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Latex yield variation among *Hevea brasiliensis* clones grown under the agro-climate of South-West Ethiopia

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ABSTRACT

Hevea brasiliensis is the primary commercial source of natural rubber in the world and its latex is a source for many industrial inputs. The latex yield potential of rubber tree plantations has been lower than the estimated potential due to latex yield variation among rubber tree clones. Nine introduced and one indigenous *Hevea brasiliensis* clones were evaluated in Ethiopia Guraferda district from July 2018 to May 2020 to determine which clones provide a better latex yield for future rubber tree plantations. Ten *Hevea brasiliensis* clones were evaluated with ten trees of the same age selected randomly from the same plantation site for each clone. The latex yield was significantly varied both from clone to clone and from month to month during the study period. Mixed, RRIC101, and Malawi clones of *Hevea brasiliensis* produced the highest latex yield, whereas the TOLIK.B clone had the lowest. The highest average latex yield was obtained in June, which has a high rainfall with moderate temperature. The results of this study indicate that latex yield potential could be increased by mass planting of rubber tree clones which give more yield and resistance to diseases.

1. Introduction

Rubber tree latex is used to make a variety of items, including tires, washers, gloves, gaskets, and waterproof clothing (Pinizzotto et al., 2021; Vrignon-Brenas et al., 2019). The largest single use of rubber tree latex is in the manufacturing of pneumatic tires, which accounts for more than half of global rubber latex production each year (Hayashi, 2009). Among economically valuable rubber-producing species, *Hevea brasiliensis* provides the raw material for the 99% of the global natural rubber production (Arias and van Dijk, 2019). Latex tapping begins in five to seven years after the date of planting, and it could last 30 to 35 years or longer, depending on applied practices of management (Carr, 2012; Nizami et al., 2014; Qi et al., 2016). Once latex yield declines, the rubber tree can be used as a timber source, reducing the need for deforestation for timber (Brahma et al., 2016; Nizami et al., 2014; Pinizzotto et al., 2021). In addition, the rubber seed is also a valuable non-edible oil source for biodiesel production (Bharadwaj et al., 2019; Sugebo et al., 2021).

Rubber latex yield varies among clones due to genetic variability, anatomical variations, and climate conditions (Pethin et al., 2015; Purwaningrum et al., 2019; Rao et al., 1998). Maximum senescence, nonoptimal temperature ranges for rubber tree plantation, and reduced precipitation can influence latex dilution reactions, altering plant metabolism and influencing the polyisoprene biosynthetic process (Raj et al., 2005). Furthermore, soil physicochemical properties have a significant impact on the tree's growth performance, and soil compaction restricts taproot growth and penetration, which could increase wind throws and damage (Dea et al., 2001).

In Ethiopia natural rubber production has not been given enough attention, despite the fact that it has been growing in various parts of the country (Ethiopian Investment Agency, 2012). According to report of the National Bank of Ethiopia for the fiscal year of 2020/2021, Ethiopia imported 111,569.5 metric tons of rubber products from several countries during 2019/2020, spending 7,698,856,0000 ETB (Ethiopian Birr). The country's demand of natural rubber destined for the manufacture of automotive rubber tires and footwear products is reliant on competitively imported raw rubber about 99%. In the year 2020, the Guraferda's District Rubber Trees Plantation Development Project Office, which is the most potent natural rubber producing district in Ethiopia, reported 350 tons of dry latex harvested from its plantation of 3000ha. The latex yield from the plantation in the district is very low when compared to theoretically achievable latex yield of 7000−12,000 kg/hectare/year as

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described by Ali et al. (2020). In addition, the latex yield from the rubber plantation in Ethiopia seems quite low when compared to yields obtained in other rubber latex producing countries (Adou et al., 2018; Meenakumari et al., 2018; Qi et al., 2016; Seneviratne et al., 2020). Despite of the country's good agro-ecological potential of rubber tree plantations, the lower yield in Ethiopia is an indication of an enormous challenge for endeavors aimed availing local supply of raw materials needed to meet the demand of rubber processing industries.

Therefore, an attempt was made to introduce and test the adaptability of the *Hevea brasiliensis* clones in Ethiopia. Currently, about 12 clones of *Hevea brasiliensis* are found on a plantation within Guraferda district. Majority of those cloned planting materials were obtained from Côte d'Ivoire and Far East countries like Srilanka and Malaysia. The clones have been considered as key contributor to the improvement of rubber tree latex yield in the country through tree improvement programs made via breeding. Characterization and evaluation of latex yield of existing clones is considered to be essential for future establishment and expansion of planted *Hevea brasiliensis* in the district. Therefore, the aim of this study was to identify and determine high-yield clones of *Hevea brasiliensis*, with the goal of expanding rubber tree plantations firstly in the Guraferda district and ultimately in other parts of the country with comparable agro-ecology.

2. Material and methods

The study was conducted in Bench-Sheko Zone in Guraferda District from July 2018 to May 2020. It is located at 34°10′0" and 35°40′0" E Latitude and 6°30′0" to 7°10′0" N Longitude (Fig. 1), the topography of the plantation site ranging from 900 to 1000 m a.s.l. Annual sunshine hours of the district are not less than 2000 h (Ethiopian Investment Agency, 2012).The average monthly maximum and minimum temperatures in the district are 32.71 °C and 15.83°C, respectively (Fig. 2). It receives a mean annual rainfall of 1862.9mm with 154 evenly distributed rainy days throughout the year (Ethiopian Investment Agency, 2012). The district has a unimodal rainfall pattern, with peak in May and low in January (Fig. 3). The soil type is Nitisols, which has a loam to clay texture and with strong to moderate acidity (Betemariyam et al., 2022; Girma and Sisay, 2020). The soil is also relatively well weathered and well drained (Betemariyam et al., 2022; Girma and Sisay, 2020). Rubber tree prefers a good stiff loamy soil with good subsoil drainage, but will thrive on clay, alluvial soils and even on hard gravelly soil (Hazir et al., 2020). Rubber tree can not tolerate salt and will not grow on land liable to frequent flooding with sea-water (Hazir et al., 2020). *Hevea brasiliensis* grows best in places with mean annual temperature ranging from 25 to 28°C and rainfall above 1500 mm, with cooler, drier, or both conditions in marginal areas, and acidic soils (pH 4.5–5.5) (Pinizzotto et al., 2021).

Five hundred (500) trees were planted in a hectare of land with a spacing of 3 m and 6 m between trees and rows, respectively. Di-ammonium Phosphate (DAP) and urea fertilizers were applied early in the rainy season at the rate of 260g and 350g, respectively, per tree per year. Reports indicate that the combined application of urea and DAP increases the latex yield (Onuwaje, 1983; Perron et al., 2021). Selected trees of each clone were assured to be of the same age, nearly of the same diameter at 1.3 m (diameter at breast height), without any previous stimulation, located within the same plantation, free from any diseases or pests and with the same planting history (Raj et al., 2005; She et al., 2013). From each clone (Table 1), were selected ten rubber trees of nearly ten years of age. The system of tapping followed on all cloned trees was a spiral cut made in the bark of each tree on every alternate day (1/2Sd/2 system) (Raj et al., 2005). Selected trees of each clone were tapped early in the morning (6:00 am), due to higher phloem turgor pressure during the early morning period (An et al., 2014). Volume of the collected latex was determined using a measuring cylinder once latex flow has completely ceased (nearly in four hours). Clonal latex yield was recorded in milliliter per tree per tapping (ml/t/t). Latex had been collected throughout the years except for a month break in March. At the same time, visual inspections had been performed so as to detect any incidence of a disease. Tapping break was made when the trees started to shed leaves (defoliate) in March due to reduced moisture content of the soil and high solar radiation (Gutiérrez-Vanegas et al.,

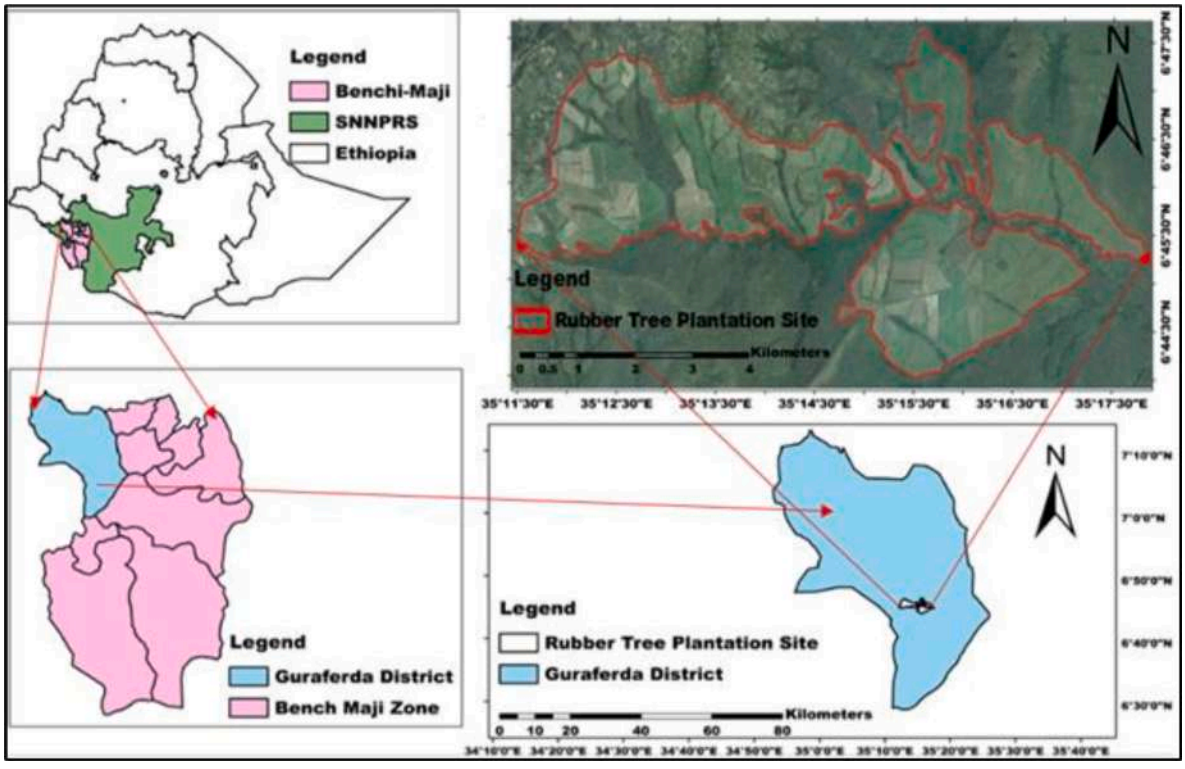

Fig. 1. Location of the District and site of the plantation of *Hevea brasiliensis* (Rubber tree).

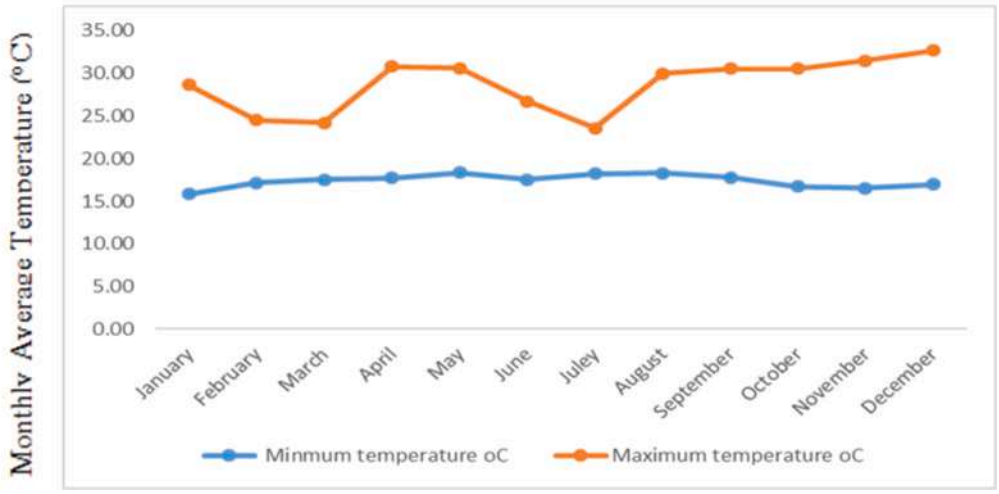

Fig. 2. The monthly minimum and maximum temperatures of the District during the study period of 2018 to 2020.

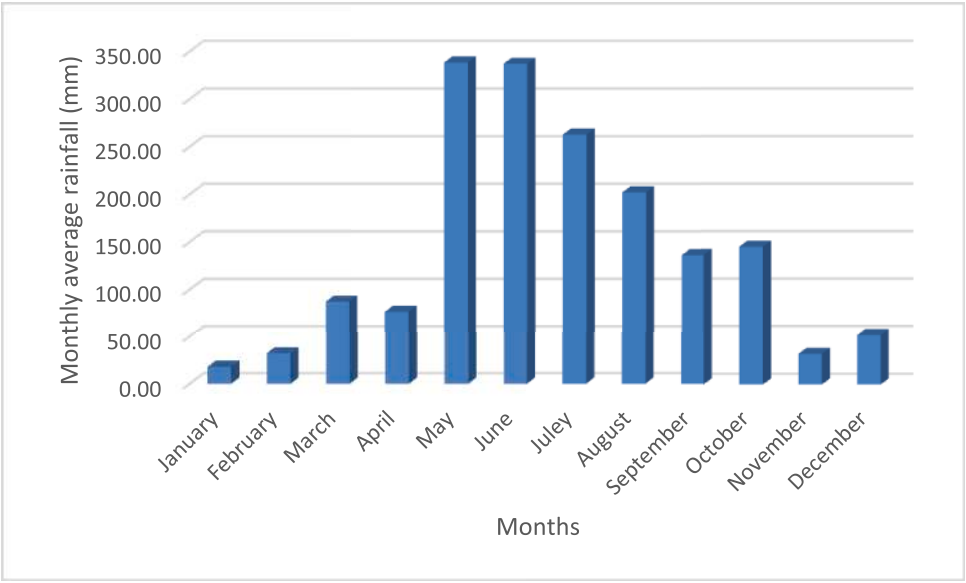

Fig. 3. Monthly average rainfall of the district during the study period of 2018 to 2020.

Table 1
List of the rubber tree clones selected for the study.

No	Clone name	Origin
1	Mixed (Breed of GT-1 with clone Malawi)	Indonesia and Malawi
2	RRIC101	Côte d'Ivoire
3	Malawi	Malawi
4	RRIC100	Côte d'Ivoire
5	RRIC102	Côte d'Ivoire
6	PB2859	Malaysia
7	RRIC121	Côte d'Ivoire
8	PB86	Malaysia
9	GT-1	Indonesia
10	TOLIK.B	Ethiopia

2020). It was resumed in April after the next refoliation when the new flush of leaves matured.

The meteorological data was obtained from Ethiopian Meteorological Agency. The data was analyzed using SPSS version 24 using analysis of variance (ANOVA) with Tukey's multiple comparison tests at $p \leq 0.05$.

3. Results and discussion

The latex yield was significantly different among rubber tree clones, across tapping months, and a significant interaction effect was observed between clones and months of tapping (Table 2). The rubber tree clones

Table 2
Analysis of variance of latex yield from rubber tree clones.

Source	Type II Sum of Squares	df	Mean Square	*F*	Sig.
Corrected Model	1530517.830[a]	109	14041.448	4.250	.000
Intercept	6974618.113	1	6974618.113	2110.978	.000
Clone	556145.319	9	61793.924	18.703	.000
Month	542080.645	10	54208.064	16.407	.000
Month * Clone	432291.866	90	4803.243	1.454	.005
Error	3270934.849	990	3303.975		
Total	11776070.790	1100			
Corrected Total	4801452.680	1099			

a. R Squared = .319 (Adjusted R Squared = .244)

Mixed, RRIC101, and Malawi produced higher latex yield than the rest, with average yield of 123.90 ml/t/t, 96.46 ml/t/t, and 90.75 ml/t/t, respectively, in decreasing order. Intermediate latex yield was obtained from clones RRIC100, RRIC102, PB2859, and RRIC121 (Table 3). On the other hand, the rubber tree clones TOLIK.B, GT-1, and PB86 had lower latex yield than the rest. Some literature sources revealed that the rubber tree clones RRIC101 and RRIC103 produced more latex yield than the GT-1 and PB86 rubber tree clones (Binang et al., 2017; Samuel et al., 2005). A high level variation in the yield of latex among the clones could be due to respective variations in photosynthetic metabolic activities, the uptake of mineral and water owing to unique root system, the resistance to moisture stress, coagulation at the level of tapping incision made, genetic variability, and resistance to changes in temperature (Ping, 2012; Priyadarshan et al., 2009). The variation in latex yield that was observed among rubber tree clones may be related to differences in phloem turgor pressure within clones as reported in An et al. (2014). In addition, Pethin et al. (2015), reported that the main variation observed in the yield latex among rubber tree clones were results of anatomical differences as the density of latex conducting vessels varied greatly among clones and with age (Carr, 2012; Pethin et al., 2015).

When compared to yields obtained in other countries with comparable agro-ecologies, the Guraferda district average latex yield from rubber clones is quite low (Adou et al., 2018; Meenakumari et al., 2018; Qi et al., 2016; Seneviratne et al., 2020). The lower latex yield in the district could be due to provenance, slivicultural management and tapping techniques. Adou et al. (2018) reported that, rubber clones RRIC100 and GT-1 gave yields of 2565 kg/ha/year and 1955 kg/ha/-year, respectively, in Côte d'Ivoire. In addition, clone RRIC100 yielded an average latex volume of 280.69 ml/t/t in india as reported by Meenakumari et al. (2018). Yield of latex could be improved through propagation of high-quality genetic material, with resistance to disease and decreased juvenile period (Puttaso et al., 2020; Samuel et al., 2005; Sterling et al., 2019; Gitz et al., 2020).

Month to month variations in the yield of latex were observed due to seasonal variations existing in the district. A high mean latex yield was obtained in June, September, July, and August, with the highest yield being 121.848 ml/t/t in June (Table 4). High latex yield months may correspond to adequate rainfall precipitations revived in those particular months having moderate solar radiation (Figs. 2 and 3). January, February, March, and December are very low-rainfall and high solar radiation months in the district (Figs. 2 and 3), resulting in a corresponding low latex yield (Table 4). The observed lower yields are consistent with previous reports which attributed the effect to unfavorable weather conditions (Chantuma et al., 2017; Hazir et al., 2020). In addition, the observed significant interaction of latex yields of clones with months of tapping is an indication of the importance of both factors for the yield of latex (Kunjet et al., 2013). The superior-yield clones such as Mixed, RRIC101, and Malawi, as well as intermediate and lower yielded clones, showed lower latex yield performance in the dry season, indicating that the clones could be influenced by weather change. During the data collection period, no trees within the latex collecting trees showed morphological symptoms of disease.

Generally, results of this study indicate the good prospect for the large-scale planting of the clone that performed better in terms of obtain yields of latex so that locally sourced raw material can be supplied to the Ethiopian tires and various items manufacturing industries. Furthermore, the rubber tree clones those with a high latex yield have a potential to mitigate climate change and environmental conservation, particularly if planted on degraded areas, by sequestering carbon emissions during their long rotation periods (Brahma et al., 2016; Dong et al., 2013; Nizami et al., 2014). Additionally, a double or single row intercropping of high-latex-yielding rubber tree clones with fruit crops, vegetables, legumes, perennial crops, coffee, and with trees which have canopy not exceeding height of the rubber trees can improve the economic performance and reduce the need for additional land clearance for food production (Huang et al., 2020; Langenberger et al., 2017; Pinizzotto et al., 2021; Gitz et al., 2020).

Table 3
Comparisons of the means of latex yields among clones.

Clone	Mean yield ml/t/t	Std. deviation
Mixed	123.909a	48.18
RRIC101	96.459^{b}	44.73
Malawi	90.748^{cbdeg}	82.06
RRIC100	83.757^{dcbfg}	34.35
RRIC102	$82.468^{efdcbhg}$	32.14
PB2859	78.929^{fdehg}	50.02
RRIC121	77.935^{gfech}	23.21
PB86	67.952^{hgfei}	18.87
GT-1	61.236^{i}	25.86
TOLIK.B	32.883^{j}	17.65

Values with the same alphabets are not significantly different from each other at $p \leq 0.05$

Table 4
Mean differences of latex yield among months'.

Month	Mean yield ml/t/t	Std. deviation
January	54.992	16.48
February	37.943	9.23
April	56.644	38.31
May	79.720	16.39
June	121.848	44.54
July	93.351	38.21
August	92.288	37.68
September	95.503	88.68
October	86.480	29.76
November	86.173	31.58
December	70.962	30.79

4. Conclusion

The rubber tree clones Mixed, RRIC01, and Malawi produced a better latex yield per tree per taping than other seven clones in the district of Guraferda. The maximum mean latex yield was obtained in June, September, July, and August, with a peak of 121.848 ml/t/t in June, which is the wet season in the district with moderate solar radiation. Better latex yield clones should be planted in Guraferda so as to improve the existing poor performance in the latex yield. It is commendable to foster adaption of other high latex yielding clones that are suitable for the location in addition to application of adequate silvicultural management practices and improved tapping methods.

Data availability

The data used to generate the results in the paper are available and, if so, the data required we can access it.

Author's contributions

The contribution of the first author was on problem identification, data collection, data interpretation and in preparation of the draft manuscript.

The contribution of the second author was on data interpretation and draft manuscript development.

The contribution of the third author was on data collection and editorial.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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