Rubber Tree Cultivation and Improvement: Rootstock-Scion Compatibility between *Hevea* Species and Cultivated Planting Materials

Shamsul Bahri Abdul Razak[1], Ong Chin Wei[2]

[1]Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
[2]Rubber Research Institute of Malaysia, Sungai Buloh, Selangor, Malaysia

***Abstract*—** *Rootstocks have a clear effect on rubber tree growth and development during the seedling and immature stages. However, the exploration of Hevea species as rootstocks is relatively uncommon in the general practices in the cultivation and improvement programmes in Malaysia. Hevea species were tested in this research including Hevea brasiliensis, Hevea benthamiana, Hevea camargoana, Hevea guianensis, Hevea nitida, Hevea pauciflora, Hevea rigidifolia and Hevea spruceana. This research examined the successful bud-grafted percentage between scion and rootstock of different Hevea species and cultivated planting materials. The results demonstrated that rootstock-scion of H. benthamiana-PB 260 achieved the highest successful bud-grafted percentage at 94.5%, followed by H. nitida-RRIM 2001 (93.8%), H. nitida-PB 350 (92.3%) and H. pauciflora-PB 260 (90.8%). The lowest successful bud-grafted percentage came from H. benthamiana-RRIM 2025 at 51.1 %. Therefore, the exploration of Hevea species as potential rootstocks based on the successful bud-grafted percentage between rootstock-scion and their compatibility could be applied as a speed indicator for rubber nurseries to produce high quality planting materials.*

***Keywords*— bud-grafted, Hevea species, rootstock-scion.**

I. INTRODUCTION

Among the famous events in the history of natural rubber is the massive amount of natural rubber produced by rubber plantations to satisfy the high demand during The Industrial Revolution. Natural rubber is a chain of polymers that exhibits high resilience, impact resistance, elasticity, stretchy strength, as well as low heat swelling during manufacturing processes. This is attributable to the unique molecular structure of the rubber, which is difficult to be matched by synthetic rubber derived from the petroleum sources. The use of natural rubber can be seen in various domestic and industrial products nowadays. This started in 1876 when Henry Wickham collected about 70,000 rubber seeds (*H. brasiliensis*) near the Tapajos River in Brazil, and attempted to sow them in the United Kingdom. This small population of sowed and germinated seedlings were later transported to Ceylon (Sri Lanka) and Singapore in 1876. Eventually, 22 seedlings survived during the transportation journey and arrived in Kuala Kangsar, Malaya (Malaysia) in 1877, since then these seedlings have formed the genetic base of rubber trees in the country (Baulkwill 1989; Barlow 1978; Loadman 2005, MRB 2005; Priyadashan, 2011). Prior to the 1950s, seedlings that germinated from rubber seeds were widely accepted as cultivated planting material, either by rubber plantations or by smallholdings. For example, the seeds obtained from established experimental gardens at Rubber Research Institute of Malaysia (RRIM) have been accepted as being good in quality and recommended for extensive planting (Heuser 1932; RRIM 1957: Ng, 1983; Ong and Shamsul, 2013). In general, seedling trees would generate variable yield and unpredicted characteristics such as growth rate, canopy density, branching habit, bark thickness, wind damage tolerance, disease tolerance *etc*., whereas cultivated planting materials recurrently showed uniformity on the mentioned characteristics.

II. BUD-GRAFTING TECHNIQUE IN RUBBER TREES

Bud-grafting technique was gradually tested and recognized as a useful way to multiply planting materials for large quantities during 1950s in Malaysia, which involved cultivated planting materials or clones that produced high latex yields for cultivated planting such as Tjirandji 1, RRIM 501, RRIM 526, AVROS 157 and PR 107 (RRIM, 1952; Webster and Baulkwill, 1989). Subsequently, planting materials derived and multiplied from the bud-grafting technique rapidly replaced the unselected seedlings from the experimental gardens and rubber nurseries, where the majority of the rubber tree improvement programmes at that period were initiated and established at RRIM (Burkill, 1959; RRIM, 1952; RRIM, 1963, RRIM, 1965; Ng, 1983; RRIM 1995; MRB 2009; Ong and Shamsul, 2013). Later, RRIM 500 Clone Series, RRIM 600 Clone Series, RRIM 700 and other cultivated planting materials were introduced and multiplied extensively through bud-grafting technique. Eventually, the cultivated planting materials and planted expansively in the country were mostly originated from the improvement programmes and experiments including RRIM 600, RRIM623, RRIM 703, RRIM 901, RRIM 2001, RRIM 2002, RRIM 2025, PB5/51, PB 260, PB 235, PB 314, PB 350, PB 355 (Ramli *et al.*, 1996; MRB, 2009; Shamsul and Ong, 2014). Recently, MRB Planting Recommendations emphasized the selection of Latex Timber Clones (LTC) as good planting materials that would generate high latex yield and rubberwood through their breeding programmes (Table 1). Latex yield remains as the most important characteristic, and rubberwood yield is also taken as one of the good characteristics in order to produce Latex Timber Clones for commercial planting (RRIM, 1995; MRB, 2009; Ratnasingam *et.al.*, 2011). However, the successful bud-grafted percentages of different rootstock-scion were varied and unpredictable even among the rubber planting materials within the same clone series. This is regularly due to the compatibility issues between rootstocks and scions, through the observations made at rubber nurseries over the years. A rootstock and a scion in a polybag that were prepared for bud-grating procedure in the rubber nursery as showed in Figure 1.

TABLE 1
CULTIVATED PLANTING MATERIALS DEVELOPED FROM BUD-GRAFTING TECHNIQUE AND PLANTED EXTENSIVELY OVER THE YEARS IN MALAYSIA.

Planting material	Parents	Country of Origin
RRIM 600	Tjir 1 x PB 86	Malaysia
RRIM 623	PB 49 x Pil B 84	Malaysia
RRIM 703	RRIM 600 x RRIM 500	Malaysia
RRIM 901	PB 5/51 x RRIM 600	Malaysia
RRIM 2001	RRIM 600 x PB 260	Malaysia
RRIM 2025	IAN 873 x RRIM 803	Malaysia
PB 5/51	PB 56 x PB 24	Malaysia
PB 260	PB 5/51 x PB 49	Malaysia
PB 235	PB 5/51 x PB S/78	Malaysia
PB 314	RRIM 600 x PB 235	Malaysia
PB 350	RRIM 600 x PB 235	Malaysia
PB 355	PB 235 x PR 107	Malaysia

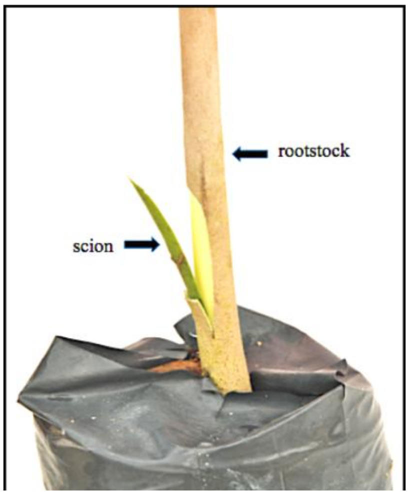

FIGURE 1: A rootstock and a scion in polybag that were prepared for bud-grafting.

III. MATERIALS AND METHODS

3.1 Rootstock-scion Compatibility between *Hevea* Species and Cultivated Planting Materials

The bud-grafting technique in rubber trees is a method used to asexually multiply rubber planting materials by grafting vegetative buds onto a rootstock in a polybag at a young age (Leong and Yoon, 1979; Jeffree and Yeoman, 1983; Ng, 1983; Webster and Baulkwill, 1989; Mercykutty and Gireesh, 2015). The bud-grafting technique was carried out in this research, where the standard methods were followed and adopted, as applied in a local rubber nursery. Seeds of rootstocks from rubber species were gathered and sowed in the seedbeds at a small-scale rubber nursery. When these rootstocks reached an age of five to six months, they were prepared to receive scions at their basal portion. Scions were prepared in the nursery from budwood that was still green in colour and not older than eight weeks. In this procedure, the basal portion of each rootstock was cleaned, and vertical budding panels of about 5 cm long and 1 cm wide were created with a knife. In a separate operation, a bud-patch carrying a vegetative bud of the scion was stripped off from the budwood collected earlier, and trimmed to a size matching that of the budding panel on the rootstock. The bud-patch was inserted into the budding panels and the region grafting was securely bound with transparent polythene tape. The budding panel was examined after 21 days through the transparent bandages, which can be removed for clearer observation if required. The retention of the green colour of the scion on the budding panel is a sign that bud-grafting procedure was successful, and the shoot portion of the original rootstock can then be cut off. This would allow a new shoot to emerge from the budding panel. The shoot was allowed to develop until the emergence of two whorls of leaves. Each *Hevea* species was tested as a rootstock and paired with different scions of selected cultivated rubber planting materials such as PB260, PB350, RRIM 2001 and RRIM 2025. These scions were collected from only fresh and healthy budwoods, to ensure their viability after the bud-grafting practice. Furthermore, they were derived from the recommended cultivated planting materials with proven records of high latex yields from RRIM (RRIM, 1995; MRB, 2005). The compatibility between rootstock-scion could be observed and calculated through the percentage of successful bud-grafted. Nevertheless, the number of bud-grafted seedlings in different rootstock-scion combinations tested was not in equal numbers because of the varied seed germination rates between the cultivated planting materials, and also because of losses from pest attacks during the sowing stages when this research was carried out.

IV. RESULTS

The observation on the successful bud-grafted percentage of different rootstock-scion combinations is presented in Table 2. Cells in the bud-grafted panel would form a cambial bridge of new vascular tissues that connected to the old cambium and vascular tissues on the rootstock and scion. Typically, cell division of parenchyma cells occurred within days after bud-grafted, and new callus tissue would continue to develop between rootstocks and scions for up to 21 days. If there was no sign of yellowish colour on the scions, an indication of rootstock-scion in high state of compatibility, that they survived through the bud-grafting procedure. The results demonstrated that rootstock-scion of *H. benthamiana*-PB 260 achieved the highest successful bud-grafted percentage at 94.5%, followed by *H. nitida*-PB 2001 (93.8%), *H. nitida*-PB 350 (92.3%) and *H. pauciflora*-PB 260 (90.8%). Meanwhile, *H. rigidifolia* showed low compatibility (<80%) relatively three of the cultivated planting materials *i.e*., PB 350, RRIM 2001 and RRIM 2025. Nevertheless, the lowest successful bud-grafted percentage was found between *H. benthamiana*-RRIM 2025 at 51.1%. Therefore, this research revealed that *H. benthamiana*, *H. nitida* and *H. pauciflora* worth to be explored as the potential rootstocks, since they were highly compatible with different scions of cultivated planting materials. Interestingly, RRIM 2025 was one of the high latex-yielding cultivated planting materials in the country, but it was seen as mediocre with low successful bud-grafted percentage (<80%) when its scions were bud-grafted with different rootstocks of *Hevea* species.

TABLE 2
SUCCESSFUL BUD-GRAFTED PERCENTAGE BETWEEN DIFFERENT ROOTSTOCKS (*HEVEA* SPECIES) AND SCIONS (CULTIVATED PLANTING MATERIALS).

Rootstock	Scion	Total number of bud-grafted (n)	Total number of successful bud-grafted (a)	Successful bud-grafted after day-21 (%)
H. benthamiana	PB 260	91	86	94.5
	PB 350	46	37	80.4
	RRIM 2001	74	58	78.4
	RRIM 2025	45	23	51.1
H. brasiliensis	PB 260	121	107	88.4
	PB 350	163	143	87.7
	RRIM 2001	86	76	88.4
	RRIM 2025	96	53	55.2
H. camargoana	PB 260	173	155	89.6
	PB 350	126	113	89.7
	RRIM 2001	144	128	88.9
	RRIM 2025	140	102	72.9
H. guianensis	PB 260	35	25	71.4
	PB 350	47	42	89.4
	RRIM 2001	45	39	86.7
	RRIM 2025	39	24	61.5
H. nitida	PB 260	67	58	86.6
	PB 350	52	48	92.3
	RRIM 2001	48	45	93.8
	RRIM 2025	75	56	74.7
H. pauciflora	PB 260	65	59	90.8
	PB 350	46	34	73.9
	RRIM 2001	63	55	87.3
	RRIM 2025	72	57	79.2
H. rigidifolia	PB 260	58	48	82.8
	PB 350	66	52	78.8
	RRIM 2001	54	40	74.1
	RRIM 2025	53	37	69.8
H. spruceana	PB 260	185	146	78.9
	PB 350	193	168	87.1
	RRIM 2001	149	127	85.2
	RRIM 2025	162	139	85.8

V. DISCUSSION

The successful bud-grafted rootstocks and scions in this research were detailed by: (1) sturdy cohesion between the rootstock and scion at the grafting panel, (2) continuous multiplication of callus cells at the grafting panel, (3) the development of new vascular cambium tissues at the grafting panel. Besides, the practice of bud-grafting technique can be carried out year-round, and rubber planting materials can be produced in large quantities under a controlled environment, and uniformity in growth when raised in the polybags. One major problem of rubber nurseries in Malaysia is the quality and authenticity of the rootstocks. The quality of rootstocks normally receives little attention, as long as there are seeds available for germination and used as rootstocks at most of the rubber nurseries in Malaysia. Even though *H. benthamiana*, *H. nitida*, and *H. pauciflora* worth to be explored as the potential rootstocks, other *Hevea* species that were not highlighted in this research, might have other uses that yet unexplored. There is limited literature describing latex yield, wood production, ornamental use, photosynthesis efficiency, water-use or even ability of drought tolerance of these species. On the other hand, cultivated planting materials that have proven records of high latex yields might not necessary compatible with rootstocks of *Hevea* species, and extra efforts are needed to find specific rootstocks, in order to produce high quality seedlings and increase the production at rubber nurseries.

VI. CONCLUSION

The combinations rootstock-scion of *H. benthamiana*-PB 260, *H. nitida*-PB 2001, *H. nitida*-PB 350 and *H. pauciflora*-PB 260 showed high successful bud-grafted percentage that should be focused by rubber plant breeders because these neglected *Hevea* species have the potential to contribute to a higher level than they currently do. From a crop improvement perspective, the genetic potential of *Hevea* specie is massively determined by the combination of genes that they have contained. Quantitative Trait Loci (QTLs) analysis and Marker-Assisted Selection (MAS) were introduced in rubber improvement programmes in many decades ago, in attempts to verify the purity of rubber planting materials, selection of parentage, population diversity analysis, and increase desired traits for commercial purposes. However, there exist no successful MAS to detect genes make-up for rootstock-scion compatibility in rubber trees. This is because of the low power of QTL detection, whereas complex traits such as callus cells multiplication and vascular cambium tissue development that alleged to associate with a series of QTLs. In short, the successful bud-grafted percentage between rootstock-scion, regardless of *Hevea* species or commercial planting materials, could be applied as a speed indicator for rubber nurseries to produce high quality planting materials.

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