods of observation. The meat thickness of healthy palms on the first day and 45th day of observation were 18.4 mm and 18.2 mm respectively while that for 225th and 270th day of observation showed a highest meat thickness of 18.8mm. The lowest meat thickness of 10.6 mm was observed on severe intensity palms on the 90th day of observation. The thickness of meat in healthy palms ranged from 17.6 to 18.8 mm, in mild intensity palms from 15.2 to 15.8 mm, in moderate intensity palms from 13.0 to 140 mm and in severe intensity palms the value ranged from 10.6 to 11.4. The mean meat thickness among the healthy, mild, moderate and severe intensity palms were 18.3, 15.5, 13.5 and 11.2mm respectively.

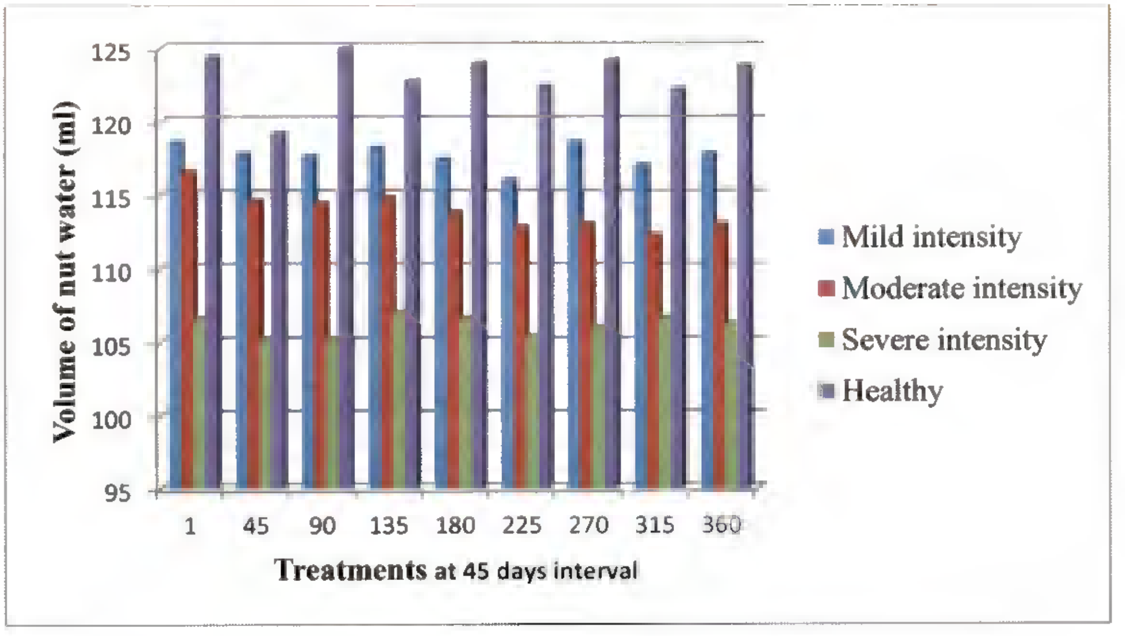

Fig.17.Volume of nut water (ml) at 45 days interval

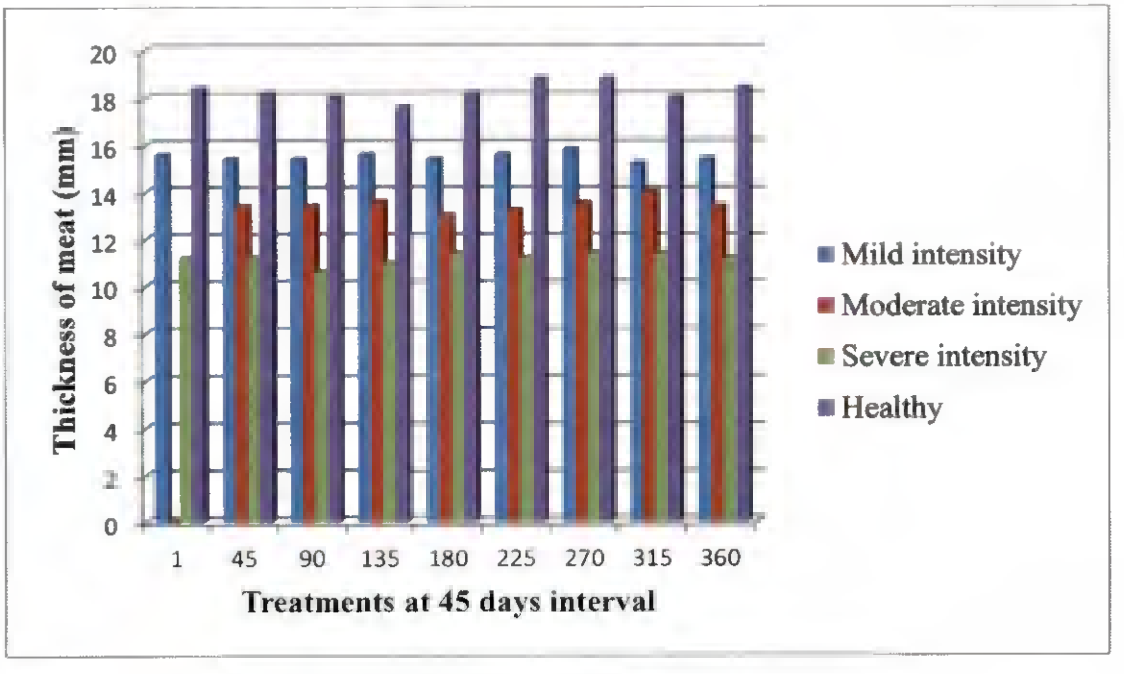

Fig.18.Thickness of meat at 45 days interval

5.3.2.16. Weight of embryo

The weight of embryo of the four groups of palms observed for an year is given in Fig.19.The weight of embryo on the first day of observation for mild and moderate intensity palms were on par and was significantly different from severe intensity and healthy palms. The weight of embryo recorded from mild intensity and moderate intensity were on par on 45th , 135th ,180 th 225 th , 270th ,315 th and 360th day of observation.

The highest embryo weight of 0.098 g was observed in the healthy palms on the 45th, 225th and 315th day of observation. The lowest embryo weight of 0.06 g was observed in the severe intensity palms on the first day of observation. The weight of embryo in the healthy palms ranged from 0.092 to 0.098g, in mild intensity palms 0.082 to 0.088g, for moderate intensity palms from 0.081 to 0.088g and in severe intensity palms it ranged from 0.060 to 0.067g. The mean embryo weight of the healthy, mild, moderate and severe intensity palms were 0.096, 0.085, 0.084, 0.065 g respectively.

5.3.2.17. Weight of shell

The weight of shell observed in four groups of coconut palms for one year is given in Fig.20. The weight of shell was on par for mild and healthy palms on 45th, 90th, 135th, 225th, 270th and 360th day of observation. On the 45th day of observation the weight of shell was on par for the palms coming under mild and moderate intensity group. On the 360th day of observation the weight of shell on moderate intensity palms were on par with severe intensity palms. The weight of shell in the healthy palms was the highest on first day of observation (166.6 g). The weight of shell ranged from 159.80 to 163.00g in mild intensity palms 155.20 to 158.20g in moderate intensity palms and 155.20 to 158.20g in severe intensity palms . The mean weight of shell for healthy, mild, moderate and severe intensity palms were 163.57, 161.40, 156.42 and 152.02 g respectively.

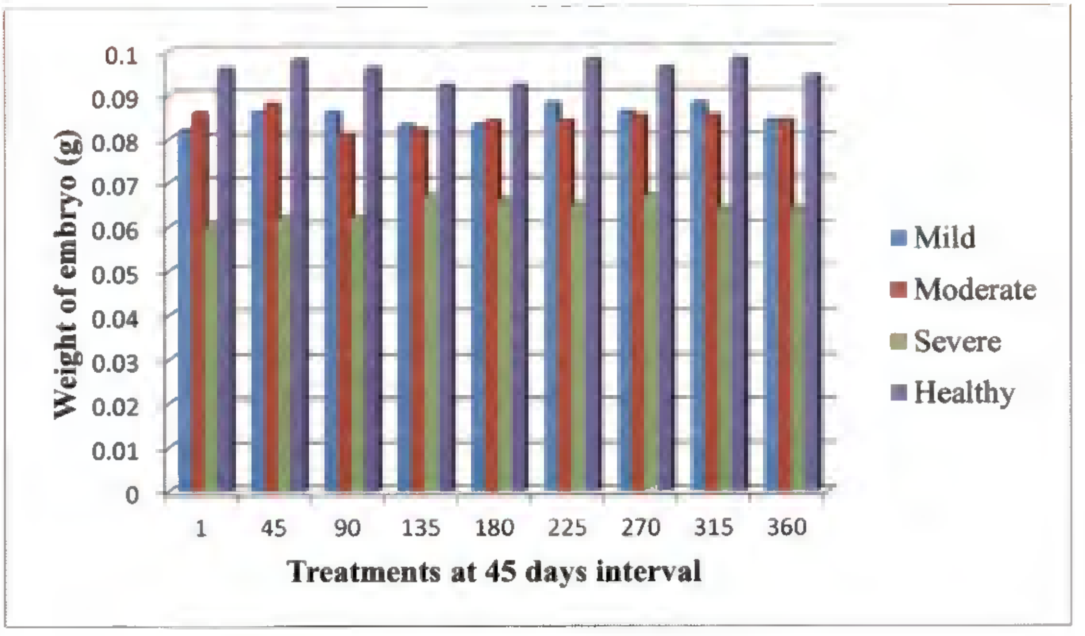

Fig.19. Weight of embryo at 45 days interval

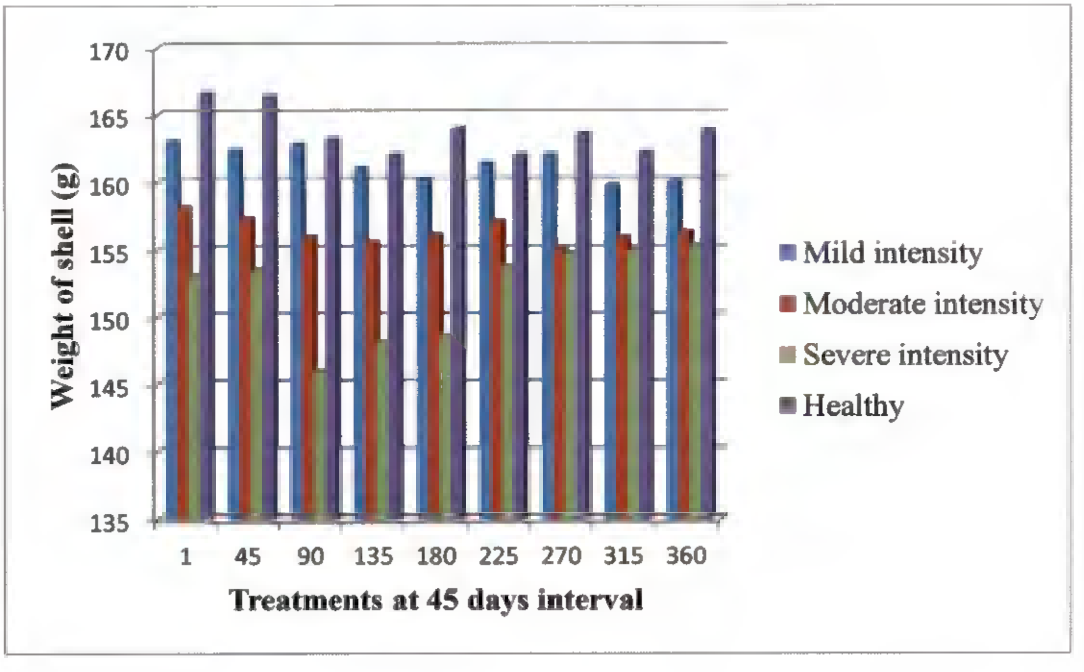

Fig .20. Weight of shell at 45 days interval

5.3.2.18. Weight of kernel

The weight of kernel of all the four groups of coconut palms is represented in Fig.21. The weight of kernel of the four groups of palms showed significant difference during all periods of observation. The healthy palms (453.20g) showed highest weight for the fresh kernel on the first day of observation. The severe intensity palms showed the lowest kernel weight of 176.80g on the 225th day of observation. The weight of kernel of the healthy palms ranged from 398.20g to 453.20g and that of the mild, moderate and severe intensity palms ranged from 288.60g to 294.60g, 222.60g to 227.20 g and 176.80g to 179.80g respectively. The yearly mean weight of kernel in the healthy, mild, moderate and severe intensity palms were 416.49, 290.67, 224.60 and 177.16g respectively. The severe intensity palms showed a yield reduction of 57.46 % over the healthy palms.

5.3.2.19. Weight of copra

The weight of copra from all four groups of coconut palms observed for a period of one year is given in Fig.22.The weight of copra showed a significant difference among all the four group. The healthy palms showed the highest copra weight of 226.10 g on the 45th day of observation and the severe intensity palms showed the lowest copra weight of 84.40 g on the 225th day of observation. The mean weight of copra in healthy palm was 208.14g compared to 88.43g in severe intensity palms. The weight of copra in the healthy , mild, moderate and severe intensity palms ranged from 199.10 to 226.10, 144.30 to 145.70, 111.30 to 113.60 and 87.40 to 89.90g respectively during all the periods of observation.

In the study conducted by Kamalakshiamma and Shanavas (2002) reported that floral necrosis and premature nut drop were associated with B deficiency in coconut. They also noted that fruits of B deficient coconut were often cracked, had blackened husks, or lacked a shell. A strong correlation between copra production and B fertilization rates had been noticed.

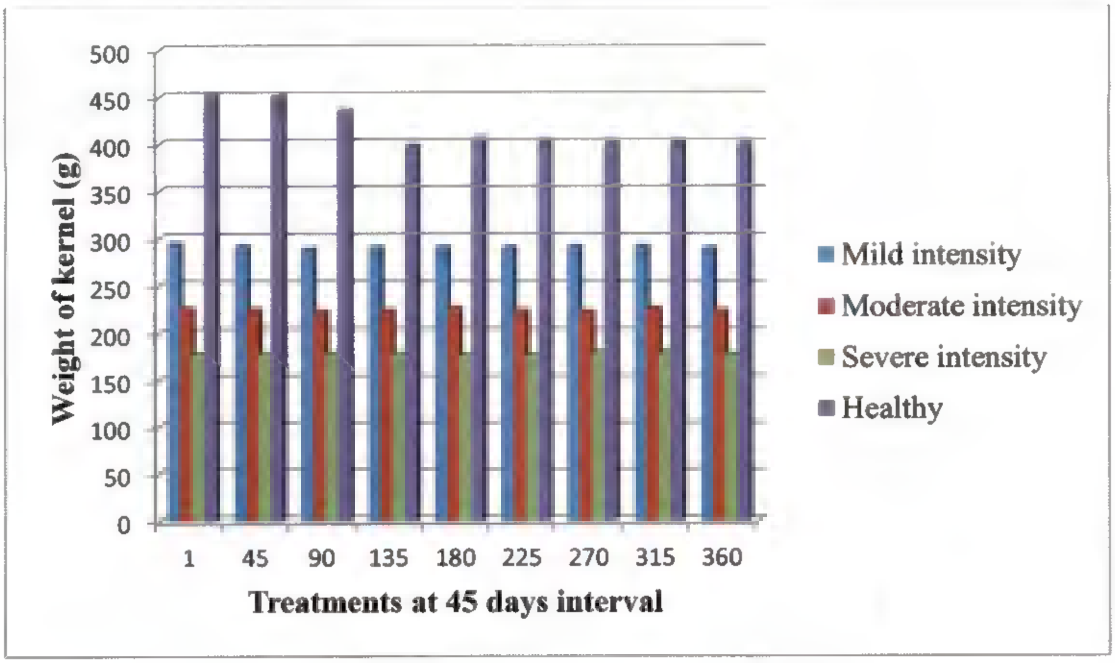

Fig.21. Weight of kernel at 45 days interval

5.3.2.20. Oil content

The oil percent among the four groups of coconut palms in all periods of observation taken for one year is given in Fig.23. The oil percent in mild, moderate, severe intensity palms and healthy palms were significantly different in all periods of observation. A mean oil content of 65 % was noticed in healthy palms while it reduced to 61% in mild , 57 % in moderate and 52 % in severe intensity palms. The oil content of healthy, mild, moderate and severe intensity palms ranged from 65.34 to 65.64% , 60.92 to 61.78% , and 51.62 to 57.48% respectively.

Sumathi *et al.* (2005) reported that the boron application in the boron deficient soils increased oil yields in sunflower cultivars.

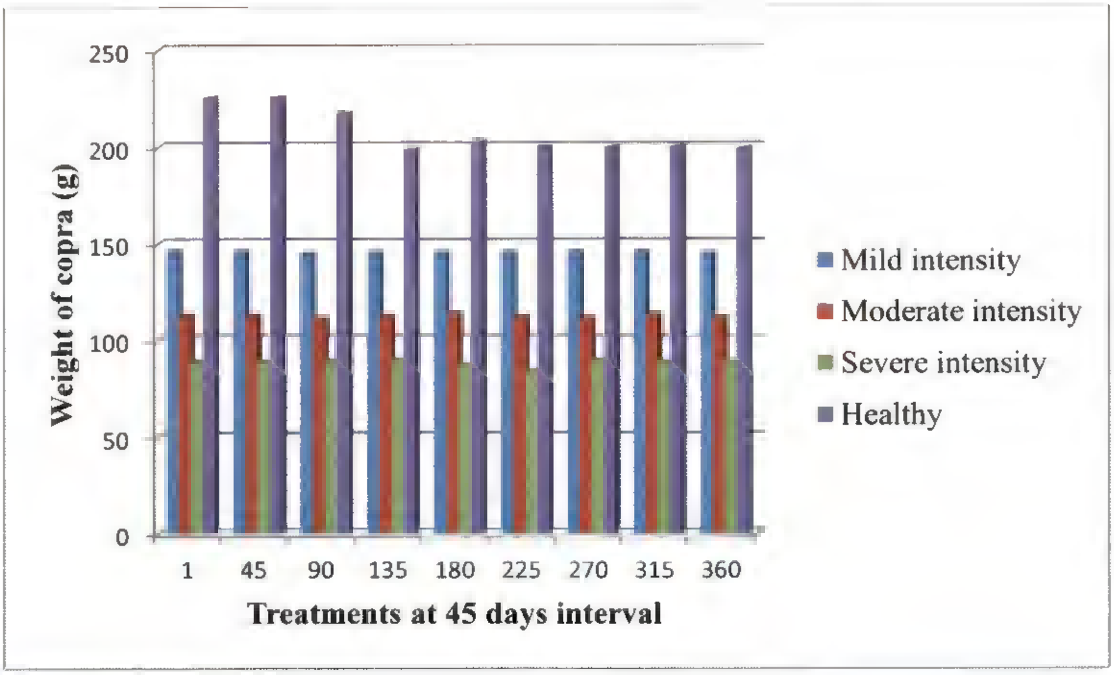

Fig 22. Weight of copra at 45 days interval

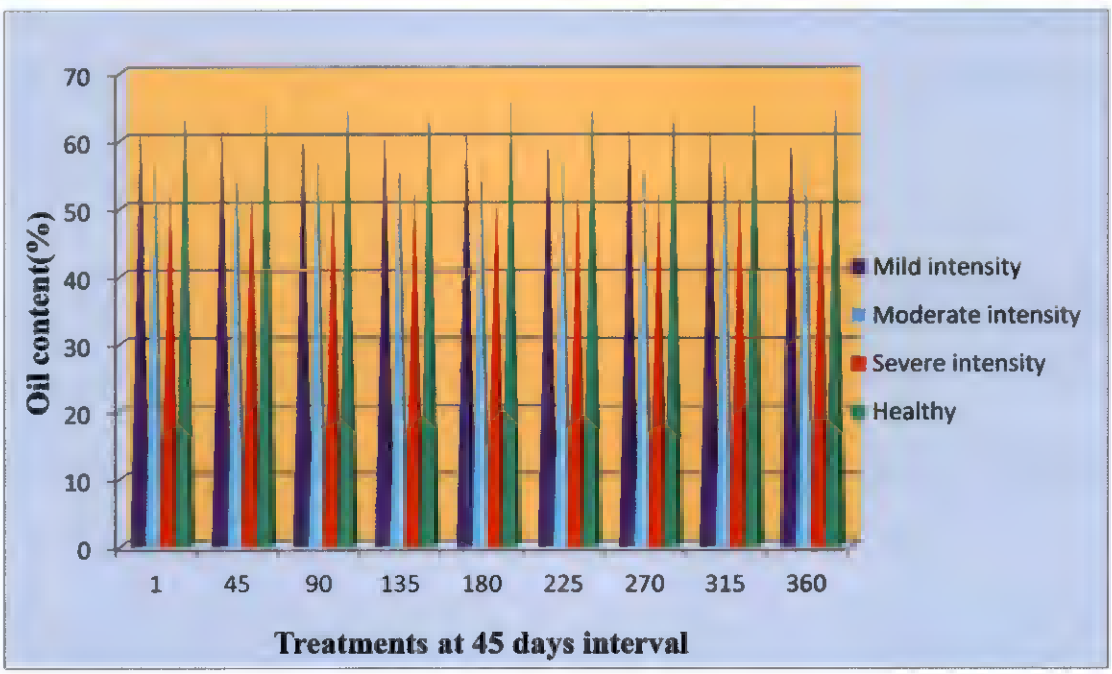

Fig. 23. Oil content (%) at 45 days interval

5.3.3. Scoring for Pest

5.3.3.1.Scoring for coreid bug

The scoring for the infestation of coreid bug in the selected twenty palms of mild, moderate ,severely intensity of boron deficiency and healthy palms revealed that in the palms with mild and moderate intensity of boron deficiency, the percentage of damage ranged between 11 to 50 %. The percentage of infestation in the palms with severe intensity ranged between 26 to 75 %. The percentage of damage for the healthy palms was the minimum and ranged from 0 to 10 percent with the mean intensity score ranging from 0 to 1.3.

The intensity of attack of coreid bug was found to be more in the palms with severe intensity represented by mean intensity score as 3.61 which was significantly different from all other three groups. The palms with moderate and mild intensity showed a mean intensity score of 2.72 and 2.58 respectively and were on par. The healthy palms had a mean intensity score of 0.724 which was the least score noticed and was significantly different from mild, moderate, and severe intensity of boron deficient palms. The results indicate that deficiency of boron had made the palm susceptible to pests like coreid bug which might also had contributed to further reducing the yield.

5.3.3.2. Scoring of mite

The results revealed that in the palms with mild intensity, the percentage of damage ranged between one to twenty five percent. The percentage of infestation in the palms with moderate intensity ranged from one to hundred percent and severe intensity ranged between eleven to hundred percent. The healthy palms were having percentage of damage ranged from 0-10. The results are an indication that the mite infestation might had increased due to boron deficiency. Deficiency of the nutrient may make the plant more susceptible to different pests.

In a study conducted by Marschner in 1995 reported that, boron is essential for the phenol metabolism. Phenolics including lignin and isoflavones have beneficial effects against diseases when plants are attacked by pathogens (Wang *et al,* 1989;). Phenolics or polyphenols are synthesized through the shikimate phenylpropanoids flavonoids pathways, producing monomeric and polymeric phenols and polyphenols (Lattanzio *et al.,* 2006;). Phenolics such as benzoquinones (C6), phenolic acid (C6-C1), flavonoids and iso- flavonoids (C6-C3-C6) and lignins (C6)n, (C6-C3-C6)n (Aoki *et al*, 2008; Whiling, 2000) are essential for growth, reproduction and protection of plants against biotic (fungus, bacteria, virus, and insect infection) or abiotic stresses such as drought and temperature.

Lethal yellowing disease (LY) of coconut is also characterized by inflorescence necrosis and premature fruit drop (Elliott *et al*., 2004). The fruits of lethal yellowing affected palms will usually show blackening of the calyx end, whereas B-deficient fruits will exhibit only random browning, if any, of immature fruits. Other foliar symptoms of either LY or B deficiency may be looked into to distinguish between these two disorders (Broschat, 2007).

SUMMARY

6.SUMMARY

The salient findings obtained from the study on "Characterisation of boron deficient coconut palms (*Cocos nucifera* L.)" is summarized in this chapter.

A survey was conducted in Kalliyoor panchayat of Thiruvananthapuram district to identify coconut palms deficient in boron based on visual symptoms listed by CPCRI. Hundred palms showing boron deficiency were identified based on its visual symptoms of leaf, inflorescence, nut and crown.

A ten scale score was developed for scoring the coconut palms showing boron deficiency into three groups based on the intensity of deficiency. Depending on the scores developed the mild intensity palms were given a score which ranged from 1 to 3, moderate intensity palms from 4 to 6 and severe intensity palms from 7 to 10. Out of the 100 boron deficient palms , 14% showed mild intensity, 80% moderate and 6% severe intensity of boron deficiency. In the mild intensity palms, 15% had hooked leaves, 92% had fused leaves with number of fused leaves occupying 7 % , 24% with high intermodal length and 20% had inflorescence with few number of female flowers. In the moderate intensity palms 23% had hooked leaves, 73.75% showed fused leaves with number fused leaves occupying 23.33%. 15% of the palms had high leaflet internodal length and reduced number of leaves, 70% of the palms had inflorescence with few number of female flowers whereas 40.12% showed aborted inflorescence and 47.5% necrotic inflorescence. Hen and chicken symptoms were noticed in 55%, crowded crown in 25%, fish bone appeared in 22.5% and discolouration of mesocarp in 4% of the moderate intensity palms. Severe intensity palms showed hooked leaves in 12%, fused leaves in 86% with number of fused leaves in 37%, high leaflet intermodal length in 11%, reduced number of leaves in 28.7% and crowded crown is 57.14%. 85.71% of the severe intensity palms had inflorescence with few female flowers with 72% showing aborted and 71.52% showing necrotic inflorescence. 71.11% showed hen and chicken symptoms, 28.78% 158
had nuts with uneven kernel development and 28.47 % had nuts without kernel and 22

% has discolouration of mesocarp. Five palms of each intensity group and five healthy palms were identified. The soil boron status recorded from mild intensity palms were 0.358 mg/kg, 0.256 mg/kg for moderate,0.122 mg/kg for severe intensity palms and 0.529 mg/kg for healthy palms. The plant boron status for mild, moderate, severe intensity and healthy palms were 3.68, 2.50,1.18 and 13.88 mg/kg respectively.

A survey was conducted in the hundred coconut growing field in the Kalliyoor panchayat of Thiruvananthapuram district to identify the predisposing factors responsible for the deficiency based on a questionnaire prepared.

The information on field, soil and plant characteristics and management aspects were collected from the 100 fields surveyed. The number of palms in the fields ranged from 10 to 320. The field characteristics had shown 100 % drainage in the selected fields and 96 % of the fields showed an elevation of 28-30 m above MSL and 4 % had an elevation of 25m above MSL. The soil type of the fields surveyed was red loam and the soil pH ranged between 6-7.5 and 30% of the fields were having medium organic matter and 70% were having low organic matter percentage. The plant characteristics of boron deficient coconut field showed that the age of the palms ranged between 20 and 40 years. The summary of the field survey in deficient areas showed that out of the 100 palms selected 52% of the field surveyed showed boron deficiency between 0 and 25 %, 26% of the fields showed 26-50% of deficiency, 51-75 % of the field showed 22 % deficiency. The management characteristics of the field showed that boron deficiency was noticed in the fields where intercropping was practiced which contributed 63% of the fields surveyed even though the field was applied with organic manure and fertilizer. Similarly 37 % were without intercrop but with poor agronomic practices might have resulted in boron deficiency. Disease incidence was noticed in 26% of the field and the among that 88.46 % was leaf rot and 11.54 % was bud rot. All fields surveyed showed pest infestation and among that 89 % of the fields were having mite infestation and 53% of the fields were having a combined infestation of mite and coreid bug.

The morphological characterization of the palms coming under mild, moderate and severe intensity of almost similar age, similar genotype and same class of soil was 159 taken for the study and the healthy palms were taken as control. Five palms from each group of mild, moderate, severe intensity and healthy palms were observed for one year at 45 days interval for morphological parameters.

The results of morphological parameters have shown that the number of leaves were found to be on par with mild and moderate intensity palms on 45th , 135th, 180th,270th and 315th day of observation. The mean number of leaves over one year in healthy palms were 31.55 that of mild were 30.75, that of moderate were 30.30 and that of severe intensity palms were 27.48.

The number of fused leaves in the severe intensity palms were found to be significantly higher compared to that of healthy, mild and moderate intensity palms in all periods of observation. There were no fused leaves in the healthy palms. The mean number of fused leaves in the severe intensity palms was 11.75, while that of mild and moderate intensity palms were 1.70 and 5.42 respectively.

The leaflet intermodal length in the four groups of palms were significantly different from each other except in the case of mild and moderate intensity palms on the first day of observation. The severely affected palms showed a higher leaflet internodal length compared to other three groups.

The number of female flowers per bunch of unfertilized inflorescence in the healthy palms differed significantly from the severe intensity palms on all periods of observation. The number of female flowers per bunch of unfertilized inflorescence of healthy palms ranged from 36 to 40.20, that of mild palms ranged from 32 to 34.40, moderate intensity palms ranged from 26.80 to 28.40 and severe intensity palms ranged from 22.40 to 24.40.

The numbers of unopened spadices in the mild and moderate palms were on par during all periods of observation. The number of unopened spadices in the healthy palms were significantly different from severe intensity palms on all periods of observation. The number of spadices of healthy palms differed significantly from the severe intensity palms on all periods of observation. The yearly mean of the observations taken for one year revealed that the number of spadices for healthy palms were 1.93 and reduced to 1.47 and 1.20 for mild and moderate intensity palms. 160

Severe intensity palms showed the least number of spadices (0.58). The number of opened spadices in the healthy palms during the period of observation ranged from 4.20 to 4.60 and that of mild and moderate intensity palms ranged from 2.60 to 3.00 and 2.20 to 2.60 respectively.

The number of bunches in the healthy palms showed a significant difference from that of moderate and severe intensity palms in all periods of observation. The number of bunches in the healthy palms ranged from 7 to 8. The number of bunches in the mild palms ranged from 5.20 to 7.20. The number of bunches in the moderate intensity palms ranged from 4.80 to 6.60 and that for severe intensity palms 2.60 to 6.00

The nut setting percentage based on yearly mean for healthy palms was 34% while that for the severely affected palms was 13 %. The nuts set per bunch of healthy palms ranged from 13.20 to 13.80 and that of mild, moderate and severe intensity palms ranged from 7.60 to 9.2 , 5.60 to 6.40 and 3.00 to 3.80 respectively. The healthy palms produced 102.8 nuts per palm per year compared to 66 nuts in mild 38 in moderate and 15.6 in severe intensity palms.

Malformed nuts were found in severe and moderate intensity palms compared to healthy and mild palms. There were no malformed nuts in the healthy palms. The number of malformed nuts in the mild , moderate and severe intensity palms ranged from 0.00 to 0.20, 0.40 to 0.80 and 1.00 to 1.40 respectively.

There were significant difference in polar diameter of nuts between mild, moderate, severe intensity and healthy palms in all days of observation. The polar diameter of the nut of healthy, mild, moderate and severe intensity palms ranged from 254.40 to 260.40 mm, 243.40 to 247.80 mm, 232 to 235.60 mm and 224 to 227.80 mm respectively.

The equatorial diameter of the unhusked nut between mild, moderate, severe intensity and healthy palms were significantly different in all days of observation. The equatorial diameter of the nut in millimeter in healthy, mild, moderate and severe palms ranged from 162.00 to 166.40, 147.40 to 151.40, 132.80 to 138.00 and 112.20 to 115.20 respectively. 161

Thickness of husk also showed significant variation between different groups in all periods of observation. The thickness of husk in millimeter of the healthy palms ranged from 18.8 to 19.2, mild palms ranged from 16.2 to 16.6, moderate palms ranged from 16.2 to 16.6 and severe intensity palms ranged from 11.4 to 13.10.

There was a significant difference in the weight of husked nut between all the four groups in all days of observation. The weight of husked nut in gram during the period of observation in healthy palms ranged from 724.00 to 740.80, mild intensisty palms ranged from 573.20 to 594.20, moderate intensity palms ranged from 474.80 to 480.00 and severe intensity palms ranged from 369.00 to 373.60.

Similarly there were significant differences in the weight of unhusked nut between mild, moderate, severe intensity and healthy palms. There was a yield reduction of fifty seven percent in severe intensity palms compared to healthy palms when the yearly mean was compared. The weight of unhusked nut in the healthy , mild, moderate and severe intensity palms during the period of observation ranged from 1303.00 to 1702.50, 1114.00 to 1261.20, 778.80 to 900.20 and 492.80 to 738.80 respectively.

The yearly mean weight of opened nut in healthy (601.46g) compared to 264.16 g in severe intensity palms showed an yield reduction of 56 % over the healthy. The weight of opened nut in healthy, mild, moderate and severe intensity palms ranged from 600.40 to 603.40, 455.40 to 470.20 in mild, 360.80 to 365.60 in moderate and 262.80 to 266.40 in severe intensity palms during the period of observation.

Volume of nut water also showed a significant reduction in boron deficient group compared to healthy palms. The volume of nut water in millilitre in the healthy palms ranged from119.20 to 125.00, in mild intensity palms ranged from 116.00 to 118.60, moderate intensity palms ranged from 112.20 to 116.60 ml and severe intensity palms ranged from 105.20 to 107.00 ml.

The thickness of meat in all four groups of palms were significantly different in all periods of observation. The thickness of meat in healthy palms ranged from 1.76 to 1.88mm, in mild palms ranged from 1.52 to 1.58mm, in moderate palms ranged from 1.32 to 1.40mm and in severe intensity palms ranged from 1.10 to 1.14mm.

The weight of embryo on the 180^{th}, 270^{th} and 315^{th} day were on par for mild and moderate intensity and it was on par between mild and healthy on the 90^{th} and 360^{th} day of observation. The weight of embryo in the healthy palms ranged from 0.092 to 0.098g, in mild palms 0.082 to 0.088g, moderate 0.081 to 0.088g and in severe intensity palms ranged from 0.060 to 0.067g.

The weight of shell was on par for mild intensity and healthy palms on almost all periods of observation. The weight of shell in the healthy palms ranged from 162.00 to 166.60g, in mild intensity palms ranged from 146.00 to 155.40g, moderate intensity palms ranged from 155.20 to 158.20g, and severe intensity palms ranged from 146.00 to 155.40g.

The weight of kernel of the four groups of palms showed significant difference during all periods of observation. The weight of kernel of the healthy palms ranged from 398.20 to 453.20g, that of the mild , moderate and severe intensity palms ranged from 288.60 to 294.60g, 222.60 to 227.20g and 177.60 to 179.80g respectively.

The weight of copra in healthy palm was 208.14g compared to 88.43g in severe intensity palms. The weight of copra in the healthy , mild, moderate and severe intensity palms ranged from 199.10 to 226.10, 144.30 to 145.70, 111.30 to 113.60 and 87.40 to 89.90 respectively during all the periods of observation.

The oil percent in mild, moderate, severe intensity and healthy palms were significantly different on all days of observation. The healthy palms showed 65 % of oil content while it reduced to 61% in mild , 57 % in moderate and 52 % in severe intensity palms. The oil content of healthy, mild, moderate and severe intensity palms ranged from 65.34 to 65.64 %, 60.92 to 61.78%, and 51.96 to 52.56% respectively.

The scoring for the infestation of coreid bug in mild, moderate and severe intensity palms revealed that in the palms with mild and moderate intensity the percentage of damage ranged between 11 to 50 %. The percentage of infestation in the palms with severe intensity ranged between 26 % to 75%.

The scoring for the infestation of mites in the selected mild, moderate and severe intensity palms revealed that in the palms with mild intensity the percentage of damage ranged between one to twenty five percent. The percentage of infestation in the palms with moderate intensity ranged from one to hundred percent and severe intensity ranged between twenty six to seventy five percent.

In the present experiment conducted the boron deficient coconut palms were categorized into groups showing mild intensity, moderate intensity and severe intensity based on the ten scale score developed. The analysis of soil and plant boron status of different groups was in tune with the ten scale score developed thus revealing that the scale developed was appropriate. The deficiency symptoms were prominent in fields where intercropping and poor agronomic practices were undertaken. The morphological parameters studied revealed a reduction in leaf production and number of female flowers of unfertilized inflorescence, nuts set per bunch, nut yield per palm per year, copra yield and oil content in different groups of boron deficient palms compared to healthy palms.

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ABSTRACT

CHARACTERISATION OF BORON DEFICIENT COCONUT PALMS

(*Cocos nucifera L.*)

by

ATHULYA S NAIR

(2014-12-119)

ABSTRACT

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DEPARTMENT OF PLANTATION CROPS AND SPICES

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2017

KERALA AGRICULTURAL UNIVERSITY
COLLEGE OF AGRICULTURE, VELLAYANI
DEPARTMENT OF PLANTATION CROPS AND SPICES
DEFENSE SEMINAR

Athulya S Nair **Date: 19-08-2015**
2014-12-119 **Time: 2.30- 3 pm**

ABSTRACT

The experiment entitled "Characterisation of boron deficient coconut palms (*Cocos nucifera* L.)" was undertaken at farmer's field in Kalliyoor panchayat of Thiruvananthapuram district during the period from April 2015 to March 2016. The objective of the study was to identify boron deficient coconut palms and predisposing factors responsible for deficiency based on the visual diagnosis and to study the morphological characters of boron deficient and healthy coconut palms.

The survey was conducted among hundred coconut palms in Kalliyoor panchayat of Thiruvananthapuram district to identify coconut palms deficient in boron based on visual symptoms listed by CPCRI. Based on the symptoms a ten scale score was developed and boron deficient palms were categorized as mild, moderate and severe intensity and compared with soil and plant boron status . The field, soil , plant characteristics and management aspects of coconut palms deficient in boron were identified based on questionnaire prepared. The morphological and yield parameters were observed at 45 days interval for one year in five palms each from mild, moderate and severe intensity and was compared with healthy palms.

The results of the survey showed that the boron deficiency in palms were restricted to age group between 20-45 years grown on red loam soil with pH 6.0-7.5. The deficiency symptoms were common in coconut fields where intercropping was practiced (63 %) and in other fields with poor agronomic management (37 %). Mite and coreid bug attack were prominent (89 % and 53 % respectively). Diseases among deficient palms were restricted to 26 percentage and leaf rot was the major one. Common visual symptoms of palms with mild intensity were reduced leaf size, hooked leaves, fused leaves, and leaflets with relatively higher internodal length. Necrotic inflorescence, reduced nut set, poor nut size, nuts with hen and chicken symptoms and crowded crown were prominent in moderate to severely intensity groups.

The morphological and yield parameters of selected palms of four groups indicated significant difference between palms of healthy and severe intensity for number of leaves, leaflet internodal length, number of female flowers per bunch of unfertilized inflorescence, opened and unopened spadices, bunches per palm, malformed nuts, volume of nut water, weight of embryo and shell throughout the observation period . The cortical cells of root were loosely packed for boron deficient palms of moderate and severe intensity. Nuts from healthy palms when compared with that from the mild, moderate and severe intensity differed significantly with respect to weight of unhusked nut, weight of husked nut, nuts set per bunch, nuts per palm per year, polar and equatorial diameter of unhusked nut, thickness of husk , weight of opened nut, thickness of meat, weight of kernel ,weight of copra and oil content and the difference was proportional to enhancement in intensity of deficiency. The available boron status in soil and plant were significantly superior in healthy palms.

Identification of predisposing factors revealed poor agronomic management, intensive cultivation and low organic matter resulted in B deficieny in Coconut growing areas. The results indicated that B had marked influence in enhancing the yield characteristics of coconut particularly of thickness of meat, weight of kernel, weight of copra, oil content etc. There is a significant reduction in the yield of deficient coconut compared to that of healthy palms. The study thus substantiate the importance of boron in the nutrition of coconut palms.

APPENDICES

APPENDIX 1

NAME OF THE FARMERS SURVEYED

Name of farmers	Address
1) SekharanNaadar	Kakkakuzhiveedu, Peringamala
2) Gipson J Stephen	Kalvary, Peringamala
3) L. Nelson	SalomNivas Thettivila, Kalliyur
4) Jose	R S Mandiram, Thettivila
5) NallathampiNadar	S N Nivas, Thettivila
6) MadhavanNadar	Madhavam, Thettivila
7) Sajeev	sajeevBhavan, Thettivila
8) DivakaranNadar	Vijadi, Thettivila
9) Ramachandran Nair	BhavaniNilayam, thettivila
10) Kamaraj	Aswathybhavan, peringamala
11) Thankan	jaya bhavan , peringamala
12) Wintson J Stephen	bethany, peringamala
13) K Vijayan	Punchiri, Peringamala
14) 14)Sudhakaran ,	Devi nivas, peringamala
15) Vasundaran (rtd police),	lekshmi , thettivila
16) Rajendran	plavilayil , thettivila
17) Surendran,	pallithekkethil, peringamala
18) Pushkaran,	kalloorkatil, thettivila
19) Lalithambika,	krishnamandiram, kalliyur
20) Sreekandan nair	Sree bhavan, vellayani
21) M C Balakrishnan Nair,	M C Villa, vellayani
22) Prasanna kumari,	Thankamalika, Kakkamoola
23) Vevekanandan C	Charivuvila Veedu, Kayalkara
24) Surendran k	akhil nivas, thettivila 9446487191
25) Dr. Yogiraj ,	kozhipura, channelkara , poonkulam,

26) Saraswathy ammal,	lekshmi nivas, kayalkara
27) Prabhakaran Nair	Anil Bhavan, Kakkamoola
28) Janardhanan Nair,	Kalloorkattu Padinjattetil, Vellayani
29) Jagannathan Nair,	Hari Nivas, Kalliyoor
30) Jyothish Kumar	Indeevaram, Kalliyoor
31) Sundaran Naadar	kakkakuzhiveedu, peringamala
32) Stephen	Grace villa , Peringamala
33) Babu	Salom Nivas, Thettivila, Kalliyur
34) Jose John	Anantha Bhavan Thettivila
35) Gopinathan	Priya Nivas, Thettivila
36) Madhavan Nair	Chandrathil, Thettivila
37) Sajeev	Sajeev Bhavan, Thettivila
38) Divakaran Nadar	Vijadi, Thettivila
39) Ramachandran Nair	Bhavani Nilayam, thettivila
40) Pushpangadhan,	Parvathy Bhavan, Poonkulam
41) Ramkrishnan	kalayail veedu, kalliyur
42) Sreeja Kumari	Sivalayam, kalliyur
43) Baby	Grace villa, kalliyur
44) Sivaraman	Sivalayam, vellayani
45) Vijayakumar	Vijayas,Kalliyur
46) Krishnan Nair	Krishanalyam, vellayani
47) Vijaya kumari	Raghu nivas
48) Kesavan Nair,	K S Vihar, Kakkamoola
49) Rajeswari ,	Pandelil, thettivila
50) Surendran P,	Aswathy bhavan, kakkamoola
51) Puroshothaman,	Parayaruvila, Poonkulam

52) Pushpangadhan	Parvathy Bhavan
53) Ramachandran	kundarathela veedu, kalliyur
54) Dr Sasikumar	Sivalayam, kalliyur
55) Baby sebastian	Grace villa, kalliyur
56) Sivakala	Sivalayam, vellayani
57) Vijayakumar	karan villa,Kalliyur
58) Krishnan Nair	Sreepadmam,
59) Vijaya kumari	Raghu nivas
60) Kesavan Nair	Pournami, Kakkamoola
61) Rajasree	Sreepadmam, Vandithadam
62) Surendran P	Manchadivila veedu, kakkamoola
63) Puroshothaman	Kaveri, Poonkulam
64) Ramachandran	kundarathela veedu, kalliyur
65) Dr Sasikumar	Sivalayam, kalliyur
66) Baby sebastian	Grace villa, kalliyur
67) Sivakala	Sivalayam, vellayani
68) Vijayakumar	karan villa,Kalliyur
69) Krishnan Nair	Sreepadmam,
70) Vijaya kumari	Raghu nivas
71) Kesavan Nair	Pournami, Kakkamoola
72) Rajasree	Sreepadmam, Vandithadam
73) Surendran P	Manchadivila veedu, kakkamoola
74) Puroshothaman	Kaveri, Poonkulam
75) Robin Alex	bethlahem, kayalkara
76) Sasikumar,	narayana mandiram, kalliyur
77) Prasannakumari	vayalarikathu veedu, kalliyur
78) Suresh kumar,	lake view, kulangara, kakkamola
79) Balakrishnan,	chadayam,poonkulam

80) Krishnan	krishnalayam, Vellayani
81) Mohanan	Greeshma, Okode
82) Narayani,	Padinjattetil, vellayni
83) Radhakrishnan	krishna Nilayam, Thettivila
84) Satheesh Kumar	Satheesh Bhavan, Thettivila
85) Samuel	Ebenezer, Kayalkara
86) Sasikumar	narayana mandiram, kalliyur
87) Prasannakumari	vayalarikathu veedu, kalliyur
88) Suresh kumar	lake view, kulangara, kakkamola
89) G Balakrishnan	chadayam,poonkulam
90) K venugopal	puthukudi, santhivila
91) Rakesh	Guruprayag, Okode
92) Narayanisumangi,	N S Bhavan, vellayni
93) Narayanan	Rajesh Bhavan, Kayalkara
94) Balakrishnan	Sreekrishnavilasom, Thettivila, Kalliyoor
95) Anandan	Sree vihar, Vellayani
96) Sanoj Kumar	Sai Vihar, Kalliyoor
97) Pramod	Thiruvonam, West poonkulam
98) Soman Nair	Jinu Bhavan, Thettivila
99) Ravi	Ambalthumkalayil,Thettivila
100) Mathew	S N Villa ,Thettivila
101) Omana	Ajitha Bhavan, Kakkamola
102) Sekharan	Sindhu Bhavan, Thettivila

103)	Sreedharan	Sree Bhavan, Kayalkara
104)	Balakrishnan	Sreekrishnavilasom, Thettivila, Kalliyoor
105)	Prabhakaran	Sree vihar, Thettivila
106)	Sanoj Kumar	Sai Vihar, Kalliyoor
107)	Praseeda	Thiruvathira, West poonkulam
108)	Somasekharan	Manu bhavan, Thettivila
109)	Ravi	Pallithekkethil,Thettivila
110)	Roy Mathew	Chris villa,Thettivila, Poonkulam

APPENDIX 2

SCORES GIVEN FOR THE PALMS SURVEYED

PALM NUMBER	SCORE OF THE PALM
PALM 1	4
PALM 2	5
PALM 3	5
PALM 4	5
PALM 5	6
PALM 6	6
PALM 7	2
PALM 8	5
PALM 9	5
PALM 10	5
PALM 11	6
PALM 12	1
PALM 13	4
PALM 14	5
PALM 15	4
PALM 16	4
PALM 17	4

PALM 18	4
PALM 19	1
PALM 20	4
PALM 21	5
PALM 22	5
PALM 23	1
PALM 4	4
PALM 25	6
PALM 26	5
PALM 27	5
PALM 28	5
PALM 29	5
PALM 30	5
PALM 31	5
PALM 32	5
PALM 33	4
PALM 34	3
PALM 35	4
PALM 36	5
PALM 37	5
PALM 38	1

PALM 39	1
PALM 40	4
PALM 41	5
PALM 42	3
PALM 43	3
PALM 44	4
PALM 45	5
PALM 46	4
PALM 47	3
PALM 48	5
PALM 49	5
PALM 50	5
PALM 51	5
PALM 52	5
PALM 53	5
PALM 54	5
PALM 55	5
PALM 56	5
PALM 57	5
PALM 58	1
PALM 59	5

PALM 60	6
PALM 61	5
PALM 62	5
PALM 63	4
PALM 64	5
PALM 65	5
PALM 66	6
PALM 67	1
PALM 68	4
PALM 69	5
PALM 70	6
PALM 71	7
PALM 72	7
PALM 73	5
PALM 74	5
PALM 75	4
PALM 76	7
PALM 77	6
PALM 78	5
PALM 79	5
PALM 80	5

PALM 81	6
PALM 82	5
PALM 83	5
PALM 84	4
PALM 85	5
PALM 86	1
PALM 87	7
PALM 88	6
PALM 89	7
PALM 90	6
PALM 91	7
PALM 92	6
PALM 93	5
PALM 94	5
PALM 95	1
PALM 96	6
PALM 97	5
PALM 98	6
PALM 99	6
PALM 100	6

APPENDIX 3
FARMERS AND PALMS SELECTED

SL NO:	NAME	ADDRESS	PALMS SELECTED			
			HEALTHY PALM	MILD INTENSITY	MODERATE INTENSITY	SEVERE INTENSITY
1	COA	College of Agriculture, Vellayani	H1	-	-	S1 S2
2	SUKUMARAN NAIR	PreethiNivas, Agriculture college P.O	-	-	M1	-
3	ANIL KUMAR	SuliNivas, AGC P.O	-	-	M2	-
4	AHI MOHAN	Salyanikethan, Channelkara, AGC P.O	-	-	M3	-

5	AJESH KUMAR	AjeshBhavan, Channelkara, AGC P.O	-	K1	-	-
6.	YOGIRAJ	Kozhipura, Channel kara, AGC P.O	H2	-	M4	S3
7	SREEKALA	Thiruvathira, Channelkara, AGC P.O	-	-	M5	-
8	VIJAYAN R	Ashish , Poonkulam	-	-	-	S4
9	CHINJU	Chinju Nivas, West Poonkulam	-	K2	-	-
10.	BALAMURALI	MuraliNivas, West Poonkulam	-	-	-	S5

11.	SARASWATHI AMMAAL	567/2,kaayalkara,Vellayani P O	H3	K3 K4	-	-
12.	MOHAMMAD AZEEZ	Punthalumvila, Keezhur, Vellayani P O	H4	-	M6	S6
13.	C SUKUMARAN NAIR	Premavilasam, Kaakamoola	H5	K5	-	-
14.	DEEPA	DeepaSadanam, Kaakamoola	-	K6	-	-

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APPENDIX 4

CATEGORIZATION OF SYMPTOMS OF CORIED BUG DAMAGE IN COCONUT PALMS

CATEGORY	NUT SYMPTOMS
CATEGORY I	Nuts without scars (uninfested)
CATEGORY II	Nuts with 1 to 5 scars
CATEGORY III	nuts with 6- 20 scars (mild damage)
CATEGORY IV	Nuts with greater than 20 scars in a single ring round the nut (moderate damage)
CATEGORY V	Nuts with greater than 20 scars distributed more or less all over the nut (heavy damage)
CATEGORY VI	Nuts heavily scarred in which the endosperm failed to develop (severe damage)

APPENDIX 5

CATEGORIZATION OF SYMPTOMS OF MITE DAMAGE IN COCONUT PALMS

Category 1	Nuts with no mite damage (0%)
Category 2	Nuts with superficial mite damage (1-10%)
Category 3	Nuts with significant mite damage but not much smaller (11-25%)
Category 4	Nuts with significant mite damage , smaller and with some distortion(26-50%)
Category 5	Nuts very heavily attacked , very much reduced in size and often greatly distorted (51-100%)