SEASONALITY IN RUBBER YIELD AND PRICE AND RATIONAL TAPPING DECISION

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Latex yield from Para rubber (*Hevea brasiliensis* Muell. Arg.) is highly sensitive to the prevailing ambient weather conditions and exhibits seasonal variations in the different agro-climatic regions where it is cultivated. Monthly share of latex yield of 260 clones from 24 field trials conducted by the Rubber Research Institute of India in four locations in the traditional region (Central and North Kerala, Kanyakumari district in Tamil Nadu and South West Karnataka), four in North and North East India (Assam, Meghalaya, Tripura and West Bengal) and two locations in Central India (Maharashtra and Odisha) was examined from published sources to identify the lean and high yielding months/seasons in each region. The traditional region experienced a productive period of 10 months which was reduced to eight months in Central and NE India due to varying stresses. The average yield during the three lean months from February to April in all three regions was to the tune of 15 per cent of the total annual yield. Price of rubber remained largely insensitive to monthly yield variations. The study throws light on how to regulate tapping by growers in each region by skipping of tapping in the extremely low yielding months and harvesting maximum yield in the high yielding months rather than abstaining from tapping altogether under low price situations.

Keywords: *Hevea brasiliensis*, Lean yield, Peak yield, Price, Region, Seasonality, Tapping rest

INTRODUCTION

Production of latex from *Hevea brasiliensis* in India follows a regular, predictable and repetitive seasonal pattern every year which closely tracks the intra-annual rhythms in weather, particularly temperature and rainfall (Rao *et al.*, 1998; Raj *et al.*, 2005; Raj and Dey, 2008; Satheesh and Jacob, 2011). Seasonality in rubber yield is more pronounced in regions that are away from the equator where distinct seasons exist. Regions experiencing more tropical or equatorial climate round the year will therefore see less seasonal variations in rubber yield than the subtropics or temperate regions where climatic conditions show more marked seasonal variations.

Compared to Malaysia, Thailand or Indonesia where the rubber growing regions share a more equitable climate, seasonality in yield is very pronounced in India where rubber is cultivated in more diverse climatic regions (Vijayakumar *et al.*, 2000). Traditional rubber growing regions of India (Western Ghats states) fall in the relatively tropical climate with less pronounced seasonal variations in climate, whereas rubber growing regions of North East (NE) Indian states (Sub-Himalayan states) have a more subtropical/temperate climate with more

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seasonal variations in temperature (Reju *et al*., 2007; Das *et al.*, 2013). Therefore, NE region is likely to show more seasonality in yield than the traditional regions. Physiological, biochemical (Sreelatha *et al.*, 2007; Sreelatha *et al.*, 2011) and molecular (Klaewklad, 2017; Wu *et al.*, 2018) factors associated with rubber biosynthesis that are sensitive to ambient weather conditions are responsible for seasonality in yield. These factors that are generally more active in high yielding clones are up-regulated during the high yielding compared to the low yielding season.

Seasonality in rubber yield will have a direct bearing on the supply chain and inventories (Veeraputhran *et al.*, 2017) with important implications for the industry. For growers, knowledge about seasonality of yield will help them make informed and economically rational decisions whether to tap or not when rubber price is low and non-remunerative for a given productivity.

In the present study, we have used long-term yield data from several field trials conducted at various regions of India, to show monthly trends in rubber yield that were closely associated with seasonal trends in agroclimate that prevailed in each region. There was no clearly discernible and corresponding seasonality in rubber price. We also discuss why and how growers should make the best use of information about seasonality of rubber yield and price to make economically rational decisions about tapping their holdings.

MATERIALS AND METHODS

An analysis of collated long-term data on monthly yield distribution was attempted from 24 statistically laid out large scale clone evaluation trials in 10 different locations across India representing all three major regions of rubber cultivation *viz*., the traditional region, the hot and dry regions of Central India and the cold-prone NE region. Seasonality trends in rubber yield were examined in time series yield data collected for 10-15 years from these field trials under S/2 d3 6d/7 system of tapping. The data came from 11 trials at four locations in the traditional region (Central and North Kerala, Kanyakumari district in Tamil Nadu and South West Karnataka), 11 trials at four locations in NE India (Assam, Meghalaya, Tripura and W. Bengal) and two trials in Central India (Maharashtra and Odisha). In the traditional region and Central India, yield data were available for all the 12 months. In the NE region, yield data for three to four months during the winter season were not available as the trees were under tapping rest during this period. Mean monthly share of yield to the annual yield was worked out for the three regions.

Mean monthly price of sheet rubber (RSS 4 in Kottayam market) was calculated for the period 2000-2019 and its seasonal variation index was worked out and compared with that of yield. The benefit-cost ratios (BCR) of harvesting rubber (*i.e.* operational profitability of mature rubber holdings) were estimated for different price and productivity scenarios during the peak and lean seasons and also during the rest of the year. For each tapping season BCRs under three different tapping systems *viz.* d2, d3 and d7 were worked out separately for the three rubber growing regions *viz.* traditional, Central and North East India. The yield scenarios considered were four, five and six kg tree^{-1} yr^{-1} for three price scenarios of Rs. 142, 150 and 160 kg^{-1}. In the analysis the cost included only the operational costs *viz.* tapping, rain guarding and processing costs and the revenue was estimated based on the annual average production and price.

RESULTS

Monthly yield contribution in different regions

Traditional region

At Central Experiment Station (CES), Chethackal representing Central Kerala which is also the rubber stronghold, March and April were the lowest yielding months with a cumulative yield contribution of eight per cent of the annual yield (Table 1). From May onwards, there was a gradual increase in yield, coinciding with both South West (SW) and North East (NE) monsoons. Kanyakumari district showed the most uniform distribution of yield round the year. April was the lone lowest yielding month which contributed only four per cent of the annual yield. The monthly yield trend in Padiyoor in North Kerala was very distinct from the rest of the traditional region with respect to two aspects *viz*. low yielding period with an extended dry summer season and a peak yielding season coinciding with the SW monsoon. The summer months of March, April and May were the lowest yielding months with a cumulative share of 15 per cent. The months of July, August and September were the highest yielding and there was a gradual decline in yield thereafter.

Moving further north towards the suboptimal D.K. district in South West Karnataka (Nettana), March and April were the lowest yielding months with a cumulative contribution of 12 per cent. The period from June to January contributed as much as 78 per cent of the annual yield across locations. Seasonal variations were less pronounced in Kanyakumari district followed by Nettana (Table 1). Growers in the traditional region are blessed with an extended productive period of 10 months with consistent high yield from June to January.

Central India

A prolonged hot and dry season of more than four months is common to the rubber growing western and eastern belts of Central India (Table 2). In Dapchari, Maharashtra (west) and Bhubaneswar, Odisha (east) April to July were the lowest yielding months with a cumulative share of 20 per cent. In Bhubaneswar, May and June produced the least yield share of four per cent each. The

Table 1. **Monthly yield contribution (%) from 11 trials across four locations in the traditional region**

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
CES Chethackal	8	5	4	4	6	10	11	10	10	10	11	11
Kanyakumari	10	6	6	4	6	9	9	10	9	9	10	11
Padiyur	8	6	5	5	5	9	11	12	11	10	10	9
Nettana	8	7	6	6	7	9	8	9	9	10	11	11
Mean	8	6	5	5	6	9	10	10	10	10	10	11

Table 2. **Monthly yield contribution (%) from two trials across two locations in Central India**

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Bhubaneswar	10	10	8	6	4	4	6	9	6	8	13	15
Dapchari	10	7	7	5	5	5	5	7	10	12	14	14
Mean	10	9	7	5	5	5	6	8	8	10	13	14

Table 3. **Monthly yield contribution (%) from 11 trials across four locations in NE India**

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Nagrakata	.	.	.	.	9	9	9	10	12	14	18	16
Assam	.	.	.	.	11	10	8	10	13	16	18	15
Agartala	9	.	.	.	7	8	8	8	10	13	17	15
Tura	11	.	.	.	9	8	8	9	11	14	16	14
Mean	8	.	.	.	9	9	8	9	12	14	17	15

productive period was only eight months (August to March) in both locations. The peak yielding months from October-January contributed nearly 50 per cent of the total share of yield. June and July were low yielding months only in the drought climate of Central India.

Northern West Bengal and North East India

May to December was the most productive period across all locations which included Northern West Bengal and the NE region (Table 3). Yield data for January was available only in two locations in NE region *viz*. Agartala and Tura and the corresponding data for Nagrakata and Assam were unavailable. The eight month period (May-December) showed two distinct yielding regimes *viz*. the period from May to August coinciding with monsoon which was steady but with relatively lower yield (35% of the annual) followed by the period from September to December with an ascending yield phase which contributed to 58 per cent of the yearly yield with the highest yield share in November (17%). Monthly yield variations were more pronounced in Agartala and the least in Assam.

Traditional *vs* non-traditional regions

Seasonality of yield was more conspicuous in the NE region and Central India. While the traditional region maintained a steady high yielding period from July to

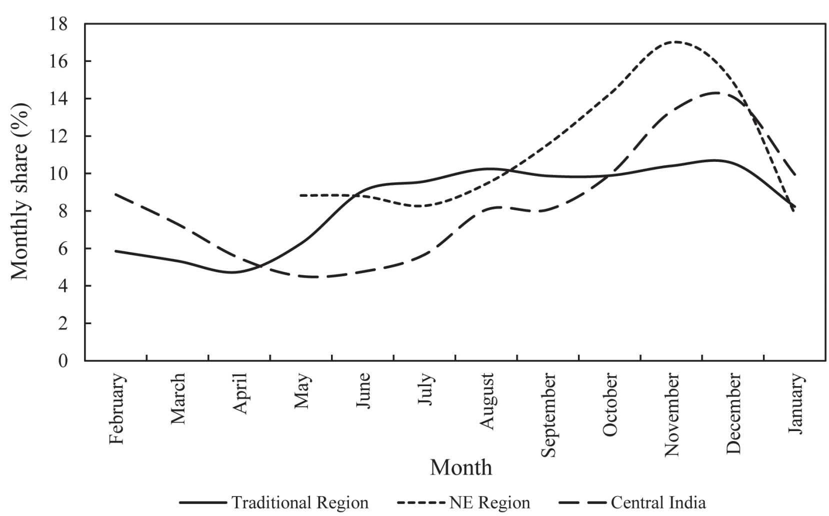

Fig. 1. Mean monthly yield (contribution %) in three different regions of India

December, the spectacular jump in yield in post monsoon period was very characteristic of the NE region (Fig.1). Central India showed a yield distribution pattern that was intermediary to the traditional and the NE regions. The lowest yield trend in the drought-affected regions of Central India during the lean months was compensated by an improved share of yield in the productive period which was better than the yield share of the corresponding months in the traditional region. Rising share of yield from July to December and a decline in January was observed across all locations. Among all regions, April was invariably the lowest yielding month. The lowest and highest yielding months in different regions of India are given in Table 4.

Seasonal yield variations in relation to weather

There were clear trends in the seasonality of rubber yield in the three regions *vis-a-vis* the prevailing weather conditions especially, temperature and rainfall (Fig. 2). Intra-annual temperature variations were less pronounced in the traditional region which recorded a mean of 29 and 26 ^{0}C during the lean and peak yielding periods, respectively. Precipitation ranged from 481mm in the lean months to 2889 mm in the peak monsoon (Fig. 2a).

In the eastern and west coast of Central India, the hottest months of March-May had a mean temperature 37 ^{0}C with rainfall as low as 0-132 mm. The winter season in Central India was cooler than the traditional region and slightly warmer than the NE states. A season of peak yield was evident during the cool months (October to January) preceding winter which was not as prominent as in the NE India, but markedly more than the traditional region. The mean temperature during the four peak yielding months was 24 ^{0}C with very low (183 mm) rainfall. Rainfall distribution was highly skewed with 2052 mm received between June to September during which season yield share was only 26 per cent (Fig. 2b).

In the NE region, a progressive increase in yield from May to December was observed. Seasonality of yield was the most pronounced in NE where 46 per cent of the annual yield could be harvested in the three

Table 4. **Lowest and highest latex yielding months in different regions of India**

Region	Most unproductive months with share of annual yield (%)	Most productive months with share of annual yield (%)
Traditional Region		
Central Kerala	Mar - Apr (8)	June - Dec (73)
Kanyakumari	April (4)	June - Jan (77)
North Kerala	Mar - Apr (10)	June - Dec (71)
South Canara	Mar - Apr (12)	June - Dec (67)
Central India		
Maharashtra and Odisha	Apr - June (15)	July - Jan (73)
NE Region		
Agartala and Meghalaya	Feb - Apr NA	May - Jan (100)
Assam and W. Bengal	Jan - Apr NA	May - Dec (100)

NA - Not available

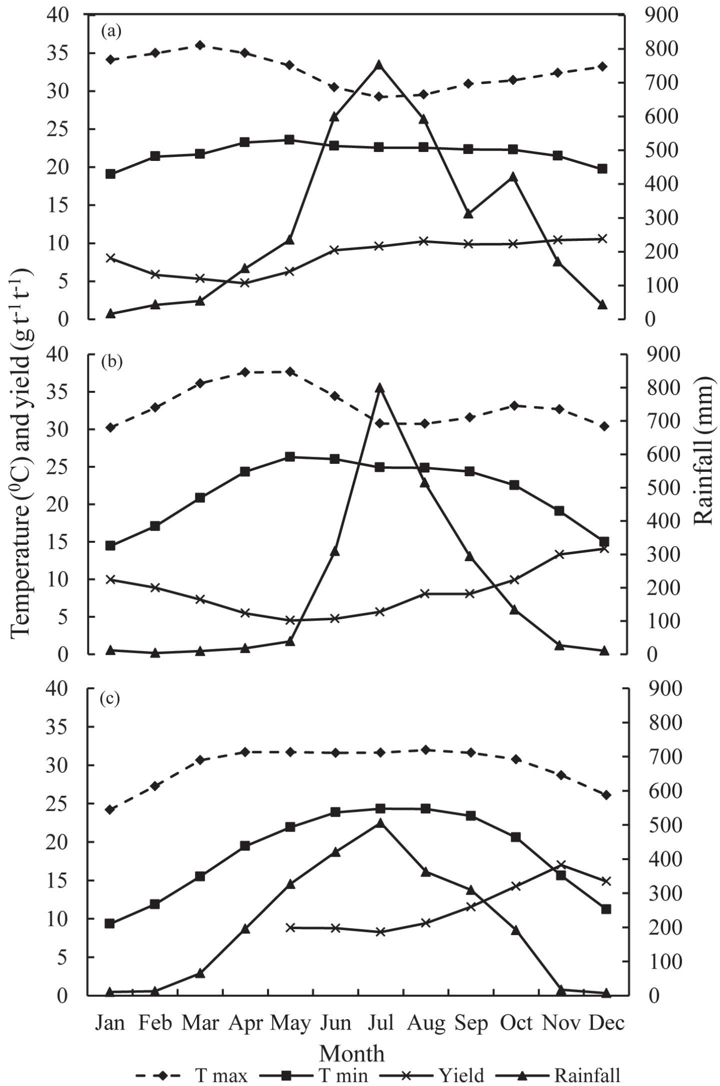

Fig. 2. Mean yield in relation to weather parameters in different rubber growing areas

cool pre-winter months of October to December (Fig. 2c). Rainfall pattern in NE region showed more uniform distribution than the Central India region. Maximum rainfall was received between May to September (1925 mm). The mean temperature during the peak (September-December) and low (January-April) yielding months were 23.5 and 21.3 ^{0}C respectively. Rainfall was 1287 mm in the monsoon period (June-August) and 525 mm in the post monsoon phase from September to December (Fig. 2c). Clearly, seasonality in rubber yield was more pronounced in the non-traditional regions

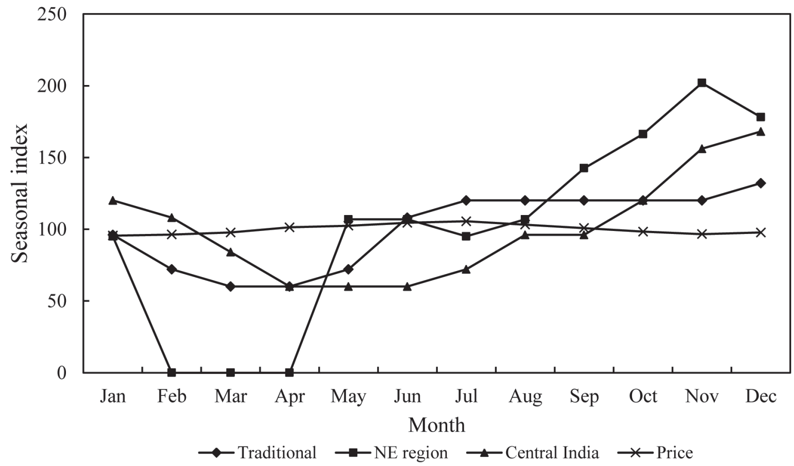

Fig. 3. Monthly share of yield in different rubber growing regions and corresponding price of rubber

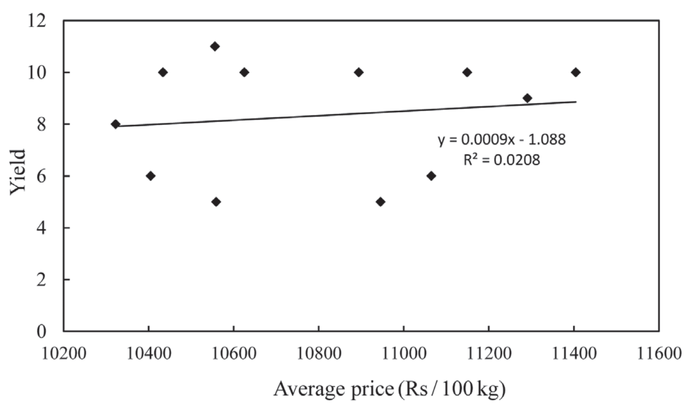

Fig. 4. Seasonal yield vs average price

where seasonal climate variation was more evident than the traditional regions.

Influence of monthly share of yield on the net income from rubber

While seasonality in yield was closely following seasonality of climatic parameters (temperature and precipitation), there was no clearly discernible trend in seasonality of price (Figs. 3 and 4). Generally speaking, when production is high, price is expected to be low. In the present instance, peak yielding and lean yielding seasons had similar prices. Compared to yield, seasonal index was the least for price indicating that the domestic rubber price remained largely insensitive to domestic production and other externalities such as imports might have had a major influence on the domestic rubber price (Veeraputhran *et al.*, 2017).

Since production was season-dependent and price was season-independent, BCR of rubber production (limited only to rubber tapping and routine cultural operations in a mature holding) showed a clear difference between the seasons. BCR of NR production during different seasons under different price and productivity scenarios is given in Tables 5-7. It can be seen that for all the three regions, BCR of tapping during peak season was above one (BCR>1) indicating that net revenue was higher than the operational cost with the annual average price of RSS 4 (Rs. 142 kg^{-1}) and productivity (1569 kg ha^{-1}). In the traditional region where the share of peak season (8 months) in annual production is 78 per cent, even under d2 tapping system and with a lower productivity of 1400 kg ha^{-1}, BCR was 1.78 during peak season. BCR increased to 2.44 and 3.59 when the tapping system was changed to d3 and d7 respectively. For Central India the peak season (4 months with 47% share in production) BCR were 1.91, 2.52 and 3.47 respectively for d2, d3 and d7 tapping systems, with 1400 kg ha^{-1} productivity and Rs. 142 kg^{-1} price. There is a clear improvement in BCR/profitability as productivity and NR price are high and this is further improved by resorting to d3 or weekly tapping. In the NE region where peak season extended only for four months with a share of 57 per cent production, the BCR for d2 tapping system was 2.28 for productivity of 1400 kg ha^{-1} and price of

Table 5a. **BCR in traditional region under different experimental and commercial productivity scenarios with price Rs. 142 kg^{-1} (Annual average price of RSS 4 in India during 2020-21)**

Tapping system	BCR											
	Peak season (78 % share)				Lean season (10 % share)				Rest of the year (12 % share)			
	Annual average yield (kg ha^{-1})											
	1400* (4 kg $tree^{-1}$)	1569**	1750* (5 kg $tree^{-1}$)	2100* (6 kg $tree^{-1}$)	1400* (4 kg $tree^{-1}$)	1569**	1750* (5 kg $tree^{-1}$)	2100* (6 kg $tree^{-1}$)	1400* (4 kg $tree^{-1}$)	1569**	1750* (5 kg $tree^{-1}$)	2100* (6 kg $tree^{-1}$)
d2	1.78	1.98	2.18	2.59	0.72	0.80	0.89	1.06	0.85	0.95	1.06	1.26
d3	2.44	2.70	2.97	3.47	0.91	1.01	1.13	1.34	1.08	1.21	1.34	1.58
d7	3.59	3.94	4.31	4.97	1.18	1.32	1.46	1.73	1.41	1.56	1.73	2.04

*Experimental yield; **Commercial yield

Table 5b. **BCR in traditional region under different price scenarios with productivity 1569 kg ha^{-1} (Annual average productivity in Kerala during 2020-21)**

Tapping system	BCR								
	Peak season (78 % share)			Lean season (10 % share)			Rest of the year (12 % share)		
	Price of RSS 4 (Rs. kg^{-1})								
	142 *	150 **	160 **	142 *	150 **	160 **	142 *	150 **	160 **
d2	1.98	2.09	2.23	0.80	0.84	0.90	0.95	1.01	1.07
d3	2.70	2.85	3.04	1.01	1.07	1.14	1.21	1.27	1.36
d7	3.94	4.16	4.44	1.32	1.39	1.49	1.56	1.65	1.76

*Annual average price of RSS 4 in India during 2020-21; **Assumed prices

Table 6a. **BCR in Central India region under different experimental and commercial productivity scenarios with price Rs. 142 kg^{-1} (Annual average price of RSS 4 during 2020-21)**

Tapping system	BCR											
	Peak season (47% share)				Lean season (21% share)				Rest of the year (32 % share) (Aug-Sep & Feb-Mar)			
	Annual average yield (kg ha^{-1})											
	1400* (4 kg tree^{-1})	1569**	1750* (5 kg tree^{-1})	2100* (6 kg tree^{-1})	1400* (4 kg tree^{-1})	1569**	1750* (5 kg tree^{-1})	2100* (6 kg tree^{-1})	1400* (4 kg tree^{-1})	1569**	1750* (5 kg tree^{-1})	2100* (6 kg tree^{-1})
d2	1.91	2.12	2.34	2.75	0.90	1.00	1.11	1.32	1.34	1.49	1.65	1.95
d3	2.52	2.79	3.06	3.58	1.20	1.34	1.48	1.76	1.78	1.98	2.18	2.57
d7	3.47	3.82	4.17	4.82	1.70	1.89	2.09	2.46	2.49	2.75	3.03	3.53

*Experimental yield; **Commercial yield

Table 6b. **BCR in Central India region under different price scenarios with productivity 1569 kg ha^{-1} (Annual average productivity in Kerala during 2020-21)**

Tapping system	BCR								
	Peak season (47 % share)			Lean season (21 % share)			Rest of the year (32 % share) (Aug-Sep & Feb-Mar)		
	Price of RSS 4 (Rs. kg^{-1})								
	142*	150**	160**	142*	150**	160**	142*	150**	160**
d2	2.12	2.24	2.39	1.00	1.06	1.13	1.49	1.57	1.68
d3	2.79	2.94	3.14	1.34	1.42	1.51	1.98	2.09	2.23
d7	3.82	4.03	4.30	1.89	1.99	2.13	2.75	2.91	3.10

*Annual average price of RSS 4 in India during 2020-21; **Assumed prices

Rs. 142 kg^{-1}. BCR increased to 2.98 and 4.07 when the tapping system was changed to d3 and d7 respectively for NE region.

BCR analyses during the lean season under different productivity and price scenarios for the different regions showed that in all regions BCR was less than 1 (BCR<1) with the annual average price of RSS 4 (Rs. 142 kg^{-1}) and productivity (1569 kg ha^{-1}) under d2 tapping system. Though BCR showed slight improvement with the hike in price and productivity and with changes in tapping system for traditional and NE regions, BCR was always less than two during the lean season. In Central India where the lean season has 21 per cent share in annual production, BCR was above two (BCR>2) during the season only with d7 tapping system and with higher price/productivity than that is prevailing now.

DISCUSSION

Across the traditional region, the lean season was distinct during the four month period from February to May with March and April giving the lowest share of annual yield (5%). The month of February was also low yielding except in Nettana, Karnataka (Reju *et al.*, 2016). The cumulative share of summer season yield reported from Central Kerala was to the tune of 10-15 per cent (Mydin and Mercykutty, 2007; Reju *et al.*,

Table 7a. **BCR in NE region under different experimental and commercial productivity scenarios with price Rs. 142 kg^{-1} (Annual average price of RSS 4 during 2020-21)**

Tapping system	BCR											
	Peak season (57 % share)				May to Aug (35 % share)				January (8 % share)			
	Annual average yield (kg ha^{-1})											
	1400* (4 kg $tree^{-1}$)	1569**	1750* (5 kg $tree^{-1}$)	2100* (6 kg $tree^{-1}$)	1400* (4 kg $tree^{-1}$)	1569**	1750* (5 kg $tree^{-1}$)	2100* (6 kg $tree^{-1}$)	1400* (4 kg $tree^{-1}$)	1569**	1750* (5 kg $tree^{-1}$)	2100* (6 kg $tree^{-1}$)
d2	2.28	2.52	2.77	3.25	1.46	1.62	1.79	2.12	0.85	0.95	1.05	1.25
d3	2.98	3.29	3.61	4.19	1.93	2.15	2.37	2.78	1.01	1.13	1.25	1.48
d7	4.07	4.46	4.86	5.59	2.69	2.98	3.27	3.81	1.20	1.34	1.48	1.76

* Experimental yield; ** Commercial yield

Table 7b. **BCR in NE region under different price scenarios with productivity 1569 kg ha^{-1} (Annual average productivity in Kerala during 2020-21)**

Tapping system	BCR								
	Peak season (57 % share)			May to Aug (35 % share)			January (8 % share)		
	Price of RSS 4 (Rs. kg^{-1})								
	142 *	150 **	160 **	142 *	150 **	160 **	142 *	150 **	160 **
d2	2.52	2.66	2.84	1.46	1.54	1.64	0.95	1.00	1.07
d3	3.29	3.48	3.71	1.93	2.04	2.18	1.13	1.19	1.27
d7	4.46	4.72	5.03	2.69	2.85	3.04	1.34	1.42	1.51

* Annual average price of RSS 4 in India during 2020-21; ** Assumed prices

2017). The remaining 10 months were highly productive with the six months from July to December giving uniformly sustained high yield (10% and above), a unique pattern observed in the traditional region only. Climatically, this part of India receives abundant rainfall with low temperature variations and a dual peak in yield has been reported (Rajagopal *et al.*, 2003; Mydin and Mercykutty, 2007; Gireesh *et al.*, 2011) except in Padiyur where the second peak was less conspicuous due to poor NE monsoon (Meenakumari *et al.*, 2015).

The hot and dry regions of Dapchari and Bhubaneswar representing the Central India region fall in between the latitudes of the traditional regions and NE states (15-20^{0}N) and seasonality in yield was intermediate of the three regions studied. Though the region receives adequate rainfall well above 2000 mm, distribution is highly skewed coupled with poor water holding capacity of soils. The summer months experience severe soil and atmospheric drought (Krishna *et al.*, 1991; Jacob *et al.*, 1999) with soaring temperatures above 40 ^{0}C, despite which rubber can be successfully cultivated in the region with irrigation in summer months (Devakumar *et al.*, 1998). Severe drought stress has a profound effect on yield in the region. Monthly share of annual yield remained below 8.3 per cent of the annual yield during the months of March- July, with April to June giving the lowest yield of five per cent each (Singh *et al.*, 2012; Meenakumari *et al.*, 2018).

In the sub-tropical environment of North West Bengal and NE India, falling around 25-29^{0}N latitude, low temperature stress along with strong wind and occasional hailstorms in Tripura (Meenattoor *et al.*, 1995; Sasikumar *et al.*, 2001) severe cold in sub Himalayan West Bengal (Das *et al.*, 2008) and high elevation in Tura, Meghalaya (Reju *et al.*, 2007) are the constraints encountered for rubber cultivation. A drop in temperature below 10 ^{0}C during peak winter, high light intensity and soil moisture deficit in March-April and *Oidium* infestation during refoliation necessitate tapping rest for 3-4 months (Saseendran *et al.*, 1993; Das *et al.*, 2000, 2008). This limits the yielding phase to 8-9 months in a year. Monthly share of yield was 8-9 per cent each from May to August. The monsoon season contributed to only 35 per cent of the annual yield. The differential response of yield was more pronounced in the peak yielding regime than during the monsoon period. This corroborates with earlier findings (Priyadarshan *et al.*, 1998; Raj and Dey, 2008).

In summary, in those regions where tapping is done for 12 months a year, the normal mean monthly share of the annual yield should be theoretically 8.3 per cent. In the traditional region, yield remained well below this during the months of February to May with March and April giving the lowest share of annual yield (5%). In Central India, monthly share of annual yield remained below the 8.3 per cent normal mean yield during the months of March-July, with April to June giving the lowest yield (5% each). In NE India, where tapping was limited to 8-9 months outside the winter season, monthly share of yield was 8-9 per cent each from May to August and January. Seasonality of yield was the most pronounced in NE where 46 per cent of the annual yield could be harvested in the three cool pre-winter months of October to December. In Central India too, a season of peak yield was evident during the couple of cool months preceding winter. In the traditional region monthly share of annual yield was more equitably distributed throughout the year, except for a clear lean yielding season during the hot/dry summer months which was also seen in Central India.

While seasonality in rubber yield is a natural phenomenon closely related to the metabolic changes associated with rubber biosynthesis as influenced by the prevailing seasonal weather conditions, tapping of rubber trees is essentially a financial decision taken by the grower. During the recent years when the price of rubber was low, close to 25 per cent of the holdings were left untapped. Perhaps some of these holdings could have been profitably tapped at least during the peak yielding season if a rational decision was made by the grower based on information about seasonality of rubber yield. It will be a rational financial decision if low-cost good agronomic practices such as weekly tapping or self-tapping are adopted and tapping is continued at least during the best yielding seasons so that growers can maximize their economic returns when rubber prices are low.

Behavioral Economists have established that human behavior, including financial decisions they take are not always rational decisions (Camerer and Loewenstein, 2004) but their economic choices can be nudged (Thaler and Sunstein, 2008; Selinger and Whyte, 2012). From a biological perspective, an organism (individual) that takes irrational decisions or fails to take rational decisions stands to lose out on her evolutionary (survival) fitness (Sunstein and Reisch, 2017) which is analogous to competitive fitness in a market economy. More precisely, the one who survives is deemed to have taken the most rational decisions, because what is rational or irrational is often unclear in the biological world *ex-ante*. But tapping decisions such as whether or not to tap (*e.g.* depending on rubber price or trends in seasonal yields), resorting to low frequency tapping or self-tapping *etc*. by a grower are unlike this. A grower can always make rational calculations based on prior knowledge about economically wise choices available. Presently, only a tiny fraction of the 1.2 to 1.3 million smallholders is doing self or weekly tapping. Precise knowledge about seasonal yield and profitability will be a good nudge for more growers to take rational decisions about when to tap.

The above results offer some valuable tips for practical applications such as the need to harvest maximum latex during the peak yielding months. This also points to the necessity to do rain guarding during the high yielding monsoon months so that no tapping days are lost. Similarly, if rubber prices are low, skipping of tapping during the extremely lean yielding months could be an option even as not tapping during the peak yielding season may cause economic loss to the grower. Another possibility to explore would be to harvest the maximum yield during the rain-free season without having to do rain guarding by suitably increasing the tapping frequency and modifying the stimulation regime. The objective should be to harvest the maximum yield for the lowest cost during the relatively high yielding rain-free months. But uncertainty in the rainfall pattern and rains extending well into November and December as we have been witnessing in recent years possibly as a result of global climate change can be a major concern here.

CONCLUSION

There was clear seasonality in yield across regions. April was the lowest yielding month invariably in all regions. Seasonal yield variations broadly fall into three quarters, i) 3-4 lean months coinciding with wintering, flowering and refoliation, ii) moderate yielding monsoon season and iii) peak period corresponding to winter/pre-winter months when early morning temperatures are cool favouring high latex production. The productive period for ten months in the traditional region was reduced to eight months in all the non-traditional regions of Central and NE India either due to drought stress in the former or severe cold in the latter. While climatic conditions are more tropical or equatorial in the traditional region, it is more sub-tropical to temperate in the NE region. Therefore, intra-annual variations in temperature and precipitation were less in the traditional region than in the NE states. This explains the more equitable distribution of yield in the traditional region. On an average the yield during the three lean months from February to April in all three regions was to the tune of 15 per cent. Yield (expressed as per cent share of total annual yield in each month) was insensitive to price of each month (taken as average monthly price since 2000). When rubber price is low and/or yields are poor, limiting tapping to the peak yielding months/season seems to be more profitable for the grower, but ensuring no tapping days are lost to rains will be critical. The present analysis helps empower the grower with scientific information and nudges him to take rational economic decision as to when to tap and when not to tap, depending on seasonality of yield, tree productivity and rubber price. The present analyses point to the need to explore the possibility of doing tapping to extract maximum yield during the peak yielding months and resting the tree for the rest of the year depending on tree productivity, prevailing tapping costs and rubber price.

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REFERENCES

Camerer, C.F. and Loewenstein, G.F. (2004). Behavioural economics: Past, present, future, In: *Advances in Behavioral Economics* (Eds. Colin F. Camerer, George Loewenstein and Matthew Rabin). Princeton, University Press, New Jersey, pp. 3-51.

Das, G., Raj, S., Pothen, J., Dey, S.K. and Varghese, Y.A. (2000). Exploitation of *Hevea* under low temperature stress situations: Studies on exploitation systems giving tapping rests based on drop in minimum temperature. In: *Recent Advances in Plantation Crops Research*: *Placrosym XIII*, 16-18 December 1998, Coimbatore, Tamil Nadu, India. (Eds. N. Muraleedharan and R. Raj Kumar). Allied Publishers, New Delhi, India, pp. 150-156.

Das, G., Singh, R.S., Gohain, T., Meti, S., Chaudhuri, D. and Nazeer, M.A. (2008). Effect of rubber on intercropped tea during immature phase of rubber cultivation. *Natural Rubber Research*, **21**(1&2): 134-138.

Das, G., Reju, M.J., Mondal, G.C., Singh, R.P., Thapliyal, A.P. and Chaudhuri, D. (2013). Adaptation of *Hevea brasiliensis* clones in three widely different cold prone areas of Northeastern India. *Indian Journal of Plant Physiology*, **18**(3): 231-239.

Devakumar, A.S., Sathik, M.B.M., Jacob, J., Annamalainathan, K., Prakash, P.G. and Vijaykumar. K.R. (1998). Effects of atmospheric and soil drought on growth and development of *Hevea brasilinsis*. *Journal of Rubber Research*, **1**(3): 190-198.

Gireesh, T., Raj, S., Mydin, K.K. and Mercykutty, V.C. (2011). Rubber yield of certain clones of *Hevea brasiliensis* and its relationship with climate variables. *Natural Rubber Research*, **24**(1): 54-60.

Jacob, J., Annamalainathan, K., Alam, B., Sathik, M.B.M., Thapliyal, A.P. and Devakumar, A.S. (1999). Physiological constraints for cultivation of *Hevea brasiliensis* in certain unfavourable agro-climatic regions of India. *Indian Journal of Natural Rubber Research*, **12**(1&2): 1-16.

Klaewklad, A., Nakkanong, K., Nathaworn, C.D. and Nualsri, C. (2017). Rubber elongation factor (REF) and small rubber particle protein (SRPP) gene expression responses to variation of seasonal change in four selected rubber clones. *Pakistan Journal of Biotechnology,* **14**(1): 115-120.

Krishna, T.M., Bhaskar, C.V.S., Rao, P.S., Chandrashekar, T.R., Sethuraj, M.R. and Vijayakumar, K.R. (1991). Effect of irrigation on physiological performance of immature plants of *Hevea brasiliensis* in North Konkan. *Indian Journal of Natural Rubber Research*, **4**(1): 36-45.

Meenakumari, T., Lakshmanan, R., Meenattoor, J.R., Joseph, A., Gireesh, T. and Mydin, K.K. (2015). Performance of new generation clones of *Hevea brasiliensis* under the dry sub-humid climate of North Kerala. *Rubber Science*, **28**(1): 40-51.

Meenakumari, T., Meenattoor, J.R., Thirunavoukkarasu, M., Vinod, K.K., Krishan, B., Gireesh, T., Thomas, V., Mydin, K.K. and Jacob, J. (2018). Dynamics of long-term adaptive responses in growth and rubber yield among *Hevea brasiliensis* genotypes introduced to a dry sub-humid climate of Eastern India. *Industrial Crops and Products*, **119**: 294-303.

Meenattoor, J.R., Vinod, K.K., Krishnakumar, A.K., Potty, S.N., Sethuraj, M.R. and Pothen, J. (1995). Hailstorm damage to *Hevea* trees in Tripura and the performance of the recovered trees. *Indian Journal of Natural Rubber Research,* **8**(1): 51-53.

Mydin, K.K. and Mercykutty, V.C. (2007). High yield and precocity in the RRII 400 series hybrid clones of rubber. *Natural Rubber Research*, **20**(1&2): 39-49.

Priyadarshan, P.M., Sudhasowmyalatha, M.K., Sasikumar, S., Varghese, Y.A. and Dey, S.K. (1998). Relative performance of six *Hevea brasiliensis* clones during two yielding regimes in Tripura. *Indian Journal of Natural Rubber Research*, **11**(1&2): 67-72.

Raj, S., Das, G., Pothen, J. and Dey, S.K. (2005). Relationship between latex yield of *Hevea brasiliensis* and antecedent environmental parameters. *International Journal of Biometeorology*, **49**(3): 189-196.

Raj, S. and Dey, S.K. (2008). Rubber Cultivation in North East India: An Agrometeorological perspective. In: *Climate Change and Food Security* (Eds. M. Datta, N.P. Singh and D. Daschaudhuri). New India Publishing Agency, New Delhi, India, pp. 149-162.

Rajagopal, R., Vijayakumar, K.R., Thomas, K.U. and Karunaichamy, K. (2003). Effect of judicious ethephon application on long term yield response of *Hevea brasiliensis* (clone RRII 105) under 1/2 S d/3 6d/7 system of tapping. *Proceedings of the International Workshop on Exploitation Technology*, 15-18 December 2003, Kottayam, Rubber Research Institute of India, Kottayam, India, pp. 146-157.

Rao, P.S., Saraswathyamma, C.K. and Sethuraj, M.R. (1998). Studies on the relationship between yield and meteorological parameters of para rubber tree (*Hevea brasiliensis*). *Agricultural and Forest Meteorology*, **90**(3): 235-245.

Reju, M.J., Thapliyal, A.P., Singh, R.P., Soman, T.A., Nazeer, M.A. and Varghese Y.A. (2007). Promising *Hevea brasiliensis* clones for the sub-tropical climate of Meghalaya. *Natural Rubber Research*, **20**(1& 2): 50-55.

Reju, M.J., Nazeer, M.A., Suryakumar, M., Chandrasekhar, T.R. and Mydin, K.K. (2016). Ortet selections from small holdings in Kerala - Long term growth and yield under small scale evaluation in Karnataka. *Rubber Science*, **29**(3): 224-237.

Reju, M.J., Mydin, K.K. and Mercykutty, V.C. (2017). Evaluation of *Hevea* rubber clones in a large scale trial in India with special reference to introductions from Malaysia. *Rubber Science*, **30**(1): 1-16.

Saseendran, S.A., Mandal, D., Sinha, R.R., Vijavakurnar, K.R., Potty, S.N. and Sethuraj, M.R. (1993). Effect of aspect on soil temperature and growth of *Hevea* on hills of North East India. *Indian Journal of Natural Rubber Research*, **6**(1&2): 105-110.

Sasikumar, S., Priyadarshan, P.M., Dey, S.K. and Varghese, Y.A. (2001). Evaluation of polyclonal seedling population of *Hevea brasiliensis* (Willd. Ex Adr. de Juss.) Muell. Arg. in Tripura. *Indian Journal of Natural Rubber Research*, **14** (2): 125-130.

Satheesh, P.R. and Jacob, J. (2011). Impact of climate warming on natural rubber productivity in different agro-climatic regions of India. *Natural Rubber Research*, **24**(1): 1-9.

Selinger, E. and Whyte, K.P. (2012). What counts as a nudge? *The American Journal of Bioethics*, **12**(2): 11-12.

Sunstein, C.R. and Reisch, L.A. (2017). Introduction. In: *The Economics of Nudge*, 4 Volumes. (Eds. Cass R. Sunstein and Lucie A. Reisch).Routledge, New York, pp. 1-12.

Singh, M., Chandrashekhar, T.R., Nazeer, M.A., Annamalainathan, K. and Mydin, K.K. (2012). Early performance of some clones of *Hevea brasiliensis* in dry sub humid region of North Konkan. *IRC 2012. International Rubber Conference*, 28-31 October 2012, Kovalam, India, Rubber Research Institute of India, Kottayam and IRRDB, Malaysia, Abstracts. p. 60.

Sreelatha, S., Simon, S.P., Kurup, G.M. and Vijayakumar, K.R. (2007). Biochemical mechanism associated with low yield during stress in *Hevea* clone RRII 105. *Journal of Rubber Research*, **10**(2): 107-115.

Sreelatha, S., Mydin, K.K., Simon, S.P., Krishnakumar, R., Jacob, J., and Annamalainathan, K. (2011). Seasonal variations in yield and associated biochemical changes in RRII 400 series clones of *Hevea brasiliensis*. *Natural Rubber Research*, **24** (1): 117-123.

Thaler, R.H. and Sunstein, C.R. (2008). *Nudge: Improving decisions about Health, Wealth and happiness*. Yale University Press, Haven, 293p.

Veeraputhran, S., Raj, S. and George, K.T. (2017). Trends in seasonality of natural rubber production in major producing countries: A disaggregate level analysis. *Rubber Science*, **30**(1): 66-75.

Vijayakumar, K.R., Chandrasekar, T.R. and Phillip, V. (2000). Agroclimate. In: *Natural Rubber*. Agromanagement and Crop Processing (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, India, pp. 97-116.

Wu, C., Lan, L., Li, Y., Nie, Z. and Zeng, R. (2018). The relationship between latex metabolism gene expression with rubber yield and related traits in *Hevea brasiliensis*. *BMC Genomics*, **19**: 897.