Progress of Rubber Breeding Program to Support Agroforestry System in Indonesia

Fetrina Oktavia[1,*], *Sahuri*[1] and *Dwi* Shinta Agustina[1]

[1] Indonesian Rubber Research Institute
Jl. Raya Palembang – Pangkalan Balai Km 29, Sembawa, Banyuasin, South Sumatra

Abstract. The use of superior rubber planting materials is one of the most important components of technology to support the cultivation and sustainability of the natural rubber industry. The effect of the genetic components of planting materials to the rubber productivity can reach 60%, and the rest is the influence of agro-climatic conditions. The aim of the rubber plant breeding program is to obtain the new superior rubber clones that have a high latex yielding potential and good agronomic characters. The fluctuations of natural rubber price and climate changes also influence the direction and objectives of the rubber plant breeding program. To deal with the conditions, it is important to provide the rubber agroforestry technology by through intercropping of rubber with various other crops. The article will provide the information about progress of rubber breeding program in Indonesia and it is role in supporting agroforestry system. Several of new superior rubber clones have been released by IRRI, and some of these clones such as IRR 112 and IRR 118 had been planting with rice, corn, and other crops by through rubber agroforestry system. The system was estimated be able to maintain latex yielding potential of clones as well as farmers' income can be improved.

1. Introduction

Rubber (*Hevea brasiliensis*) is one of the commodities that has the most important role for the Indonesian economy, both as a source of employment opportunity and income for farmers as well as a source of foreign exchange. Until 2018, the total area of rubber plantations in Indonesia was recorded at 3.67 million hectares, consisting of 88.13% smallholder plantations, 5.16% private plantations and 6.7% state plantations with total production reaching 3.63 million tons. Based on this information, it is known that the largest contribution to Indonesian natural rubber production was obtained from smallholder plantations. However, if we pay attention to the productivity of smallholder rubber plantations which just 1153 kg ha^{-1} per year, it is still low and below the productivity of state and private rubber plantations, 1529 kg ha^{-1} per year and 1549 kg ha^{-1} per year respectively, as well as under of the average productivity of Indonesian rubber productivity about 1205 kg ha^{-1} per year [1].

[*]Corresponding author: fetrina_oktavia@yahoo.com

According to observations in the fields, it is known that the low productivity is mainly due to the fact that there are still many old rubber plants that are less productiv ity (2.6%) as well as low of adoption and implementation of rubber cultivation technology and management [2]. Limitation of capital, land and labour were the main cause of the low of technology adoption in Indonesia [3]. Other factors contributed to exacerbating the condition of rubber productivity in Indonesian recently was the outbreak of a new disease named by Pestalotipsis leaf fall disease that attacked rubber plantations in 2018. This condition also affects the productivity of Indonesian rubber plantations which results in a significant decrease in farmers' income.

Various efforts must be done to increase the productivity of rubber plantations, especially smallholder rubber plantations which dominate the rubber plantations area in Indonesia. Several important factors that influence to productivity of rubber plantations are the use of high-yielding superior planting materials with a balanced type and age of clone composition as well as planting of clones in the appropriate agroecosystem, application of right cultivation techniques which includes land clearing, fertilization with appropriate dosage, frequency and method of application, prevention and control of disease, application of exploitation systems according to clone physiological characteristics, control of tapping panel dryness, and replanting of non-productive rubber plantation [4,5]. In addition, the change in the rubber cultivation system from monoculture to intercropping during the immature phase is also a solution in dealing with the problem of fluctuating rubber prices, especially related to farmers' income in smallholder plantations [6,7].

Productivity of rubber plantation will influence by two main factors. The most factors is genetic, the kind of clone that used as a planting material which will give effect about 60% to growth and productivity of rubber plant, and remains is environment effect such as rainfall, elevation, soil and management of rubber plantation. Using of of the superior rubber clones will increase the rubber productivity. This paper will report the progress of rubber breeding program to obtain the superior rubber clone to assist increasing of rubber productivity and using of the superior clones to support agroforestry systems in Indonesia.

2. Progress of rubber breeding program

2.1 Purpose, direction and strategy of the rubber breeding program in Indonesia

The rubber breeding and selection activities in Indonesia began in 1910 and continued until present. At the first, the aim of rubber breeding program just to produce the high latex yielding clone, but along with the development of environmental conditions and climate change, there were a change not only focused on latex yielding, but also to obtain the plants that have a good agronomic character. Some of the agronomic characters that had been taken into consideration include fast and robust growth, resistant to biotic stress especially to major diseases, tolerant to abiotic stress such as drought and tapping panel dryness, have a good quality wood as well as have a good canopy architectural typology [8].

2.2 Genetic material

The success and progress of the rubber breeding program to increase rubber productivity depends on the availability of a wide variety of genetic material sources. Generally the rubber breeding still use a widely cultivated clones that come from Wickham population. Based on the genetic analysis it is known that these clones have a narrow genetic basis [9, 10, 11, 12].

This is estimated due to the clones came from the same area in Brazil. Another problem is rubber plants are inbreeding depression, so steadily using of Wickham's clones in crossing programs can lead to a decrease in the genetic value of important agronomic characters such as a latex production and thickness, increasing risk of disease epidemics and pest attacks as well as reducing the adaptability of plants to environmental changes [13].

The problem can be overcome by using the new germplasm resulted exploration of IRRDB (International Rubber Research Development Board) in three districts of Brazil, namely Rondonia, Acre and Matto Grosso in 1981. The genotypes were resulted from exploration called Amazonian or IRRDB 1981 population. According to growth and yield testing, it is known that the germplasm had fast growth the potential of latex yielding was below the Wickham clones[14]. This becomes a limitation to being the germplasm directly into production clones, but had the potential to be a source of genetic material in crossing for a good agronomic characters [15].

2.3 Rubber breeding stage

There are some stages in rubber breeding program to produce the new superior clones consists i.e hand pollination, selection of F1 progenies, small scall clone trial (SSCT), large scale clone trial (LSCT) and multilocation trial for adaptation selection of clone in different agroclimate. The program need a long time, begin from pollination up to the clone ready to release about 25-30 years which each step take a different time as showed in scheme of standard operating procedure of rubber breeding (figure 1). Some of constrains faced in the breeding process especially related to limitation of genetic material availability as a source of genes for the desired agronomic character, low low of success rate of crossing which was less than 3.2% [16], limitation of testing area, large of cost for every testing stage as well as the length of time required for a clone to be released as a new superior clone to public, it is about 25-30 years [17].

Fig. 1. Scheme of standard operating procedure of rubber breeding

Regarding to type of planting material used and the increasing of planting material productivity, the progress of rubber breeding program in Indonesia can be clustered into five generations as listed in Table 1. There were a plenty high increasing of rubber productivity from only about 500 kg ha^{-1} per year to about 2500 kg ha^{-1} per year by change the using of rubber planting material from seedling of selected high-yielding mother trees become directed crossing from selected parents clones. Continuously efforts to increase the rubber productivity up to reach the maximum potential of the latex production about 7000 - 8000 kg ha^{-1} per year [18].

Table 1. Milestone of rubber planting material in Indonesia

Generation	Period	Planting Material	Clone	Productivity (kg ha^{-1} per year)
I	1910-1935	Selected seedling	Selected seedling	< 500
II	1953-1960	Propagation of selected seedling	Tjir I, Tjir 16, GT 1, LCB 479, LCB 1320, PR 107	500 - 1000
III	1960 - 1985	Propagation clone which obtained from hand pollination	AVROS 2037, BPM 1, PR 228, PR 255, PR 261, PB 5/51, RRIM 600	1000 - 1500
IV	1985 - 2010	Propagation clone which obtained from hand pollination	BPM 24, BPM 107, BPM 109, PB 260, PB 330, PB 340, RRIC 100	1500 - 2000
V	2010 - present	Propagation clone which obtained from hand pollination	Latex Clone IRR 220, IRR 118, IRR 112, IRR 104, BPM 24, PB 260, PB 330 and PB 340 Latex Timber Clone IRR 230, IRR 5, IRR 39, IRR 42, IRR 119 and RRIC 100 Root Stock Clone AVROS 2037, GT 1, PB 26, PB 330, BPM 24 and RRIC 100	2000 - 2500

2.4 Inovation technology of superior rubber clone IRR series

Several studies showed that there are no universal clones or plant varieties, which have the same performance at different locations. The use of superior rubber clones as planting material can increase the productivity of rubber plantations. Type of clones will give an effect about 60% to growth and productivity of rubber plant, while the rest is environmental factors.

There are two important environmental factors that influence the performance of a rubber clone, namely the agroclimate conditions such as soil, elevation and rainfall, as well as the management of cultivation such as planting systems, maintenance, fertilization, disease control and harvesting system. According to the results of selection in multilocation which have a different agroclimate condition, IRRI had been released some of superior rubber clones that have a good adaptatation in all of these location. The clones were named with IRR (Indonesian Rubber Research), and untill present IRRI has been release IRR series 00,100 and 200.

The newest clones that released to public are IRR 112, IRR 118, IRR 220 and IRR 230. These clones are a latex yielding and a good agronomic characters such as a robust and fast growth, fast open tapping time, resistant to leaf disease, responsive to stimulants and have a good of canopy architecture typologi. Table 2 shows the latex yielding potential and agronomic characters of the each clone.

Table 2. Characteristics of Indonesian superior rubber clones

Characteristic	IRR 112	IRR 118	IRR 220	IRR 230
Production potential (kg ha^{-1} per year)	2452	2200	2487	2008
Open tapping (year)	4	4.5	4	4
Resistance to leaf fall disease	Resistant	Moderate	Resistant	Resistant
Response to Stimulant	High	Moderate	Low	Moderat
Adaptation to Agroclimate	All	Dry climate	All	All
Type of Clone	Latex clone	Latex clone	Latex clone	Latex-timber clone
Suitable of latex	Concentrate latex	SIR 3WF	SIR 3CV, SIR 3L and concentrate latex	SIR 3CV, SIR 3L, RSS

Beside released clones, IRRI have been prepared the new superior clones which currently in the evaluation process in various agroclimate conditions. The prospective superior clones called IRR 300 and 400 series which are expected have the potential of production above the previous released IRR series clones. Both series of clones are expected to be released in the near future. Figure 2 shows the increased productivity of IRR 300 and 400 series compare to IRR 00 100 and 200 series [8,17].

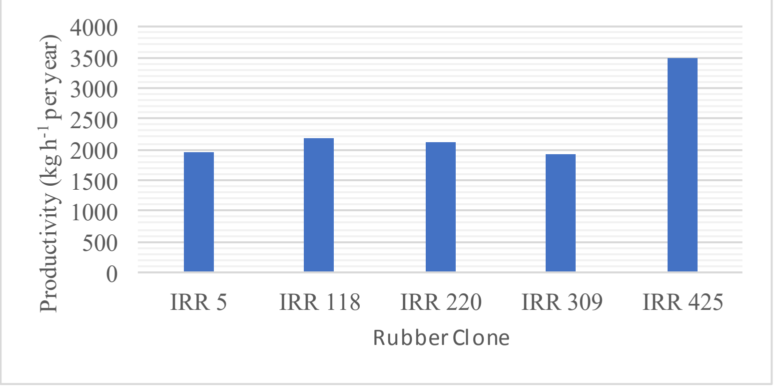

Fig. 2. Progress of increasing of latex productivity of IRR 00 – 400 series of rubber clone on 5 years tapping

3. Utilization and role of superior clones in rubber agroforestry system

There are efforts to increase the income and welfare of rubber farmers through increasing the productivity of rubber plantations through some approaches, including the provision the technology of superior rubber clones as a planting material and the use of intercropping plants. The change of the planting system from monoculture to agroforestry system is expected to be able to increase the land productivity. The main aims of RAS was to increase and to maintain the sustainability of farmers' income, wherein as long as the rubber plant on immature periode, they can still get the income from the intercrops. Based on this concept, usually the farmers choose the annual crops such as a rice, chilie, corn and soybeans, which can faster produce than perennial crops. In addition, RAS is estimated can reduce the cost of maintaining the rubber plantation, increase the soil fertility, avoid the soil erosion and maintain the biodiversity compared to the monoculture planting systems [19, 20, 21].

Development of RAS in Indonesia has been started since rubber cultivated by smallholders, but have not applied good agriculture practical. In order to increase the rubber productivity of smallholder, so since 1994 the World Agroforestry Center (ICRAF) in collaboration with the Center de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) France and Indonesian Rubber Research Institute launched the SRAP (Smallholder Rubber Agroforestry) project. The networking established on farm trials in several central areas of smallholder rubber plantations in Indonesia such as South Sumatra, Jambi, West Sumatra, and West Kalimantan. The primary aim of the project was to study some of option to improved the RAS under management of the farmer that was being monitored by professionals and researcher. There were three types of distinct RAS technology that developed in the project. RAS-1 that used unselected rubber seddling were replaced by recommended clones. In RAS-2 rubber are planted with other perennial crops. RAS-3 is designed for rubber with fast growing and multipurpose of tree species that can be harvested before rubber trees reach tapping size. In the RAS-3 also using the cover crops such as Mucuna to suppress the growth of Imperata [22]

The RAS system are developed to get the optimal gain. Based on the kind of planting material that be used and adoption of good agriculture practical (GAP) in the rubber plantation, so RAS in Indonesia can be classified into four stage:

Stage 1. Non clonal planting material

In the stage, smallholders still used rubber seedling as a planting material which planting together with the perennial crops such as Acacia sp, Shorea sp as well as fruits tree. In the other side, the smallholders were not adopted GAP to manage and maintain their plantation so that the plantations often look like a jungle rubber. The condition caused the low of rubber productivity in the smallholder just about 500 kg ha^{-1} per year.

Stage 2. Clonal planting material and non GAP

The generation II and III of rubber had started to be used in smallholder rubber plantations, however, there were not a good maintenance such as fertilizer, weeding and protection of disease infection this case. Some of G-II clones that had been widely adopted by smallholders was GT 1 and LCB 1230 and G-III such as BPM 1 and RRIM 600. The rubber plants were planted together with various perenial crops such as Acacia sp and Shorea sp as well as seasonal crops such as upland rice and maize. The use of superior rubber clones without being followed by GAP will cause the latex potential of clone is not being maximally achieved. In the condition non application GAP, the potential of the clones G-II and G-III will be decrease under 1000 kg ha^{-1} per year.

Stage 3. Clonal planting material and GAP

There is a significantly increasing of rubber productivity in the third stage wherein the G-III and G-IV clones such as BPM 24, PB 260 and RRIC 100 as well as application of GAP under monitoring of research institute were implemented in the smallholder rubber plantations. The latex production in the stage could be reached 1500 kg ha^{-1} per year [23].

Stage 4. New Superior rubber clone planting material and GAP

The differences of stages 3 and 4 can be seen from the using of the clones and improved of planting system. In the stage, the smallholder have been adopted the new superior rubber clones that recommended by Indonesian Rubber Research Institute. The clones have a good latex potential and a good agronomic character such as resistant to rubber main disease, high response to stimulant and good canopy architecture. Some of new superior clones that adopted in RAS are IRR 112 and IRR 118 which have a latex potential reach 2500 kg ha^{-1} per year. There is a implementation of GAP and improving of planting system such as a double row spacing for intercropping with annual crops at this stage.

The information showed the importance of the role of rubber planting material in effort to increase the rubber productivity in RAS. The progress of productivity some of rubber clones that be used in stage 1 to 4 in the RAS in Indonesia, starting from seedling as a planting material in stage I up to utilize the new superior clone in stage 4 can be seen in Table 3. Eventhough the productivity has not been maximally achieved according to the potential of clone which it can reach up to 8000 kg ha^{-1} per year [18], there has been a significant increasing of latex production between the planting material be used. Sahuri [24] stated that intercropping crops give the positive effect to girth of rubber plant in the RAS. This is due to the return of intercropping plant biomass compost to the soil, so that the soil structure becomes more loose and rich of nutrients [25]. The intercropping had no effect on latex yield per tree per tapping but yield per hectare was greater in the intercropping than monoculture due to the number of trees that could be tapped was significantly higher.

Table 3. Productivity of rubber planting material on the 3rd year of tapping in RAS in Indonesia

Description	Seedling	BPM 1	RRIM 600	PB 260	RRIC 100	IRR 112
Yield g/tree/tapping	15	28	27	32	29	30
Nb. tappings/year	120	134	136	135	134	113
Nb. trees/ha	339	371	375	422	371	550
Yield kg/ha/year	518	1430	1442	1794	1508	1864

Source : Wibawa et al, 2008; Sahuri, 2019

4. Conclusions

1. It is important to use the superior rubber clone as a planting material to increase the rubber productivity
2. RAS can increase the land rubber productivity, so as to increase the income and welfare of rubber farmers
3. According to experiments showed that RAS significant increase the growth of rubber tree, reduces unproductive plant phases, and had no effect on latex yield per tree per tapping.
4. Utilization of superior rubber clone is one of the important key to success of RAS

References

1. Directorate General of Estate Crops. Rubber Tree Crops estate Statistic of Indonesia. Directorat General of estate Crops, Jakarta (2019)
2. D. I. S. Simamora, J. Yusri, N. Dewi. J. Online Riau University Faculty of Agriculture. 4 (2):1–12 (2017).
3. D. Iskandar. J. Sains and Technology Indonesia. 13(3):165-170 (2011).
4. Boerhendhy, K. Amypalupy. J. Agriculture Res & Dev. 30(1): 23-30 (2011).
5. Junaidi. Perspective. 19(1):17-28. (2020)
6. Sahuri, M.J. Rosyid. Indonesian Bulletin of natural Rubber. 34(2):77-88 (2015).

7. Sahuri, A. Nurcahyo, I.S. Nugraha. Indonesian Bulletin of natural Rubber.35(2):107-120 (2016).
8. Daslin, S. Woelan, M. Lasminingsih. H. Hadi. *Progress of rubber breeding and selection in Indonesia*, in Proceedings of National Rubber Breeding Seminar, 4-6 Auhust 2009, Batam, Indonesia (2009).
9. N. Lekawipat, K. Teerawatanasuk, M. Rodier-Goud, M. Seguin, A. Vanavichit, T. Toojinda, S. Tragoonrung. J. Rubber Res. 6(1):36-47 (2003).
10. L.R.L. Gouvêa, L.B. Rubiano, A.F. Chioratto, M.I. Zucchi, P.D.S Gonçalves. Gen Mol Bio. 33:308-318 (2010)
11. F. Oktavia, M. Lasminingsih, Kuswanhadi. Hayati J. Biosci. 18(1):27-32
12. F. Oktavia, Kuswanhadi, D. Dinarty, Widodo, Sudarsono. Agrivita J. Agriculture Sci. 39(3): 239-251 (2017)
13. U.V. Lopes, J.R.B. Marques. Agrotrópica. 27(1):33-44 (2015).
14. Daslin. The selected of genotypes of IRRDB rubber germplasm for a latex timber producer. Prospect and development or rubber timber. Indonesian Rubber Research Institute: 75-84 (2009)
15. K. Mydin, C. Narayanan, T. Abraham. Incorporation of the 1981 IRRDB wild amazonian germplasm in Hevea breeding in India. IRRI-IRRDB Rubber Plant Breeding Seminar. Medan, Indonesia. (2012).
16. S. Woelan. Indonesian J. Natural Rubber. 24(1):17-31 (2006).
17. S.A. Pasaribu. M.R. Darojat, E. Bukit. *Technolgy assembly of superior rubber clone with cost component*. Talenta Confrence series. 1:42-46 (2018).
18. Azis. Introducing research result into practice. Research Management RRIM Kuala Lumpur (1998).
19. G. Wibawa, L. Joshi, M.V. Noordwijk, E. penot. In Proceeding of workshop : land use after the tsunami: Supporting Education, Research and Development in the Aceh Region. Syah Kuala University, Banda Aceh, Indonesia November 4-6 November 2008. Indonesia (2008).
20. C. Pye-Smith. Rubber Agroforestry. World Agroforestry Centre (2013).
21. W. Sukmawati, Y. Arkeman, S. Maarif. Industrial techniq J. 58-64 (2014).
22. E. Penot. From Shifting Cultivation to Sustainable Jungle Rubber: A History of Innovations in Indonesia. Chapter 48 of the book Voices from the Forest Integrating Indigenous Knowledge into Sustainable Upland Farming. Malcolm Cairns, editor. Browse Book. 880 p. (2006).
23. Budi, G. Wibawa, Ilahang, R. Akiefnawati, E. Penot, Janudianto. Manual for rubber agroforestry system -RAS. World Agroforestry Centre (2008).
24. Sahuri. J. Agriculture R & D. 38(1):23-34 (2019).
25. W. Pansak. Kasetsart J. 49:785-794 (2015).