J Rubb Res , 1(2), 125–132

Characteristics Related to Higher Rubber Yield of Hevea brasiliensis *Juvenile-type Clone GI1*

XIE-HUI YUAN*, SHANG-QIONG YANG*, LAI-YU XU*,
JI-LIN WU* AND BING-ZONG HAO*#

In a comparative trial between GI1 juvenile-type buddings (JT buddings) and mature-type buddings (MT buddings), the structural and physiological characteristics of the JT buddings tapped for about 5 years were studied in relation to their higher yield performance The JT buddings were derived from the juvenile buds of 1 5-year-old anther somatic plants produced by tissue culture and the MT buddings from normal planting materials The dry rubber yield in g/tree/tapping during the first 4 years was 25%–40% higher in the JT buddings than in the MT buddings In comparison with the MT buddings, the JT buddings had increased girth and bark thickness, larger total number of laticifer rings, higher dry rubber content, higher mean initial rate of latex flow, lower plugging index and lutoid bursting index, higher latex sucrose and inorganic phosphorus contents, and a similar level of latex thiol content Based on these results and data available, it is inferred that the juvenile-type clones are superior to the corresponding mature-type clones both in latex flow and in latex regeneration and they may be promising planting materials in future rubber production

It is well known that the rubber tree developes from seed through a juvenile phase to a mature phase[1,2]. This developmental change is reflected by differences of the characteristics along the stem axis of the mature tree. The seedling tree trunk exhibits some juvenile characteristics, such as greater conicity Being different from seedling trees, the planting materials used commercially are buddings which are called mature-type buddings (MT buddings) as they originate from budding seedling rootstocks with buds at a mature stage of the seedling mother-trees. The buds therefore grow into the trunks without juvenile characteristics, the trunks being not conic but almost cylindrical. However, there are still buddings known as juvenile type buddings (JT buddings) in which the buds come from young seedling trees at juvenile phase or from the dormant buds in the base of the older seedling trees. The JT-buddings show characteristics similar to seedling trees.

As early as 1950s, proof has been obtained that the MT buddings in general had a production level below that of their mother trees[3]. The unfavourable performance of the MT buddings was ascribed to the development differences between the MT buddings and their mother trees. Since then, few researchers had

* Key Laboratory of Ministry of Agriculture for Tropical Crop Physiology, Rubber Cultivation Research Institute, Chinese Academy of Tropical Agricultural Sciences, Danzhou, Hainan 571737, China
# Corresponding author

paid attention to this field except for the scholars in China. Recently, Lui Songquan and his colleagues provided evidence that juvenile-type clones (JT clones) had much higher yield than their mature-type clones (MT clones) and suggested that the JT clones might be used as commercial planting materials to enhance rubber production by 10%–50%[4–6].

In the present study, we characterise the properties of JT clone GI1, which was derived from juvenile buds of anther somatic plants produced by tissue culture. Based on the present results and other available data the reasons leading to higher yield of the JT clones are discussed.

MATERIALS AND METHODS

Comparative Trial between JT clone and MT clone

The trial was carried out in the Experimental Farm of the Chinese Academy of Tropical Agricultural Sciences on Hainan Island. GI1 shoots (bud stick) at juvenile phase were kindly provided by Prof. Wang Zeyun and they were collected from 1.5-year-old anther somatic plants produced by tissue culture. The GI1 JT buddings were produced by budding unselected seed-borne seedling stocks with the buds of GI1 juvenile shoots. The GI1 MT buddings were produced also by using unselected seed-borne seedlings as stocks. The GI1 buds at mature phase were obtained from normal material in budwood nursery. Both the JT and MT buddings were planted in 1985. The two treatments respectively had 15 trees with 3 replicates of 5 trees. Tapping commenced in 1992 on a ½S d/2 tapping system.

Yield, Dry Rubber Content and Girth Measurements

Latex yields and dry rubber content (DRC) were measured at ten-day intervals with one sample from each replicate. Tree trunk girth at 160 cm above union was measured at the end of each year, and tree-trunk conicity expressed by percentage of girth at 0.2 m height to that of 1.6 m measured in September 1996.

Bark Microscopy

Bark structure was observed using light microscopy in November 1996, the 5th year of tapping.

Bark samples were collected from all the experimental trees with a punch at the left end of the tapping cut. The samples were fixed in 80% ethanol, treated with iodine and bromine in glacial acetic acid, and embedded in paraffin after dehydration. The laticifers in sections could be recognised as the rubber in the laticifers which were brown in colour due to the iodine-bromine treatment[7].

Measurement of Physiological Parameters

Physiological parameters were determined in September 1996, the 5th year of tapping. The determinations were done for three tappings on an individual tree basis for all the trees in the trial (29 trees except a dry tree of MT-budding).

Initial rate of latex flow and plugging index were determined in the field by the methods of Milford *et al*[8].

The other parameters were determined with latex samples that were collected at ambient temperatures, 5 min–10 min after tapping and then stored in ice for laboratory analysis.

For DRC determinations, 1 g latex was coagulated with acetic acid, rinsed with water and oven dried to a constant weight.

The bursting index of lutoid was determined according to Ribaillier[9].

For sucrose, thiols and inorganic phosphorus assays, latex was treated following Eschbach *et al*[10]. 2 ml latex was added to a 18 ml solution of 2.5% (w/v) trichloroacetic acid for flocculation before centrifugation at 4000 r.p.m. for 10 min. The resultant supernatant was taken out for analysis. The anthrone reaction was used for determination of sucrose content[11], Ellman reagent for the thiol content[12], and ammonium molybdate for the inorganic phosphorus content.

RESULTS

Yield Performance

Based on the mean annual dry rubber yield in g/tree/tapping during the first 4 tapping years, the JT clone had yields 25%–46% higher than the MT clone (*Figure 1*).

Girth and Bark Structure

Girth growth of the JT clone was more rapid than that of the MT clone, as is shown by the measurement in 1996 (*Table 1*) and that of the first 4 years of tapping (*Figure 1*). According to the measurement in 1996, no significant difference was found in the tree trunk conicity between the JT and MT clone (*Table 1*).

The comparison of bark structure between the JT clone and MT clone is shown in *Table 1*. The bark thickness of the JT clone was significantly larger than that of the MT clone while no significant difference was found for the thickness of the functional phloem. The JT clone had a larger laticifer ring number than the MT clone.

Parameters Related to Latex Flow

The JT clone had higher DRCs than the MT clone based on the measurement during the first 4 years (*Figure 1*) and in September 1996 (*Table 2*). The initial rate of latex flow was significantly higher in the JT clone than in the MT clone, while the plugging index, and the lutoid bursting index were lower (*Table 2*). The latex thiols in the JT and the MT clone were at a similar level.

Parameters Related to Rubber Regeneration

The DRC and latex thiols which have been mentioned above are also linked with rubber regeneration. According to the measurement in 1996 (*Table 2*), sucrose and inorganic phosphorus content were significantly higher in the JT clone latex than in the MT clone latex.

DISCUSSION

In this study, we show that the JT clone had a higher yield than its MT clone. Although Paardekooper suggested in 1956[2] that the JT buddings in general would have 10% higher yield in comparison with the corresponding MT buddings, the proof was not obtained until 1980s when Lui's group published their results of the comparative trial between JT buddings and MT buddings[4]. At present there have been several comparative trials, all of which have shown that the JT clones have better yield performance (*Table 3*). In these trials, the JT clones were derived in different ways.

From the available data (*Table 3*), increased girth and bark thickness may be one of the most important factors resulting in the higher yields of JT clones. It is well known that the relatively strong growth rate is an essential

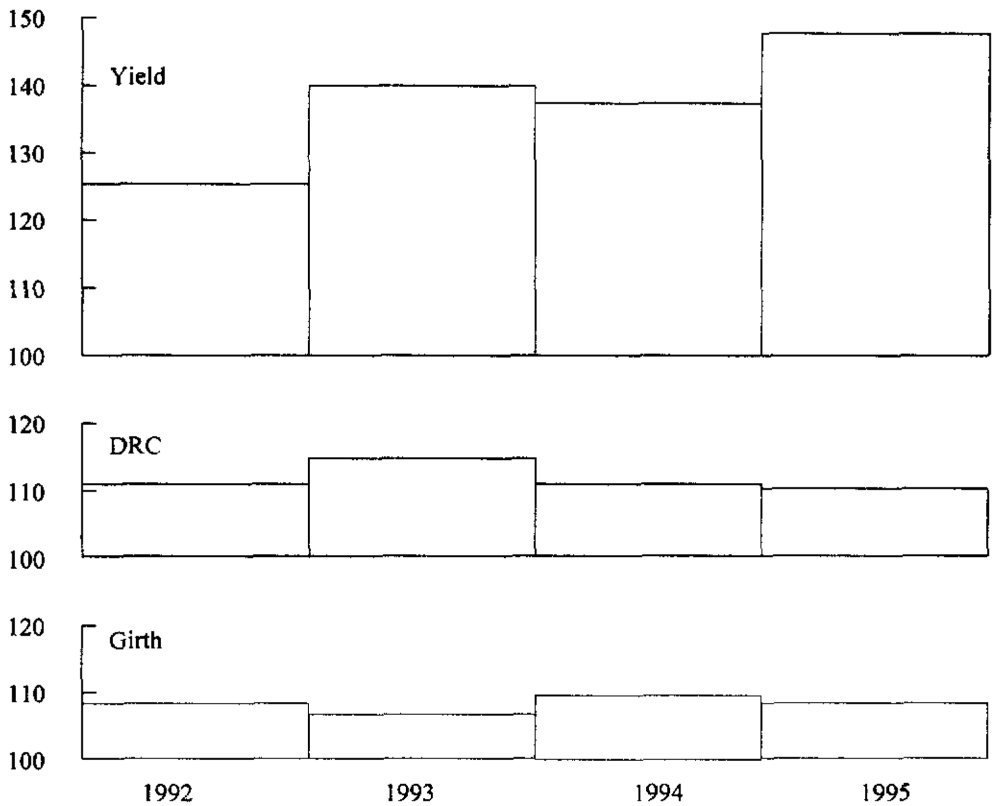

Figure 1 The mean annual rubber yield (g/tree/tapping), DRC and the mean girth at the end of the year of GII JT buddings, expressed as percentage of the MT buddings.

characteristic of the juvenile condition of plant[15] and that the girth of *Hevea* is one of the most important structural factors which determine the rubber yield within clones[16]. Paardekooper stated that rapid growth may be the most important practical advantage of the JT buddings and just on this premise he deduced that higher yield could be expected from the JT buddings[2].

Larger total number of laticifer rings may be another factor that results in the higher yield of JT clones. In addition to the data of the present study, there is at least another example of a larger total number of laticifer rings in JT clones in a comparative trial between JT and MT clones (Unpublished data). We believe that further evidence could be obtained. With increased girth, the studied JT clones (*Table 3*) should have a larger laticifer ring number as it is generally accepted that there is a highly significant correlation between the girth and the laticifer ring number within clones[16].

TABLE 1. GIRTH AND BARK STRUCTURE: COMPARISON BETWEEN JT AND MT BUDDINGS OF GI1[a]

	JT	MT	P(JT-MT)
Girth (cm)	58.4	54.9	<0.05
Conicity (%)	82.0	82.7	
Bark thickness (mm)	6.31 ± 0.44	6.05 ± 0.48	<0.001
Functional phloem thickness (mm)	0.69 ± 0.15	0.70 ± 0.15	>0.1
Total number of laticifer rings	20.8 ± 2.9	16.2 ± 3.5	<0.001

[a]In the 5th tapping year, samples were collected from 13 trees for JT and MT buddings, respectively.

TABLE 2. PHYSIOLOGICAL PARAMETERS: COMPARISON BETWEEN JT AND MT BUDDINGS OF GI1[a]

	JT	MT	P(JT-MT)
Rubber yield (g/tree/tapping)	35.15 ± 5.10(139)	25.24 ± 3.60 (100)	<0.001
DRC (%)	29.93 ± 0.09 (108)	27.76 ± 0.23 (100)	<0.001
Mean initial rate of latex flow (ml/min)	2.90 ± 0.19 (119)	2.44 ± 0.16 (100)	<0.001
Plugging index	2.58 ± 0.19 (85)	3.02 ± 0.19 (100)	<0.001
Lutoid bursting index	26.04 ± 0.69 (95)	27.57 ± 0.91 (100)	<0.001
Latex sucrose (mg/ml)	10.17 ± 0.92 (163)	6.26 ± 0.71 (100)	<0.001
Latex thiols (mmol/ml)	0.54 ± 0.02 (99)	0.55 ± 0.02 (100)	>0.1
Latex inorganic phosphorus (mmol/ml)	9.54 ± 0.02 (114)	8.36 ± 0.09 (100)	<0.001

[a]In the 5th tapping year, samples were collected from 15 trees for JM buddings and 14 trees for MT buddings.

The figures in brackets indicate the percentage of the MT buddings.

TABLE 3. YIELD AND GIRTH OF JT CLONES FROM COMPARATIVE TRIALS BETWEEN JT AND MT CLONES

JT clones[a]	Dry rubber/tree/tapping (in percentage to that of MT clones)	Girth (in percentage to that of MT clones)	Trees (JT clones)	References
1. SCATC 1-29	134 (mean of 8 years)	129 (8th tapping year)	1	Liu *et al.*, 1990[5]
2. SCATC 2-8	160 (mean of 8 years)	122 (8th tapping year)	1	*Ibid*
3. SCATC 2-19	159 (mean of 8 years)	123 (8th tapping year)	1	*Ibid*
4. Haiken 1	131 (mean of 2 years)	112 (2nd year)	9	Wang *et al.*, 1989[13]
5. Haiken 2	142 (mean of 2 years)	128 (2nd year)	9	*Ibid*
6. Haiken 1	117 (mean of 5 years)	108 (5th tapping year)	14	Wang Zeyun, 1997[b]
7. Haiken 2	125 (mean of 5 years)	111 (5th tapping year)	11	*Ibid*
8. SCATC 43	134 (mean of 1 year)	106 (1st tapping year)	29	Xu Lai-Yu[c]
9. GI1	135 (mean of 3 years)	106 (3rd tapping year)	10	Wu *et al.*, 1996[14]

[a]1–3: Buddings derived from juvenile buds of seedling mother trees; 4–5: Tissue-culture produced anther somatic plants with self-born roots; 6–9: Buddings derived from juvenile buds of anther somatic plants.
[b]Private communication
[c]Unpublished data

As to latex physiological characteristics of the JT clones, there are data of three clones including GI1 in this study. The other two JT clones are Haiken 1 and Haiken 2[17] both of which are not buddings but self-rooting anther somatic plants produced by anther culture. In comparison with their MT clones, all the three JT clones have significantly lower plugging index and lutoid bursting index and thus they gain an advantage in latex flow.

In the parameters linked to latex regeneration or yield potential, the three JT clones seem to be quite different. In comparison with their MT clones, JT GI 1 and Haiken 2 show much higher yield potential as all their parameters are superior (DRC, sucrose and inorganic phosphorus for the three clones, and thiols for Haiken 2) or at the similar level (thiols for GI 1). Two JT clones gain yields of 125%–142% to that of their MT clones. By contrast, the JT Haiken 1 has a much lower level of DRC and sucrose than its MT clone. Nevertheless with a yield of 131% to that of its MT clone, the JT Haiken 1 does not show a lower yield potential.

In summary, the JT clones studied so far show significant advantages over their MT clones in yield level and related characteristics. These characteristics are the reflection of the developmental change from juvenile phase to mature phase and thus they must be the intrinsic qualities of the species, *Hevea brasiliensis*. More JT clones will be studied which might have advantages over the corresponding MT clones in varied degrees.

Finally, it should be noticed that the trunks of the GI 1 JT buddings in the present study had no obvious conical appearance, so did the trunks of the Haiken 1 and Haiken 2 JT buddings in a comparative experiment[13]. There is no doubt as to the juvenility of the JT buddings of the three clones as all the buddings originated from the anther somatic plants that were less than 2 years' old. Although the conical trunk and other morphological characteristics were usually emphasised to recognise the juvenile phase, they are in fact not essential for distinguishing the juvenile phase from the mature one[5,6].

ACKNOWLEDGEMENT

This study was supported by the National Science Foundation of China. We thank Prof. Wang Zeyun for valuable suggestions, and Tan Hai-yan for technical assistance.

Date of Receipt: September 1997
Date of Acceptance: March 1998

REFERENCES

1. WEBSTER, C.C., PAARDEKOOPER, E.C. (1989) The Botany of the Rubber Tree. *Rubber. (Webster, C.C. and Baulk Will, W.J. eds.)*, Chap. 2. New York: Longman Sci. & Tech.

2. PAARDEKOOPER, E.C. (1956) The Occurrence, Properties and Possible Application of Juvenile Type Buddings. *Arch. Rubb. Cult.*, **33**, 141.

3. DIJKMAN, M.J. (1951) *Hevea. Thirty Years of Research in the Far East.* Coral Gables, Florida: Univ. Miami Press, Chap. 15.

4. LIU SONGQUAN, YUAN XIEHUI, HUANG XIANG AND XU LAIYU (1985) Comparative Studies on Yield and Properties of Juvenile Type- and Its Mature Type-Clone. *Trop. Crop Res.* (Hainan, China), **1985(2)**, 1.

5. LIU SONGQUAN, YUAN XIEHUI, HUANG XIANG AND XU LAIYU (1990) Developmental Phase Change of *Hevea brasiliensis* and Applications of Juvenile Type Clones. *Proc. IRRDB Symp. on Breeding* Hevea brasiliensis, *1990, Kunming, China,* 26.

6. HAO B.-Z. AND WU J.-L. (1996) Characteristics Related to Higher Rubber Yield of Juvenile Type-Clone of *Hevea brasiliensis. Trop. Crop Res.* (Hainan, China), **1996(2)**, 1.

7. SHIH, T. AND HU, Z. (1965) A Histological Method for Rubber-Bearing Tissues of Plants. *Acta Bot Sinica*, **13**, 179.

8. MILFORD, G.F.J., PAARDEKOOPER, E.C. AND HO, C.Y. (1969) Latex Vessel Plugging. Its Importance to Yield and Clonal Behaviour. *J. Rubb. Res. Inst. Malaya*, **21(3)**, 274–282.

9. RIBAILLIER, D. (1968) Action *in vitro* de Certainsions Minéraux et Composés Organiques sur la Stabilité des Lutoïdes du Latex d'*Hevea. Rev. Gen. Caoutch. Plast.*, **45**, 1395.

10. ESCHBACH, J.M., ROUSSEL, D., VAN DE SYPE, H. AND JACOB, J.-L. (1984) Relationships between Yield and Clonal Physiological Characteristics of Latex from *Hevea brasiliensis. Physiol. Veg.*, **22**, 295.

11. ASHWEL, G. (1957) Colorimetric Analysis of Sugars. *Methods in Enzym.*, **3**, 73.

12. BOYNE, A.F. AND ELLMAN, G.L. (1972) A Methodology for Analysis of Tissue Sulfhydryl Components. *Analytical Biochem.*, **46**, 639.

13. WANG A. EYUN, WU HUDIE AND CHEN XIONGTING (1989) Desirable Characteristics of Anther Somatic Plants of *Hevea brasiliensis. Chinese J. Trop. Crops*, **10(2)**, 17.

14. WU HUDIE, WANG ZEYUN AND CHEN TINGXIONG (1996) Growth and Yield of Juvenile Type Clone Derived from Anther Somatic Plants. *Trop. Crop Res.* (Hainan, China), **1996(1)**, 4.

15. LAOPOLD, A.F. *Plant Growth and Development.* (2nd ed.) New York: McGraw-Hill, Inc., Chap. 11.

16. NARAYANAN, R., GOMEZ, J.B. AND CHEN, K.T. (1973) Some Structural Factors Affecting the Productivity of *Hevea brasiliensis* II. Correlation Studies between Structural Factors and Yield. *J. Rubb. Res. Inst. Malaya*, **23**, 285.

17. YANG SHAOQIONG AND MO YEYONG (1994) Some Physiological Properties of Latex from Anther Somatic Plants of *Hevea brasiliensis. Chinese J. Trop. Crops*, **15(2)**, 13.