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INHERITANCE OF TAPPING PANEL DRYNESS IN FULL-SIB POPULATION OF *HEVEA BRASILIENSIS*

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Tapping panel dryness (TPD) is a serious problem of Para rubber tree (*Hevea brasiliensis*) causing significant losses in latex yield. The present study was conducted to assess heritability of TPD using a full-sib population planted in a small scale trial at Central Experimental Station, Chethackal (Pathanamthitta, Kerala). Symptom of TPD among the full-sibs was confirmed through tapping for two consecutive years. Narrow-sense heritability of TPD was estimated based on parent-offspring regression. There was considerable variation for TPD in the population. Incidence of TPD ranged from 3.6 per cent in clone PB 5/51 to 46.4 per cent in PB 235. Clone RRII 33 did not show any incidence of TPD. Progenies of PB 5/51 x RRII 208 showed minimum TPD incidence (3.6%) while those of RRIM 600 x PB 235 exhibited maximum incidence (29.6%). Progenies of RRIM 600 x RRII 33 did not exhibit TPD symptoms. The study showed high narrow-sense heritability (h^2=0.50) for TPD. Progenies from hybridization between clones with very low TPD incidences (*e.g.* RRII 33) exhibited very low TPD incidences. Similarly, progenies from hybridization between clones with very high TPD (*e.g.* PB 235) possessed more TPD incidences. Overall, the study indicated that TPD may be governed by heritable gene action, which may possibly imply scope for achieving appreciable genetic gain through breeding for TPD tolerance.

Keywords: Breeding, Full-sib, Narrow-sense heritability, Selection, Tapping panel dryness

INTRODUCTION

Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg. (family, Euphorbiaceae; diploid, 2n=36), the Para rubber tree, is monoecious, entomophilic and predominantly out-crossing. Laticifer cells in the bark tissue of the tree yield significant amount of natural rubber latex in the entire plant kingdom. TPD is a symptom expressed by the tree when laticifer cells do not exude latex on tapping which ultimately causes significant loss in yield in almost every rubber plantation. The precise cause of TPD is yet to be recognized (Jacob and Krishnakumar, 2005). It is generally observed that trees which yield precocious amount of latex may ultimately show high incidence of TPD, and the symptom of TPD may be reversible or permanent. It has also been observed that a gap in tapping sometimes result in alleviation of TPD symptoms. Numerous studies have already been done on TPD, however, from breeding and yield-improvement point of view, we still need more information on TPD causing factors and ways to address this important problem affecting yield.

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Resemblance among relatives is a basic genetic phenomenon, and the degree of resemblance determines heritability, which in turn facilitates the choice of a breeding method for use in genetic improvement (Falconer and Mackay, 1996). Several studies have shown variable levels of heritability for yield and related traits in rubber (Tan *et al.*, 1975; Tan, 1979; Liu *et al.*, 1980; Maohuan *et al.*, 1980; Alika and Onokpise, 1982; Alika, 1985; Tan, 1987; Licy *et al.*, 1992; Gonçalves *et al.*, 2004; Narayanan and Mydin, 2012). However, only very few studies have been carried out on heritability of TPD in *Hevea* (Mydin *et al.*, 1999). With reference to TPD, it is important to know heritability of TPD among various clones in order to achieve appreciable level of genetic gain through breeding. This information would be a decisive factor in *Hevea* breeding. In the present study, an attempt was made to assess the heritability of TPD among full-sibs of various clones of *H. brasiliensis*.

MATERIALS AND METHODS

The experimental population consisted of 11 separate families of full-sib progenies (hybridization involving 14 parental clones; Table 1) and their parent clones, planted in 1993 in a small scale trial at Central Experimental Station, Chethackal (Pathanamthitta District, Kerala), following a replicated simple lattice design (5x5 design, four replicates, seven trees per replication). The above full-sib families were generated through hybridization between parental clones during the year 1986. Due to variable survival percentage of full-sibs (from different parental cross combinations), only those with adequate family size were used in the experiment. For the present study, observation was taken on the occurrence of TPD in all the experimental clones during 2011. The symptom of TPD was further confirmed through tapping the affected trees during 2012. Rubber yield (coagulated latex weighed in per tap; g $t^{-1}t^{-1}$) based on annual mean of 12 month observations (January-December) was recorded separately in all the trees following cup coagulation method. Based on data from all the replicate trees of full-sibs and their parent clones, narrow-sense heritability of TPD was estimated based on parent-offspring regression. The regression was computed based on standard biometrical techniques using regression of offspring on parent, covariance of offspring on parents and variance of parents (Zobel and Talbert, 1984; Falconer and Mackay, 1996). The regression (b_{op}) is expressed as equation [1]:

$$b_{op} = \frac{COV_{op}}{\sigma_p^2} \quad [1]$$

where b_{op} is the regression of offspring on parent, COV_{op} is the covariance of offspring on parents and σ^2_p is the variance

Table 1. **Parental clones of the full-sib population**

Clone	Parentage	Origin
RRIM 600	Tjir 1 x PB 86	Malaysia
GL 1	Ortet selection	Malaysia
RRII 203	PB 86 x Mil 3/2	India
RRII 33	Ortet selection	India
PB 235	PB 5/51 x PB S/78	Malaysia
RRII 105	Tjir 1 x Gl1	India
PB 5/51	PB 86 x PB 24	Malaysia
PB 86	Ortet selection	Malaysia
PB 217	PB 5/51 x PB 6/9	Malaysia
RRII 118	Mil 3/2 x Hil 28	India
PR 107	Ortet selection	Indonesia
RRII 208	Mil 3/2 x AVROS 255	India
PB 242	PB 5/51 x PB 32/36	Malaysia
PB 28/59	Ortet selection	Malaysia

of parents. For regression analysis, the mean values of parents and that of progenies were subjected to regression in which the sloping line indicates the linear regression of offspring on mid-parent. The slope of the line (b) provides a direct estimation of narrow-sense heritability (h^2) for the particular trait. The regression equation is expressed as in [2]:

$$y = bx + e \quad [2]$$

(where y = average of progeny values, bx = regression coefficient (slope of line), x = mid-parent value, e = error (lack of fit of values to the line)

Heritability estimates were derived with the data grouped in the following ways (Steinhoff and Hoff, 1971): (1) Progeny on female parents, (2) Progeny on male parents and (3) Progeny on mid-parent. When analysis is performed using values of progenies and one of the parents (either female or male parent) the regression coefficient b or correlation coefficient (r) equals half the narrow-sense heritability. However, when progeny values were regressed on the mid-parent values, the regression coefficient (b) equals narrow-sense heritability (Zobel and Talbert, 1984).

Genetic correlation of TPD, yield and girth was computed based on the offspring-parent relationship (Falconer and Mackay, 1996). For estimation of genetic correlation between two traits, "cross-variances" were obtained from the product of the value of 'X' in parents and the value of 'Y' in offspring. The covariance of offspring and parents for each trait, which provide estimation on genetic correlation, was computed using COV_{XY} (cross-variance) and COV_{XX} and COV_{YY}, the offspring-parent covariances of each trait separately, as equation [3]:

$$r_A = \frac{\mathrm{cov}_{xy}}{\sqrt{\mathrm{cov}_{xx}\mathrm{cov}_{yy}}} \quad [3]$$

In general, cross-variance may be calculated from 'X' in parents and 'Y' in offspring or from 'Y' in parents and 'X' in offspring. In the present study since both the values were available, the arithmetic mean was used.

RESULTS AND DISCUSSION

There was considerable variation for TPD in the population (Tables 2 and 3). There was no incidence of TPD in the parental clone RRII 33. Among the remaining clones, occurrence of TPD exhibited significant variation ranging from 3.6 per cent in RRII 5/51 to 46.4 per cent in PB 235 (Table 2). Among full-sibs, progenies of cross combination RRIM 600 x RRII 33 were devoid of any TPD symptoms. In the remaining hybrids, progenies of

Table 2. **Yield and tapping panel dryness in the parental clones of *H. brasiliensis***

Clone	TPD (%)	Annual mean yield ($g\,t^{-1}t^{-1}$)	Girth (cm)
RRIM 600	16.7	74.3	73.5
GL 1	27.4	29.8	62.3
RRII 203	26.2	89.6	86.8
RRII 33	0.0	29.2	64.1
PB 235	46.4	98.8	90.4
RRII 105	9.2	82.9	68.5
PB 5/51	3.6	38.5	62.7
PB 86	29.5	42.5	58.7
PB 217	28.8	87.3	79.9
RRII 118	15.5	73.8	91.7
PR 107	24.3	27.1	60.0
RRII 208	28.9	42.2	60.6
PB 242	10.0	64.0	60.7
PB 28/59	8.6	39.0	64.5

Table 3. **Yield and tapping panel dryness in the full-sib population of *H. brasiliensis***

Clone	TPD (%)	Annual mean yield (g $t^{-1}t^{-1}$)	Girth (cm)
PB 242 x RRII 105	29.2	59.5	76.6
PB 5/51 x RRII 208	3.6	72.5	83.3
RRII 105 x PB 217	7.1	80.8	77.2
RRII 105 x PB 5/51	7.1	67.2	70.6
RRII 105 x PB 86	7.1	126.4	75.3
RRII 105 x PR 107	14.3	78.7	76.1
RRII 105 x RRII 118	19.3	107.6	87.9
RRIM 600 x GL 1	8.3	68.3	70.6
RRIM 600 x PB 235	29.6	87.5	83.2
RRIM 600 x RRII 203	21.7	66.1	76.1
RRIM 600 x RRII 33	0.0	51.9	84.1

combination PB 5/51 x RRII 208 showed minimum TPD occurrence (3.6%) while progenies of RRIM 600 x PB 235 showed maximum incidence (29.6%).

Rubber yield (g $t^{-1}t^{-1}$) in parental clones ranged from 27.1 in clone PR 107 to 98.8 in PB 235. In full-sibs, rubber yield ranged from 51.9 in progenies of RRIM 600 x RRII 33 to 126.4 in RRII 105 x PB 86 (Table 3). Among the parent clones, RRII 203 (91.7 cm) followed by PB 235 (90.4 cm) showed maximum girth. PB 86 recorded minimum girth of 58.7 cm. Progenies of RRII 105 x RRII 118 showed maximum girth (87.9 cm) while progenies of RRIM 600 x Gl 1 and RRII 105 x PB 5/51 had minimum girth (70 cm).

Data on TPD incidence in parental clones and their full-sib progenies was analysed using parent-offspring regression. Heritability estimates were derived with the data grouped in the following ways: (1) progeny on female parents, (2) progeny on male parents and (3) progeny on mid-parent. In the present study, when heritability was estimated using values of progenies and female parent there was high

Table 4. **Heritability of tapping panel dryness (TPD) in the full-sib population of *H. brasiliensis***

Narrow-sense heritability estimates (h^2)	TPD (%)
Offspring- 'mid-parent' mean	0.50
Offspring - female parent	1.12
Offspring – male parent	0.30

estimate for narrow-sense heritability (h^2=0.56; Table 4). When heritability was estimated using values of progenies and male parent, there was low estimate for narrow-sense heritability (h^2=0.15). However, when progeny values were regressed on the mid-parent values, there was high narrow-sense heritability (h^2=0.50). Comparatively more estimate of heritability based on female parent mean regression indicated possible maternal governance of TPD related genetic factors in the present experimental population. Interestingly, another recent study reported that heritability for annual mean rubber yield based on offspring-male parent grouping resulted in very high heritability estimation as compared to offspring-female parent grouping (Narayanan and Mydin, 2012). Studies in other perennial tree species like pines have previously revealed similar variable estimates using different parent-offspring groupings (Steinhoff and Hoff, 1971).

High estimates of broad-sense heritability for TPD have been reported earlier in *H. brasiliensis*. Using a clonal population comprised of 20 hybrid RRIM clones of Malaysian origin and one primary clone (Tjir 1) from Indonesia, Mydin *et al.* (1999) reported very high estimate of heritability (H^2=68%) for TPD. Attributing predominance of non-additive gene effects in case of TPD, Mydin *et al.* (1999) opined that the high heritability in the clonal population could be due to favourable environmental effects including root stock and soil factors rather than the genotype alone and selection for the trait may not be rewarding. Heritability is a population parameter and the estimates depend on population-specific factors like allele frequencies, the effect of gene variants, and environmental variation. Although heritability is not the proportion of a phenotype that is genetic, but rather the proportion of phenotypic variance that is due to genetic factors and does not necessarily predict the value of heritability in other populations or species, it is surprising to know how constant heritabilities are derived across populations and species (Visscher *et al.*, 2008). High estimates of heritability for TPD across different populations (the present study using full-sib population as well as similar estimate using a clonal population reported by Mydin *et al.*, 1999) showed that most of the variation in TPD may be caused by variation in genotypes. However, predictions for determining the phenotype based on the genotype might sometimes be misleading, because different environments can change or can be manipulated to alter the phenotype (Visscher *et al.*, 2008).

Based on parent-offspring cross-variances, TPD showed negative correlation with annual mean yield (-0.25) and girth (-0.41). Earlier study using a clonal population reported that TPD was not correlated with yield but strongly correlated with girth (Mydin *et al.*, 1999). Based on data on TPD recorded in parental clones and their full-sibs, the above study also showed some relationship between occurrence of TPD in offspring and various parental cross combinations (Tables 1 and 2). For *e.g.* among the clones in the trial, RRII 105 showed comparatively lesser level of TPD incidence. Hybridization of RRII 105 as female parent with those clones possessing high levels of TPD (as male parents) resulted in progenies with lesser TPD incidences. Almost similar trend was noted among hybrids of RRIM 600 and those clones with high incidence of TPD. Besides, progenies generated by cross between RRII 33, a clone with almost no TPD incidence, and RRIM 600, a clone with comparatively high TPD, resulted in progenies with no TPD incidence. Also, progenies generated through hybridization between clone PB 235 with highest level of TPD and RRIM 600 produced progenies with more TPD incidence.

CONCLUSION

High estimate of heritability for tapping panel dryness indicated that variation for TPD in the population may be caused by variation in genotypes. Negative genetic correlation between TPD and yield reiterates the advantage of using clones with low levels of TPD as parental clones in *Hevea* breeding. Overall, the study indicated that TPD may be governed by heritable gene action, which may possibly imply scope for achieving appreciable genetic gain through breeding for TPD tolerance. The study also indicated that using clones with less TPD as female parents may be profitable in developing progenies with lesser levels of TPD but this needs further detailed investigation using more diverse full-sib populations.

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