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Mini Review of Breeding Program on Rubber Trees

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A B S T R A CT

Rubber trees are one of the main tree crops in Southeast Asia that provides latex as the primary source of tire production. However, commercial clones of rubber trees are attacked by pests such as root and foliage diseases and are exposed to abiotic stresses such as drought, which make the development of resistant rubber clones to biotic and abiotic stresses crucial. This mini review highlights the breeding program to develop resistant rubber tree crops through crossing and biotechnology, including in vitro culture and genetic transformation.

INTRODUCTION

Rubber tree (*Hevea brasiliensis Muell. Arg.*) is widely cultivated to produce latex as a main source of tire production accounting for 70 % of latex uses (Clément-Demange et al., 2007; Onoji et al., 2016;). The later authors added that the rubber tree crops are mainly cultivated in South and Southeast Asia and account for 92% of worldwide farms. The rubber tree is originally from Brazil, but it is now commonly grown in Thailand, Indonesia, Malaysia and India. The rubber tree is less cultivated in South America than in South and Southeast Asia because South American Leaf Blight (SALB) fungus, *Microcyclus ulei* P. Henn. Von Arx (Mazlan et al., 2019; Bevenuto et al., 2021) that attacks rubber tree leaves can result in plant death (Mazlan et al., 2019). However, there is a little information about adaptable rubber clones to SALB fungus. Plant breeding programs play a key role in developing adaptable rubber tree crops for SALB fungus (Mazlan et al., 2019).

The *Microcyclus ulei* fungus, which causes SALB in rubber trees, has been a major obstacle to rubber tree production (Sobha et al., 2019; Sayurandi et al., 2022). Through breeding initiatives and genetic analysis, SALB-tolerant rubber tree cultivars have been developed (Sayurandi et al., 2022). These breeding projects focus on finding and choosing rubber tree varieties with some amount of SALB tolerance (Sobha et al., 2019). Researchers collaborate to create rubber tree clones that can tolerate the disease to some extent by careful selection and breeding, reducing its influence on output and productivity (Sobha et al., 2019). A rubber tree clone of IRR 220 has been recorded to be moderately tolerant to SALB and cannot survive a severe attack (Sayurandi et al., 2022). However, no clones of rubber trees are entirely immune or resistant to this fungus.

Abiotic stresses such as drought, flooding, salinity, and heat can negatively impact plant growth, development, and productivity (Carvalho et al., 2015; Falqueta et al., 2017; Guo et al., 2017; Yang et al., 2020). Drought stress can be caused by a lack of water availability, resulting in wilting, senescent leaves, and even plant mortality (Falqueto et al., 2017). Flooding is often caused by high rainfall and may result in root damage, stunted growth, and increased susceptibility to diseases due to high humidity (Carvalho et al., 2015). Heat stress develops when rubber trees are exposed to high temperatures. Reduced photosynthetic activity, leaf blistering, the loss of flowers and fruits, and general growth retardation can result from heat stress (Guo et al., 2017).

This literature review aims to identify the progress of recent research on rubber tree breeding programs to provide superior clones with optimum latex. The review will address the explanation of rubber tree products, abiotic and biotic stresses, and types of breeding programs (conventional and biotechnology).

THE FUNCTION OF RUBBER TREE

The main product of rubber trees is latex, 70% of which is used to produce tires and gloves (Clément-Demange et al., 2007; Sobha et al., 2019). Clément-Demange et al. (2007) added that the first harvesting (tapping) usually occurs between 4 and 7 years after planting depending on soil, climate, clones and agricultural practices. The rubber tree can be harvested for more than 20 years (Clément-Demange et al., 2007; Chantuma and Jogloy, 2017). Tapping in rubber trees means periodically encasing the bark of the trunk, which can generate and create latex flow during harvesting (Krishnakumar et al., 2001; Duangngam et al., 2020). The first tapping begins when the trunk diameter is 450 mm at 1300 mm high and 5 mm in skin depth of 60% total population (Krishnakumar et al., 2001). The tapping intensity is usually every 2, 3, 4, and 5 days in combination with plant hormones (e.g. etherphone, an ethylene-generating compound) to gain optimum latex (Silva et al., 2013). Depending on clones, one hectare of rubber trees can produce approximately 2000 and 3000 kg of latex (Clément-Demange et al., 2007; Jayashree et al., 2018; Sobha et al., 2019).

The secondary product of rubber trees is wood from unproductive plants (more than 30 years old after planting) which can enhance 15% of farmer’s income (Clément-Demange et al., 2007). The wood can be processed into furniture, plywood or particle board (Gouvêa et al., 2013; Khoo et al., 2018). Rubber trees can also produce antifungals because of the containing of protein (*hevein*) in latex which attacks fungi hyphae (Berthelot et al., 2016; Thaochan et al., 2020).

However, competitive clone quality plays a crucial role in achieving high latex and premium-quality secondary products. Clones in markets are usually a result of budding between vigorous root as a rootstock and high latex production as a scion (Clément-Demange et al., 2007; Sobha et al., 2019). Clément-Demange et al. (2007) added a bottleneck development of the meeting point between rootstock and scion identifies a valuable quality of clones. Environmental factors, including abiotic and biotic stresses, influence latex and secondary product productivity (Nguyen and Dang 2016; Wang and Tian, 2017).

ABIOTIC AND BIOTIC STRESS

Rubber trees are economically important plants grown for natural rubber manufacture (Sobha et al., 2019). Like other plants, rubber trees can be subjected to various abiotic and biotic stresses that might impact on their growth and output (Furtado et al., 2019). Guyot and Guen (2018) stated that abiotic variables such as excessive temperature and humidity can promote the spread and severity of SALB. Moreover, temperature and the duration of leaf wetness have been demonstrated to substantially impact the occurrence and severity of SALB infection (Guyot and Guen, 2018; Furtado et al., 2019).

Abiotic Stress

Rubber trees are imposed with a regular wounding during harvesting latex on the bark (tapping). This harvesting system disturbs the trunk trees, which influences plant growth and development and causes necrosis and browning of the inner bark (Silva et al., 2013; Soumya et al., 2016). The leaf necrosis could worsen when inappropriate harvesting timing are applied (Ayutthaya and Do, 2014). For example, in Thailand, farmers harvest latex during the dry season in August so that the rubber tree can result in a high number of leaf necrosis and low stomatal conducting and reduce the flux density of latex (Ayutthaya and Do., 2014).

Biotic Stress

Biotic stress caused by pest attacks is comparatively low compared to other tree crops. However, fungal diseases, including *Rigidoporus lignosus* (white root rot disease) and *Phellinus noxius* (brown root rot disease), cause damage to the root and are lethal to the rubber tree crops (Clément-Demange et al., 2007; Balasundaram et al., 2017). These two fungi attack the root of the different tissue, where R. *lignosus* attacks the lignin of the root and P. *noxius* degrades polysaccharide fraction of wood (Ogbebor et al., 2014). However, the fungi are relatively not adaptable to dry environments (Clément-Demange et al., 2007). Therefore, the dry season is an appropriate time to control the spread and attack of both fungi.

In wet areas such as Sri Lanka, Indonesia and Malaysia, Gloeosporium leaf disease (GLD) is one of the main diseases on the leaf of rubber trees that causes yield losses. The disease is caused by fungi (*Colletotrichum gloeosporioides*) and attacks young leaves, green shoots and pods (Jayasinghe et al., 1997; Liyanage et al., 2016). Jayasinghe et al. (1997) added that the disease could cause severe damage to the plant during high rainfall and humid conditions. This disease generally does not adapt to dry season and late leaf defoliation. Thus, clones that start leaf defoliation during early dry season are recommended to be planted in areas with GLD (Clément-Demange et al., 2007). Another main leaf disease is SALB causing several defoliations throughout the year and weakening of the tree. SALB destroyed more than 100,000 ha plantations in Brazil in 1972 (Hashim, 2006). However, clones tolerant to SALB disease are under experimental trial and unavailable to farmers (Sterling et al., 2020).

There are some alternatives for reducing the attack of SALB disease (Mohammed et al., 2014; Suryanarayanan and Azevedo, 2023). Sanitation techniques, including removing and destroying infected leaves, cutting infected branches, and maintaining a clean planting area, can reduce the spread and severity of SALB (Mohammed et al., 2014; Suryanarayanan and Azevedo, 2023). Balanced and proper fertilization makes the trees less vulnerable to SALB (Mohammed et al., 2014). Moreover, macronutrients and micronutrients contribute to the vigour and resilience of rubber trees (Mohammed et al., 2014).

BREEDING PROGRAM

The main reason for breeding program is generally an improvement of latex productivity, rapid growth and disease resistance (Souza et al., 2015; Adifaiz et al., 2018; Liu et al., 2019). However, to achieve this aim, challenges have occurred due to long live cycle. Therefore, rubber trees were propagated through budding in order to quicken their life cycle in conventional and biotechnology breeding programs. However, to achieve these aims, challenges such as a long-life cycle of rubber trees have occurred. As a consequence, clones of rubber trees are not significantly different compared to their parents because new clones are often produced through budding between scion for good bark performance and rootstock for good root performance (Sterling et al., 2020). The methods for breeding programs (conventional and biotechnology) are as follows:

Conventional Breeding

The breeding program in rubber trees is through three selection stages: a Seedling Evaluation Trial (SET, or nursery), a Small Scale Clonal Trial (SSCT), and a Large Scale Clonal Trial (LSCT) (Clément-Demange et al., 2007). All these processes can take up to 30 years and the most time-consuming is the last stage, LSCT, for approximately 15 years. This is because observation of latex quantity and quality variation occurs in LSCT. Moreover, multi-location tests also happen in LSCT to achieve wide adaptability of the selected clones.

In conventional breeding, two parents are from crossing between Wickham and Amazonia (Figure 1). Wickham represented a domesticated variety because this variety has been grown since 1876 in Asia (Singapore, Malaysia, SriLanka, Indonesia, and India), while Amazonia is a wild variety with low latex content and high disease resistance (Clément-Demange et al., 2007). The process and time of conventional breeding is shown in Figure 1.

Biotechnology

The biotechnology approach, a combination of recombinant DNA and cellular techniques, has increased the selection methodologies and tools of rubber trees. The two most common biotechnology techniques are in vitro culture and genetic transformation.

a. In Vitro Culture

Anther culture, protoplast fusion and embryo rescue are generally applied in vitro culture. First, anther culture was applied to achieve homozygous genotypes from double haploid lines of pure lines. The anther culture of rubber trees succeeded in 1977 at the tropical crop research institute in Hainan, China (Fa-tsu et al., 1979). Second, protoplast fusion was applied by isolating protoplast from the immature inflorescence, and this technique was successful (Figure 2) (Sushamakumari et al., 2000; Tisarum et al., 2018). Last, embryo rescue aimed to increase the success rate of genetic recombination. The embryo rescue technique had a high probability, 90%, if the embryo moved to in vitro after 3 to 3.5 months of formalization. However, this technique is costly (Clément-Demange et al., 2007), so this method is usually applied for rescuing rare progenies.

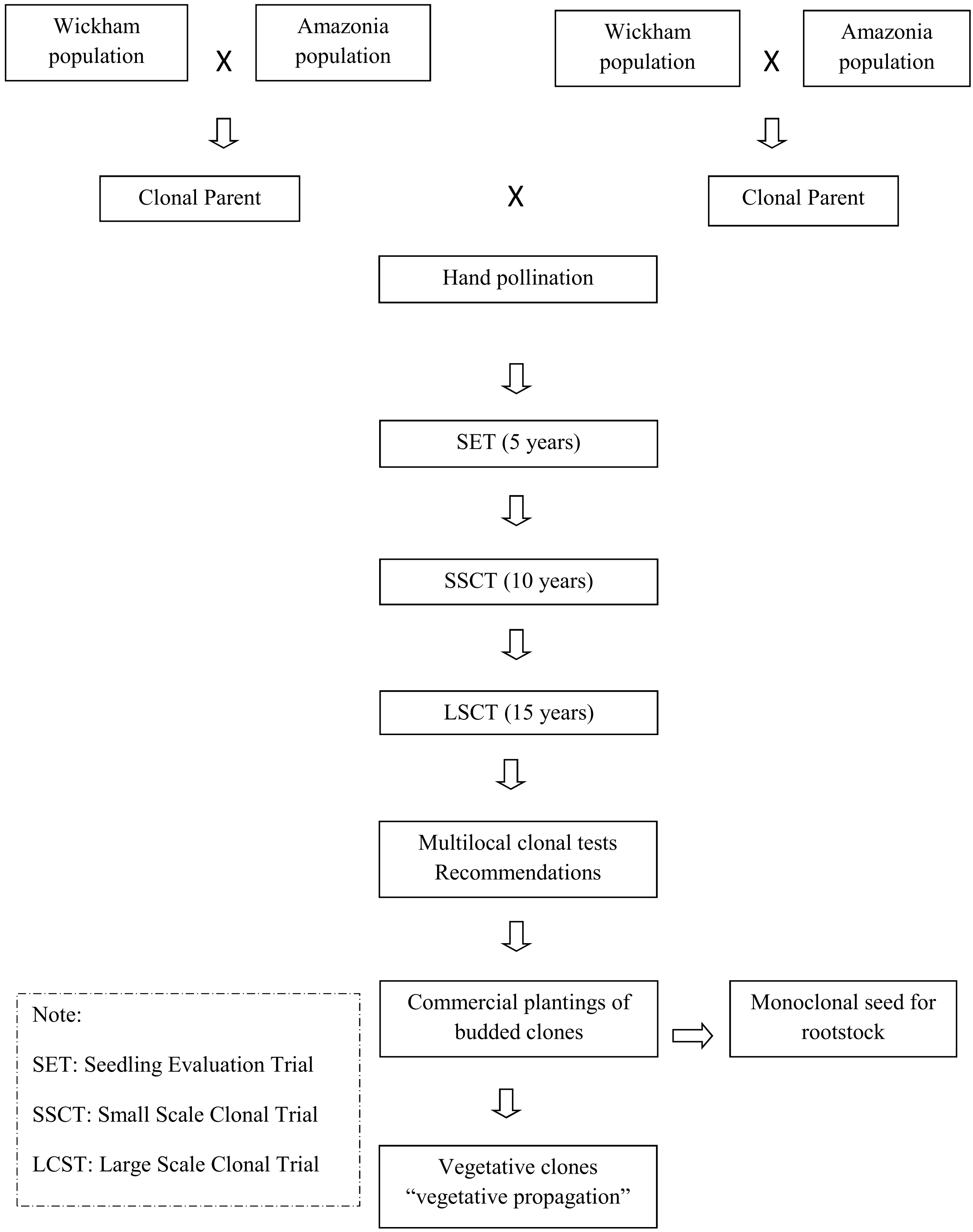

Figure 1. Conventional selection on rubber trees (adapted from Clément-Demange et al., 2007)

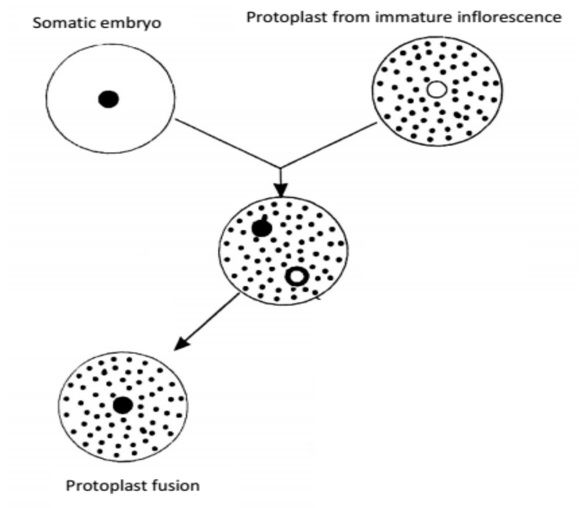

Figure 2. Protoplast fusion (adapted from Sushamakumari et al., 2000)

b. Genetic Transformation

Genetic transformation is popular in the breeding program because it is a more rapid process than somatic embryo genesis in increasing the number of genetic variations. The genetic transformation through mutagenesis is started by transforming *Hevea* cells in a targeted and complemented plant to achieve variation (Clément-Demange et al., 2007; Fan et al., 2020). Then, the specific genes are identified to choose or select high-performing clones. According to Kalawong (2014), *Agrobacterium tumefaciens* can mediate the regeneration of transgenic plants and genetic transformation in rubber trees. This bacterium can transfer *gus* and *nptII* genes because this bacterium is resistant to an antibiotic such as kanamycin. The trial of genetic modification on rubber trees succeeded because the transformed genes were passed to three generations of vegetative reproduction (Wang et al., 2013).

CONCLUSION

A breeding program is one of the keys to developing new adapted and disease-resistant clones to abiotic and biotic stresses in rubber trees. Clones with vigorous roots and resistance to root fungi, such as *Rigidoporus lignosus* are recommended for rootstock, while clones resistant to leaf diseases such as SALB and able to produce high amount of latex, are recommended for scion. However, the finding on tolerant rubber trees is still on a laboratory scale; therefore, the following experiments are crucial to be developed.

RECOMMENDATION OF PROSPECTS

The future research of a breeding program in SALB on rubber trees can be pest resistance clones combined with disease management. The pest resistance clones can be produced through in vitro culture and genetic transformation, where disease management can be sanitation. Furthermore, future research on SALB resistance can be integrated with abiotic stress such as waterlogging and drought. Therefore, the new rubber tree clones can adapt to disease resistance and climate change.

REFERENCES

Adifaiz, A., Maiden, N., Shamin, N., Roslinda, S., Suleiman, Z., & Rafii, M. (2018). Genetic diversity of the 1995 rrim hevea germplasm collection for utilisation in the rubber breeding programme. *Journal of Rubber Research, 21*, pp. 153-164.

Ayutthaya, S.I.N. & Do, F.C. (2014). Rubber trees affected by necrotic Tapping Panel Dryness exhibit poor transpiration regulation under atmospheric drought. In *Advanced Materials Research* (Vol. 844, pp. 3-6). Trans Tech Publications Ltd.

Balasundaram, S., Hess, J., Durling, M., Moody, S., Thorbek, L., Progida, C., LaButti, K., Aerts, A., Barry, K., Grigoriev, I., Boddy, L., Högberg, N., Kauserud, H., Eastwood, D., & Skrede, I. (2017). The fungus that came in from the cold: dry rot's pre-adapted ability to invade buildings. *The ISME Journal, 12*, pp. 791-801.

Berthelot, K., Peruch, F. & Lecomte, S. (2016). Highlights on *Hevea brasiliensis* (pro) hevein proteins. *Biochimie*, *127*, pp.258-270.

Bevenuto, J.A.Z., Passos, J.R.D.S. & Furtado, E.L. (2021). Development parameters of the latent period as a response of rubber tree resistance to South American leaf blight. *Summa Phytopathologica*, *47*, pp.103-109.

Carvalho, P.A D., Lira, J.M.S., de Oliveira, L.E.M., de Carvalho, J.N., Domiciano, D. & Cárdenas, H.B.W. (2015). Nitrate addition improves photosynthesis and flooding tolerance of rubber tree plants. *Australian Journal of Crop Science*, *9*(7), pp.684-689.

Clément-Demange, A., Priyadarshan, P., Hoa, T. T. T. & Venkatachalam, P. (2007). Hevea rubber breeding and genetics. In Janick, J (Ed) *Plan Breeding reviews,* (pp.177-200). John Willey and Sons, Inc, The USA.

Duangngam, O., Desalme, D., Thaler, P., Kasemsap, P., Sathornkich, J., Satakhun, D., Chayawat, C., Angeli, N., Chantuma, P., & Epron, D. (2020). In situ $^{13}CO_2$ labelling of rubber trees reveals a seasonal shift in the contribution of the carbon sources involved in latex regeneration. *Journal of Experimental Botany, 71(6)*, pp. 2028-2039.

Falqueto, A.R., da Silva Júnior, R.A., Gomes, M.T.G., Martins, J.P.R., Silva, D.M. & Partelli, F.L., (2017). Effects of drought stress on chlorophyll a fluorescence in two rubber tree clones. *Scientia Horticulturae, 224*, pp.238-243.

Fan, Y., Xin, S., Dai, X., Yang, X., Huang, H., & Hua, Y. (2020). Efficient genome editing of rubber tree (*Hevea brasiliensis*) protoplasts using CRISPR/Cas9 ribonucleoproteins. *Industrial Crops and Products, 146*, pp. 1-7.

Fa-Tsu, C. C.-H. C., Chuan-Hua, C. C.-F. W., Hsu-En, C. S.-C. H., Shiao-Huei, O. & Tsun-Min, H. Y.-T. L. (1979). A process of obtaining pollen plants of *Hevea brasiliensis Muell. Arg*. In Yuan, Z. K. X (Ed) Scientia Sinica, (pp. 100-120). Academia Sinica, Taiwan.

Furtado, E.L., Moraes, W.B., de Jesus Junior, W.C., dos Anjos, B.B. & da Silva, L.G. (2019). Epidemiology and Management of South American Leaf Blight on Rubber in Brazil. In *Horticultural Crops*. Intech Open.

Gouvêa, L. R. L., Silva, G. A. P., Verardi, C. K., Oliveira, A. L. B., & de Souza Gonçalves, P. (2013). Simultaneous selection of rubber yield and girth growth in young rubber trees. *Industrial Crops and Products, 50*, pp. 39-43.

Guo, D., Zhou, Y., Li, H.L., Zhu, J.H., Wang, Y., Chen, X.T. and Peng, S.Q., 2017. Identification and characterization of the abscisic acid (ABA) receptor gene family and its expression in response to hormones in the rubber tree. *Scientific Reports, 7*(1), pp.1-10.

Guyot, J. & Guen, V. L. (2018). A review of a century of studies on South American Leaf Blight of the rubber tree. *Plant disease*, *102*(6), pp.1052-1065.

Hashim, I. (2006). South American leaf blight (*Microcyclus ulei*) of hevea rubber. *Protection against South American Leaf Blight of Rubber in Asia and the Pacific Region; FAO: Bangkok, Thailand*, *2*, pp. 21-133.

Jayashree, R., Nazeem, P., Rekha, K., Sreelatha, S., Thulaseedharan, A., Krishnakumar, R., Kala, R., Vineetha, M., Leda, P., Jinu, U., & Venkatachalam, P. (2018). Over-expression of 3-hydroxy-3-methylglutaryl-coenzyme A reductase 1 (*hmgr1*) gene under super-promoter for enhanced latex biosynthesis in rubber tree (*Hevea brasiliensis* Muell. Arg.). *Plant Physiology and Biochemistry, 127*, pp. 414-424.

Jayasinghe, C., Fernando, T. & Priyanka, U. (1997). *Colletotrichum acutatum* is the main cause of Colletotrichum leaf disease of rubber in Sri Lanka. *Mycopathologia, 137*(1)**,** pp.53-56.

Kalawong, S., (2014). *A study on agrobacterium tumefaciens-mediated gene transformation in rubber tree (Hevea brasiliensis muell. arg.)* (Doctoral dissertation, Prince of Songkla University).

Khoo, P., H'ng, P., Chin, K., Bakar, E., Mamiński, M., Raja-Ahmad, R., Lee, C., Ashikin, S., & Saharudin, M. (2018). Peeling of small diameter rubber log using spindle less lathe technology: evaluation of veneer properties from outer to inner radial section of log at different veneer thicknesses. *European Journal of Wood and Wood Products, 76*, pp. 1335–1346.

Liu, J., Shi, C., Shi, C., Li, W., Zhang, Q., Zhang, Y., Li, K., Lu, H., Shi, C., Zhu, S., Xiao, Z., Nan, H., Yue, Y., Zhu, X., Wu, Y., Hong, X., Fan, G., Tong, Y., Zhang, D., Mao, C., Liu, Y., Hao, S., Liu, W., Lv, M., Zhang, H., Liu, Y., Hu-Tang, G., Wang, J., Wang, J., Sun, Y., Ni, S., Chen, W., Zhang, X., Jiao, Y., Eichler, E., Li, G., Liu, X., & Gao, L. (2019). The chromosome-based rubber tree genome provides new insights into spurge genome evolution and rubber biosynthesis. *Molecular Plant, 13*, pp. 336-350.

Liyanage, K., Khan, S., Mortimer, P., Hyde, K., Xu, J., Brooks, S., & Ming, Z. (2016). Powdery mildew disease of rubber tree. *Forest Pathology, 46*, pp. 90-103.

Mazlan, S., JAAFAR, N.M., Wahab, A., Rajandas, H. & Zulperi, D. (2019). Major diseases of rubber (*Hevea brasiliensis*) in Malaysia. *Pertanika Journal of Scholarly Research Reviews*, *5*(2), pp.10-21.

Mohammed, C.L., Rimbawanto, A. & Page, D.E. (2014). Management of basidiomycete root-and stem-rot diseases in oil palm, rubber and tropical hardwood plantation crops. *Forest Pathology*, *44*(6), pp.428-446.

Nguyen, B., & Dang, M. (2016). Temperature dependence of natural rubber productivity in the southeastern Vietnam. *Industrial Crops and Products, 83*, pp. 24-30

Ogbebor, N.O., Omorusi, V.I., Orumwense, K. & Ijie, K. (2014). The status of white root rot in rubber plantations in Nigeria. *Journal of Plantation Crops*, *42*(1), pp.142-144.

Onoji, S., Iyuke, S., Igbafe, A., & Nkazi, D. (2016). Rubber seed oil: A potential renewable source of biodiesel for sustainable development in sub-Saharan Africa. *Energy Conversion and Management, 110*, pp.125-134.

Sayurandi, S., Dalimunthe, C.I., Febrianto, E.B. & Sianturi, G.A. (2022). Uji ketahanan genetik klon karet seri IRR terhadap penyakit gugur daun pestalotiopsis di laboratorium. *Jurnal Penelitian Agrosamudra*, *9*(1), pp.49-55.

Silva, G.A.P., Gouvêa, L.R.L., Verardi, C.K., de Oliveira, A.L.B. & de Souza Gonçalves, P. (2013). Annual growth increment and stability of rubber yield in the tapping phase in rubber tree clones: Implications for early selection. *Industrial Crops and Products*, *52*, pp.801-808.

Sobha, S., Rekha, K. & Uthup, T.K. (2019). Biotechnological advances in rubber tree (*Hevea brasiliensis* Muell. Arg.) breeding. *Advances in Plant Breeding Strategies: Industrial and Food Crops: Volume 6*, pp.179-236.

Soumya, S.J., Vishnu, R.S., Arjun, R.N. & Bhavani, R.R. (2016). Design and testing of a semi automatic rubber tree tapping machine (SART). In *2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)* (pp. 1-4). IEEE.

Souza, L., Guen, V., Cerqueira-Silva, C., Silva, C., Mantello, C., Conson, A., Vianna, J., Zucchi, M., Júnior, E., Fialho, J., Moraes, M., Gonçalves, P., & Souza, A. (2015). Genetic diversity strategy for the management and use of rubber genetic resources: more than 1,000 wild and cultivated accessions in a 100-genotype core collection. *PLoS ONE, 10*(7), pp. 1-20.

Sterling, A., Martínez-Viuche, E.J., Suárez-Córdoba, Y.D., Agudelo-Sánchez, A.A., Fonseca-Restrepo, J.A., Andrade-Ramírez, T.K. & Virguez-Díaz, Y.R. (2020). Assessing growth, early yielding and resistance in rubber tree clones under low South American Leaf Blight pressure in the Amazon region, Colombia. *Industrial Crops and Products*, 158, pp.1-10.

Suryanarayanan, T.S. & Azevedo, J.L. (2023). From forest to plantation: a brief history of the rubber tree. *Indian Journal of History of Science*, *58*(1), pp.74-78.

Sushamakumari, S., Asokan, M., Anthony, P., Lowe, K., Power, J. & Davey, M. (2000). Plant regeneration from embryogenic cell suspension-derived protoplasts of rubber. *Plant cell, tissue and organ culture, 61*(1)**,** pp.81-85. doi: https://doi.org/10.1023/A:1006494404224

Thaochan, N., Pornsuriya, C., Chairin, T., & Sunpapao, A. (2020). Roles of systemic fungicide in antifungal activity and induced defence responses in rubber tree (*Hevea brasiliensis*) against leaf fall disease caused by *Neopestalotiopsis cubana*. *Physiological and Molecular Plant Pathology, 111*, pp. 1-9.

Tisarum, R., Samphumphung, T., Theerawitaya, C., Prommee, W., & Cha-um, S. (2018). In vitro photoautotrophic acclimatization, direct transplantation and ex vitro adaptation of rubber tree (*Hevea brasiliensis*). *Plant Cell, Tissue and Organ Culture (PCTOC), 133*, pp. 215-223.

Wang, J., Li, Y., & Tian, W. (2017). Physiological responses of two rubber tree clones with differential cold-tolerant potential to cold stress. *Journal of Rubber Research, 20*, pp. 117-129.

Wang, Y., Chen, X., Peng, S., Wu, K. & Hong, L. 2013. Genetic transformation and regeneration of *Hevea brasiliensis* transgenic plant with GAI gene by microparticle bombardment. *Romanian Biotechnological Letters, 18*(1)**,** pp.1-10.

Yang, H., Dai, L., Wei, Y., Deng, Z. & Li, D. (2020). Melatonin enhances salt stress tolerance in rubber tree (*Hevea brasiliensis*) seedlings. *Industrial crops and products, 145*, pp.1-10. doi: https://doi.org/10.1016/j.indcrop.2019.111990.