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Effect of Intercropping on Latex Physiological Parameters and it's Economic Impact at Juvenile Phase of Para Rubber (*Hevea brasiliensis* Mull. Arg.)

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ABSTRACT

An experiment was carried out during January, 2020–21 and December, 2021–22 at Horticulture instructional farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal, India to find out the performance of growth and latex physiological parameters as well as the effect of intercropping on latex physiological parameters and its economic impact at juvenile phase of Para rubber (*Hevea brasiliensis* Mull. Arg.). The experiment was laid out in Randomized Block Design with three times replication comprising with 15 treatment combination. The five different clones were namely RRII 105, RRIM 600, RRII 430, RRII 429 and RRII 114. The results showed that clone RRII 430 excelled with regards to growth behavior followed by RRII 429 and RRII 414. However, RRIM 600 demonstrated its superiority in terms of latex physiological parameters apart from DRC% and TSC%. Highest average dry rubber content was observed in clone RRII 105 (40.28%) and total solid content in RRII 430 (68.43%). The positive impact of intercropping specially with annual crops on growth parameters were observed in various rubber clones due to continuous cultural management and inclusion of legumes in the cropping system and proved the profitability of the system with better remuneration to the growers. Intercropping with short duration crops with in most of the clones, improved plant growth, allowing the plant to reach tappable girth sooner compared to sole cropping under North Bengal agroclimatic situation.

KEYWORDS: Clones, growth parameters, latex physiology, intercropping

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1. INTRODUCTION

Natural rubber (*Hevea brasiliensis* Mull, Arg.) an indigenous to tropical rain forest of the Amazon River basin. Decades after the augmentation of rubber plantation throughout the Asian countries, the world is getting 89% of natural rubber production out of 10 million ha area from the Asian countries (Anonymous, 2017). In India, even though it has become one of the major industrial crops, still it is having 80% share under small and marginal farmers. As per the rubber board of India, in 2023 total area under rubber in India was 8,50,000 ha with total production of 839,000 tonnes and contributing 5.3% of the global natural rubber market and stand fourth in the position (Anonymous, 2024). Even though Kerela and Tamil Nadu is traditional region for rubber cultivation but due to the rapid increasing population with rising standards of living in country the demand and production of natural rubber has also been increase leading to the verge of exhaustion of rubber cultivation under this area. Recent years, the rubber cultivation has stretched from Tripura to Assam and then some part of West Bengal due to its socio economics importance (Das et al., 2015).

Growth and maturity of rubber tree can be assessed by measuring the increase in the main trunk girth (Antony et al., 2018) and tapping starts at 6–7 year old plant (Qi et al., 2016). Monocropping of rubber cultivation causes adverse environmental impacts, such as deforestation, soil erosion, greenhouse gas carbon dioxide emissions, and the loss of natural resources (Umami et al., 2019; Vrignon-Brenas et al., 2019). However, intercropping with short duration vegetable and fruit crops in the early year of plantation improve the soil physiochemical properties (Chen et al., 2019; Sahuri, 2023; Wang et al., 2017; Couedel et al., 2018). Many studies have also shown positive results of intercropping with rubber plantation at juvenile phase and ensuring sustainable crop yields for long-term economic benefits (Min et al., 2017; Bybee-Finley and Matthew, 2018; Zaw et al., 2022; Zaw, 2023). The double-row rubber plantation system allowing intercrops that were adopted for yam bean, common bean, soybean, peanut, and coffee which increases land use efficiency and enhanced the plant growth (Huang et al., 2020) and helps to restore the ecological imbalance as well as mitigates the negative effect of monocropping (Roy et al., 2014)

The latex is the main product of commerce which consists of water (60%), Cis-1, 4-polyisoprene (35%) and non-isoprene molecules (5%) (Herlinawati et al., 2022; Bottier, 2020). The latex physiological parameters like DRC%, TSC%, thiol, inorganic phosphorus, sucrose and magnesium content in latex are responsible for latex flow rate, regeneration of bark, rubber biosynthesis (Purwaningrum et al., 2019). The latex physiology variables depend on the exploitation and internal condition of the plants (Rukkhun et al., 2020). Dry rubber content is rubber particles while total solid content constitutes rubber, proteins, lipid, sucrose, inorganic phosphorus and thiols in latex (Christophe et al., 2018). Thiol is an enzyme activator and stress indicator and optimal range of thiol is from 0.4 mm^{-1} to 0.9 mm^{-1} Inorganic phosphorus is the indicator of metabolic activity and its concentration range lies between 10 to 30 mm and it depends on the latex harvesting techniques (Atsin et al 2017). According to Tristama et al., 2019, the function of sucrose is to regenerate latex cell and energy production (Priyadarshan, 2017). Therefore, present study was carried out with five different Hevea clones in non-traditional rubber growing region of North Bengal to observe the effect of cropping system on growth, latex physiological parameters and its economic impact on the poor and marginal rubber growers.

2. MATERIALS AND METHODS

The experiment was carried out at the instructional farm of the Department of Plantation Crops and Processing, UBKV, Cooch Behar, West Bengal in three year old 5×5 m^2 spaced rubber plantation during the year January, 2020–December, 2022, planted with five different clones. The experimental site is situated at 26°19'86" N latitude and 89°23'53" E longitude at an elevation of 43 m above the mean sea level. The experiment was conducted to evaluate the performance on growth and latex physiological parameter such as latex physiology such as total solid content (TSC%), dry rubber content (DRC%), thiol (R-SH), inorganic phosphorus (Pi), magnesium (Mg) and sucrose (Suc) content of latex of five rubber clones viz., RRII 105, RRIM 600, RRII 430, RRII 429 and RRII 414 under intercropping at juvenile phase by following the two factorial randomized block design having three replications under I_0 (sole crop), I_1(intercropping with annual crops) and I_2 (intercropping with perennial crops).

The tree was first opened in the fifth year after the planting as a test tapping at 15 cm above the bud union on those plant which had attained girth of 50 cm at 10 cm height. The growth parameters were recorded annually and the girth increment were monitored by measuring the circumference of each rubber plant at a height of 10 cm and 125 cm from the bud union annually to examine the maximum percentage of tree attaining tappable girth with the help of measuring tape. The number of leaf flushes was recorded before the new leaf initiation in the month of March through counting the number of nodes present on the selected branch after the marked point and the crown radius was measured in N-S and E-W spread of the canopy with the help of measuring tape. The data was recorded and was interpreted in centimetres. The economics of intercropping

was calculated kg ha^{-1}.

Test tapping was done for assessing the physiological parameters of latex to observed the effect of different cropping system on different latex physiological parameters. The tapping was done at every morning 6:00 am to 7.00 am and fetched at 8:30–9:00 am. 20 ml of fresh latex was collected in tube to analyzed the latex physiological parameters. DRC% and TSC% of latex was determined by following standard laboratory method (Tillekeratne et al., 1989).

The percentage DRC and TSC of the sample was calculated as follow:

DRC (%)=$w_2/w_1 \times 100$

Where,

W_1=Weight of the fresh latex taken

W_2=Weight of the dry rubber or the total solid remaining.

Whereas thiol (R-SH) estimation was done by following TCA (Trichloroacetic Acid) serum based on the reaction principle with 5,5'-dithiobis (2-nitrobenzoic acid) (DTNB) to form yellow TNB absorbed at 421 nm according to the McMullen method (McMullen, 1960). Sucrose content was determined by following the Dische's anthrone method (Dische, 1962) at 627 nm. The estimation of inorganic phosphorus content was done with the formation of a Rhodamine B-Phosphomolybdate Complex method at 555 nm (Debruyne, 1983) and magnesium content was estimated by using Eriochrome Black T method (Anonymous, 2014). All parameters were measured using spectrophotometer with their respective absorbance. The collected data were analyzed by using the statistical package SPSS statistics 17.0. Pooled analysis of the two years data was made following the recommendation of Gomez and Gomez (1984)

3. RESULTS AND DISCUSSION

3.1. Growth parameters

The maturity of rubber tree was determined by its growth and rate of expansion of the canopy and ultimately attainment of the tappable girth. All the growth parameters were studied for two years and it was revealed that among all the rubber clones RRII 430 shows its superiority with respect to girth increment at height of 10 cm and 125 cm, total number of leaf flushes in a year, and crown radius increment (cm). Highest percentage of clones that attained tappable girth for test tapping at 10 cm height above bud union was recorded in clone RRII 430 (25%) followed by RRII 429 (24%), RRII 414 (18%), RRIM 600 (17%) at the age of six years and lowest girth was found in RRII 105 (16%) irrespective of the cropping system (Figure 1). It was conformity with the study of Meenakumari et al., 2018 and found that RRII 430 was the first clone to reached tappable girth with 89% in the non-traditional rubber region among the others clone in Bhubaneswar due to its better adaptability. The maximum number of plants under intercropping reached tappable girth earlier due to continuous good management of the intercrops.

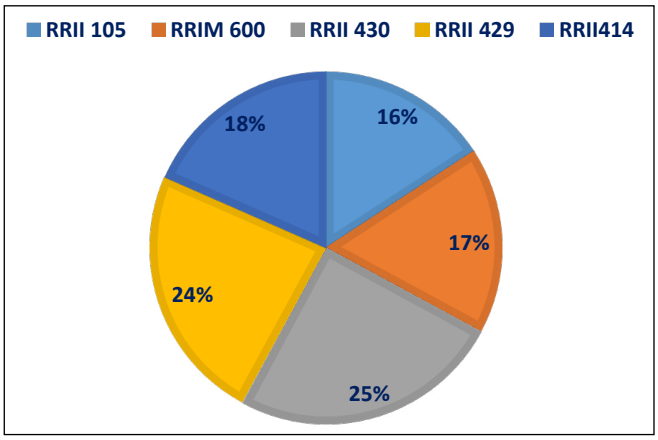

Figure 1: Percentage of plant attained tappable girth at 10 cm above bud union

Clone RRII 430 showed remarkable performance in plant growth parameters, with the highest average number of flushes (3.10), increased crown radius (144.83 cm), girth increment at 10 cm height (10.32 cm), and at 125 cm tappable height (9.17 cm) among five different clones studied. Table 1 showed that clone RRII 429 performed similarly to RRII 430 overall, but was surpassed by clone RRIM 600 in number of flushes (2.89 vs 2.23). While RRII 414 had the lowest number of flushes (1.80), similar trends were observed in other growth parameters like crown radius increment (104.41 cm) and an increase in girth at both 10 cm and 125 cm, with measurements of 8.45 cm and 7.02 cm respectively. Clones grown in various cropping systems have displayed a beneficial effect on growth metrics. Rubber plants in intercropping had the highest number of leaf flushes (2.75) as well as an increase in crown radius (150.33 cm) and girth increment at 10 cm (9.81 cm) and 125 cm (8.35 cm) compared to plants grown as sole crops. Likewise, the interaction effect of clone RRII 430 with annual intercrop with French bean and elephant foot yam showed significant positive results compared to clone RRII 429 under sole cropping. The exceptional results of clones in intercropping with annual crops may be attributed to the consistent intercultural practices and management employed in a successive cropping method. The highest amount of leaf growth cycles shows the highest level of photosynthesis and sugar supply, causing the plant's crown radius and girth to expand quickly as it provides necessary energy and nutrients for girth increment. Even though the cropping system was applied in the same manner for all five clones,

Table 1: Growth parameters of different rubber clones under different cropping system

Treatment	No. of leaf flushes/Year			Increased in crown radius year^{-1} (cm)			Increment in girth at collar region year^{-1}			Increment in girth at tappable height year^{-1}		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
V_1	2.24	2.22	2.23	137.87	113.99	125.93	8.02	9.82	8.92	7.95	7.16	7.55
V_2	2.68	3.09	2.89	143.16	119.44	131.31	8.14	9.96	9.05	7.97	7.57	7.77
V_3	3.16	3.04	3.10	151.38	138.30	144.83	8.53	12.12	10.32	9.65	8.68	9.17
V_4	2.69	2.81	2.75	148.71	125.77	137.23	8.38	11.43	9.91	8.63	7.98	8.30
V_5	1.73	1.87	1.80	108.04	100.78	104.41	7.85	9.05	8.45	7.03	7.00	7.02
SEm±	0.04	0.06	0.04	0.80	0.21	0.39	0.11	0.12	0.08	0.09	0.09	0.07
CD (p=0.05)	0.13	0.16	0.11	2.30	0.60	1.13	0.32	0.34	0.24	0.25	0.26	0.19
I_0	2.70	2.07	2.39	127.91	106.76	117.33	7.81	9.68	8.75	7.73	7.25	7.49
I_1	2.74	2.75	2.75	159.28	141.40	150.33	8.57	11.06	9.81	8.81	7.90	8.35
I_2	2.06	3.00	2.53	126.32	110.80	118.56	8.17	10.68	9.43	8.20	7.88	8.05
SEm±	0.03	0.04	0.03	0.62	0.16	0.31	0.09	0.09	0.07	0.07	0.07	0.05
CD (p=0.05)	0.10	0.13	0.09	1.78	0.47	0.87	0.24	0.26	0.19	0.19	0.20	0.15

Table 2: Interaction effect of growth parameter on different rubber clones under different cropping systems

Treatment	No. of leaf flushes year^{-1}			Increased in crown radius year^{-1} (cm)			Increment in girth at collar region year^{-1}			Increment in girth at tappable height year^{-1}		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
V_1I_0	2.44	2.04	2.24	122.38	105.00	113.70	7.58	9.48	8.53	7.05	7.08	7.06
V_2I_0	2.85	2.86	2.86	131.21	107.09	119.15	7.71	9.58	8.64	7.36	7.19	7.28
V_3I_0	3.45	2.00	2.73	138.21	117.56	127.88	8.13	11.15	9.64	9.39	7.93	8.66
V_4I_0	2.89	2.23	2.56	139.28	108.71	123.98	8.10	9.78	8.94	8.40	7.15	7.78
V_5I_0	1.89	1.23	1.56	108.46	95.42	101.95	7.55	8.41	7.98	6.45	6.93	6.69
V_1I_1	2.44	2.19	2.32	161.00	129.58	145.28	8.53	10.03	9.28	8.53	7.15	7.84
V_2I_1	2.89	3.41	3.15	164.68	134.92	149.80	8.55	10.18	9.36	8.95	8.18	8.57
V_3I_1	3.45	3.43	3.44	170.56	176.00	173.28	8.85	12.90	10.88	9.83	8.72	9.28
V_4I_1	3.01	2.54	2.78	167.83	149.67	158.73	8.80	12.30	10.55	9.38	8.58	8.98
V_5I_1	1.89	2.21	2.05	132.33	116.83	124.58	8.10	9.90	9.00	7.35	6.85	7.10
V_1I_2	1.83	2.44	2.14	130.25	107.39	118.80	7.95	9.95	8.95	8.27	7.25	7.76
V_2I_2	2.31	3.00	2.66	133.60	116.30	124.98	8.15	10.13	9.14	7.60	7.35	7.48
V_3I_2	2.59	3.68	3.13	145.35	121.33	133.35	8.60	12.30	10.45	9.75	9.40	9.58
V_4I_2	2.17	3.67	2.92	139.04	118.92	128.98	8.25	12.20	10.23	8.10	8.20	8.15
V_5I_2	1.42	2.19	1.81	83.34	90.08	86.70	7.90	8.85	8.38	7.30	7.22	7.26
SEm±	0.08	0.10	0.07	1.39	0.36	0.68	0.19	0.21	0.14	0.15	0.16	0.12
CD (p=0.05)	N/A	0.28	0.19	3.98	1.04	1.95	N/A	0.59	0.41	0.43	0.45	0.34

*Clones: V_1: RRII 105; V_2: RRIM 600; V_3: RRII 430; V_4: RRII 429; V_5: RRII 414; Cropping system: I_0: sole crops; I_1: Intercropping with annual crops; I_2: Intercropping with perennial crop

RRII 430 displayed its superiority because of its exceptional adaptability and response to micro environmental condition of the region. Many commercially significant food crops, including annual vegetables, peanuts, bananas, cassava, pineapples, chili, and maize, were frequently interplanted with rubber when they were still in their juvenile stages (Langenberger et al., 2017). Prior research had also shown that the growth of rubber plants can be affected by the practice of intercropping, resulting in earlier maturity compared to growing them as a sole crop (Rosyid et al., 1997; Rodrigo et al., 2005). Meenakumari et al. (2018) and Das et al. (2015) found similar results on the growth characteristics of various rubber clones in Bhubaneswar a non-traditional rubber-growing region. The research demonstrated that RRII 430 and RRII 429 had a higher maximum girth increment than the clones RRIM 600 and RRII 105. Das et al. (2015) and Das et al. (2014) have also evidenced the superiority of RRII 429 with respect to girth increment compared to clone RRII 105 and RRIM 600.

3.2. Latex Physiological parameters

The latex physiological parameters of different rubber clones expressed their significant variability with respect to their annual average contents. RRII 105 recorded significantly high average dry rubber (DRC content (40.28%) and lowest in RRII 429 (33.24%). On the other hand, different cropping system also significantly influenced the DRC content, with sole cropping (I_0) being the highest (38.76%). Constant water management practices followed under intercropping system leading to decrease in average DRC content as evidenced by Mak et al. (2008).

The highest TSC% content was found in RRII 430 (68.43%), with RRII 429 close behind at 67.28%, both slightly exceeding the recommended TSC content range of 30–60% (Tillekrayne et al., 1989). The elevated TSC level indicates that the laticiferous system was functioning well in producing rubber and regenerating latex (Jacob et al., 1989). RRIM 600 and RRII 105 had statistically similar minimum TSC% content, with RRIM 600 at 64.56% and RRII 105 at 65.07%. Intercropping had no major impact on TSC levels, indicating that it does not affect the total solid content, and instead relies more on latex flow rate and climate conditions.

The information presented in table 3 shows the mean levels of thiol (R-SH), inorganic phosphorus (Pi), sucrose, and magnesium ion (Mg^{2+}) in latex from various rubber clones. The rubber clones RRIM 600, RRII 414, and RRII 429 had varying thiol content levels, with RRIM 600 having the highest at 0.528 mm l^{-1}, followed by RRII 414 at 0.483 mm l^{-1}, and the lowest recorded in RRII 429 at 0.464 mm l^{-1}, which falls within the safe range of 0.04–1.00 mm l^{-1}, as stated by Purwaningrum et al. (2019), indicating their safety. Additionally, RRIM 600 was found to have the highest average levels of inorganic phosphorus (33.04 mm l^{-1}) and sucrose (6.89 mm l^{-1}) compared to other varieties. Pi and sucrose levels in latex have a mutually beneficial relationship. Elevated levels of Pi can enhance sucrose metabolism, leading to a rise in latex production (Roux et al., 2000). The lowest levels were seen in RRII 430 (29.23 mm l^{-1}) and RRII 105 (6.25 mm l^{-1}), regardless of the amount of Pi and sucrose present. Vinod (2001) also

Table 3: Pooled data on the latex physiological parameters of different rubber clones under different cropping system

Treatment	DRC %	TSC %	Thiol (mm l^{-1})	Inorganic phosphorus (mm l^{-1})	Sucrose (mm l^{-1})	Magnesium (%)
V_1	40.28	65.07	0.475	31.65	6.25	0.037
V_2	35.99	64.56	0.528	33.04	6.89	0.031
V_3	38.31	68.43	0.474	29.23	6.56	0.026
V_4	33.24	67.28	0.464	27.89	6.47	0.030
V_5	38.41	65.90	0.483	27.34	6.46	0.035
SEm±	0.25	0.28	0.004	0.18	0.05	0.001
CD (p=0.05)	0.71	0.80	0.012	0.50	0.14	0.002
I_0	38.76	66.29	0.476	29.40	6.23	0.031
I_1	36.52	66.27	0.489	30.00	6.65	0.032
I_2	36.45	66.19	0.491	30.09	6.69	0.032
SEm±	0.19	0.22	0.003	0.14	0.04	0.000
CD (p=0.05)	0.55	NS	0.010	0.39	0.11	NS

*Clones: V_1: RRII 105; V_2: RRIM 600; V_3: RRII 430; V_4: RRII 429; V_5: RRII 414; Cropping system: I_0: sole crops; I_1: Intercropping with annual crops; I_2: Intercropping with perennial crop

pointed out that the sucrose levels in RRII 105 were lower compared to those in other clones. Handling magnesium levels averaged was significantly expressed in Mg^{2+} content and was highest in RRII 105 (0.031%) and lowest in RRII 430 (0.026%). Beadle and Steven (1913) also mentioned in their study that Mg^{2+} % in field latex was around 0.02% while Belmus (1947) stated that the concentration of field latex was about 0.002%. Regarding thiol, Pi, and sucrose content, rubber plants grown under intercropping with annual and perennial crops observed difference within a very narrow range compared to each other. While the magnesium levels in rubber plants were unaffected by varying cropping systems, it was noted that rubber plants with lower sucrose content had higher DRC content.

3.3. Impact of economy of intercropping

The economics of intercropping under different rubber clones had been presented in table 4. Perusal of the data shows that gross income and net income had revealed preeminence towards the additional income generation under rubber clones at juvenile phase. Table 4 expressed about the economy of annual intercrops (French bean, Elephant foot yam and Okra) and perennial intercropping (pineapple) with the rubber clones. The data revealed that there were no significant differences in net returns among the different rubber clones with pineapple yield. The maximum gross (₹ 243323.00) and net returns (₹ 64918.00) were procured in pineapple yield as intercropping under the clone RRII 414 followed by yield under clone RRII 105. The benefit cost ratio (B:C) was 1.36:1 showing profitability of pineapple intercropping under rubber clones at juvenile phase. Rajasekharan (1989) also recorded benefit cost ratio of 2.25:1 after cultivating pineapple as intercropping with rubber plant at juvenile phase in some parts of Kottayam district.

Whereas the yield procured from intercropping with annual crops such as French bean, elephant foot yam and okra have enumerated more yield kg ha^{-1} than the perennial crops. Similarly, the benefit cost ratio (B:C) i.e., 2.34:1 was recorded highest in intercropping under clone RRII 414 with highest gross (₹ 448508.90) and net returns (₹ 257115.00). The present studies signify that intercropping with shade loving annual and perennial crops under rubber clones at juvenile phase extort surplus monetary help as the rubber plant had long gestation period. Mehta et al. (2022) also noted that intercropping with rubber plantation had benefited the farmers of Tripura than the sole crop in many aspects.

Table 4: Benefit cost ratio with annuals and perennial as intercrops under rubber-based cropping system grown

Clones	B:C ratio	
	Intercropping with annual crops (French bean, elephant foot Yam, Okra)	Intercropping with perennial crops (Pineapple)
RRII 105	2.19:1	1.36:1
RRIM 600	2.19:1	1.34:1
RRII 430	2.04:1	1.34:1
RRII 429	2.15:1	1.32:1
RRII414	2.34:1	1.36:1

4. CONCLUSION

The clone RRII 430 showed preeminence in growth parameters followed by RRII 429 and RRII 414 and had out performed RRII 105. However, RRIM 600 proved its superiority in terms of latex physiological parameters. The positive impact of intercropping on growth parameters was observed in various rubber clones due to continuous management practices followed in different intercrops. The research also revealed that intercropping had minimal effects on latex physiological parameters, but did not have a significant impact on TSC and magnesium content.

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