EARLY YIELD PREDICTION IN CLONES FROM DIVERSE LOCATIONS IN A CLONAL NURSERY IN THE TRADITIONAL REGION

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A clonal nursery evaluation incorporating 20 clones including five hybrids and 15 ortets selected from diverse locations was laid out in Central Kerala region along with three check clones *viz.* RRII 105, RRII 414 and RRII 430. The selections were from Kanyakumari (traditional region), Guwahati (non-traditional region) and Wayanad (a high altitude region within the traditional belt). The hybrids from Kanyakumari performed better than the ortets from the region. Par 18 was the best performer with the highest test tap yield of 17 g t^{-1} t^{-1} and highest girth of 45.8 cm in the 6th year of planting. Three other hybrids from the region Par 10, Par 9 and Par 11 also showed high test tap yield comparable to RRII 414 and RRII 430, among which Par 10 recorded superior secondary traits in terms of girth and latex vessel rows (LVR). Two ortets from Guwahati *viz.* RRSG 9 and RRSG 4 performed significantly superior to RRII 105 and on par with the modern check clones for growth and test tap yield. One ortet from Wayanad (P 270) recorded test tap yield on par with RRII 105 and exhibited high growth vigour and LVR distribution comparable to RRII 414 and RRII 430. Six clones were identified for further evaluation based on test tap yield, girth and bark characters. RRSG 9 showed good response to stimulation. The performance of specifically adapted clones under ideal climatic conditions is discussed in the light of early selection in *Hevea* breeding.

Key words: Clones, Clonal nursery, Early selection, *Hevea brasiliensis*, Hybrids, Ortets

INTRODUCTION

Breeding cycle in *Hevea* involves long multiple evaluation stages spanning class to three decades. Clones are added to the pipeline every year through small scale evaluation following hybridisation and ortet (plus tree) selection. The three phase field testing from small scale to large scale and onfarm trials is no longer feasible due to the diversified breeding objectives in the current scenario (Mydin, 2014). Lack of fool-proof early selection parameters is yet another disadvantage. Molecular interventions to reduce the period of field testing remain a

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challenge in *Hevea* as in any other perennial tree crop (Priyadarshan, 2017). So the best viable practice is to reduce the duration of the selection cycle.

The concept of clonal nurseries (close spacing of 2.5 x 2.5 m) was first introduced in RRII in 1992 whereby the number of breeding cycles remains the same but the duration of testing can be considerably reduced. A clonal nursery approach can advance the small scale testing period by seven years, minimise the field area through close spaced planting and accomodate more number of test clones so as to cull out the inferior ones at an early stage. Since the yield of clones in the clonal nursery and yield from field trial were positively correlated (Mydin *et al*., 2004), the testing period could be reduced to 23 years (Varghese *et al*., 2006; Abraham *et al*., 2016; Gireesh *et al*., 2017; Antony *et al*., 2018). The modified breeding scheme, which saves land, labour, time and resources, is a major step forward in classical *Hevea* breeding and evaluation in India. According to Wu (1999), reducing the length of breeding cycle is obviously the major advantage of early selection in tree breeding.

Ortet (plus tree) selection programmes which were undertaken concurrently with hybridization in both traditional and non traditional areas could identify potential high yielders specifically adapted to various agro-climatic regions. In the present study, five hybrids and five ortets selected from Kanyakumari (ideally suited for NR), four ortet selections from Wayanad, a high altitude region within the traditional belt (Lakshmanan *et al*., 2006) and six ortet selections from Guwahati in NE India, a non traditional NR growing tract (Mondal *et al*., 2006) were evaluated in a clonal nursery in Central Kerala. The climatic variables of locations from which the selections were made are given in Table 1. The test varieties were judged in comparison with modern high yielding check clones *viz*. RRII 414 and RRII 430 apart from RRII 105. In addition, response to ethephon stimulation was studied for an early indication of the suitability for low frequency tapping. There is a good chance that some of these regionally selected clones may show general adaptation across a wide range of environments. Hence, the objectives of the present study were to evolve next generation *Hevea* clones with wide adaptation and high productivity potential through early selection.

Table 1. **Details of locations of the original hybrids/ortet selections**

Ordinates/ Climatic variables	Kanyakumari (Tamil Nadu)	Wayanad (Kerala)	Guwahati (Assam)
Latitude	08^0 26N	$11^0$37N	$26^0$35N
Longitude	77^0 36E	$76^0$12E	90^0 52E
T max(^{0}C)	32.3	27.5	29.3
T min(^{0}C)	23	17.8	19.3
Rainfall	2000	2333	1800
Elevation (m above MSL)	33	974	50-105

MATERIALS AND METHODS

Location and field planting

The clonal nursery evaluation trial was planted in the research farm of Rubber Research Institute of India ($9^0$32'N $76^0$36'E 73 m above MSL) in Kottayam district, Kerala state of south India. The trial was laid out in 2007 in a randomized complete block design with three replications and plot size of six trees at a spacing of 2.5 m x 2.5 m. Twenty clones including a total of fifteen ortets and five hybrids were included in the trial. Of these, ten clones were from Paraliar in Kanyakumari (Par 3, Par 4, Par 14, Par 15, Par 19, Par 9, Par 10, Par 11, Par 17 and Par 18), six polyclonal selections identified from

Regional Research Station in Guwahati (RRSG 1, RRSG 3, RRSG 4, RRSG 5, RRSG 6, and RRSG 9) and four ortets selected from Panamaram (P 1, P 213, P 270 and P 280), in Wayanad. The selections were multiplied by budgrafting in the respective locations and budded stumps were transported to RRII. The budded stumps were raised in root trainer cups and transplanted to the field at the two whorl stage. Recommended practices were followed for root trainer plants in the nursery and after field planting.

Data recording

Girth was measured annually at a height of 125 cm from the bud union. Dry rubber yield was determined on a seasonal basis following S/2 d3 6d/7 from a total of 15 tappings during lean (Apr-May) and peak season (Nov-Dec) from the 3rd to 5th year after planting, after excluding the latex collected from the first five tappings. Bark characters were recorded following standard procedures. Response to stimulation was determined based on pre and post stimulated test tapping by panel application of 2.5 per cent ethephon in the subsequent year after regular test tapping. The clonal performance was assessed based on growth, test tap yield, structural parameters and response to stimulation. Incidence of pink disease and tapping panel dryness (TPD) was recorded at the end of study period.

RESULTS AND DISCUSSION

Exchange of high yielding hybrids and ortets between traditional and non-traditional rubber growing areas in India has been pursued in the recent past, so as to identify widely adapted clones. The test clones included in the present study were originally selected from three diverse locations representing ideal climate (Kanyakumari), high elevation (Wayanad) and non-traditional (Guwahati) rubber growing areas. Among the check clones,

Table. 2. **Annual mean test tap yield (g t^{-1} t^{-1}) over three years**

Clone	Test tap yield	Clone	Test tap yield
Par 3	4.8 ghi*	RRSG I	9.1 cdefg*
Par 4	4.8 ghi	RRSG 3	8.7 cdefgh
Par 14	8.9 cdefgh	RRSG 4	12.3 abcd
Par 15	8.6 cdefgh	RRSG 5	5.8 fghi
Par 19	10.7 bcdef	RRSG 6	7.7 cdefghi
Par 9 (PB 260 x RRII 105)	11.1 bcde	RRSG 9	11.0 bcde
Par 10 (PB 260 x RRII 105)	11.4 bcde	P 1	4.0 hi
Par 11 (RRII 105 x PB 260)	10.6 bcdef	P 213	4.8 ghi
Par 17 (RRII 105 x PB 260)	7.2 defghi	P 270	9.8 cdefg
Par 18 (RRII 105 x PB 235)	16.8 a	P 280	3.0 i
		RRII 105	9.4 cdefg
		RRII 414	12.4 abc
		RRII 430	15.5 ab
		CD (P=0.05)	4.3

*Values followed by a common letter are not significantly different at 95 per cent confidence level by DMRT

RRII 430 was the highest yielder with a mean test tap yield of 15.5 g t^{-1} t^{-1} followed by RRII 414 (12.4 g t^{-1} t^{-1}). Test tap yield of the test clones showed wide variation ranging from 3 (P 280) to 17 g t^{-1} t^{-1} (Par 18) (Table 2). Three hybrids *viz*. Par 9, Par 10 and Par 11 and one ortet Par 19 from Paraliar also showed yields comparable with the high yielding check clones. The hybrids from Paraliar performed better than the ortets from the region. Test tapping of the original 3 year old seedlings in Paraliar also showed better yield for the hybrids than the ortets (unpublished). Among the Guwahati ortets, RRSG 4 and RRSG 9 recorded a test tap yield (11-12 g t^{-1} t^{-1}) comparable to the high yielding checks. The superiority of RRSG 9 in clonal nursery trials has been already reported from two locations in the NE India *viz*. Guwahati in Assam (Mondal *et al*., 2016) and Tura in Meghalaya (Chandra *et al*., 2016). The test tap yield of ortets from Panamaram was poor compared to those from the other locations. However, the Panamaram ortet P 270 showed test tap yield comparable to the check clone RRII 105.

The diversity of locations was reflected in the variation in growth rate also. Girth at opening varied from 13.2 cm (RRII 105) to 26.8 cm (Par 10). Growth vigour was better in the selections from Kanyakumari and Guwahati compared to that of the clones from Wayanad. Par 10 and Par 18 (42-43 cm) recorded better growth than the high girthing check clone RRII 414 (39 cm) at the end of test tapping (Table 3). Within the traditional region, growth of trees in Kanyakumari was reported to be better than other locations (Meenakumari *et al*., 2017). Moreover, the RRII 400 series clones in general and RRII 414 in particular were noted for their vigorous growth, early tappability and precocious yield (Mydin *et al*., 2011). The growth advantage of the Paraliar hybrids Par 10 and Par 18 over the vigorous check clones in the entire study period is noteworthy

Table 3. **Girth at opening and structural parameters**

Clone	GAO (cm)	BT*	LVR#	Clone	GAO (cm)	BT	LVR
Par 3	23.3 abcd**	3.92	6.60 cdefgh**	RRSG I	22.1 abcde**	4.79	7.07 bcdefgh**
Par 4	19.0 cdefg	4.36	8.60 abcde	RRSG 3	17.5 defg	4.97	5.33 efgh
Par 14	16.6 efg	5.08	8.42 abcde	RRSG 4	21.4 abcde	4.71	8.70 abcde
Par 15	21.5 abcde	5.50	8.83 abcd	RRSG 5	18.5 cdefg	4.5	4.83 fgh
Par 19	22.4 abcde	3.22	6.87 bcdefgh	RRSG 6	18.3 cdefg	5.07	10.27 ab
Par 9	17.8 cdefg	4.76	7.93 abcdefg	RRSG 9	20.2 bcdef	4.92	6.93 bcdefgh
Par 10	26.8 a	4.60	9.63 abc	P 1	17.4 defg	5.02	4.70 gh
Par 11	21.8 abcde	5.29	7.53 abcdefg	P 213	18.3 cdefg	3.85	5.62 defgh
Par 17	19.8 bcdef	4.11	6.03 defgh	P 270	20.3 bcdef	5.28	8.20 abcdef
Par 18	25.8 ab	5.50	10.63 a	P 280	14.7 fg	4.61	4.07 h
				RRII 105	13.2 g	3.74	6.80 bcdefgh
				RRII 414	23.9 abc	5.32	7.30 abcdefgh
				RRII 430	22.1 abcde	4.86	9.75 abc
				CD(P=0.05)	6.14	NS	2.9

GAO: Girth at opening; *Bark thickness (mm); # Number of latex vessel rows

*Values followed by a common letter are not significantly different at 95 per cent confidence level by DMRT

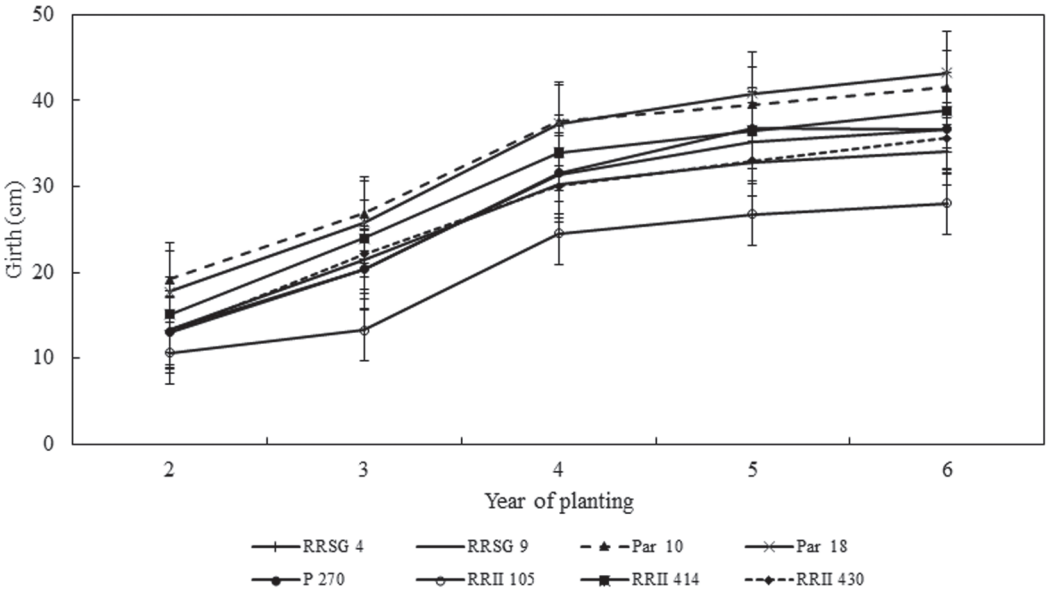

Fig. 1. Growth of the promising clones

(Fig.1). The growth of two high yielding ortets from Guwahati *viz*. RRSG 4 and RRSG 9 was also on par with RRII 414 and RRII 430 despite the fact that they were originally selected from non-traditional NE India, where severe cold adversely affects the growth of rubber trees.

The average girth of trees in the fifth year of planting was 33 cm (RRSG 4) and 41 cm (RRSG 9) as against 29 cm and 33.5 cm respectively reported from Guwahati (Mondal *et al*., 2016). Similarly the ortet selection from Wayanad, P 270, which recorded an average girth of 17 cm (5th year of planting) in the region (Lakshmanan *et al*., 2006) showed better growth vigour (36 cm) when tested in Central Kerala. Reju *et al.* (2017) recently observed that growth of locally recruited seeds from abiotic stress prone areas improved when tested under ideal climatic conditions. Our observations indicate similar trend in the case of budgrafted clones also.

Bark thickness of the test clones was 4-5 mm and did not show much clonal variability. Number of latex vessel rows (LVR) was the highest in Par 18 (10.6) followed by Par 10 (10.3). RRSG 6 and RRSG 4 also registerd high LVR. In general, there exists a linear relationship with number of LVR and age and LVR distribution undergoes a gradual shift away from the cambium with age. According to Obouayeba *et al*. (2000) accelerated differentiation of LVR takes place from six years of growth and continues upto 15 years. Hence, it may be presumed that the extent of clonal variation expected for this trait may not be fully realised in a clonal nursery. However, eventhough bark thickness did not show conspicous variation in the first five years of growth, the significant variability in LVR differentiation

Table 4. **Incidence of pink disease and tapping panel dryness (TPD)**

Clone	No. of trees affected by Pink disease	TPD (%)	Clone	No. of trees affected by Pink disease	TPD (%)
Par 3	5	-	RRSG I	1	-
Par 4	1	5	RRSG 3	-	5
Par 14	5	-	RRSG 4	1	5
Par 15	-	5	RRSG 5	2	22
Par 19	-	-	RRSG 6	-	-
Par 9	-	5	RRSG 9	1	-
Par 10	4	-	P 1	-	11
Par 11	-	-	P 213	1	-
Par 17	2	5	P 270	2	11
Par 18	2	5	P 280	-	5
			RRII 105	3	-
			RRII 414	4	16
			RRII 430	-	-

indicated the strength of this component trait as an adjunct to selection based on yield *per se* in the clonal nursery.

Pink disease incidence was the highest in Par 3 and Par 14 (Table 4). Among the high yielders, Paraliar hybrid, Par 10 showed a higher incidence of the disease. The highest TPD was observed in RRSG 5. No incidence of TPD was observed in 11 clones including the RRSG 9 and Par 10 and the checks RRII 105 and RRII 430. Two trees each of the Panamaram ortets *viz*., P 1 and P 270 showed symptoms of TPD whereas RRSG 4 and Par 18 recorded relatively low incidence.

All the clones included in this study were location specific and were selected in comparison with the then available local check clones *i.e*. RRII 105 in Kanyakumari and Wayanad and RRIM 600 in Guwahati. In Assam, the original mother tree of RRSG 9 as well as the budgrafted clone recorded the highest yield and very good response to stimulation. This clone also exhibited high girth, and low coeffecient of variation for girth and yield indicating its inherent stability and tolerance to cold stress conditions during establishment stage in North-East India (Mondal *et al*., 2006, 2016). So also, the Panamaram ortet P 270 is performing well in the clone trial at Ambalavayal. The superiority of P 270 over RRII 105 has been established for girth, test tap yield and latex vessel rows coupled with high tolerance to powdery mildew disease (Lakshmanan *et al*., 2006) indicating its suitability for high elevation areas. In the present clonal nursery trial, the test clones were budgrafted and evaluated against the modern clones RRII 414 and RRII 430 which are superior to RRII 105 in the traditional region (Licy *et al.,* 2003) and RRIM 600 in non-traditional areas (Meenakumari *et al*., 2011). RRII 430 is also known for temporal and spatial stability for yield (Meenakumari *et al*., 2011, 2018). The superior overall performance of the high yielding hybrids

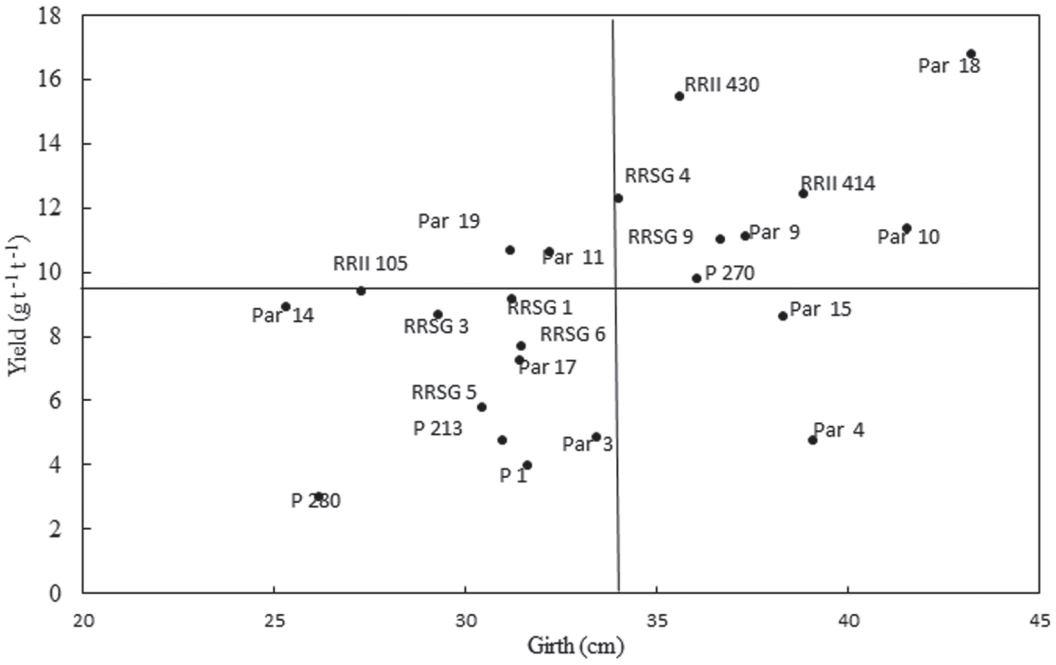

Fig . 2. Selection of clones for high yield and girth

Par 18 and Par 10 from Paraliar, and ortets RRSG 9 from Guwahati and P 270 from Wayanad in Central Kerala region indicates their general adaptation over variable agro-climatic conditions and their capacity to express higher yield in high yielding environments. Moreover, the growth improvement of these clones under conducive climate is remarkable for their ability to sustain yield in the long run. On the other hand, RRSG 4, a clone with high girth and moderate yield in NE India recorded high test tap yield in Central Kerala region whereas RRSG 1, a high yielder in NE India was a poor performer in traditional region indicating high genotype x environment interaction for these two clones. Guwahati and Wayanad are both low temperature stress prone areas. In the former this is due to its high latitude and in the latter this is due to high altitude. The growth and yield attributes of the selections from Guwahati was better than that from Wayanad when tested under ideal environment.

Strategies for early selection in *Hevea* breeding essentially include a combination of growth and yield (Narayanan and Ho, 1973; Varghese *et al.*, 1993). Gouvea *et al.* (2013) stressed the need for simultaneous selection for high girth and dry rubber yield in the initial stages of rubber tree breeding. A scatter plot to identify the clones combining vigorous growth and superior yield is given in Figure 2. Six clones *viz*. Par 18, Par 10, Par 9, RRSG 4, RRSG 9 and P 270 could be selected as top performers falling in the high girth as well as high yielding quadrant along with RRII 414 and RRII 430. Among these, Par 18 was the best performer. It may be presumed that Par 18 could

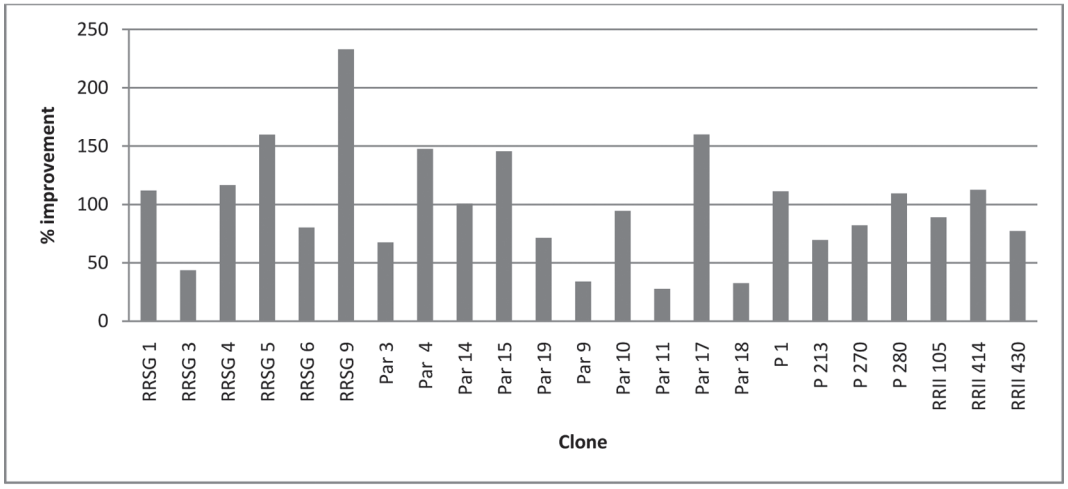

Fig. 3. Test tap yield improvement (%) following ethephon stimulation

combine the high latex yield of RRII 105 (female parent) and vigorous growth and timber yield of PB 235 (male parent) making it suitable as a latex-timber clone. Two clones Par 19 and Par 11 showed above average yield with less vigour and were comparable to RRII 105. Par 15 and Par 4 were vigorous but poor yielders. Ten clones were inferior in terms of both girth and test tap yield.

Response to ethephon stimulation was introduced into early evaluation programmes in seedlings (Meenattoor *et al.*, 2003) as well as clones (Mydin *et al.*, 2005) in order to select genotypes amenable to low frequency tapping. Eventhough all the clones in the present study responded to stimulation, the response showed wide variability. RRSG 9 showed the best response to stimulation with superior post stimulated yield improvement (Fig. 3). The very high response to stimulation for RRSG 9 was reported from Guwahati also (Mondal *et al.*, 2016) indicating its amenability to low frequency tapping systems.

Today, rubber cultivation is being extended to more and more unexplored areas in several countries. Conventional methods for testing *Hevea* clones to specific environments will not be sufficient in the current scenario which calls for identifying clones for optimal adaptation. According to Hamblin *et al*. (1980), while selecting for high yield and general adaptation, it is important that the yield of selected genotypes in the test locality should correspond to the yield when grown over a range of environments for which they are intended. It appears that in the present study, the general adaptation of selected ortets and hybrids in the early testing phase in the traditional region is promising for further large scale and on farm evaluation. Broad adaptation is an indicator of high stability (Finlay and Wilkinson, 1963). High yielding *Hevea* clones with stable and consistent performance across locations are going to be the clones for the future.

CONCLUSION

Evaluation of ortets and hybrids in clonal nurseries has the dual advantages of reducing the duration of the early testing phase and selecting precocious high

yielders. High yielding and widely adapted clones could be identified from the present study. The hybrids Par 18, Par 10, Par 9 and Par 11 from Kanyakumari, the ortets RRSG 9 and RRSG 4 from Guwahati and P 270 from Wayanad showed superior performance to RRII 105 and comparable performance with RRII 430 and RRII 414 in Central Kerala region. Par 18 was the best clone based on overall performance. The selections can be further evaluated in large scale multi locational trials so as to stepup the development of commercial cultivars. The high response to stimulation observed in RRSG 9 could be exploited for low frequency tapping systems.

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