REGION-SPECIFIC ADVISORY ON *HEVEA* CLONES SUITED TO TRADITIONAL AND NON-TRADITIONAL RUBBER GROWING AREAS OF INDIA

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The Rubber Board of India has evolved clone recommendations for the traditional and non-traditional regions and updating of these recommendations is done periodically based on data that is made available from the clonal evaluation trials in various regions. In addition to these recommendations, the formulation of a region-specific clone advisory based on agroclimatic zoning was a long felt need of the rubber plantation sector, so as to enable maximisation of rubber yield from each region and thereby improve rubber production *per se*. Based on results of 29 long term field evaluation trials of rubber clones in the traditional regions as well as studies on disease reaction, genotype x environment interaction studies and yield from nine large scale and on farm evaluation trials of these clones in Tripura, Assam and northern part of Bengal, region specificity in performance of the clones was determined. This paper details the specificity in performance of clones in the planting recommendations across the various agroclimatic zones where rubber is presently cultivated. A new region-specific advisory of clones suited to each of the nine agroclimatically distinct zones in the traditional region and the non-traditional regions of rubber cultivation in India is formulated for the first time.

Key words: Agroclimatic zones, Disease tolerance, Growth, Region specificity, Rubber clones, Rubber yield, Stability.

INTRODUCTION

Rubber cultivation in India is spread across diverse agroclimatic regions stretched over the sub continent from its peninsular southern tip to the foothills of the Himalayas in the North East. Being a commercially important perennial cash crop that exhibits versatility in performance across varied climatic regimes, *Hevea brasiliensis* has covered over 827 thousand ha

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of arable land in India (ANRPC, 2016). Confined to the most suitable agroclimatic zone in South India in the early years, its cultivation has in the recent decades extended to non-traditional zones including Central and North East India. This necessitated gearing of crop improvement efforts to evolve indigenous *Hevea* clones to meet the planting requirement of each agroclimatic zone where the crop is cultivated.

Hevea brasiliensis, the natural habitat of which is the rain forests of the Amazon basin situated within 5^0 latitudes at altitudes below 200 m has a preference for warm, humid weather (Polhamus,1962; Opeke, 1982). Therefore its cultivation is more successful in the tropics where an equatorial climate prevails. Climatic conditions necessary for optimum growth and yield of rubber are evenly distributed annual rainfall of 2000 mm or more, temperature ranging from 20 to 34^0C, about 80 per cent humidity with moderate wind and bright sunshine amounting to 2000 h per annum at the rate of 6 h per day (Webster and Baulkwill, 1989). Only some regions in India meet all these requirements.The rubber growing regions of India are classified into traditional and non-traditional on the basis of agroclimatic conditions (Vijayakumar *et al.*, 2000).

Traditional region

The major portion of the rubber area in India is confined to the traditional zone which is the South-West coast of the country extending from Kanyakumari district of Tamil Nadu state in the South to Coorg district of Karnataka state in the North (Vijayakumar *et al.*, 2000). In the traditional zone, the rubber plantations are confined to a narrow belt towards the West of the Western Ghats which enjoys the benefit of both the South West and North East monsoons. This traditional zone can be further divided into seven agroclimatic regions *viz.* the South Tamil Nadu, South Kerala, Central Kerala, North Central Kerala, North Kerala, South West Karnataka and the Tropical high altitude region as detailed in Table 1.

Non-traditional region

Non-traditional regions are those areas where the soil is suitable but climatic constraints like drought, wind and cold limit the growth and productivity of rubber (Jacob *et al.*, 1999). The non-traditional rubber growing areas in India are classified into three regions *viz.* North eastern, Konkan and Eastern region.

North Eastern region

The North Eastern region comprises the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. The Northern part of Bengal also falls within this region because of similarities in climate. In the North Eastern states, the major environmental constraint is the low temperature encountered in winter (Jacob *et al.*, 1999). From December to February, the mean minimum temperature hovers around 10^0C. This retards growth and affects productivity and budding success. In the yielding phase, prolonged latex flow in winter leads to a drop in dry rubber content, hence tapping rest is advised during the cold season. Annual rainfall in the region ranges from 1500 to 2500 mm. Storms and hail are a regular feature in the region where Powdery Mildew disease is also a concern.

Table 1. **Agroclimatic zones within the traditional rubber growing region of India**

Sl. No.	Zone	Districts	Agroclimatic conditions
1	South Tamil Nadu	Kanyakumari	Moderate, evenly distributed rainfall, temperature variations not marked. Low incidence of *Phytophthora.* Annual rainfall of 2000 mm.
2	South Kerala	Kollam, Thiruvananthapuram	Plentiful seasonal rainfall, aggressive summer, tropical humid climate. Annual rainfall ranges from 2000 to 4500 mm.
3	Central Kerala	Ernakulam, Kottayam, Pathanamthitta, Alappuzha	3000-4000 mm annual rainfall received from both the SW and NE monsoons, climatic conditions conducive to Pink and *Phytophthora* diseases.
4	North Central Kerala	Thrissur, Palakkad	Premonsoon and winter rainfall weak with annual rainfall of 2300 to 3000mm. Wet and dry seasons pronounced. High summer temperature variability with strong wind in certain regions.
5	North Kerala	Kozhikode, Malappuram, Kannur, Kasaragod	Annual rainfall of about 3400 mm received from both monsoons, but a prolonged dry spell of 4-5 months duration from December to May. High temperatures.
6	Tropical high altitude regions	Wynad, Idukki, Kulathupuzha, Vithura	Altitudes above 450 m. Heavy rainfall from SW monsoon. Annual rainfall is about 4000 mm. Dry spell for 4 months from December to March. Temperatures lower than other regions. January temperature 1 to 15 ^{0}C, with over hanging mist. Conditions conducive to powdery mildew.
7	South-West Karnataka	Dakshin Kannada, Coorg	SW monsoon contributes major part of rainfall. NE monsoon weak. Annual rainfall various from 2100 to 4500 mm. Very high summer temperatures. Hot spot of *Phytophthora* and *Corynespora* diseases.

Konkan region

The Konkan region comprises a narrow strip of land on the Western side of the Western Ghats of Goa and Maharashtra. The region includes the state of Goa and four coastal districts of Maharashtra *viz.* Sindhudurg, Ratnagiri, Raigad and Thane. The rainfall in this region is appreciable but its distribution is far from suitable for rainfed rubber cultivation since there is a long dry

period extending from October to May. Summer is accompanied by very severe soil drought, high temperature and high light intensity. The temperatures can soar upto 50^0C in peak summer. Tapping rest in summer is advised in the region. Young plants are given irrigation.

Eastern region

The eastern region includes selected localities in Odisha, Madhya Pradesh and Andhra Pradesh in the Eastern Ghats. The agroclimatic conditions are similar to the drought prone Western Konkan belt, with soil moisture stress, high temperatures and high light intensities being the factors that limit growth and productivity of rubber (Gupta *et al.,* 2002).

Planting material recommendations for various rubber growing regions of India

The Rubber Board has specific clone recommendations for the traditional and non-traditional regions (Rubber Board, 2017) and updating these recommendations is done periodically based on data that is made available from the clonal evaluation trials in various regions. For the traditional region and North East India, recommended clones are classified into three categories (Table 2). Category 1 clones are those officially released for planting by the Rubber Board. These have proved their worth in all three stages of evaluation viz. small scale, large scale and multilocational on farm evaluation. These clones are recommended for wide scale planting, but only upto 50 per cent of the area planted each year may be planted with any single clone under this category and the rest of the area should be planted with any other desired clone/ clones to avoid monoclonal planting.

Category 2 clones are those which have shown consistently good performance over the long term in large scale trials. It is recommended that combinations of two or more of these clones may be used to plant in upto 50 per cent of the total area of a large holding together with 50 per cent of category 1 clones. Category 3 consists of superior clones with proven merit in small scale trials and in the early years in large scale trials in India or abroad (in the case of introduced clones). These clones are recommended only for experimental planting on a limited scale, not to exceed 15 per cent of the area planted in large holdings. Polyclonal seeds are also included in this category and recommended for planting in marginal lands (Table 2).

In practice, small holders almost always plant their entire area with category 1 clones and usually plant just one clone. The current recommendation of clones for the various regions is provided in Table 2.

Table 2. **List of clones recommended for traditional and North Eastern regions under categories 1, 2 and 3 and clone advisory for North Konkan, Karnataka and South Konkan.**

Traditional region

Category 1	Clones RRII 105, PB260, RRII 414, RRII 417, RRII 422 and RRII 430
Category 1I	Clones RRIM 600, GTl, RRII 5, RRII 203, PB 28/59, PB 217, PB 312, PB 314, PB 255 and PB 280
Category 111	Clones RRII 118, RRII 208, RRII 300, RRII 429, PR 107, PR 255, PR 261, PB 86, PB5/51, PB 235, PB 311, PB 330, RRIM 605, RRIM 701, RRIM 703, RRIM 712, RRIC 100, RRIC 102, RRIC 130, KRS 163, IRCA 111, IRCA 109, IRCA 130, SCATC 88-13, BPM 24 and polyclonal seeds

Non-traditional region

North East India	
Category 1	Clones RRIM 600 and RRII 208
Category 11	Clones RRII 105, GT1, PB 235, RRII 203, RRII 429, RRII 417 and RRII 430
Category 111	Clones RRII 5, RRII 422, RRII 118, PB 260,PB 310, PB 311, RRIM 703, SCATC 88-13, SCATC 93-114, Haiken 1 and polyclonal seedlings.
North Konkan	RRIM 600, RRII 208, RRII 105, RRII 6, RRII 5, PB 260, PR 255 and RRIC 100 perform well in this region. The RRII 400 series clones have not been evaluated in North Konkan. However, the drought tolerant and stable clone RRII 430 shows good initial establishment and growth and could be planted in the region. Life saving irrigation is to be given to all clonal plantings in the first three years.
Karnataka and South Konkan	GT 1, RRII 203*, PB 260, PB 217*, RRII 414, RRII 430, RRII 422, RRII 429, PB 280, PB 312, PB 314, PB 235, RRII 5, RRII 300, PB 311* and RRII 105* have exhibited good growth and yield in the region.

* RRII 105 is highly susceptible to *Corynespora* leaf disease. Hence recommended prophylactic and control measures are to be adopted. PB 217 and RRII 203 are also susceptible to the disease and require prophylactic protection. PB 311 is wind susceptible; hence planting of this clone in wind prone areas is to be avoided.

Most of the modern high yielding clones are prone to tapping panel dryness when tapped under half spiral alternate daily system. It is therefore, strongly recommended that all such clones be tapped at a lower intensity, *i.e.*, on half spiral once in three days or lower frequencies. Prophylactic protection against diseases is recommended for the cultivation of all these clones.

The present effort was to collate long term data on clonal performances in the various traditional and non-traditional regions of India and formulate region specific clone recommendations for agroclimatic zones. This was a felt need of the rubber plantation sector, so as to enable maximisation of rubber yield from each region and thereby improve rubber production *per se*, ever since several clones were upgraded to category 1 in recent years.

EXPERIMENTAL

In addition to the category 1 clones recommended for planting in the various rubber growing areas of India, performance of a couple of other promising clones such as GT1 and RRII 429 (category 2) were also evaluated from a large number of clone evaluation trials across all regions. The clonal performances were examined with respect to the various agroclimatic zones in which the field evaluations were laid out. The traditional belt comprised seven such zones and the non-traditional regions were situated in three different zones. The Rubber Research Institute of India has Regional Research Stations (RRS) in all the non-traditional zones, *viz.* Agartala, Guwahati and Tura in North East India, a Regional Experiment Station (RES) at Nagrakata in Bengal, Dhenkanal in Odisha and Dapchari in Maharashtra. The existing planting recommendations and clone advisories for each of the non-traditional zones have been evolved based on results of clone evaluations done in the stations and in growers fields in the respective regions. However, the entire traditional region had been issued only a blanket clone recommendation for all its agroclimatic zones. Processing of the large volume of data that has accrued over 25 to

Table 3. **List of field trials of the RRII 400 series clones carried out in various zones within the traditional region**

	Trial			Year of planting	Location
1	**Small Scale Evaluation**			1985	RRII, Kottayam
2	**Large Scale Evalaution**				
	2. 1	Large Scale Evalaution		1993	CES,Chethackal,Pathanamthitta
	2. 2	Large Scale Evalaution		1996	RRS, Padiyur, Kannur
	2. 3	Large Scale Evalaution		1996	New Ambady Estate,Kanyakumari
	2. 4	Large Scale Evalaution		1998	HBSS, Nettana, Karnataka
3.	**On Farm Evaluation in Large Estates**				
	3.1	On Farm Evaluation		1998	Cheruvally, Pathanamthitta
	3.2	On Farm Evaluation		1998	Kaliyar, Thodupuzha, Idukki
	3.3	On Farm Evaluation		2000	Vaikundam, Kanyakumari
	3.4	On Farm Evaluation		2003	Shaliakary, Kollam
	3.5	On Farm Evaluation		2006	RPL , Kulathupuzha, Kollam
	3.6	Block Trial		2006	CES, Chethackal, Pathanamthitta
	3.7	On Farm Evaluation		2009	Chemony, Thrissur
	3.8	On Farm Evaluation		2006	Bethany, Kanyakumari
	3.9	On Farm Evaluation		2006	Paalaali, Kanyakumari
4.	**On Farm Evaluation in Small Holdings**				
	4.1	South Kerala			
		4.1.1	On Farm Evaluation	2001	Ayur, Kollam
	4.2	Central Kerala			
		4.2.1	On Farm Evaluation	1997	Aiymkombu, Kottayam
		4.2.2	On Farm Evaluation	2000	Malayatoor, Ernakulam
		4.2.3	On Farm Evaluation	2002	Elanji, Ernakulam
		4.2.4	On Farm Evaluation	2002	Chettuthodu, Kottayam
		4.2.5	On Farm Evaluation	2003	Ponkunnam, Kottayam
		4.2.6	On Farm Evaluation	2003	Pinnakkanadu, Kottayam
		4.2.7	On Farm Evaluation	2004	Thiruvankulam, Ernakulam
		4.2.8	On Farm Evaluation	2005	Kanjirappally, Kottayam
	4.3	North Kerala			
		4.3.1	On Farm Evaluation	2000	Wandoor, Malappuram
		4.3.2	On Farm Evaluation	2002	Kunnamkulam, Thrissur
		4.3.3	On Farm Evaluation	2003	Mannarkkad, Palakkad
		4.3.4	On Farm Evaluation	2003	Ottapalam, Palakkad
		4.3.5	On Farm Evaluation	2004	Nilambur, Malappuram

Table 4. **List of field trials of RRII 400 series clones and RRII 208 in non-traditional areas**

1	**Evaluation of RRII 400 series clones and RRII 208 in Maharastra and Odisha**				
	1.1	Large Scale Evaluation of RRII 208			
		1.1.1	Large Scale Evaluation	1985	RRS, Dapchari, Maharastra
		1.1.2	Clone Trial	1990	RRS, Dhenkanal, Odisha
		1.1.3	Clone Trial	1991	RRS, Dhenkanal, Odisha
		1.1.4	Clone Trial	1999	RRS, Dhenkanal, Odisha
	1.2	Large Scale Evaluation of RRII 400 series			
		1.2.1	Large Scale Evaluation	1996	CSIR, Bhubaneswar, Odisha
2	**Evaluation of RRII 400 series clones in North East India**				
	2.1	Large Scale Evaluation			
		2.1.1	Large Scale Evaluation	1996	Agartala, Tripura
		2.1.2	Large Scale Evaluation	1996	Nagrakata, W. Bengal
	2.2	On Farm Evaluation			
		2.2.1	On Farm Evaluation	2004	Goalpara, Assam
		2.2.3	On Farm Evaluation	2005	Pathalia, Tripura

30 years from 38 field evaluations across the traditional and non -traditional regions led to the formulation of a region specific advisory of clones suited to the nine different agroclimatic zones.

Among the already recommended category 1 clones, those that have shown specific adaptation in terms of the best growth, yield and tolerance to diseases in each of the agroclimatic zones within the traditional region were identified. The RRII 400 series, the latest among the rubber clones released for the traditional region in 2005 and 2009 have also been evaluated in large scale trials in the non-traditional regions.

Table 5. **Region–wise score* for yield of the clones with respect to yield of RRII 105 in five large scale evaluations on station**

Clone	SST RRII (Kottayam)	LST CES (Pathanamthitta)	Mean score for Central Kerala	LST Padiyoor (North Kerala)	LST Nettana (Karnataka)	LST New Ambadi (Kanyakumari)
RRII 414	1	0	0.5	0	1	-1
RRII 417	1	1	1	0	-	-1
RRII 422	0	0	0	0	1	-1
RRII 429	1	0	0.5	-1	1	-1
RRII 430	0	1	0.5	1	1	-1

*Based on CD values: 1: Superior to RRII 105; 0: On par with RRII 105; 1: Inferior to RRII 105
SST: Small Scale Trial LST: Large Scale Trial

In addition, disease reaction of RRII 400 series clones and RRII 105 in various locations and inference from genotype environment (G x E) interaction studies have been considered in the categorisation of clones for region specificity. A list of the various field trials considered in the study is given in Tables 3 and 4.

RESULTS AND DISCUSSION

The results on yield of the RRII 400 series clones from small scale and large scale evaluations (Licy *et al*., 2003; Mydin *et al*., 2011; Mydin *et al*., 2012, Meenakumari *et al*., 2011, 2015) done on station and reported earlier were analysed in comparison to the high yielding check clone RRII 105 and are presented in Table 5 on a regional basis. Tables 6 to 13 show the relative rankings of performance of these and other clones from on farm evaluations in various agroclimatic zones.

Performance of RRII 400 series clones in field trials in the traditional region

Station evaluations

In Central Kerala, clone RRII 417 with the highest mean score 1 was the best performer in terms of yield ($gt^{-1}t^{-1}$) in statistically laid out trials. This was followed by clones RRII 430, RRII 414 and RRII 429 which were also superior to RRII 105. Clone RRII 422 was only on par with RRII 105. In North Kerala, RRII 430 was the best clone superior to RRII 105 in Kannur district. In the South Karnataka region, all the four RRII 400 series clones evaluated *viz.* RRII 430, RRII 414, RRII 422 and RRII 429 were superior to RRII 105. In Kanyakumari, the LST proved RRII 105 to

Table 6. **Yield ranking of RRII 400 series clones and RRII 105 in large estates in Kanyakumari**

Clone	Vaikundam	Bethany	Paalali	Mean Rank
RRII 414	3	6	3	4.0
RRII 417	4	5	4	4.3
RRII 422	2	1	5	2.7
RRII 429	1	4	-	2.5
RRII 430	3	2	1	2.0
RRII 105	5	3	2	3.3

Table 7. **Yield ranking of RRII 400 series clones and RRII 105 in large estates in South Kerala**

Clone	Punalur	Kulathupuzha	Mean Rank
RRII 414	3	6	4.5
RRII 417	4	3	3.5
RRII 422	2	1	1.5
RRII 429	1	2	1.5
RRII 430	-	5	5.0
RRII 105	4	4	4.0

Table 8. **Yield ranking of RRII 400 series clones and RRII 105 in large estates in Central Kerala**

Clone	Cheruvally	Chethackal	Kaliyar	Mean Rank
RRII 414	1	2	2	1.7
RRII 417	3	-	4	3.5
RRII 422	4	3	5	4.0
RRII 429	2	1	6	3.0
RRII 430	2	-	1	1.5
RRII 105	5	-	3	4.0

Table 9. **Yield ranking of RRII 400 series clones and RRII 105 in large estates in North Central Kerala**

Clone	Rank
RRII 414	4
RRII 417	3
RRII 429	1
RRII 430	2
RRII 105	5

be best suited to the region, followed by RRII 430 (Table 5).

On farm evaluation in large estates

Results from on farm evaluations in large estates are presented in terms of relative rankings of the clones in terms of yield ($gt^{-1}t^{-1}$) (Tables 6 to 9) in Kanyakumari district of Tamil Nadu, South Kerala, Central Kerala and North Central Kerala.

Clone RRII 430 with a mean rank of 2.0 was superior to the rest of the clones in Kanyakumari region, followed by clones RRII 429 and RRII 422 with mean ranks 2.5 and 2.7, respectively. RRII 105 was only the fourth best clone in on farm evaluations in large estates in the region.

In terms of yield performance in large estates in South Kerala, clones RRII 429 and RRII 422 with mean rank of 1.5 were superior indicating their better suitability to the region. RRII 422, followed by RRII 429 and RRII 417 were specifically suited to the tropical high altitude region of Kulathupuzha.

Clone RRII 430 with a mean rank of 1.5 followed by RRII 414 with a mean rank of 1.7 were superior to RRII 105 in terms of yield in on-farm evaluations in Central Kerala. RRII 429 with mean rank of 3.0 followed by RRII 417 with a mean rank of 3.5 were also superior to RRII 105. In Kaliyar (Thodupuzha) which falls in a tropical high altitude region, in terms of yield, RRII 430 followed by RRII 414 performed the best.

Clone RRII 429 was the top yielder in the North Central Kerala region, followed by RRII 430. RRII 414 and RRII 417 also registered better yield than RRII 105.

Table 10. **Yield rankings of RRII 400 series clones and RRII 105 in small holding (Ayur), Kollam, South Kerala**

Clone	Rank
RRII 414	5
RRII 417	3
RRII 422	1
RRII 429	4
RRII 430	2
RRII 105	6

On farm evaluation in small holdings

Performance rankings of the clones based on yield in small holdings across Kerala (Tables 10 to 13) were examined with respect to yield in South, Central, North Central and North Kerala

RRII 422 proved to be the best yielding clone followed by RRII 430 in the small holding in Ayur, South Kerala. RRII 417, RRII 429 and RRII 414 were also better than RRII 105.

Table 11. **Yield rankings of RRII 400 series clones and RRII 105 in small holdings in Central Kerala**

Clone	Kottayam						Ernakulam				Mean for
	K1	K2	K3	K4	K5	Mean	E1	E2	E3	Mean	Central Kerala
RRII 414	1	2	2	-	-	1.7	1	5	1	2.3	2.0
RRII 417	-	3	-	-	-	3.0	-	1	-	1.0	2.0
RRII 422	-	6	-	1	-	3.5	-	2	-	2	3.0
RRII 429	-	5	-	-	1	3	-	3	-	3	3.0
RRII 430	-	1	-	-	-	1	-	4	-	4	2.5
RRII 105	2	4	1	2	2	2.2	2	6	2	3.3	2.6

Table 12. **Yield rankings of RRII 400 series clones and RRII 105 in small holdings in North Central Kerala**

Clone	Thrissur	Ottapalam	Mannarkad	Mean Rank
RRII 414	3	3	-	3.0
RRII 417	-	-	1	1.0
RRII 422	2	-	-	2
RRII 429	-	2	-	2
RRII 105	1	1	2	1.3

Table 13. **Yield ranking of RRII 400 series clones and RRII 105 in small holding in North Kerala**

Clone	Malappuram
RRII 414	2
RRII 417	-
RRII 422	3
RRII 429	-
RRII 105	1

Table 14. **Rankings of RRII 400 series clones, RRII 105 and RRIIM 600 for yield and girth of clones in the large scale trial at Agartala, Tripura**

Clone	Girth	Mean yield over 12 years
RRII 414	3	7
RRII 417	2	3
RRII 422	5	1
RRII 429	1	2
RRII 430	4	5
RRIM 600	6	4
RRII 105	7	6

In the small holdings in Kottayam district, RRII 430 had the highest mean rank of 1 and was the best clone, superior to RRII 105. This clone was also superior to RRII 105 in the large scale evaluation in Central Kerala. RRII 414 was the second best clone

Table 15. **Rankings for yield and girth of RRII 400 series clones, RRII 105 and RRIIM 600 clones in the large scale trial at Nagrakata, Bengal**

Clone	Girth	Mean yield over 12 years
RRII 414	4	7
RRII 417	2	2
RRII 422	7	3
RRII 429	1	1
RRII 430	3	4
RRIM 600	5	6
RRII 105	6	5

Table 16. **Rankings for yield and girth of RRII 400 series clones, RRII 105 and RRIIM 600 in an on farm trial at Pathalia, Tripura**

Clone	Girth	Mean yield over 3 yrs
RRII 414	4	6
RRII 417	3	3
RRII 422	7	7
RRII 429	1	1
RRII 430	6	5
RRIM 600	2	2
RRII 105	5	4

with a mean rank of 1.7 in small holdings of Kottayam district. Clone RRII 105 only ranked third in Kottayam district. In the small holdings of Ernakulam district, RRII 417 ranked best followed by RRII 422, RRII 414 and RRII 429. RRII 105 ranked fifth

Table17. **Rankings for yield and girth of RRII 429 and RRIIM 600 in an on farm trial at Goalpara, Assam**

Clone	Girth	Mean yield over three years
RRII 429	1	1
RRIM 600	2	2

in Ernakulam district with a mean rank of 3.3. In terms of overall yield ranking for Central Kerala, RRII 417 and RRII 414 followed by RRII 430 performed the best in small holdings, while RRII 105 was only in the fourth position. RRII 417 followed by RRII 105 performed well in North Central Kerala. RRII 429 was better than RRII 414. RRII 105 had the highest mean rank of 1 which was better than the RRII 400 series in the two holdings in North Kerala.

Performance of RRII 400 series clones in North East India

Large scale evaluation of the RRII 400 series clones was initiated in Agartala and Nagrakata in North East India as early as 1996. The results of these station trials have been reported in detail by Antony *et al*. (2010) and Das *et al.* (2015). On farm trials were laid out in Tripura, Assam and Meghalaya after 2005.

In Tripura clones RRII 422 and RRII 429 were superior in terms of yield (Table 14). However, RRII 422 is cold susceptible and is not recommended for wide scale planting in the region. RRII 429 was the clone most suited to the region in terms of growth and yield. Similarly, in terms of growth and yield, clone RRII 429 was the best performer in Bengal (Table 15), followed by RRII 417. In terms of growth and yield, in on farm evaluation in Tripura, clone RRII 429 was the best, followed by RRIM 600 (Table 16).

When compared to clone RRIM 600 in on farm evaluation in Assam, RRII 429 was superior in both girth and yield (Table 17). Large scale and on farm evaluations in North Eastern Indian states have proved that RRII 429 is the most suitable clone for the region. This clone is superior in both yield and girth compared to the local check clone RRIM 600.

Table 18. **Rankings for yield and girth of RRII 400 series clones, RRII 105 and RRIM 600 clones in the large scale trial at Bhubaneswar, Odisha**

Clone	Girth	Mean yield over four years
RRII 414	4	6
RRII 417	2	4
RRII 422	3	3
RRII 429	5	1
RRII 430	1	2
RRIM 600	6	5
RRII 105	7	7

Performance of RRII 400 series clones and RRII 208 in Odisha and North Konkan

Large scale evaluation of the RRII 400 series and a few other clones including RRII 208, the clone which was released in 2016 for wide scale planting in North East India,

Table 19. **Yield ranking of RRII 208 and RRII 105 in comparison to RRIM 600 in Dhenkanal (Odisha) and Dapchari (Maharashtra)**

Clone	Clone trials in Dhenkanal (Odisha)			Mean ranking across trials in Odisha	1985 clone trial Dapchari (mean over 15 years)
	1990	1991	1999		
	Mean yield over 17 years	Mean yield over 16 years	Mean yield over six years		
RRII 208	1	1	1	1	1
RRII 105	-	2	3	2	2
RRIM 600	2	3	2	3	-

Table 20. **Overall assessment of the disease reaction of the RRII 400 series (%)**

Clone	ALF - leaf retention		Disease intensity			Pink
	Unsprayed	Sprayed	*Oidium*	*Corynespora*	*Colletotrichum*	Incidence
RRII 414	83.9	72.1	61.1	7.3	10.0	18.6
RRII 417	75.6	71.9	67.6	24.6	18.3	18.7
RRII 422	62.8	69.5	46.3	30.6	16.2	13.6
RRII 429	77.7	73.3	81.2	20.8	11.5	47.7
RRII 430	82.8	78.9	72.8	6.3	16.1	7.1
RRII 105	52.9	74.1	67.1	60.1	43.3	23.4

was conducted in Odisha, results of which have enabled identification of the most suitable clones for the area.

The results of large scale evaluation of the RRII 400 series in Odisha (Table 18) show that in terms of growth, RRII 430 was the most vigorous followed by RRII 417 and RRII 422. In terms of yield, clone RRII 429 was the best, followed by RRII 430 and RRII 422 which were superior to RRIM 600. RRII 208 was the top ranking clone in all the three clone evaluations at Dhenkanal, Odisha (Table 19). RRII 105 performed better than or comparable with RRIM 600 in Dhenkanal.

A large scale evaluation of popular clones was conducted over the long term in Dapchari, Maharastra also. Over 15 years of tapping, RRII 208 was ranked first over the rest of the clones (Table 19).

Table 21.**Intensity of powdery mildew in RRII 400 series clones in North East India**

Clones	Per cent disease intensity over five years		
	Nagrakata	Agartala	Mean
RRII 414	37.2	42.0	39.6
RRII 417	39.6	42.4	41.0
RRII 422	54.8	49.6	52.2
RRII 429	33.6	33.6	33.6
RRII 430	61.6	58.0	59.8
RRII 105	54.4	52.0	53.2
RRIM 600	38.4	38.8	38.6

Disease reaction of the RRII 400 series clones

Disease reaction of the RRII 400 series clones with respect to powdery mildew, abnormal leaf fall, pink disease, *Corynespora* leaf fall and *Colletotrichum* leaf spot was studied in the traditional region (Table 20). Powdery mildew being the only major disease of rubber in North East India, the disease intensity over five years was scored in two locations *viz.* Nagrakata and Agartala (Table 21).

In the traditional region, RRII 429 was highly susceptible to pink disease. RRII 422, RRII 414 and RRII 417 showed moderate disease incidence. All the clones were susceptible to powdery mildew, with RRII 430 being highly susceptible and RRII 422 showing the lowest intensity among the six RRII clones. RRII 430 and RRII 414 showed very good leaf retention under *Phytophthora* infestation indicating tolerance to abnormal leaf fall disease. Intensity of Corynespora leaf fall was lowest in RRII 430 followed by RRII 414 indicating the disease tolerance of these two clones. In general, the RRII 400 series clones had better tolerance to the disease than RRII 105. The RRII 400 series clones also

exhibited tolerance to Colletotrichum leaf spot and were more tolerant than RRII 105.

In North East India, intensity of powdery mildew disease was moderate in clones RRII 429, RRII 414 and RRII 417 while it was high in RRII 422 and RRII 430. Clones RRII 105 and RRII 430 were highly susceptible at both the locations in NE India (Varghese *et al*., 2009)

Genotype - Environment Interaction (GEI) in growth and yield of RRII 400 series clones across the traditional and non-traditional rubber growing areas

Twelve clones including the RRII 400 series were evaluated in geographically diverse locations across traditional and non-traditional rubber growing tracts in India. The variability for growth, latex yield and timber yield among RRII 400 series clones across three diverse locations within the traditional rubber growing region was also specifically studied (Meenakumari *et al*., 2017). The objectives were to identify the best qualifier as latex-timber clone (the clone with stable latex and timber yields) and also examine the location specificity. Twenty year old trees of five RRII 400 series clones were selected from three locations *viz.* Kanyakumari (ideally suited for rubber), Central Experiment Station (CES) in Central Kerala (the major cultivation belt) and Padiyoor in North Kerala (seasonally drought prone area) for recording growth and timber yields (in terms of clear bole volume). Latex yield over a period of nine years of tapping was also recorded on a monthly basis. RRII 105 was used as the check clone.

In general, in the traditional region, RRII 414 and RRII 430 showed better performance for tree girth, bole height and timber yield (Meenakumari *et al.,* 2017). RRII 430 was superior for latex yield in all locations in the traditional area. Across locations within the traditional region RRII 414 and RRII 429 exhibited the highest mean girth. RRII 430 was invariably the highest and stable yielder in the traditional region. RRII 429 showed better growth in Kanyakumari region, but RRII 105 was the top yielder. The yield of RRII 430 and RRII 203 were on par with that of RRII 105.

Genotype Environment Interactions (GEI) in rubber yield was analysed from traditional and non-traditional regions across the country with a view to identifying clones with wide adaptability as well as specific adaptation (Meenakumari *et al*., 2011). AMMI model was used to quantify GEI and the analysis revealed that environment (E) and GEI together contributed to the major proportion (72.8%) of the variations in rubber yield. In Agartala, Tripura, RRII 422 followed by RRII 429 were the top yielders and registered significantly superior yield to both the controls RRII 105 and RRIM 600. In Nagrakata, Bengal, RRII 429 was the highest yielder and RRII 417 and RRII 422 also recorded significantly superior yield than the controls.

Clones RRII 429, RRII 422, RRII 417, RRII 430 and RRII 105 were high yielding across environments. RRII 429 was the highest yielding clone in the non-traditional region, but showed the highest GEI interaction indicating low stability of performance. RRII 105 and RRII 430 were best suited for the traditional region. RRII 429, RRII 422 and RRII 417 were more suited to non-traditional areas. Among the high yielding clones, RRII 430 (averaged across environments) can be judged the best based on the high yield and low GEI (showing relatively less variation in yield across environments). RRII 430 could also be considered a potential genotype in

Table 22. **Region-specific clone advisory for the different rubber growing districts and states of India**

Region	Districts/States	Clones recommended*@#
South Tamil Nadu	Kanyakumari	RRII 430, RRII 105, RRII 429
South Kerala	Kollam, Trivandrum	RRII 422, RRII 430, RRII 417
Central Kerala	Ernakulam, Kottayam, Pathanamthitta, Alleppey	RRII 430, RRII 414, RRII 417
North Central Kerala	Thrissur, Palghat	RRII 417, RRII 429, RRII 430
North Kerala	Kozhikode, Malappuram, Kannur, Kasargode	RRII 430, RRII 417, RRII 105
Tropical high altitude regions	Wynad, Idukki, Kulathupuzha, Vithura.	RRII 422, RRII 429, RRII 417
South-West Karnataka and Goa	Goa and Dakshin Kannada	RRII 430, RRII 414, GT 1, RRII 203
Konkan and Eastern region	Maharashtra, Odisha	RRII 429, RRII 208, RRII 430, RRIM 600
North East India	Tripura, Assam, Meghalaya Northern Bengal	RRII 208, RRII 429, RRIM 600

*RRII 429 has proved to be high yielding and can be considered for planting in locations as recommended above in the traditional tract subject to effective management of pink disease. Clone RRII 430 is not suitable for high altitude regions and NE India where high severity of *Oidium* infection is experienced.
@ Recommended plant protection measures are advised in all rubber growing regions.
# The system of tapping recommended for the above high yielding clones is S/2 d3. Clone RRII 105 can also be tapped at lower frequencies as recommended by the Rubber Board.

future breeding programme to incorporate stability for rubber yield.

Region-specific clone advisory

Based on results of 29 field evaluations of the RRII 400 series clones and RRII 105 in the traditional region as well as studies on disease reaction, genotype x environment interaction studies and yield from several large scale and on farm evaluations of these and other clones in Tripura, Assam and Northern part of Bengal presented in the foregoing paras, region-specificity in performance of the clones was evident and accordingly the clones have been grouped (Table 22).

Results of long term clone evaluations undertaken at RRS, Dapchari have helped in formulating a recommendation of clones/ planting material suited for cultivation in the Konkan belt along the Western part of the Indian peninsula (Table 22). Clones adapted to the intense summer heat and moisture deficit stress suited to North Konkan were identified. The recommendations of planting materials for this region were made in the form of an advisory of clones suited to North Konkan region. This includes clones RRIM 600 and RRII 208 for the drought prone regions. Odisha is a region that experiences intense summer stress with high temperatures and moisture deficit like Dapachari. Therefore, drought tolerant clones would perform well in both regions, as proved by the superior performance of clone RRII 430 and RRII 208 in large scale evaluations.

RRIM 600 is already an approved Category 1 clone for all non-traditional regions.

CONCLUSION

The region-specific clone advisory was arrived at taking into consideration the yield, growth and disease reaction of clones in each of the nine agroclimatic zones as well as the already existing clone recommendations for the four broad traditional and non-traditional regions. This is the first time a recommendation of region- specific clones is made in India, which is one of the major purposes of starting Regional Research Stations in different agroclimatic regions where natural rubber can be potentially grown. Together with location specific fertiliser recommendation that is now available for adoption through the internet and mobile App, growers are in a better position to take informed decisions about scientific cultivation of natural rubber in terms of selecting the most apt clones and fertilisers which will help increase productivity and reduce costs.

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