Vol. 13(40), pp. 2098-2103, 4 October, 2018
DOI: 10.5897/AJAR2018.13352
Article Number: 86A165E58715
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Review

Corynespora leaf fall of *Hevea brasilensis*: Challenges and prospect

Umoh Florence[1*] and Fashoranti Ebenezer L.[2]

[1]Rubber Research Institute of Nigeria, P. M. B. 1049, Benin city, Edo State, Nigeria.
[2]International Institute of Tropical Agriculture, P. M. B 5320, Ibadan, Oyo State, Nigeria.

Received 27 June, 2018; Accepted 21 August, 2018

***Hevea brasiliensis* is the major source of natural rubber. Natural rubber being a unique biopolymer of strategic importance needs to be continuously well managed and protected against biotic damages. Many rubber producing countries include South East Asia, Africa and Latin America among others. *Corynespora* leaf fall caused by *Corynespora cassiicola* is currently considered as the most destructive leaf disease of *Hevea* rubber in Asian and African continents causing about 45% of yield loss. It had caused great loss to the rubber industry in various countries, thus the need for prompt action against the disease. The rubber breeding over the years have been on the development of clones with high yield combined with the desirable secondary traits. The resistance of rubber clones to *C. cassiicolla* depends on its ability to neutralize the toxin or its use of the hypersensitive response of the clone. The major objective of this review was to awaken the consciousness to *C. cassiicolla,* having in mind that rubber clones once tolerant to the disease had later become susceptible.**

Key words: Bio polymer, *Corynespora cassiicolla, Hevea brasiliensis,* natural rubber, tolerant.

INTRODUCTION

Rubber tree (*Hevea brasiliensis*) is a deciduous plant that belongs to the Euphorbiaceae family. The common names are Pará rubber tree, in Spanish it is called 'sharinga' tree, 'seringueira', 'jebe'. The Portuguese call it 'seringueira-rosada', 'seringueira-verdadeira' while Italian and Malay call it 'della gomma' and 'pokok getah', respectively (Heuzé and Tran, 2017). Amazon basin is the centre of diversity for major commercial rubber in the world. *H. brasiliensis* was introduced to tropical Asia in 1876 through Kew garden, from the seeds brought from Rio Tapajo'z region of the upper Amazon region of Brazil by Sir Henry Wickam (Dijkman, 1951). There, the planting materials were assembled from the native land, propagated and then distributed to other botanical gardens around the world (Baulkwill, 1989). The successful transfer of *H. brasiliensis* to Asia and the subsequent establishment of rubber plantations were successful due to the demand for its raw material (Venkatachalam et al., 2013). Natural rubber is produced from the Para rubber tree, which is of the height of 30 to 40 m in the Amazonian forest (its natural habitat) (Venkatachalam et al., 2013).

Cultivated trees are usually smaller because the tapping activity reduces its growth and they are cut after

*Corresponding author. E-mail: umohflorencem1@gmail.com.

30 years due to decline latex production (Döring, 2018). The bark has patches of white and gray. The leaves are trifoliate and spirally arranged. The tree starts its productive phase from 5 to 8 years, after planting it has a productive life span of 25 to 30 years (HAL, 2014).

Flowers are monoecious and small with no petals. It is a pungent bright or cream-yellow coloured flower pollinated by insects, mostly midges and thrips (Priyadarsha, 2017). The fruit is a capsule that contains three large seeds (Blackley, 1997)

Natural rubber is synthesized from 2000 plant species confined to 300 genera of seven families which consist of Euphorbiaceae, Apocynaceae, Asclepiadaceae, Asteraceae, Moraceae, Papaveraceae and Sapotaceae (Cornish et al., 1993). Only three species of the genus namely *H. brasiliensis*, *Hevea guianensis* and *Hevea benthamiana* yield usable rubber (Sharpe, 2017). Other species have excessively high resin to rubber ratio in their latex (Mekonnen, 2015). The major content of latex is cis1-4 polyisoprene (94%), while protein and fatty acids make up 6% (Sakdapipanich, 2007). Cis-1, 4-polyisoprene biopolymers are made up of C5 monomeric isopentenyl diphosphate (IPP), units and are formed by sequential condensation on the surface of rubber particles. The rubber chain elongation is catalyzed by cis-prenyltransferases (CPTs), known as rubber polymerases (Asawatreratanakul et al., 2003). The molecular weight of the resulting polymer is an important determinant of rubber quality (Rahman et al., 2013). Latex contains some stress and plant defense-related proteins called *hevein* and *hevein amine* (Yeang et al., 2002). However, latex preparations are often contaminated with allergens. These allergens are carried through the manufacturing process and are present in the finished products (Flaherty, 2012). Latex has multiple commercial uses and is commonly found in a number of products (Sando et al., 2008).

H. brasiliensis is the primary source of natural rubber (NR) (Rahman et al., 2013) and also the only species planted commercially (Kew Science, 2017). According to the International Rubber Study Group (www.rubberstudy.com), global production of NR got to almost 11 million tons in 2011 and its demand is steadily on the increase over the years. NR is a latex polymer with high elasticity, flexibility, resilience, impact resistance, and efficient heat dispersion (Mooibroek and Cornish, 2000). These useful properties are due to the large and complex molecular structure of rubber (Milliken et al., 2009). The natural rubber obtained from the Para rubber tree (*H. brasiliensis*) is a unique bio-polymer of great importance. Thus, it cannot be replaced by synthetic rubber alternatives because of its significant applications (Venkatachalam et al., 2013). No other synthetic substitute has comparable elasticity, resilience and resistance to high temperature (Davis, 1997). Also, natural rubber is a renewable (green) elastomer and its production requires less oil than that of synthetic rubber (one-sixth) (Jules, 2007).

South-East Asia produces 92% of natural rubber, followed by Africa and Latin America with 6 and 2%, respectively. Major rubber producing countries includes Vietnam, Thailand, Indonesia, India, Malaysia, China, Côte d'Ivoire, Liberia, Sri-Lanka, Brazil, Philippines, Cameroon, Nigeria, Cambodia, Guatemala, Myanmar, Ghana, Democratic Republic of Congo, Gabon and Papua New Guinea (Saha and Priyadarshan, 2012).

Other products obtained from *H. brasiliensis* include seed oil and wood. Rubber wood has generated a profitable industry not only in Malaysia and Thailand, but also in India, Vietnam, Indonesia, Cambodia (Venkatachalam et al., 2013) and Nigeria. Its natural light colour and excellent physical properties make it suitable for flooring, household furniture, boards and packing boxes (FAO, 2001). Owing to the value of this product, several superior latex-timber clones have been developed (Rahman et al., 2013).

Wood quality has been associated with several lignocellulose biosynthesis genes (Dillon et al., 2010). Lignin, a heteropolymer of monolignols, determines the texture and hardness of the wood. Para rubber seeds are sources of seed oil, recommended for manufacturing soap, paints, leather (Ohikhena, 2006), biofuel or compression engines (Ikwuagwu, 2000; Ramadhas et al., 2005), wood polish (Bello and Otu, 2015) among others.

BACKGROUND AND DAMAGE CAUSED BY *CORYNESPORA* LEAF FALL DISEASES (CLFD)

Diseases are the major constraints of Para rubber tree. These include the abnormal leaf fall caused by *Phytophthora* species, *Colletotrichium* leaf fall caused by *Colletotrichum acutatum*, powdery mildew caused by *Oidium heveae* and C*orynespora* leaf fall caused by *Corynespora cassiicola* (Manju et al., 2002). The scientific classification of *C. cassiicola* is shown in Table 1. In Nigeria, the most devastating diseases of rubber seedlings and budded plants in the nursery are the leaf diseases (Begho, 1995; Omorusi et al., 2011); while in some countries like The United States of America, the South American Leaf Blight (SALB) ranks the top of leaf disease especially in mature plantation. The disease was first reported in Malaysia in 1960 (Newsam, 1960), India in 1961 (Ramakrishnan and Pillai, 1961), Nigeria in 1966 (Jayasinghe and Fernando, 2009) and afterwards in Sri Lanka in 1985 (Liyanage et al., 1986). The disease is generally severe in areas with high rainfall without any prolong dry period (MCR, 2000).

Cassiicolin produced by *C. cassiicola* causes many types of symptoms in over 80 host plants under diverse environmental conditions (Jayasinghe, 2000a). The host plants are tomato, cowpea, cucumber, tobacco, ground nut among others. The toxin for the pathogenicity results in the symptoms of the CLFD in rubber trees (Manju et

Table 1. Scientific Classification of *Corynespora cassiicola*.

Kingdom	Fungi
Phylum	Ascomycota
Class	Dothideomycetes
Sub class	Pleosporomycetidae
Order	Pleosporales
Family	Corynesporascaceae
Genus	*Corynespora*
Species	*cassiicola*

Table 2. Optimum environment.

Host	Temperature (°C)	leaf wetness
Tomato	20-28	>16 h necessary
Cucumber	25-30	-
Tobacco	27.5-30	-
Rubber	25-30	Greatest at 90%

Source: Fulmer (2011).

al., 2002). The pathogen causes the fall of both young and old leaves all year round. This may lead to dieback (Figure 2), delay in maturation of young rubber trees, yield reduction of about 45% of mature rubber trees (Ogbebor, 2010) and even plant death on susceptible clones (Jinji et al., 2007). According to Malaysian observations, spore dispersal is at the peak during dry season, but infections occur when the leaf surface is wet (Table 2) (Jayasinghe, 2000a).

Corynespora disease (caused by the fungus *C. cassiicola*) is more severe during refoliation, between December and April (Reshma et al., 2016). Though it affects leaves of all stages, young leaves in the light green stage appear to be the most susceptible. One of the unique features of this pathogen is the production of different types of symptoms depending on the type of the clone and maturity state of the plant. The symptoms diversity is a serious limiting factor to its early diagnosis and management.

However, circular lesions of varying sizes with papery centre, brown margin and a yellow halo is the most common symptom (Manju, 2011). The central region of the lesions may disintegrate, leaving holes. Sometimes, the shot hole effect is also noticed on leaves due to the disintegration of the centre of the spots (Figure 1) (Jinji et al., 2007). High temperature and humidity during refoliation period favours the disease incidence (Manju et al., 2016).

Its survival and spread is also a contributory factor. Pernezny and Simone (1993) reported several means of survival and spread of *C. cassiicola* in the field. They noted its survival in crop debris for about 2 years. Boosalis and Hamilton (1957) and Seaman et al. (1965) also reported that it can survive during the wet period in the root debris and stem in the field. Manju et al. (2016) reported that it could survive for 11days in infected leaf litter and also on infected intact leaves.

Figure 1. Fish-bone like, shoot pole effect on rubber leaf.

MANAGEMENT OF *C. CASSIICOLLA*

A number of management approaches (use of

Figure 2. Die back caused by *C. cassicolla*.

fungicides, cultural practices and integrated management of disease) have been evaluated and recommended as the control of CLFD in nursery and field (Manju, 2011). Chemical control of CLF is practiced in polybag and budwood nursery. Many fungicide combinations have been recommended by different researchers as an effective control. Jayasinghe (2000b) have recommended frequent spraying of fungicides on polybag nurseries during the rainy season, due to the fact that all rubber clones including highly resistant ones in the field are extremely susceptible to CLF during juvenile stage. Joseph and Manju (2002) also recommended different water based fungicides for the control of CLFD of rubber, stating that a mixture of mancozeb (0.2%), carbendazim (0.5%) and a combination of metalaxyl + mancozeb (0.2%) were consistently found more effective in nurseries. They also noted that spraying of mancozeb at weekly intervals was recommended, as it was the cheapest and most effective fungicide available. Fernando et al. (2010) concluded from their investigations that, to manage CLFD in the nursery, a combination of overhead shading and the application of fungicide mancozeb was the most effective method.

The timing of the spraying, however, is very important. When the leaves are light green during refoliation, it should be sprayed. The leaves may be affected if the spraying is delayed till the leaves are fully mature (Manju et al., 2016).

Critically speaking, many manual hours of labour and enormous quantities of fungicides are required every year for the management of CLF in many rubber plantations all over the world. The cost of fungicides and their long-term effect on the environment justify the need for breeding disease resistant trees. A multidisciplinary breeding program for development of disease resistant clones would have to continuously utilize Wickham resource as well as wild germplasm in addition to other *Hevea* species, in order to have sustainable rubber production (Narayanan and Mydin, 2012).

However, the hygiene of the plantation is of great importance as un-kept plantations give room for the causal organism to thrive. This is supported by the findings of Ogbebor (2010) which revealed that low management practice in both nursery and plantation supported the increasing rate of diseases.

FUTURE OF THE PARA RUBBER TREE WITH *C. CASSIICOLA* INFECTION

CLFD has become a threat to the natural rubber plantation industry by limiting its productivity level. There have been 72 documented report of *C. cassicolla* infection, from 1957 to 2013 (Fulmer, 2011). The increase and severity of the disease may be connected to its wide host range, variability of the pathogen (Dede et al., 2012) and ability to cause different kinds of disease in the host plant (Dixon et al., 2009). Ogbebor (2010) reported that *Corynespora* had the highest incidence of leaf diseases with an index range of 26.19 to 40.19; while the least, 7.61 to 17.91, was recorded for *Colletotrichum* leaf fall.

The major objective of *H. brasilensis* breeding is to develop high yielding clones with secondary characters, like resistance or tolerance to leaf disease. This will be effective with the understanding of the function of Para rubber tree (Venkatachalam et al., 2013). The resistance of some rubber clones to *C. cassiicolla* infections may be as a result of their ability to neutralize toxin or due to the fact that the toxin is poorly or not recognised by its specific receptors (Breton and D'Auzac, 1999). The identification of disease resistance genes is one of the major focuses of the Para tree research. Hypersensitive response (HR) is the early defense response that causes necrosis and cell death to restrict the growth of the pathogen (Yu et al., 1998). Plant signalling molecules, salicylic, and jasmonic acids play a critical role in activating systemic acquired resistance (SAR) and induce certain pathogenesis-related (PR) proteins (Durrant and Dong, 2004). The nucleotide-binding site (NBS)-coding R gene family is the largest group of disease resistance genes in plants (Mun et al., 2009).

It had been identified in *H. brasiliensis* similar to that of *Oryz asativa* (Ahmad et al., 2013). Some *Hevea* clones have been tested for their capacity to produce phytoalexins and a strong correlation between phytoalexin accumulation and clone resistance. More lignin accumulation was often associated with clone resistance (Narayanan et al., 2012).

However, genetic improvement through conventional breeding has been hampered by long experimental period, insufficient fruit production, and a high level of heterozygosity (Masson et al., 2013).

In conclusion, the fungus (C. *cassiicolla*) could be used as a bio-herbicide and biological pest control; since it infect many plants considered as weeds (Dixon et al., 2009).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ahmad YAR, Abhilash OU, Biswapriya BM, Gincy PT, Kandakumar J, Yun F, Shaobin H, Su YO, Fui LN, Ling SL, Hock ST, Muhd KLMS, Beng S T, Bee FK, Siti SB, Nurohaida AA, Anton Y, Bjarne K, Alexandre D, Nokuthula PM, Qingyi Y, Brennick JL, Tracey AKF, Aaron GY, Rui C, Lei W, Nazalan N, Jennifer AS, Maqsudul A (2013). Draft genome sequence of the rubber tree *Hevea brasiliensis*; BMC Genomic 14:75.

Asawatreratanakul K, Zhang YW, Wititsuwannakul D, Wititsuwannakul R, Takahashi S, Rattanapittayaporn A, Koyama T (2003). Molecular cloning, expression and characterization of cDNA encoding cis-prenyltransferases from Hevea brasiliensis: a key factor participating in natural rubber biosynthesis. European Journal Biochemistry 270:4671-4680.

Baulkwill WJ (1989). The history of natural rubber production. In: Webster C. C. and Baulkwill W. J. (eds.), Rubber. Longman Scientific and Technical, Essex, England pp. 1-56.

Begho ER (1995). Hevea plantation establishment. Proceeding of training workshop on the *Hevea* Plantation establishment held at RRIN Iyanomo 2nd – 4th August, 55 p.

Bello EI, Otu F (2015). Physicochemical Properties of Rubber (Hevea brasiliensis) Seed Oil, Its Biodiesel and Blends with Diesel, British Journal of Applied Science and Technology 6(3):261-275.

Blackley DC (1997), Polymer Latices: Science and technology: Types of latices 2nd edition, Springer Science & Business Media 2:2-7.

Boosalis M G, Hamilton RI (1957). Root and stem rot of Soybean caused by *Corynespora cassiicola* (Berk & Curt) Wei. Plant Disease Reporter 41(8):696-698.

Breton F, D'Auzac J (l999). Cassiicoline, a host selective toxin produced by *Corynespora cassiicola* causative agent of *Hevea* leaf fall disease. IRRDB Annual Meeting and Symposium 1999. Haicau, China. http://dl.nsf.ac.lk/bitstream/handle/1/9078/BRRISL-42-56.pdf?sequence=2

Cornish K, Siler DJ, Grosjean OK, Godman N (1993). Fundamental similarities in rubber particle architecture and function in three evolutionarily divergent plant species; Journal of Natural Rubber Research 8:275-285.

Davis W (1997). The rubber industry's biological nightmare. Fortune 136(3):86

Dede A, Akpaja EO, Akendolor A (2012). Susceptibility of *Hevea brasiliensis (Willd Ex Adr. De Juss)* Muell Arg) and *Lycopersicon esculentum L.* Leaves to selected isolates of *Corynespora cassiicola* (Berk. and Curt.) boson.org.ng/uploads/SUSCEPTIBILITY%20OF%20HEVEA%20BRASILIENSIS

Dijkman MJ (1951). *Hevea:* Thirty years of research in the Far East. University of Miami press, Florida pp. 5-7.

Dillon SK, Nolan M, Li W, Bell C, Wu HX, Southerton SG (2010). Allelic variation in cell wall candidate genes affecting solid wood properties in natural populations and land races of Pinus radiata. Genetics 185:1477-1487.

Dixon L, Schlub R, Pernezny K, Datnoff L (2009). Host specialization and phylogenetic diversity of Corynespora cassiicola. Phytopathology 99(9):1015-1027.

Döring M (2018). *Hevea brasiliensis* Müll. Arg. in English Wikipedia - Species Pages. Wikimedia Foundation. Checklist Dataset https://doi.org/10.15468/c3kkgh

Durrant WE, Dong X (2004). Systemic acquired resistance. Annual Review of Phytopathology 42(1):185-209

Food and Agricultural Organization (FAO) (2001), Non-forest tree plantations. Report based on the work of W. Killmann. Forest Plantation Thematic Papers, Working Paper 6. Forest Resources Development Service, Forest Resources Division. FAO, Rome (unpublished).

Fernando TH, Jayasinghe CK, Wijesundera RL, Siriwardana D (2010). Screening of fungicides against Corynespora leaf fall disease of rubber under nursery conditions Journal of Plant Diseases and Protection 117(3):117-121.

Flaherty DK (2012). Immediate Allergic Reactions in Immunology for pharmacy, St. Louis, Mo Elsevier pp. 118-126 ISBN 9780323069472.

Fulmer A (2011). The (Emerging) Reality of *Corynespora* cassiicola: Insights from a literature review. Unpublished thesis

Hevea Africa Limited (HAL) (2014), factsheet. http://www.heveaafricaltd.com/rubber-tree/factsheet/

Heuzé V, Tran G (2017). Rubber *(Hevea brasiliensis)* Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, https//www.Feddipedia.org/node/39

Ikwuagwu OE, Ononogbu IC, Njoku OU (2000). Production of biodiesel using rubber (Hevea brasiliensis (Kunth. Muell.)) seed oil. Industrial Crops and Products 12:57-62.

Jayasinghe CK (2000a). *Corynespora* Leaf Fall: The Most Challenging Rubber Disease in Asian and African Continents. Bulletin of the Rubber Research Institute of Sri Lanka 42:56-64.

Jayasinghe CK, Fernando THPS (2009). *Corynespora* leaf fall of Hevea Rubber: The most threatening leaf disease leaf disease in Asia and African continents ISBN: 978-955-50917-1-8.

Jayasinghe CK (2000b). *Corynespora* Leaf Fall of Rubber in Sri Lanka. Diversity of the Pathogen and Pathogenesis. International Rubber Research and Development Board Corynespora leaf fall disease workshop in Kuala Lumpur and Medan from 6th to 14th June, 2000.

Jinji P, Zhang X, Qi Y, Xie Y, Zhang H, Zhang H (2007). First record of *Corynespora* leaf fall disease of *Hevea* rubber tree in China, Australasian Plant Disease Notes 235-236. DOI:10.1071/DN07017

Joseph A, Manju MJ (2002). Control of *Corynespora* leaf disease in rubber nurseries. Nation. Symp. on Crop Protection and WTO – An Indian Perspective, CPCRI, Kasaragod, Kerala, Jan. 22 – 25, 2002.

Jules J (2007). *Hevea* rubber breeding and genetics, Horticultural reviews, 33: 176- 203 Kew Science (2017); http://www.ipni.org and http://apps.kew.org/wcsp

Liyanage AS, Jayasinghe CK, Liyanage NIS, Jayaratne R (1986). Corynespora leaf spot disease of rubber (*Heveabrasiliensis*) a new record. Journal of the Rubber Research Institute of Sri Lanka 65:47-50.

Malaysian Country Report (MCR) (2000). International Rubber Research and Development Board (IRRDB) Workshop on *Corynespora* leaf fall of Rubber; 6-9 June 2000. P 2.

Manju MJ, Mushrif SK, Parasappa HH, Shankarappa TH, Benagi VI, Idicula SP, Hegde LN (2016). Survival ability of *Corynespora cassiicola* in rubber (*Hevea brasiliensis* Muell. Arg.) plantations. International Journal of Life Sciences Scientific Research 2(2):43-45.

Manju MJ (2011). Epidemiology and Management of *Corynespora* Leaf Fall Disease of Rubber caused by *Corynespora cassiicola* (Berk & Curt.) Wei., PHD thesis (unpublished)

Manju MJ, Idicula SP, Jacob CK, Vinod KK, Prem E (2002). Management of Corynespora leaf fall (CLF) disease of rubber with water based fungicide formulations. Plantation Crop Research and Development in the New Millennium pp. 527-530.

Masson AJ, Julien M, Boedt L (2013). Industrial propagation by rooted cuttings of mature selected clones of *Hevea brasiliensis*; Boisetforêts Destropiques 317(3):51-58

Mekonnen A (2015). The West and China in Africa: Civilization without Justice, Wipf and Stock Publishers P 177, ISBN 13: 978-1-4982-2018-7

Milliken W, Klitgard B, Baracat A (2009). Neotropikey - Interactive key and information resources for flowering plants of the Neotropics. http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:349913-1

Mooibroek H, Cornish K (2000). Alternative sources of natural rubber.

Applied Microbiology and Biotechnology 53:355-365.
Mun JH, Yu HJ, Park S, Park BS (2009). Genome-wide identification of NBS-encoding resistance genes in Brassica rapa. Molecular Genetics and Genomics 282:617-631.
Narayanan C, Mydin KK (2012). Breeding for disease resistance in *Hevea* spp. - status, potential threats, and possible strategies. In: Sniezko, Richard A.; Yanchuk, Alvin D.; Kliejunas, John T.; Palmieri, Katharine M.; Alexander, Janice M.; Frankel, Susan J., tech. coords. Proceedings of the fourth international workshop on the genetics of host-parasite interactions in forestry: Disease and insect resistance in forest trees. Gen. Tech. Rep. PSW-GTR-240. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture pp. 240-251.
Newsam A (1960). Plant Pathology Division Report. Rubber Research Institute of Malaysia, Kuala Lumpur, Malaysia.
Ogbebor ON (2010). The status of three common leaf disease of Para rubber in Nigeria. Journal of Animal and Plant Sciences 6(1):567-570.
Ohikhena SO (2006). Small scale industrial application of rubber seed oil in soap manufacture. Ife Journal of Science 8(2):207-210.
Omorusi VI, Ikerodah-Omo EE, Mokwunye MUB (2011). Evaluation of effect of antagonistic fungi and arbuscular mycorrhizal fungi (AMF) on incidences of some disease *Hevea brasiliensis* (Muell. Arg). Nature and Science 9(12):151-154.
Pernezny K, Simone GW (1993). Target spot of several vegetable crops. Florida Cooperative Extension Services. Institute of Food and Agricultural Sciences, University of Florida 39 p.
Priyadarsha PM (2017). Biology of *Hevea* Rubber, pp 10-25, Springer Nature. ISBN 978-3- 319-34304-2
Rahman AYA, Usharraj AO, Misra BB, Thottathil GP, Jayasekaran K, Yun F Hou S, Ong SY, Ng FL, Lee LS, Tan HS, Sakaff MK, Muhd L, The BS, Khoo BF, Badai SS, Aziz NA, Yuryev A, Knudsen B, e Dionne-Laporte A, Mchunu NP, Yu Q, Langston BJ, Freitas TAK, Young AG, Chen R, Wang L, Najimudin N, Saito JA, Alam M (2013). Draft genome sequence of the rubber tree *Hevea brasiliensis*; BMC Genomics 14:75.
Ramadhas AS, Jayaraj S, Muraleedharan C (2005). Characterization and effect of using rubber seed oil as fuel in the compression ignition engines. Renewable Energy 30(5):795-803.
Ramakrishnan TS, Pillay PNR (1961). Abnornal leaf fall disease of rubber caused by *Phytopthora palmivora* (Butler) Butler 2. Rubber Board Bulletin 5(2):76-84.
Reshma M, Philip S, Rose D, Joseph A, Prem E, Joseph J (2016). Pathogenicity and toxin production of *Corynespora cassiicola* isolates causing *Corynespora* Leaf Fall Disease In *Hevea brasiliensis* Rubber Science 29(3):277-285
Saha T, Priyadarshan PM (2012). Genomics of tree crops. Springer Science and Business Media pp. 261-300.
Sakdapipanich JT (2007). Structural characterization of natural rubber based on recent evidence from selective enzymatic treatments. Journal of Bioscience Bioengineering 103:287-292.
Sando T, Takeno S, Watanabe N, Okumoto H, Kuzuyama T, Yamashita A, Hattori M, Ogasawara N, Fukusaki E, Kobayashi A (2008). Cloning and characterization of the 2-C-methyl-D-erythritol 4-phosphate (MEP) pathway genes of a natural-rubber producing plant *Hevea brasiliensis*. Bioscience, Biotechnology and Biochemistry 72:2903-2917
Seaman WL, Shoemaker RA (1965). *Coryncspora cassiicola* on Soybean in Ont. Plant Disease Reporter 48(1):69.
Sharpe K (2017). Genus & Species of Rubber wood, KEW: Hevea brasiliensis (rubber tree). https://www.gardenguides.com/131330-genus-species-rubberwood.html
Venkatachalam P, Geetha N, Sangeetha P, Thulaseedharan A (2013). Natural rubber producing plants: An overview; African Journal of Biotechnology 12(12):1297-1310
Yeang HY, Arif SAM, Yusuf F, Sunderasan E (2002). Allergenic protein of natural rubber latex, Methods 27:32-45.
Yu I, Parker J, Bent AF (1998). Gene-for-gene disease resistance without the hypersensitive response in *Arabidopsis dnd1* mutant. Proceedings of the National Academy of Sciences 95(13):7819-7824.