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RESPONSE TO YIELD STIMULATION IN ELITE PIPELINE CLONES

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Adoption of high yielding clones Low Frequency Tapping (LFT) are essential for sustainable rubber cultivation. The present paper reports the response to yield stimulation in 31 newly developed high yielding pipeline clones. Yield under pre-stimulation and stimulation were recorded to understand the response to yield stimulation in each clone in comparison to that of the check clone RRII 105. As a result of stimulation, 23 clones showed higher yield than RRII 105 of which seven clones *viz*. HS PB 242/**172**, HS PB 242/**117**, HS PB 252/**132**, HS Ch 26/**161**, HS PB 5/51/**82**, HS RRII 105/**112** and HS PB 217/**180** had significantly higher yield. Three clones, despite being low yielders compared to RRII 105 in the unstimulated condition showed better yield on stimulation. When response to stimulation in clones under different yield categories was analyzed, all clones in the top yield category except clone HS RRII 105/**112** and HS PB 252/**132** showed low response to stimulation and hence not suitable for LFT. Clone HS RRII 105/**112** was found to be an ideal candidate for LFT with an increase in yield of 85 per cent by virtue of stimulation. In contrast to top yield category, clones in middle and bottom category generally showed very high relative response to stimulation. Response to stimulation in clones under each family indicated that yield category to which the clone belongs rather than the family played a much more important role in deciding the clone's relative response to stimulation. The dry rubber yield pattern after the application of stimulation was identical in all months under study and was found to be the highest in the first tapping day immediately following the application of stimulation as expected.

Key words: Elite pipeline clones, *Hevea*, Low Frequency Tapping, Yield stimulation

INTRODUCTION

Conventional breeding and selection was successful in generating a number of promising rubber clones with high rubber yield under normal system of tapping. Along with the use of high yielding clones, adoption of technologies for reducing input cost and maximizing output plays a critical role in any kind of sustainable agriculture especially in perennial crops such as *Hevea*. Use of yield stimulants, a prerequisite for Low Frequency Tapping (LFT) is one such practice to reduce tapping cost without compromising on latex yield (Vijayakumar *et al.*, 2001; Soumahin *et al.*, 2009). Ethephon used as yield stimulant releases ethylene gas to enhance latex yield by increasing the duration of latex flow after tapping with the reduction of latex coagulation by activating latex cell metabolism (Jacob *et al.*, 1989; d'Auzac *et al.*, 1997). In the present scenario of sustainable rubber cultivation, it is

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important to understand the suitability of newly developed high yielding clones to LFT, for which their response towards yield stimulants should be studied.

Different reports showed the advantage of application of yield stimulants and the practice of LFT in reducing the tapping cost. Sainoi *et al.* (2017) reported that low frequency tapping systems (d3) with stimulation resulted in an equivalent yield in cumulative latex production compared with the other tapping systems and also had higher latex production per tapping. They reported few other advantages of LFT including reduced bark consumption leading to the possibility of lengthening the economic lifespan of the tree.

Rodrigo *et al.* (2011) reported that the cumulative yields from the low frequency tapping systems were not significantly different from the conventional treatment, S/2 d2 and S/3 d2 with ethylene stimulation. However, low frequency tapping systems (d3) markedly had the highest yield per tree and per tapping. This indicated that the reduction in the tapping frequency with stimulation can compensate for the cumulative yield per tree with higher yield per tapping. Jetro and Simon (2007) also reported that a low frequency tapping system must be applied with stimulation to increase the potential of this system. Senevirathna *et al.* (2007) noted that this tapping system was more suitable to minimize the incidence of tapping panel dryness (TPD).

The present paper reports the response to stimulation in 31 high yielding pipeline clones from nine parents and also analyses the response of progeny clones from each parent to find out the genetic/hereditary background if any, in the stimulation response. The pipeline clones under consideration in the present study are in the final stage of evaluation. Significant variability among and within progenies for yield and girth (Mydin, 2010) and long term rubber and timber yield of the clones (Mydin, 2019) have been reported. In the present system of clone recommendation, the suitability of clones for LFT is determined only after the release of clones for large scale planting. Under such circumstances, we will have to lay out another field trial and wait till the trees attain tappable girth and the yield to stabilize which all together will take minimum 12 years. The drawback is that the rubber growers carryout stimulation on the newly released clones without having any clue of its response on the clone. The advantage of the present study is that we will be able to understand whether a particular pipeline clone is responsive to stimulation or not. Based on the present study further research can be taken up to find out the best stimulation practice to be followed only in those clones which showed very good response to stimulation.

MATERIALS AND METHODS

Half-sib progenies developed from a systematic polycross breeding programme involving likely prepotent parents were the base materials for the present study. This included 150 progeny clones from 10 parents which were evaluated in two field trials for a period of 23 years. The clonal evaluation in both the trials were conducted in a compact family block design with three replications of 10 families and four to five trees per plot at a spacing of 4.9 x 4.9 m. The field trials were laid out at the Central Experiment Station of the Rubber Research Institute of India at Chethackal (9.41°N 76.82°E) in Ranni, Central Kerala. Clone RRII 105 was planted as the high yielding reference clone in both the trials. For

Table 1. **List of progeny clones and their parentage**

Parent clone	Progeny clone
RRII 105	HS RRII 105/**4**, HS RRII 105/**106**, HS RRII 105/**112**
PB 242	HS PB 242/**116**, HS PB 242/**117**, HS PB 242/**172**
PB 252	HS PB 252/**19**, HS PB 252/**69**, HS PB 252/**132**
PB 217	HS PB 217/**27**, HS PB 217/**180**
PB 28/83	HS PB 28/83/**35**, HS PB 28/83/**37**, HS PB 28/83/**80**, HS PB 28/83/**81**, HS PB 28/83/**140**, HS PB 28/83/**188**, HS PB 28/83/**191**
PB 5/51	HS PB 5/51/**38**, HS PB 5/51/**40**, HS PB 5/51/**82**, HS PB 5/51/**147**
PB 215	HS PB 215/**47**, HS PB 215/**89**, HS PB 215/**90**, HS PB 215/**93**, HS PB 215/**151**
Ch 26	HS Ch 26/**161**, HS Ch 26/**162**, HS Ch 26/**199**
PB 5/76	HS PB 5/76/**52**

selecting the promising clones for the present study, the trees were tapped for a period of 12 years under S/2 d3 6d/7 system of tapping, without application of yield stimulants. Based on long term yield, the best clones were selected in terms of their superiority over the high yielding check clone RRII 105. 31 promising clones from nine parents were selected for the present study (Table 1) based on the long term data on yield in virgin panels. Clone RRII 105 was used as check clone in both the trials.

A two year study of clones that were found promising in the two trials was conducted on application of 2.5 per cent ethephon, by panel application thrice a year, *i.e.* in the months of May, September and November and the system of tapping followed was S/2 d3 6d/7.

Yield performance of clones on stimulation

Yield under pre-stimulation and stimulation were recorded consecutively for two years during May, September and November. Dry rubber yield recorded on the tapping day before the application of ethephon was taken as pre-stimulation yield and dry rubber yield recorded consecutively for ten tapping days after the application of ethephon was taken as yield on stimulation. Response to stimulation was worked out by analyzing mean yield (g t^{-1} t^{-1}) for six rounds/seasons under stimulation along with yield under pre-stimulation and the per cent increase in yield on application of stimulant was calculated. Even though the clones selected for the study were all promising clones with high yield, the unstimulated yield varied between clones. In order to determine the variation in response to stimulation in clones under different yield categories, clones were grouped into top, middle and bottom category based on the unstimulated yield. Clones with unstimulated yield of more than 80 g t^{-1} t^{-1} were grouped as top category, between 50-80 g t^{-1} t^{-1} as middle category and below 50 g t^{-1} t^{-1} as bottom category. Based on per cent increase in yield on application of stimulant, clones were categorized as high and low response. If the per cent increase in yield on application of stimulant is above 50 per cent it was categorized as high response clones and less than 50 per cent as low response clones.

Family-wise response to stimulation

The response of progeny clones from each parent was analysed to find out genetic/

hereditary background if any, in the stimulation response.

Monthly variation in yield on stimulation

Yield on stimulation in the month of May, September and November was analyzed by pooling the yield of all the clones in each month to study the variability in yield and prolongation of the stimulation response in respective months.

RESULTS AND DISCUSSION

Yield performance of clones on stimulation

Yield on stimulation varied between clones. In Trial 1, clone HS PB 242/**172** showed significantly higher yield compared to RRII 105 as a result of stimulation. Other clones which showed higher yield compared to RRII 105 as a result of stimulation included HS PB 5/51/**147**, HS RRII 105/**106**, HS PB 217/**27**, HS PB 242/**116**, HS PB 28/83/**37**, HS PB 28/83/**80**, HS RRII 105/**4**, HS PB 215/**151** and HS Ch 26/**162**. Of these, clones HS PB 215/**151** and HS Ch 26/**162** despite being low yielders compared to RRII 105 in the unstimulated conditions showed better yield on stimulation.

In Trial 2, clones HS PB 242/**117**, HS PB 252/**132**, HS Ch 26/**161**, HS PB 5/51/**82**, HS RRII 105/**112** and HS PB 217/**180** showed significantly higher yield compared to RRII 105 as a result of stimulation. Other clones which showed higher yield compared to RRII 105 included HS PB 252/**69**, HS Ch 26/**199**, HS PB 215/**93**, HS PB 252/**19**, HS PB 28/83/**188**, HS PB 28/83/**191** and HS PB 215/**89**. Of this, clone HS PB 215/**89** despite being low yielder compared to RRII 105 in the

Table 2. **Response to stimulation in clones under Trial 1 (mean of 6 seasons)**

Clone	Yield categories	Pre-stimulation yield (g t^{-1} t^{-1})	Yield on stimulation (g t^{-1} t^{-1})	Per cent increase
HS PB 242/**172**	Top	92.4	121.6	31.7
HS PB 5/51/**147**		86.8	110.5	27.4
HS RRII 105/**106**		80.5	112.5	39.8
HS PB 217/**27**	Middle	65.5	111.5	70.1
HS PB 242/**116**		63.8	109.4	71.6
HS PB 28/83/**37**		62.4	88.7	42.1
HS PB 28/83/**80**		58.1	93.3	60.6
HS RRII 105/**4**		55.9	77.8	39.2
HS PB 5/51/**38**	Bottom	48.5	69.2	42.7
HS PB 215/**151**		48.4	84.3	74.1
HS PB 215/**47**		43.9	69.9	59.2
HS Ch 26/**162**		40.9	78.5	92.2
HS PB 215/**90**		40.5	68.5	69.0
HS PB 28/83/**35**		29.6	41.6	40.6
RRII 105 (Check)		48.6	77.7	59.9
CD(P=0.05)			40.6	

unstimulated conditions showed better yield on stimulation.

Earlier reports clearly show that response to stimulation varies between clones (Lacote *et al.*, 2013; Gohet *et al.*, 1995). The pipeline clones under consideration in the present study are in the final stage of evaluation. Mydin (2019), reported the selection of 12 clones as promising from the study which included HS PB 252/**132**, HS PB 252/**19**, HS Ch 26/**161**, HS RRII 105/**112**, HS RRII 105/**106**, HS PB 5/51/**82**, HS PB 5/51/**147**, HS PB 242/**172**, HS PB 242/**117**, HS PB 217/**180**, HS PB 215/**93**, HS PB 28/83/**80**. The clones identified from the present study can be employed for large scale evaluation under various stimulation practices for release of the clones suited to LFT for the rubber growers.

Variation in response to stimulation in clones under different yield categories

When response to stimulation in clones under different yield categories was analyzed, all clones in the top yield category in Trial 1 and 2 except clone HS RRII 105/**112** and HS PB 252/**132** in Trial 2 showed low response to stimulation. Hence, these high yielding clones are not suitable for LFT and can be recommended for plantations which follow normal system of tapping. Clone HS

Table 3. **Response to stimulation in clones under Trial 2 (mean of 6 seasons)**

Clone	Yield categories	Pre-stimulation yield ($g\ t^{-1}\ t^{-1}$)	Yield on stimulation ($g\ t^{-1}\ t^{-1}$)	Per cent increase
HS PB 242/**117**	Top	95.6	140.3	46.8
HS PB 252/**132**		91.9	138.3	50.4
HS Ch 26/**161**		87.9	127.9	45.4
HS PB 5/51/**82**		85.1	118.4	39.1
HS RRII 105/**112**		82.8	153.6	85.4
HS PB 217/**180**	Middle	64.6	120.2	86.2
HS PB 252/**69**		63.2	103.4	63.8
HS Ch 26/**199**		56.4	86.2	52.9
HS PB 215/**93**		56.0	99.6	77.8
HS PB 252/**19**		55.7	100.2	79.7
HS PB 28/83/**188**	Bottom	49.8	88.6	77.9
HS PB 28/83/**191**		46.0	79.3	72.2
HS PB 5/76/**52**		44.4	64.1	44.6
HS PB 28/83/**81**		34.6	54.4	57.1
HS PB 215/**89**		31.3	76.7	145.3
HS PB 28/83/**140**		31.2	56.2	80.1
HS PB 5/51/**40**		29.0	53.1	83.0
RRII 105 (Check)		42.9	70.9	65.4
RRII 105 (Check)		42.6	68.9	61.8
CD(P=0.05)			47.3	

RRII 105/**112**, a progeny of RRII 105 showed an increase in yield of 85 per cent and became the top yielder due to stimulation. The results show that clone HS RRII 105/**112** is an ideal candidate for LFT.

In contrast to top yield category, clones in middle category generally showed very high response to stimulation. All clones under middle category in Trial 2 and three clones out of five in Trial 1 showed very good yield increase of more than 50 per cent on stimulation. Most of the clones in middle category showed comparable yield with top category on stimulation. Based on this, clones such as HS PB 217/**27** and HS PB 242/**116** from Trial 1 and clone HS PB 217/**180** from Trial 2 can be selected for LFT.

In bottom category also, majority of the clones showed very good response to stimulation. Four clones out of six in Trial 1 and six clones out of seven in Trial 2 showed high response to stimulation. But these clones have inferior yield even with stimulation and hence, cannot be selected for further evaluation.

Lacote *et al.* (2013) studied the long-term behavior of the rubber tree under different ethephon stimulation treatments in clones IRCA 130, IRCA 230, GT 1 and PB 217. They attributed the ability of the trees to produce more latex under ethephon stimulation to the sucrose and inorganic phosphorus contents of the latex cells. They found that high-yielding clones with low sugar content and high inorganic phosphorus content like IRCA 130, stimulation was not necessary to obtain high yield. Conversely, the effect of ethephon stimulation on latex yield increase was significant in clones with high sucrose content and low inorganic phosphorus content such as PB 217. This could be true with those high yielding clones under the present study in the top yield category which showed less response to stimulation such as clones HS PB 242/**172**, HS PB 5/51/**147**, HS RRII 105/**106**, HS PB 242/**117**, HS Ch 26/**161** and HS PB 5/51/**82**. Thus, we can assume that such clones were already delivering their maximum potential yield. The high response of clone HS RRII 105/**112** to

Table 4. **Family-wise response to stimulation**

Parent clone	Progeny clone with high response	Progeny clone with low response
RRII 105	HS RRII 105/**112**	HS RRII 105/**4**, HS RRII 105/**106**
PB 242	HS PB 242/**116**	HS PB 242/**117**, HS PB 242/**172**
PB 252	HS PB 252/**19**, HS PB 252/**69**, HS PB 252/**132**	—
PB 217	HS PB 217/**27**, HS PB 217/**180**	—
PB 28/83	HS PB 28/83/**80**, HS PB 28/83/**81**, HS PB 28/83/**140**, HS PB 28/83/**188**, HS PB 28/83/**191**	HS PB 28/83/**35**, HS PB 28/83/**37**
PB 5/51	HS PB 5/51/**40**	HS PB 5/51/**38**, HS PB 5/51/**82**, HS PB 5/51/**147**
PB 215	HS PB 215/**47**, HS PB 215/**89**, HS PB 215/**90**, HS PB 215/**93**, HS PB 215/**151**	—
Ch 26	HS Ch 26/**162**, HS Ch 26/**199**	HS Ch 26/**161**
PB 5/76	—	HS PB 5/76/**52**

stimulation could also be attributed to the metabolism as in the case of PB 217. Thus, we can assume that medium and bottom category clones were not performing up to their full potential and these clones can be extracted to the their maximum level by stimulation. Clones IRCA 230 and GT 1 (Lacote *et al.*, 2013) had an intermediary behaviour, explained by medium sucrose content. Furthermore, the authors concluded that the above findings will help planters to optimize latex production by choosing the most adapted ethephon stimulation to clones according to their latex cell biochemistry and their position in a clonal functional typology. Zhu and Zhang (2009) also reported that acceleration of sucrose metabolism by ethylene may be one of the main reasons for the stimulation of latex yield by ethylene.

Family-wise response to stimulation

The clone's response to stimulation under each family was analyzed. Among the clones under study, progenies of some clones responded uniformly while some independently to stimulation (Table 4). All the progenies of clone PB 252, PB 217 and PB 215 showed high response to stimulation. Among the progenies of PB 252, clone HS PB 252/**19** and HS PB 252/**69** coming under the middle yield group of clones responded very well to stimulation as expected. But another progeny under this family namely clone HS PB 252/**132**, despite being a top yielder showed high response to stimulation. Progenies of PB 217 and PB 215 showed high response to stimulation, but none of them were from top yield group. Clone HS PB 5/76/**52**, the sole progeny of PB

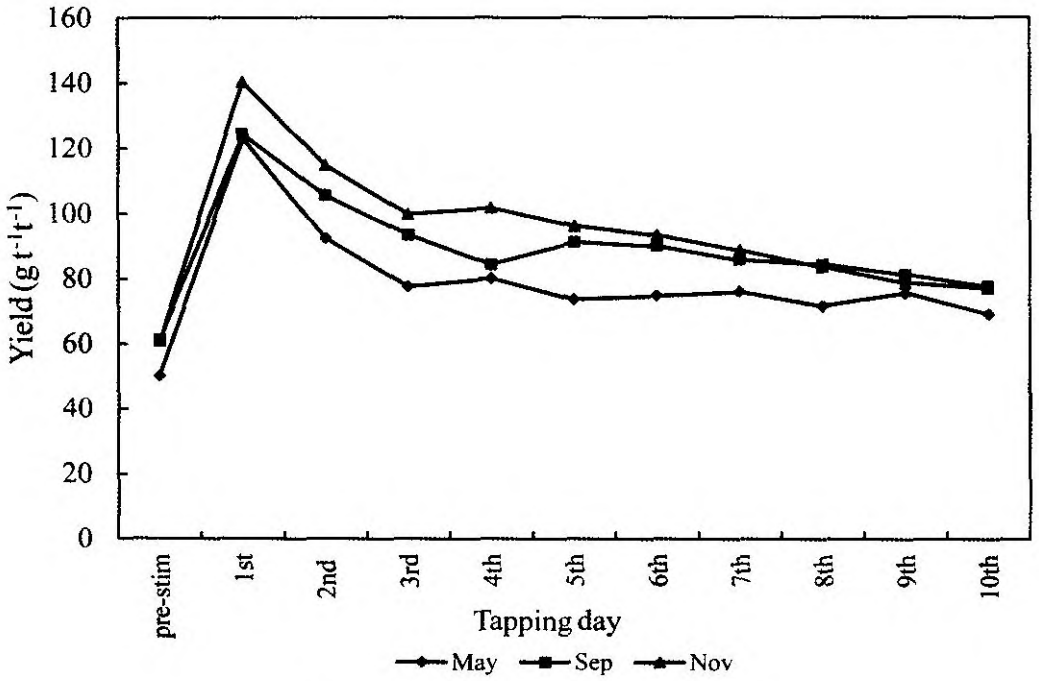

Fig. 1. Dry rubber yield pattern under stimulation

5/76 showed low response to stimulation even though it belonged to bottom yield category.

The varying response of clones under a family is more evident among the progenies of clone PB 242, where clone HS PB 242/**116** a medium yielder responded very well to stimulation and clones HS PB 242/**117** and HS PB 242/**172** coming under the top yielders responded very less. In the case of progenies of PB 28/83, clones HS PB 28/83/**81**, HS PB 28/83/**140**, HS PB 28/83/**188** and HS PB 28/83/**191** coming under the low yield group and clone HS PB 28/83/**80** from the medium yield group showed high response to stimulation, whereas clones HS PB 28/83/**35** and HS PB 28/83/**37** coming under low and medium category respectively showed low response. Clone HS PB 5/51/**82** and HS PB 5/51/**147** being progenies of the top yield group progeny clones of PB 5/51 showed low response to stimulation. Clone HS PB 5/51/**38** and HS PB 5/51/**40**, both from low yield group responded differently with former showing low response and the latter showing high response. Response to stimulation in progenies of RRII 105 also varied with clone HS RRII 105/**112** with high response and HS RRII 105/**106** with low response both coming in the top yield group. Another clone from the family, HS RRII 105/**4** which was a medium yield group clone showed less response to stimulation. In the case of progenies of Ch 26, HS Ch 26/**161** being a top yielder showed low response and HS Ch 26/**162** and HS Ch 26/**199** coming under low and medium yield group respectively showed high response to stimulation. These results indicated that yield category to which the clone belongs rather than the family played a more significant role in deciding the clone's response to stimulation.

Monthly variation in yield

Analysis of dry rubber yield on stimulation showed that maximum yield on was observed during the month of November (Fig. 1). The dry rubber yield pattern from the first tapping day to the 10th tapping day after the application of stimulation was identical in all months under study. Maximum response was observed in the first tapping day immediately following the application of stimulant. The effect of stimulation was reduced thereafter and stabilized from the fifth tapping day after the stimulation.

CONCLUSION

The present paper reports the response to yield stimulation in a set of newly developed 31 high yielding pipeline clones. The study revealed that out of the 12 clones already selected from the final evaluation, seven clones namely HS PB 242/**172**, HS PB 242/**117**, HS PB 252/**132**, HS Ch 26/**161**, HS PB 5/51/**82**, HS RRII 105/**112** and HS PB 217/**180** had significantly higher yield. It was found that clones in the top yield category showed low response to stimulation, whereas clones in middle and bottom category generally showed very high response to stimulation. Clone HS RRII 105/**112** was found to be an ideal candidate for LFT. The results also indicated that yield category to which the clone belongs rather than the family played a much more important role in deciding the clone's response to stimulation. The findings from the present study will aid us at the time of recommendation of these clones for large scale planting as the stimulation response of each clone is identified through the study.

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