Rubber Science, **32**(1): 17-25, 2019 *RESEARCH ARTICLE*

BIOMASS AND YIELD PARTITIONING IN *HEVEA BRASILIENSIS:* THE CONCEPT OF HARVEST INDEX REDEFINED

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The concept of harvest index (HI) requires redefining in a perennial crop like *Hevea brasilienis* where the economic yield is a secondary metabolite that is produced in small quantities by large trees. Partitioning of total biomass into shoot biomass and rubber yield was accounted in tapped trees of *Hevea brasiliensis* on an annual basis for 12 consecutive years in five clones *viz.* RRII 105, RRII 300, PB 235, PB 260 and PB 311. Ratio of rubber yield per year to annual increment in shoot biomass per year was defined as HI in this tree crop. Among the five clones studied, RRII 105 had the highest HI (0.32) indicating that this clone is an efficient clone capable of partitioning more photosynthates in to rubber. But high yield and HI in this clone came with the cost of reduced shoot biomass compared to the PB clones. Rubber yield in PB 235 and PB 260 was on par with RRII 105, but the PB clones had much less HI than RRII 105. Improving HI in high biomass genotypes will result in better rubber yields and break the yield ceiling. Biomass production in untapped rubber trees was estimated and their CO_2 sequestration potential is also discussed.

Key words: Biomass, CO_2 sequestration, Harvest index, Rubber yield

INTRODUCTION

Harvest index (HI) of a crop is a measure of the partitioning of biomass into economic yield, typically defined as the ratio of yield to total biomass (Brown, 1984, Hay, 1995). In annual crops such as rice, wheat *etc*. HI is the ratio of the grain yield to total biomass. One of the major reasons behind the success of green revolution has been the development of short duration crop varieties with high HI. In some varieties of rice and wheat, harvest index is as large as 0.5-0.6 (Austin *et al*., 1980; Yang and Zhang, 2010).

Obviously, HI defined as above will be very low in tree crops such as apple, orange, mango *etc*. where the total wood (shoot) biomass is very large compared to the economic yield. However, breeding for very small phenotypes with profuse fruiting has been successful in certain fruit crops (Webster, 2002). In the case of a perennial tree crop like *Hevea brasiliensis* where the economic yield is not a fruit or a seed but a secondary metabolite (cis-1, 4-polyisoprene), the concept of HI needs redefining. Total wood biomass of a mature rubber tree may be one ton or more, but it may produce a rubber yield of 3-6 kg tree^{-1} year^{-1}. When a virgin rubber tree is newly opened for tapping, rubber yield will be practically nil. With repeated tapping, the tree starts to produce more rubber. In other

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words, natural rubber is a crop in which economic yield does not exist in the tree in appreciable quantities until the tree is brought under regular tapping which stimulates rubber biosynthesis (Templeton, 1969; Jacob *et al*., 1998; Chrestin *et al*., 1989). Tapping induces increased sink demand, diverting more photosynthates into biosynthesis of rubber. Thus the concept of HI assumes a different dimension in this tree crop.

Within a clone, tree girth normally has a strong positive correlation with rubber yield as girth is directly related to the length of the tapping cut and thus the number of latex vessels that will be cut during tapping (Templeton, 1969). Also, the larger the girth, the higher the biomass of a rubber tree (Shorrocks *et al*., 1965; Silpi *et al*., 2006) making more photosynthates available for rubber production. A large timber biomass does not necessarily give high rubber yield which is dependent on the efficiency of the mevalonate pathway through which photosynthates are converted into polyisoprene. This is essentially a genetic trait.

Diverting of more photosynthates into rubber biosynthesis occurs in high rubber yielding clones. In such cases timber biomass may be less due to competition for carbon between biomass production and yield. Although this is generally true, through focused breeding and selection, clones with high rubber yield as well as timber yield have been successfully developed in India and other countries (Ong, 2000; Mydin *et al*., 2011). A tapped tree obviously will have less biomass than an untapped tree of the same clone and age, because rubber biosynthesis competes for more diversion of photosynthates which otherwise would have been used for timber production. It is also known that rubber production does not fully account for the amount of biomass lost due to tapping and this missing factor termed ‘K factor’ (Sethuraj, 1992) is essentially wasted biomass. It is likely that the ‘K factor’ is directly related to the amount of photosynthates lost through the cyanide resistant alternative respiration which also increases in response to tapping (wounding) and loss of sugars, proteins and ATP through latex in high yielding clones (Annamalainathan *et al*., 2013). High rates of respiration in the bark and enhanced metabolic activity, including energy metabolism are reported in high yielding clones (Annamalainathan *et al*., 2001; Sreelatha *et al*., 2004). Better understanding of the science behind carbon partitioning between biomass and rubber synthesis will help in developing smart clones that can produce both rubber and timber in high quantities.

In the present study we compared annual biomass increment in untapped rubber trees with rubber trees of same age that were tapped under S/2 d2 and S/2 d3 frequencies of tapping for 12 years. We propose the ratio of rubber yield to the incremental shoot biomass per year as a measure of HI in this unique tree crop which gives out a secondary metabolite as its economic yield.

MATERIALS AND METHOD

Five *Hevea* clones, *viz.* RRII 105, RRII 300, PB 235, PB 260 and PB 311 planted during 1987 at the *Hevea* Breeding substation of Rubber Research Institute of India at Nettana, in Dakshin Kannada district of Karnataka, India (12^o 43′ N and 75^o 32′ E) were used in the present study. Twenty five trees were planted in each plot in factorial randomized blocks with three replications. Trees were tapped under two tapping systems *viz.* S/2 d2 6d/7 frequency (half spiral cut at alternate daily tapping frequency, six days in tapping followed by one day tapping rest) and S/2 d3 6d/7 frequency (half spiral cut at third daily frequency, six days in tapping followed by one day tapping rest) (Vijayakumar *et al.*, 2009) from the year 1999 onwards. The trees were not subjected to any yield stimulation throughout the study period. Another set of trees (25 trees per plot with three replications) for each clone were maintained untapped throughout the study period. Growth and yield observations were continued for twelve consecutive years from 1999 to 2011.

Annual shoot biomass increment was estimated from the measurement of trunk girth of all trees under each treatment at a height of 150 cm from bud union every year from first year of tapping onwards. The shoot dry biomass (W) of tapped and untapped trees (kg) was calculated using the Shorrocks regression model (Shorrocks *et al.*, 1965), $W=0.002604\,G^{2.7826}$, where G is the mean trunk girth (cm) at 150 cm from bud union.

Latex volume (ml) and dry rubber content (drc) of latex were recorded from the tapped plots on all tapping days to estimate average annual dry rubber yield (kg ha^{-1} $year^{-1}$). HI was calculated as the ratio of dry rubber yield per year to shoot biomass increment for the corresponding year. The partitioning of carbon to wood biomass and rubber was also worked out using standard values for carbon equivalents of carbohydrate and cis -1, 4-polyisoprene.

RESULTS AND DISCUSSION

The annual increment in shoot biomass of a tapped tree was lesser than that of untapped tree irrespective of the clones (Table 1). Loss of shoot biomass gradually increased from the first year of tapping onwards corresponding to rising rubber yield. After twelve years of tapping, it was observed that trees tapped under S/2 d2 6d/7 system lost more biomass than trees under S/2 d3 6d/7 systems (Table 2) except in PB 260. Exceptionally, RRII 300 under S/2 d3 6d/7 system of tapping could maintain growth similar to untapped trees with no difference in biomass loss. Rubber yield under S/2 d2 6d/7 system of tapping was better than S/2 d3 6d/7 system only in clone RRII 105, whereas S/2 d3 system of tapping yielded more rubber than S/2 d2 6d/7 in RRII 300 (Table 1). No significant yield difference was observed between two tapping systems in other clones.

HI defined as the ratio of dry rubber yield to biomass increment per year is an indicator

Table 1. **Mean annual shoot biomass increase, annual rubber yield and harvest index (HI) in five clones of *Hevea* under S/2 d2 6d/7 and S/2 d3 6d/7 systems of tapping for 12 years**

Clone	Mean annual shoot biomass increase (BI) (kg $tree^{-1}$ yr^{-1})			Mean annual rubber yield (kg $tree^{-1}yr^{-1}$)		Harvest Index (HI) (Y/BI)	
	Untapped	Tapped		Tapped		Tapped	
		S/2 d2 6d/7	S/2 d3 6d/7	S/2 d2 6d/7	S/2 d3 6d/7	S/2 d2 6d/7	S/2 d3 6d/7
RRII 105	38.0	16.9	18.8	5.1^{a}	4.0^{b}	0.32	0.23
RRII 300	34.7	21.8	30.8	2.5^{c}	3.1^{c}	0.12	0.12
PB 235	73.1	41.7	50.1	5.6^{a}	5.3^{a}	0.15	0.11
PB 260	55.0	33.0	36.5	4.96^{a}	4.9^{a}	0.17	0.15
PB 311	45.4	27.0	30.0	4.8^{a}	4.9^{a}	0.20	0.17

Means followed by a common letter are not significantly different at $P<0.05$

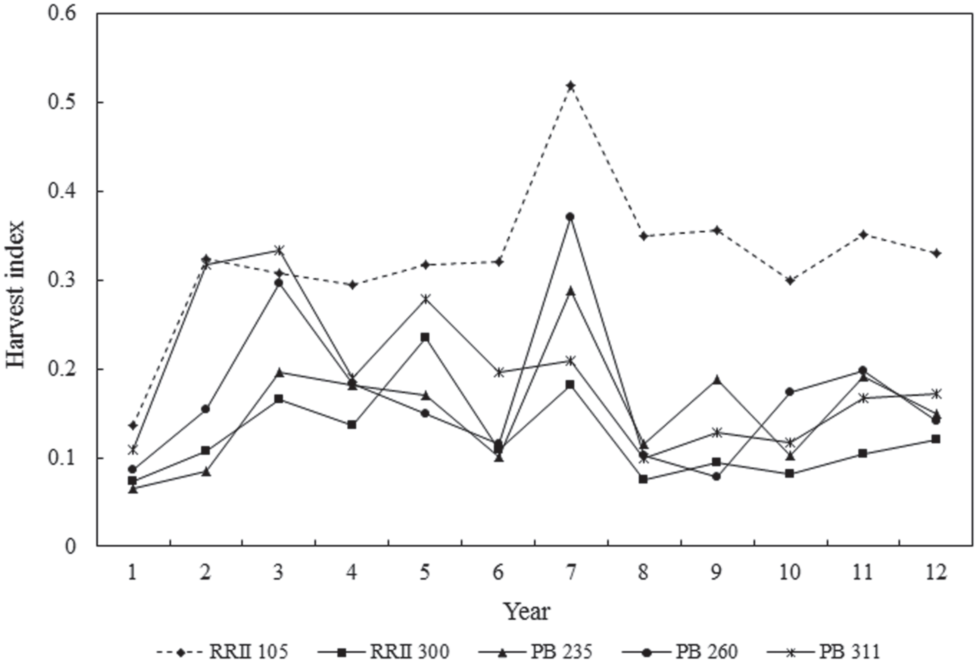

Fig. 1. a. Harvest index (HI) of five different *Hevea* clones tapped for 12 years under S/2 d2 6d/7 system of tapping

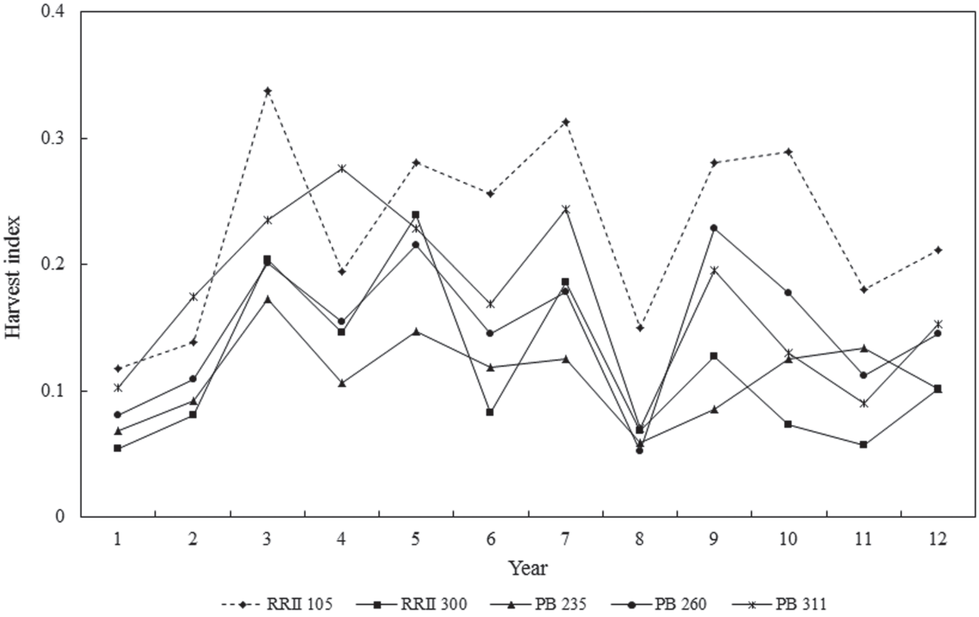

Fig. 1 b. Harvest index (HI) of five different *Hevea* clones tapped for 12 years under S/2 d3 6d/7 system of tapping of partition of resources in tapped trees of *Hevea*. This partitioning was very different in the clones under two different systems of tapping (Table 1 and Fig. 1a, 1b). This clearly indicated that the genotype and tapping system had different impact on the physiological processes associated with partitioning of photosynthates between growth and rubber production. Latex biosynthesis and biomass production compete for the same carbon sources supplied from photosynthesis. Apparently, allocation of carbon resources for these two physiological processes seems to be genetically determined. There was strong positive correlation between the extent of biomass loss and annual dry rubber yield in different clones (Annamalainathan *et al.*, 2013). In PB clones, the tapping induced shoot biomass loss was comparatively smaller than RRII clones for a given tapping system (Table 1).

HI in the popular clone RRII 105 was the highest among all clones studied under both tapping systems (Table 1) indicating better rubber biosynthetic efficiency. In clone RRII 105 under S/2 d2 6d/7 frequency the HI was as large as 0.32. A high HI meant tapped trees in this clone had relatively less timber production than other clones. Among the PB clones there was no much difference in HI (0.15 - 0.2) under S/2 d2 tapping system (Fig. 1a). In these clones the HI was always lesser in S/2 d3 6d/7 than S/2 d2 6d/7 system (Fig. 1a and 1b). This is because the PB clones recorded greater biomass production under S/2 d3 6d/7 system for a given unit of rubber production. Templeton (1969) estimated the harvested dry rubber as 3-11 per cent of total dry weight of shoot biomass during first two years but, this proportion was increased up to 20 per cent in subsequent years indicating development of sink strength in the course of tapping process. HI also can be used for the prediction of rate of source-sink supply in physiologically impaired or abiotically stressed rubber plants (Mokhatar *et al.*, 2011). No clones studied by Templeton had an HI as high as that RRII 105 (0.32). The PB clones recorded a small HI compared to the RRII clones (Table 2). The rubber yield of PB 235 and PB 260 clones was on par with RRII 105 but the timber yield was higher in the PB clones. Thus the PB clones can be considered as latex-timber clones. Factors contributing to high HI need to be elucidated for exploiting the same for genetic improvement of yield potential of this crop. Little information exists on the genetics and heritability of HI in *Hevea*.

Table 2. **Shoot biomass loss in tapped trees after 12 years of tapping in S/2 d2 6d/7 and S/2 d3 6d/7 systems. The percentage of yield partition from the lost biomass was calculated**

Clone	Biomass of untapped tree (UT) kg tree^{-1}	Biomass of tapped tree (T) kg tree^{-1}		Lost Biomass (UT-T) kg tree^{-1}		Cumulative rubber yield for 12 yrs kg tree^{-1}		Percentage yield to lost biomass (Yield/lost biomass *100)	
		S/2 d2	S/2 d3	S/2 d2	S/2 d3	S/2 d2	S/2 d3	S/2 d2	S/2 d3
RRII 105	694	422	494	272	200	59.2	50.5	21.9	25.3
RRII 300	528	412	534	116	-6	29.9	35.5	25.8	-
PB 235	1175	820	870	355	305	64.8	62	18.3	20.3
PB 260	959	668	661	291	298	57.4	57.6	19.7	19.3
PB 311	765	558	577	207	188	56.8	59	27.4	31.4

The difference in the biomass between untapped and tapped tree is considered as lost biomass on account of rubber production. The loss of biomass was not accounted fully by the rubber yield. The putative mechanism of missing biomass or 'K factor' in tapped tree has been already explained elsewhere (Sethuraj, 1992; Annamalainathan *et al.*, 2013). Rubber harvested from tapped trees hardly accounted for of the lost biomass (in tapped trees) in different clones. In RRII 300 under S/2 d3 6d/7 frequency of tapping there was no loss of biomass in the tapped trees with respect to their untapped control trees (Table 2). There was more recovery of rubber per unit lost biomass in S/2 d3 6d/7 than S/2 d2 6d/7 tapping system (Table 2). The unaccountable missing biomass (K factor) is higher in S/2 d2 6d/7 system of tapping than S/2 d3 6d/7 system in PB clones (Fig. 2 and Table 3) indicating higher wounding frequency enhanced the 'K factor'. It is well known that low frequency tapping gives comparable yield with S/2 d2 6d/7 system of tapping but tree growth will be more in low frequency tapping (Atsin *et al.*, 2014; Sainoi *et al.*, 2017).

One gram dry rubber (cis-1, 4-polyisoprene) is equivalent to 2.5 g of carbohydrate comparing the calorific content of the two (Sethuraj and Raghavendra, 1987). One gram of dry wood (carbohydrate) is equal to approximately 0.45 g of carbon (45% of dry wt) or 1.647 g of assimilated CO_2. Hence, theoretically for the biosynthesis of one gram of dry rubber around 4.12 g of CO_2 (1.647x2.5) is required. Average annual increase in dry shoot biomass of a tapped rubber tree in case of the popular clone RRII

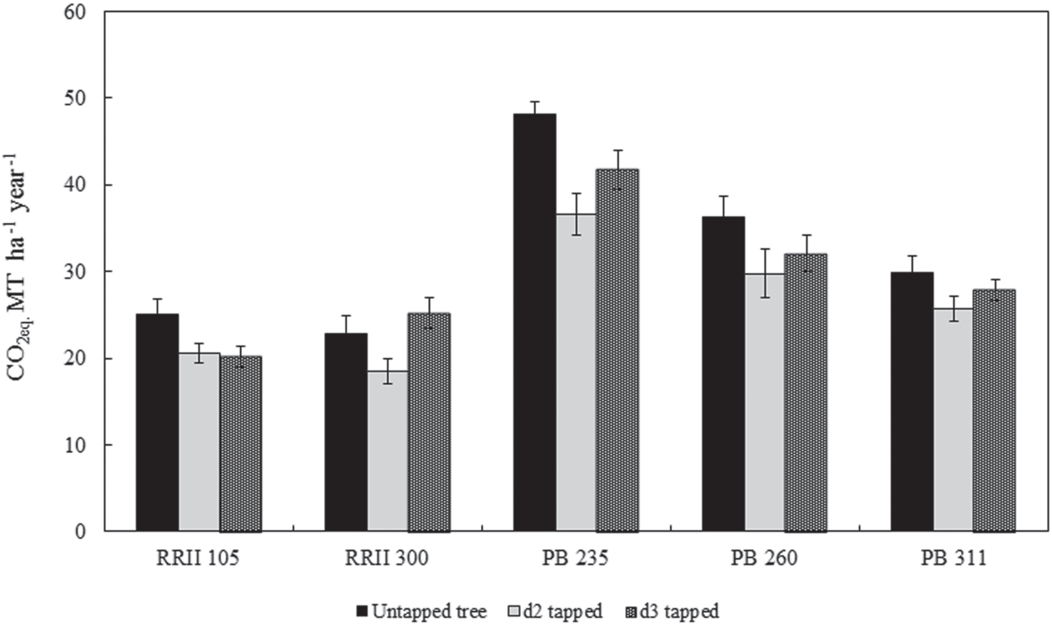

Fig. 2. Projected CO_2 sequestration rates of tapped and untapped trees of five different clones based on biometric estimation over a period of 12 years of tapping

Table 3. **Biomass equivalent (plant biomass + yield) of five clones of *Hevea* grown as untapped (UT) throught the study period and tapped for twelve years under S/2 d2 6d/7 and S/2 d3 6d/7 systems**

Clone	Biomass MT ha^{-1}		
	Tapping frequency		
	Untapped trees (UT)	S/2 d2 6d/7	S/2 d3 6d/7
RRII 105	277.63^{f}	227.7^{hi}	247.7^{gh}
RRII 300	211.2^{ij}	194.1^{j}	248.8^{g}
PB 235	470.0^{a}	392.8^{bc}	410.3^{b}
PB 260	383.7^{c}	325.1^{d}	321.7^{d}
PB 311	306.1^{de}	279.2^{f}	288.1^{ef}

Means followed by a common letter are not significantly different at $P<0.05$

105 was roughly 30 kg tree^{-1} (Table 1). This is equivalent to 49.4 kg CO_2 tree^{-1} as per the theory explained above. This means that a mature stand of rubber plantation with 400 trees ha^{-1} converts almost 20 tons CO_2 ha^{-1} year^{-1} into shoot biomass. Annually a tapped rubber tree with an average yield of 5 kg tree^{-1} converts around 21 kg CO_2 into dry rubber (Table 4) that is equal to 8.4 tons CO_2 ha^{-1} year^{-1}. Thus, a mature stand of rubber plantation can sequester around 28.4 tons of CO_2 ha^{-1} year^{-1} (20 ton in shoot biomass + 8.4 ton in rubber yield) (Fig. 2). In addition to this about 15 per cent biomass is stored in roots (Ambily *et al.*, 2012) and a significant amount of carbon is sequestered as organic carbon in soil (Mandal *et al.*, 2012). In rubber plantations soil organic carbon status is 1.5-2 per cent in traditional regions and at the end of the cultivation cycle organic carbon increased by 10-20 per cent compared to the planting time (Abraham and Philip, 2017). Taking 15 per cent of total biomass in roots the total amount of CO_2 sequestered comes to 32.7 ton CO_2 ha^{-1} year^{-1}. In case of untapped trees, this is as large as 37.0 ton CO_2 ha^{-1} year^{-1}. Annamalainathan *et al.* (2011) have reported using eddy covariance analysis that annual average net ecosystem exchange of CO_2 in a traditional rubber growing region of Kerala was around 11g CO_2 m^{-2} day^{-1} which is equivalent to 33.5 tons CO_2 ha^{-1} year^{-1}. The present estimate of CO_2 sequestration in rubber plantation based on long term biometric observations of growth and yield closely agrees with the ecosystem level measurements based on eddy covariance flux measurements.

The present results explain biomass and rubber yield partitioning trends in five *Hevea* clones. The partitioning or HI was better in S/2 d2 6d/7 frequency than S/2 d3 6d/7 in high yielding clones which indicated their improved efficiency of rubber biosynthesis. Those clones with little difference in HI

Table 4. **Carbon dioxide equivalents (CO_2 eq.) of annual shoot biomass increment and dry rubber yield in five clones of *Hevea***

Clone	CO_2 eq. of shoot biomass (kg tree^{-1} yr^{-1})			CO_2 eq. of dry rubber yield (kg tree^{-1} yr^{-1})	
	Untapped tree	S/2 d2 6d/7	S/2 d3 6d/7	S/2 d2 6d/7	S/2 d3 6d/7
RRII 105	62.6	30.6	34.0	21.0	16.5
RRII 300	57.2	36.0	50.7	10.3	12.6
PB 235	121.6	68.7	82.4	23.0	22
PB 260	90.6	54.4	60.0	20.0	20.3
PB 311	74.8	44.5	49.4	19.8	20.2

between S/2 d2 6d/7 and S/2 d3 6d/7 may probably be less efficient in assimilates partition towards rubber biosynthetic process. The concept of HI index as described in this study has relevance for selection of clones with high latex, timber or both.

REFERENCES

Abraham, J. and Philip, A. (2017). Impact of natural rubber cultivation on nutrient status in tropical soils: A case study in Kerala, India. *Rubber Science,* **30**(2): 160-168.

Ambily, K.K., Meenakumari, T., Jessy, M.D., Ulaganathan, A. and Nair, N.U. (2012). Carbon sequestration potential of RRII 400 series clones of *Hevea brasiliensis. Rubber Science,* **25**(2): 233-240.

Annamalainathan, K., Krishnakumar, R. and Jacob. J. (2001). Tapping induced changes in respiratory metabolism, ATP production and reactive oxygen species scavenging in *Hevea*. *Journal of Natural Rubber Research,* **4**(4): 245-254.

Annamalainathan, K., Satheesh, P.R. and Jacob, J. (2011). Ecosystem flux measurements in rubber plantations. *Natural Rubber Research,* **24**(1): 28-37.

Annamalainathan, K., Jacob, J., Vinod, K.K., Thomas, K.U., Sreelatha, S., Sumesh, K.V. and Suryakumar, M. (2013). Tapping induced biomass loss in natural rubber (*Hevea brasiliensis)* trees: Putative factors to explain the unknown mechanism. *Rubber Science,* **26**(1): 23-35.

Atsin, G.J.O., Soumahin, E.F., Kouakou, H.T., Coulibaly, L.F., Traore, S.M., J.Y. Alle, J., N'guessan, A.E.B., Kouame, C. and Obouayeba, S. (2014). Impact of reduced tapping frequency on agronomic, physiological and biochemical aspects of clone PB 260 of *Hevea brasiliensis* in the centre west of Cote D'Ivoire. *Journal of Rubber Research,* **17**(1): 45-56.

Austin, R.B., Bingham, J., Blackwell, R.D., Evans, L.T., Ford, M.A., Morgan, C.L. and Taylor, M. (1980). Genetic improvements in winter wheat yields since 1900 and associated physiological changes. *Journal of Agricultural Science,* **94**(3): 675-689.

Brown, R.H. (1984). Growth of the green plant. *In:* Physiological Basis of Crop Growth and Development (Ed. M.B. Tesar). American Society of Agronomy – Crop Science Society of America, Madiso, pp. 153-174.

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Chrestin, H., Marin, B., Jacob, J.L. and d' Auzac, J. (1989). Metabolic regulation and homeostasis in the laticiferous cell. In: *Physiology of Rubber tree latex*. (Eds. J. d' Auzac, J.L. Jacob and H. Chrestin). CRC Press, Florida, pp. 165-218.

Hay, R.K.M. (1995). Harvest Index: A review of its use in plant breeding and crop physiology. *Annals of Applied Biology*, **126**(1): 197-216.

Jacob, J.L., Prevot, J.C., Lacote, R., Gohet, E., Clement, A., Gallois, R., Joet, T., Pujade-Renaud, V. and d'Auzac, J. (1998). The biological mechanisms controlling *Hevea brasiliensis* rubber yield. *Plantation, Recherche, D'eveloppment,* **5**(1): 14-16.

Mandal, D., Pal, T.K., Dey, S.K. and Jacob, J. (2012). Changes in organic carbon and some soil properties under rubber (*Hevea brasiliensis)* plantation in sub-tropical Tripura. *Natural Rubber Research*, **25**(1): 13-20.

Mokhatar, S.J., Daud, W. N. and Md Zamri, N. (2011). Evaluation of *Hevea brasiliensis* (Latex Timber Clone: RRIM 2001 and RRIM 3001) in relation to different water stress. *American Journal of Agricultural and Biological Sciences,* **6**(1): 122-127.

Mydin, K.K., Thomas, V. and Mercykutty, V.C. (2011). Yield and related attributes of certain new generation clones of *Hevea brasiliensis* under large scale evaluation. *Journal of Rubber Research,* **14**(3): 167-183.

Ong, E.L. (2000). Characterization of new Latex-Timber clones of natural rubber. *Journal of Applied Polymer Science,* **78**(8): 1517-1520.

Sainoi, T., Sdoodee, S., Lacote, R. and Gohet, E. (2017). Low frequency tapping system applied to young-tapped trees of *Hevea brasiliensis* (Willd. Ex A. Juss.) Muell. Arg. in Southern Thailand. *Agriculture and Natural Resources*, **51**(4): 268-272.

Sethuraj, M.R. (1992). Yield components in *Hevea brasiliensis*. In: *Natural Rubber: Biology, Cultivation and Technology* (Eds. M.R. Sethuraj and N.M. Mathew). Elsevier Science Publishers, Amsterdam. pp. 137-163.

Sethuraj, M.R. and Raghavendra, A.S. (1987). Rubber. In: *Tree Crop Physiology*, (Eds. M.R. Sethuraj and A.S. Raghavendra). Elsevier Science Publishers, Amsterdam, pp.193-223.

Shorrocks, V.M., Templeton, J.K. and Iyer, G.C. (1965). Mineral nutrition, growth and nutrient cycle of *Hevea brasiliensis* III. The relationship between girth and shoot dry weight. *Journal of Rubber Research Institute of Malaya*, **19**(2): 85-92.

Silpi, U., Thaler, P., Kasemsap, P., Lacointe, A., Chantuma, A., Adam, B., Gohet, E., Thanisawanyangkura, S. and Ameglio, T. (2006). Effect of tapping activity on the dynamics of radial growth of *Hevea brasiliensis* Muell. Arg. A dynamic study at seasonal scale. *Tree Physiology*, **26**(12): 1579-1587.

Sreelatha, S., Simon, P. S. and Jacob, J. (2004). On the possibility of using latex ATP concentration as an indicator of high yield in *Hevea*. *Journal of Rubber Research,* **7**(1): 71-78.

Templeton, J.K. (1969). Partition of assimilates. *Journal of Rubber Research Institute of Malaya,* **21**(3): 259-263.

Vijayakumar, K.R., Gohet, E., Thomas, K.U., Xiaodi, W., Sumarmadji, Rodrigo, L., Thanh, D.K., Sopchoke, P., Karunaichamy, K. and Md Said, M.A. (2009). Revised international notation for latex harvest technology. *Journal of Rubber Research*, **12**(2): 103-115.

Yang, J. and Zhang, J. (2010). Crop management techniques to enhance harvest index in rice. *Journal of Experimental Botany*, **61**(12): 3177-3189.

Webster, T. (2002). Dwarfing rootstocks: Past, present and future. *The compact fruit tree,* **35**(3): 67-72.