CHARACTERIZATION OF LATEX AND RUBBER FROM SELECTED *HEVEA BRASILIENSIS* CLONES

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Properties of latex and rubber from 12 exotic *Hevea brasiliensis* clones along with RRII 105 have been studied for different seasons. Clonal difference, seasonal variation and clone to season interaction have been examined. Possible influence of various latex components and other factors on some of the properties are discussed. Most of the clones studied yielded latex with average to high rubber content and the highest DRC was obtained for RRII 105. Majority of the clones yielded rubber with medium to high viscosity and RRII 105 had a relatively higher viscosity. Good correlation was observed between Mooney viscosity and initial Wallace plasticity of rubbers from these clones. Correlation between initial Wallace plasticity and accelerated storage hardening was also significant. ASHT and gel content showed significant indirect relationship. The molecular weight distribution was extremely wide for these rubbers. The molecular weight and the related characteristics showed less variation. Infrared spectroscopic and thermogravimetric analyses of rubber showed only minor variations between the different clones studied.

Key words: Clonal variation, Dry rubber properties, Exotic clones, Latex properties, Seasonal variation.

INTRODUCTION

The breeding programme for *Hevea brasiliensis* aims mostly at improvements in biological characterization such as latex yield, girth increment and resistance to biotic and abiotic stress. However, a high yielding clone with vigorous growth need not always produce latex (rubber) of desirable properties. Hence, latex qualities also require attention in breeding. A major source of variability within and among natural rubber (NR) grades probably is the clone from which the latex is derived (Fuller, 1988). Properties of latices from different clones have been studied previously (Subramaniam, 1975; Saraswathyamma *et al.*, 1990). However, there are very few reports on the physical properties of rubbers from different clones, which may vary. The colour and composition of latex and the plasticity of rubber tend to be uniform within a clone but differ among clones (Martin, 1961). Environmental and soil factors may also influence both the quantity and composition of latex (Ebi and Kolawole, 1992).

Besides rubber particles, latex consists of non-rubber substances such as lipids, proteins, carbohydrates, acids, amines and some inorganic substances. Some of these non-rubber constituents affect the properties of latex concentrates and the solid rubber derived from field latex. Clonal variations may influence the non-rubber constituents, which in turn affect the properties of latex and bulk rubber.

RRII 105 is the most popular *Hevea*

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brasiliensis clone developed by the Rubber Research Institute of India (RRII) and is widely cultivated in Kerala. The present study is to evaluate the variation in properties of latex and rubber from RRII 105 and 12 other exotic clones over different seasons.

MATERIALS AND METHODS

The clones selected for the study, namely, RRII 105, PB 217, PB 235, PB 255, PB 260, PB 280, PB 310, PB 311, PB 312,PB 314, KRS 25, KRS 128 and KRS 163, were planted in the RRII Farm, Kottayam, Kerala, during 1989 in randomized block design with five replications and with seven trees per plot. All the trees were opened for tapping during 1996 and tapped ½ S d/3 without stimulation. Latex samples were collected from three replications of each clone at specific intervals to represent three seasons, namely, January to April (S1), May to August (S2) and September to December (S3). For analysis, the samples were bulked to form one composite for each clone in a season. Latex from each clone was then processed into sheet rubber.

Properties of field latex such as pH, dry rubber content (DRC) and non-rubber solids (NRS) were analysed as per Bureau of Indian Standards (BIS) specifications. Dry rubber properties for raw NR as per BIS specification were also tested. In order to understand the influence of Wallace plasticity (P_0) on Mooney viscosity (V_R) and accelerated storage hardening test (ASHT), regression analyses were carried out. Regression analysis between ASHT and gel content was also undertaken.

Acetone extract and gel content of the rubber samples were measured as per IS 3660 and ASTM D-2765-84 respectively. Thermogravimetric analysis (TGA) and derivative thermogravimetric analysis (DTGA) were carried out to study the thermal stability and degradation of NR. A thermal analyser (TA 2100) thermal analyzer (TA 2100) with 951 TG Module was used for thermal characterization of the samples in nitrogen atmosphere (flow rate 60 ml/min). A sample mass of 10 ± 1 mg was scanned from 30 to 550°C at a heating rate of 10°C per minute and the initial decomposition temperature (IDT), the temperature of maximum rate of mass loss (T_{max}), final temperature of decomposition (T_f) and weight loss were determined from TG traces. The molecular weight ($\bar{M}w$) and molecular weight distribution (MWD) were determined using gel permeation chromatograph (GPC-Waters 510) attached to a 410 diffraction refractometer. HPLC grade toluene was used as solvent at a flow rate of 1 ml/min. The GPC columns were calibrated with polystyrene standards. Masticated NR was dissolved in chloroform (spectroscopy grade) and a thin film was cast on NaCl disc. The infrared spectra of the samples were recorded using Shimadzu Fourier Transform Infrared Spectrophotometer (FTIR-8101M) in the electromagnetic spectrum (4600/cm to 400/cm).

RESULTS AND DISCUSSION

The pH measured in fresh latex is that of the cytosol part in which most of the rubber regeneration process takes place (Lynen, 1969). The cytosol pH is therefore a metabolic regulation factor of major importance and highly significant positive correlation has been shown between pH and rubber production under certain conditions (Eschbach *et al.*, 1984). The clonal and seasonal variations for pH were significant but clone to season interaction was not (Table 1). The latex pH of RRII 105 was nearly neutral and KRS 163, the highest.

Table 1. **Clonal variation in pH**

Clone	S1	S2	S3	Mean
RRII 105	7.04	7.04	7.01	7.03
PB 217	7.00	7.12	7.13	7.08
PB 235	7.07	7.37	7.14	7.19
PB 255	7.10	7.41	6.99	7.17
PB 260	7.19	7.41	7.13	7.24
PB 280	7.21	7.40	7.10	7.24
PB 310	7.11	7.28	6.97	7.12
PB 311	7.16	7.34	7.08	7.20
PB 312	6.99	6.99	7.13	7.04
PB 314	7.18	7.41	7.16	7.25
KRS 25	7.15	7.11	7.06	7.11
KRS 128	7.14	7.22	7.1	7.15
KRS 163	7.21	7.42	7.15	7.26
Mean(Season)	7.12	7.27	7.09	
F	4.01**#	21.38**##	1.35^{NS}###	
CD ($P \leq 0.01$)	0.12	0.06	-	

Clone ## Season ### Clone x Season

Dry rubber content (DRC) was observed to vary depending on various factors. When tree is opened for tapping it produces unstable latex with a high DRC. With the progress of tapping, in a regular tapping system, the latex stability increases and the DRC falls to a steady level between 25 and 45 per cent depending on the planting material. Clonal characteristics, age of the tree, length of tapping cut, frequency of tapping, stimulant application, time of tapping and environmental conditions are some of the factors that affect DRC of latex (Kang and Hashim, 1982; Esah, 1990). Clonal and seasonal variations and clone to season interaction were observed to be significant (Table 2). High DRC was observed for KRS 128 and RRII 105 followed by PB 255 and PB 280. PB 310 and PB 312 showed low values and most of the other clones medium (34 to 41%).

Table 2. **Clonal variation in DRC**

Clone	S1	S2	S3	Mean
RRII 105	42.52	40.20	38.80	40.50
PB 217	34.70	34.27	33.14	34.04
PB 235	40.75	38.27	35.49	38.17
PB 255	42.57	39.73	37.02	39.77
PB 260	38.36	35.74	35.39	36.50
PB 280	41.67	39.10	37.92	39.56
PB 310	35.00	32.73	31.08	32.93
PB 311	34.66	36.65	31.61	34.30
PB 312	30.92	34.34	31.87	32.37
PB 314	36.13	34.64	32.24	34.34
KRS 25	37.23	35.59	32.88	35.23
KRS 128	43.38	40.88	38.29	40.85
KRS 163	40.99	39.53	35.77	38.76
Mean(Season)	38.37	37.05	34.73	
F	24.26**#	18.45**##	3.72**###	
CD ($P \leq 0.01$)	1.79	0.48	1.74	

Clone ## Season ### Clone x Season

The non-rubber constituents (NRC) values for the latex from different clones are presented in Table 3. There was no direct correlation between the DRC and NRC because the non-rubber constituents may have originated in the latex serum. Organic non-rubber constituents may vary both in com-

Table 3. **Clonal variation in non-rubber constituents (%)**

Clone	S1	S2	S3	Mean
RRII 105	3.19	3.02	2.65	2.95
PB 217	3.31	3.12	3.20	3.21
PB 235	3.06	2.84	2.34	2.75
PB 255	3.54	3.29	3.62	3.48
PB 260	3.13	3.10	2.99	3.08
PB 280	3.51	3.26	3.17	3.31
PB 310	3.31	3.14	3.26	3.24
PB 311	3.47	3.15	3.26	3.29
PB 312	2.95	2.80	2.67	2.81
PB 314	3.22	3.11	3.19	3.17
KRS 25	3.64	3.33	3.61	3.53
KRS 128	3.20	3.29	3.37	3.29
KRS 163	2.83	2.99	2.57	2.80
Mean(Season)	3.26	3.11	3.07	
F	8.15**#	15.91**##	3.11**###	
CD ($P \leq 0.01$)	0.26	0.07	0.25	

Clone ## Season ### Clone x Season

position and concentration, depending on various physiological and physical parameters (Gelling and Porter, 1988; Pakianathan *et al.*, 1992). Clonal and seasonal variations and clone to season interaction were significant. KRS 25 and PB 235 had the highest and the lowest NRC, though DRC was in the reverse order.

Ash content in dry rubber represents the quantity of mineral matter present in rubber, such as carbonates and phosphates of potassium, magnesium, calcium, sodium and other trace elements. A high ash content in rubber could also result from contamination during latex collection or processing. Table 4 shows that rubber derived from all the 13 clones had ash contents varying from 0.15 to 0.25 per cent and significant differences were not observed among clones, seasons and their inter-relationships.

Nitrogen content of dry rubber is contributed by the proteinaceous material either tenaciously held or chemically bonded to the rubber (Burfield *et al.*, 1976). Certain proteinaceous materials had been shown to influence the technological properties of rubber (Alias and Hasma, 1988). Although the proportion of nitrogen varies in different types of proteins, the formula protein = 6.25 x nitrogen content, though not a precise indication of protein content, is generally accepted (Bengtson and Stenberg, 1996). Nitrogen content ranged from 0.38 to 0.49 per cent (Table 5). Clonal and seasonal variations and clone to season interaction were significant.

Table 4. **Clonal variation in ash content (%)**

Clone	S1	S2	S3	Mean
RRII 105	0.19	0.26	0.14	0.20
PB 217	0.15	0.14	0.26	0.18
PB 235	0.13	0.16	0.20	0.16
PB 255	0.20	0.16	0.19	0.18
PB 260	0.10	0.14	0.22	0.15
PB 280	0.25	0.09	0.23	0.19
PB 310	0.23	0.11	0.24	0.19
PB 311	0.24	0.17	0.25	0.22
PB 312	0.14	0.35	0.27	0.25
PB 314	0.13	0.16	0.30	0.20
KRS 25	0.11	0.24	0.28	0.21
KRS 128	0.21	0.18	0.23	0.21
KRS 163	0.12	0.10	0.21	0.17
Mean(Season)	0.16	0.17	0.23	
F	1.32^{NS}#	1.26^{NS}##	1.31^{NS}###	

Clone ## Season ### Clone x Season

Table 5. **Clonal variation in nitrogen content (%)**

Clone	S1	S2	S3	Mean
RRII 105	0.43	0.38	0.45	0.42
PB 217	0.41	0.40	0.43	0.41
PB 235	0.39	0.37	0.39	0.38
PB 255	0.46	0.34	0.39	0.40
PB 260	0.41	0.42	0.40	0.41
PB 280	0.38	0.39	0.48	0.46
PB 310	0.48	0.41	0.48	0.46
PB 311	0.52	0.41	0.50	0.48
PB 312	0.49	0.48	0.50	0.49
PB 314	0.50	0.48	0.46	0.48
KRS 25	0.48	0.42	0.43	0.44
KRS 128	0.40	0.38	0.41	0.40
KRS 163	0.42	0.34	0.39	0.38
Mean(Season)	0.44	0.40	0.44	
F	7.13**#	33.60**##	3.96**###	
CD ($P \leq 0.01$)	0.04	0.01	0.04	

Clone ## Season ### Clone x Season

Mooney viscosity gives an indication of the molecular weight, degree of branching, entanglement and crosslinking and also suggests the quantum of mechanical work required on the raw rubber to give mixes with consistent rheological properties after mastication, compounding and mixing. A rubber with a high Mooney viscosity may require longer premastication time or need expensive peptisers to obtain a product of a workable and consistent viscosity. The present study (Table 6) indicated that rubber obtained from three clones (*viz.*, KRS 163, PB 260 and PB 312) has a viscosity range (V_R) of 60 to 70 units, almost close to the processable range of viscosity. Six clones produced medium to hard rubbers with V_R between 70 to 80 units. The remaining four clones including RRII 105 produced hard rubbers with V_R >80. The rubber from PB 255 had the highest Mooney viscosity. Significant differences were observed among clones, seasons and their interaction. This difference in Mooney viscosity is attributed to the variation in gel content as will be discussed later.

Table 6. **Clonal variation in Mooney viscosity**

Clone	S1	S2	S3	Mean
RRII 105	85.22	78.52	81.32	81.68
PB 217	87.67	74.83	87.08	83.19
PB 235	75.75	72.00	81.67	76.47
PB 255	91.53	83.28	89.92	88.24
PB 260	60.68	65.47	67.07	64.41
PB 280	70.52	69.15	76.88	72.18
PB 310	71.53	74.80	68.03	71.46
PB 311	68.08	72.77	69.04	70.08
PB 312	67.85	64.23	66.25	66.11
PB 314	69.38	75.27	66.32	70.32
KRS 25	75.37	70.42	74.08	73.29
KRS 128	87.52	78.32	82.07	82.63
KRS 163	62.38	60.68	67.33	63.47
Mean(Season)	74.88	72.29	75.19	
F	36.30**#	15.50**##	7.16**###	
CD ($P \leq 0.01$)	3.78	1.15	4.15	

Clone ## Season ### Clone x Season

Bulk viscosity of rubber measured by the Wallace plasticity (P_0) is also an important property. The plasticity values determined for the clones showed a range varying from 43 to 61 units (Table 7). Like Mooney viscosity, the clones KRS 163 and PB 255 had the lowest and the highest values of P_0 respectively. Clonal and seasonal variations and clone to season interactions were significant. As in the case of Mooney viscosity, plasticity was also affected by gel content.

Table 7. **Clonal variation in initial Wallace plasticity (P_0)**

Clone	S1	S2	S3	Mean
RRII 105	60.33	49.33	54.33	54.67
PB 217	67.00	48.50	58.83	58.11
PB 235	53.17	46.00	58.33	52.50
PB 255	65.00	53.83	63.17	60.67
PB 260	42.83	43.33	45.33	43.83
PB 280	48.00	44.00	52.83	48.27
PB 310	46.67	49.17	47.17	47.67
PB 311	42.00	51.50	45.17	46.22
PB 312	50.17	39.33	43.17	44.22
PB 314	48.33	48.17	43.83	46.78
KRS 25	53.33	44.17	50.17	49.22
KRS 128	62.33	52.33	57.50	57.39
KRS 163	42.83	38.83	46.83	42.83
Mean(Season)	52.46	46.81	51.28	
F	21.41**#	53.32**##	8.48**###	
CD ($P \leq 0.01$)	3.72	1.16	4.19	

Clone ## Season ### Clone x Season

Plasticity retention index (PRI) is a measure of the resistance of rubber to molecular breakdown by heat. It is assessed by the percentage change of the original plasticity when the rubber is heated at 140°C for 30 min. High values correspond to good resistance to heat and oxidative degradation. The rubbers from the different clones showed PRI values ranging from 80 to 88 per cent (Table 8). Significant differences were not noticed among the clones and clone to season interaction was not significant. Seasonal variations were highly significant.

Mooney viscosity of NR changes during storage as it undergoes hardening, resulting in higher bulk viscosity, when stored at ambient temperature and humidity over a period of time. This hardening process is accelerated at elevated temperature and dry conditions. The hardening is due to the

Table 8. **Clonal variation in plasticity retention index (PRI)**

Clone	S1	S2	S3	Mean
RRII 105	84.00	88.33	73.33	81.89
PB 217	85.50	82.50	71.83	79.94
PB 235	88.50	80.17	72.50	80.39
PB 255	88.33	80.50	76.83	81.89
PB 260	91.50	86.00	81.83	83.44
PB 280	94.67	86.67	81.17	87.50
PB 310	95.67	82.33	77.67	85.22
PB 311	89.67	76.50	80.33	82.17
PB 312	90.50	82.17	73.83	82.17
PB 314	88.17	79.83	82.33	83.44
KRS 25	90.00	89.67	77.17	85.61
KRS 128	87.50	86.30	73.00	82.28
KRS 163	90.33	87.67	82.67	86.89
Mean(Season)	89.56	83.74	77.27	
F	2.09^{NS}#	85.34**##	2.05*###	
CD ($P \leq 0.01$)	-	1.89	6.82	

Clone ## Season ### Clone x Season

Table 9. **Clonal variation in ASHT**

Clone	S1	S2	S3	Mean
RRII 105	10.00	30.00	28.33	22.78
PB 217	9.67	32.00	14.30	18.65
PB 235	16.00	34.67	18.21	22.96
PB 255	7.00	27.33	15.67	16.67
PB 260	17.67	37.00	24.33	26.33
PB 280	27.67	35.67	21.33	28.22
PB 310	23.00	32.00	20.00	25.00
PB 311	15.67	28.33	17.00	20.33
PB 312	14.67	41.67	15.33	23.89
PB 314	19.33	29.33	22.67	23.78
KRS 25	15.33	34.33	17.00	22.22
KRS 128	10.67	36.33	21.33	22.78
KRS 163	21.67	40.33	27.00	29.67
Mean(Season)	15.26	33.77	20.19	
F	3.94**#	61.93**##	1.26^{NS}###	
CD ($P \leq 0.01$)	5.91	3.44	-	

Clone ## Season ### Clone x Season

crosslinking among the rubber molecules involving the aldehyde or carbonyl groups (Subramaniam, 1975) and certain aldehyde condensing groups in the non-rubber phase including some amino acids (Gregory and Tan, 1976). The hardening phenomenon of NR is usually assessed by the accelerated storage hardening test (ASHT) in which the rubber is stored at 60°C over phosphorus pentoxide for 24 h, and the extent of storage hardening is expressed in terms of the resulting increase in Wallace plasticity number, ΔP. Table 9 shows the results obtained for rubber from different clones. Significant differences existed among the clones and the seasons but clone to season interaction was not significant. The concentration of aldehyde groups and aldehyde condensing groups varies with rubber clones (Subramaniam, 1975). The concentration of aldehyde condensing groups in rubber is ten to twenty times that of aldehyde groups and the extent of accelerated storage hardening of the rubbers would depend only on the aldehyde group concentration. The clones PB 235 and KRS 163 showed the lowest value and the highest values respectively. Significant differences were observed among the clones and seasons but clone to season interaction was not significant.

A regression line was fitted by taking V_R as dependent variable and P_0 as independent variable, following the regression equation:

$$V_R = 1.052\ P_0 + 21.2874$$

where the coefficient of correlation $R^2 = 0.66$

The regression between V_R and P_0 was highly significant and around 66 per cent of variation in V_R could be explained by P_0. Another regression line was fitted by taking ASHT as dependent variable and P_0 as independent variable. The regression equation is

$$ASHT = -0.7020\ P_0 + 57.922$$

where the coefficient of correlation $R^2 = 0.27$

The regression between P_0 and ASHT was also significant but only 27 per cent of the variation in ASHT could be explained by P_0. Rubbers with low P_0 undergo higher extent of storage hardening and *vice versa.* This is in agreement with the higher aldehyde group concentration generally found in the softer rubbers, compared to the harder rubbers.

Table 10 gives mean values of acetone extract for the latex from different clones. Clonal variation, seasonal variation and clone to season interaction were significant. The acetone extract of NR contains naturally occurring non-rubber constituents such as lipids, fatty acids, quebrachitol, sterols and esters. In addition, acetone will extract the degraded rubber, if the rubber has been exposed to oxidative influences such as strong sun light (Bengtson and Stenberg, 1996). Lipids are responsible for the stability of the rubber particles (Ho *et al.*, 1976). The sterols and esters are believed to contain the antioxidant, which is effective in preserving the raw rubber against oxidation and softening during storage (Bengtson and Stenberg, 1996). Fatty acids influence strongly the rate of vulcanization with certain accelerator system (Ebi and Kolawole, 1992). Generally acetone extract varies between 2 to 5 per cent in dry rubber (Esah, 1990) and for all the clones, the values were within this limit. KRS 128 yielded the minimum and PB 260 the maximum acetone extract values.

Gel is the insoluble fraction when the rubber is dissolved in a solvent. Two types of gels exist in NR; micro gel and macro gel. Micro gel consists of particles of submicron size, which are crosslinked latex particles. Macro gel appears to be a secondary bonded network incorporating micro gel and most of the proteinaceous materials. The gel content of the rubber from the different clones is represented in Table 11. Rubber from PB 255 showed the highest gel content followed by that from RRII 105 and KRS 163, the least. Clonal and seasonal variations and

Table 10. **Clonal variation in acetone extract**

Clone	S1	S2	S3	Mean
RRII 105	2.81	2.74	3.01	2.80
PB 217	3.83	4.26	4.06	4.08
PB 235	3.49	4.24	4.35	3.96
PB 255	2.23	3.42	3.00	2.93
PB 260	3.55	4.61	4.4	4.17
PB 280	3.03	3.18	3.76	3.50
PB 310	2.91	3.59	3.60	3.29
PB 311	2.58	2.81	3.28	3.03
PB 312	2.86	2.68	2.92	2.93
PB 314	2.55	3.09	3.10	2.93
KRS 25	2.81	3.52	3.07	3.14
KRS 128	2.67	2.52	2.75	2.60
KRS 163	3.78	4.25	4.23	4.07
Mean(Season)	3.14	3.33	3.54	
F	35.06**#	40.25**##	2.42**###	
CD ($P \leq 0.01$)	0.29	0.09	0.32	

Clone ## Season ### Clone x Season

Table 11. **Clonal variation in gel content**

Clone	S1	S2	S3	Mean
RRII 105	14.96	18.99	16.05	16.67
PB 217	12.43	13.57	14.16	13.39
PB 235	1.91	5.84	10.65	6.13
PB 255	21.21	20.48	27.00	22.90
PB 260	2.69	5.13	6.53	4.78
PB 280	4.62	8.12	10.74	7.83
PB 310	9.47	14.99	12.56	12.34
PB 311	11.22	12.74	18.41	14.12
PB 312	6.45	12.03	12.42	10.34
PB 314	8.95	13.85	13.01	11.94
KRS 25	9.28	6.04	16.23	10.52
KRS 128	6.48	11.08	13.71	10.42
KRS 163	1.74	5.18	6.37	4.43
Mean(Season)	8.57	11.39	13.69	
F	24.92**#	78.89**##	3.95**###	
CD ($P \leq 0.01$)	2.96	0.82	2.96	

Clone ## Season ### Clone x Season

clone to season interaction were significant. Significant indirect relationship was observed between ASHT and gel content.

Thermogravimetric plot of NR from the clone RRII 105 is represented in Fig. 1. Three regions of temperatures (up to 250°C, 250 to 450°C and higher than 450°C) are considered in discussing the thermal stability of NR. Below 250°C, solid rubber is quite stable. In the absence of oxygen, crude rubber may be kept for long periods with no loss of low molecular weight products from thermal reaction. Degradation of NR occurs in two steps. The first step degradation starts at about 300°C and completes at 431°C. During this stage, 79.98 per cent weight loss was observed due to rapid volatilization and substantially complete distillation. The weight loss observed at 300°C was 1.51 per cent. The second step of degradation starts at 431°C and completes at 490°C. During this stage, the weight loss observed was 16.03 per cent. The first step degradation occurred at a sharp rate compared to the second step. In the DTGA curve, the major peak was observed at 398°C. This corresponds to the temperature at which

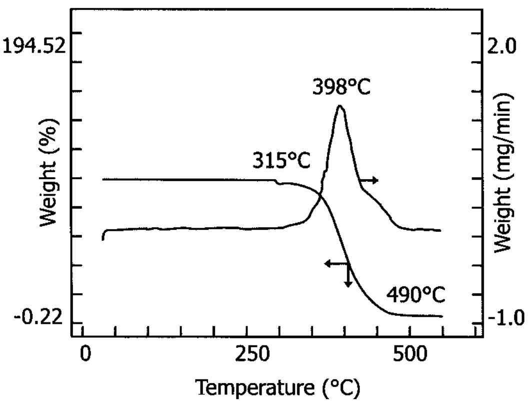

Fig. 1. Thermogram of the rubber from the clone RRII 105

maximum rate of degradation of NR takes place. Above 300°C, volatilization becomes rapid. Complete degradation occurred in 30 min at temperature near 400°C. Results obtained for the clones are given in Table 12. The degradation behaviour does not show variation among samples indicating low influence of non-rubber constituents.

Table 12. **Clonal variation in thermogravimetric parameters**

Clone	IDT°C	T max°C	Peak area	weight loss (%)
RRII 105	315	398	6.79	96.16
PB 217	315	398	7.03	95.27
PB 235	315	398	6.95	94.93
PB 255	315	398	6.81	96.47
PB 260	315	398	6.76	95.02
PB 280	315	398	6.99	96.19
PB 310	315	398	6.59	94.98
PB 311	315	398	7.09	94.75
PB 312	315	398	6.80	96.56
PB 314	315	398	7.26	96.36
KRS 25	315	398	7.04	96.23
KRS 128	315	398	6.62	94.86
KRS 163	315	398	7.22	96.02

The molecular weight distribution of rubber for all the clones studied was extremely wide and the molecular weight was in the range of 10^4 to about 10^7. The molecular weight distribution curve obtained by GPC for the clone RRII 105 is represented in Fig. 2. $\bar{M}_n$ (number average molecular weight), $\bar{M}_w$ (weight average molecular weight) and polydispersity ($\bar{M}_w / \bar{M}_n$) of the 13 clones for the three seasons are given in Table 13. The molecular weight characteristics did not show wide variations either within the different clones studied or with change in seasons as observed from the low CV values.

The infrared (IR) spectra of the films from all the clones were recorded. IR spectrum of the film from the clone RRII 105

Table 13. **Clonal variation in molecular weight**

Clone	S1			S2			S3		
	$\bar{M}_n$ (Daltons)	$\bar{M}_w$ (Daltons)	Polydispersity	$\bar{M}_n$ (Daltons)	$\bar{M}_w$ (Daltons)	Polydispersity	$\bar{M}_n$ (Daltons)	$\bar{M}_w$ (Daltons)	Polydispersity
RRII 105	2.11×10^5	10.30×10^5	4.87	2.15×10^5	11.52×10^5	5.33	2.06×10^5	9.84×10^5	4.77
PB 217	2.05×10^5	9.73×10^5	4.75	2.28×10^5	11.56×10^5	5.07	1.94×10^5	10.34×10^5	5.34
PB 235	1.95×10^5	9.90×10^5	5.07	2.20×10^5	10.85×10^5	4.94	2.09×10^5	10.89×10^5	5.20
PB 255	2.19×10^5	10.80×10^5	4.93	1.84×10^5	9.63×10^5	5.23	1.84×10^5	8.67×10^5	4.71
PB 260	2.40×10^5	10.70×10^5	4.21	1.95×10^5	9.86×10^5	5.06	1.83×10^5	9.56×10^5	5.21
PB 280	2.04×10^5	10.30×10^5	5.05	1.98×10^5	10.76×10^5	5.42	1.99×10^5	10.78×10^5	5.41
PB 310	2.39×10^5	11.60×10^5	4.84	2.22×10^5	10.47×10^5	4.72	1.75×10^5	9.44×10^5	5.41
PB 311	2.20×10^5	10.30×10^5	4.69	1.86×10^5	9.48×10^5	5.11	1.70×10^5	8.34×10^5	4.93
PB 312	2.07×10^5	9.27×10^5	4.47	1.95×10^5	10.13×10^5	5.19	1.88×10^5	9.36×10^5	4.98
PB 314	2.25×10^5	10.50×10^5	4.66	1.95×10^5	9.95×10^5	5.10	1.82×10^5	9.80×10^5	5.38
KRS 25	1.99×10^5	9.25×10^5	4.64	2.26×10^5	11.35×10^5	5.03	1.83×10^5	9.36×10^5	5.11
KRS 128	2.05×10^5	10.20×10^5	4.99	2.37×10^5	11.54×10^5	4.87	1.86×10^5	10.23×10^5	5.49
KRS 163	2.01×10^5	10.10×10^5	5.03	2.11×10^5	10.76×10^5	5.11	1.89×10^5	10.19×10^5	5.38
CV	6.81	6.10	5.25	8.28	7.06	3.63	6.07	7.70	4.99

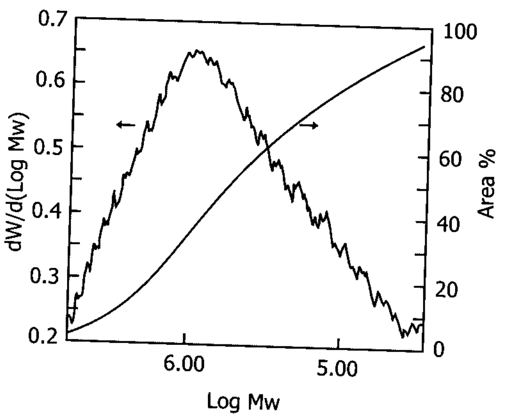

Fig. 2. Molecular weight distribution curve of the rubber from the clone RRII 105

for the range 3600/cm to 400/cm is represented in Fig. 3. It exhibited characteristic absorption peaks due to the C-H deformation of cis C=C-H at 835/cm, C=C oscillation at 1665/cm, $-CH_3$ mode at 1375/cm, $-CH_2$ mode at 1449/cm (George *et al.*, 1992). N-C=O vibration at 1540/cm (Aik-Hwee *et al.*, 1992) and absorption at 890/cm corresponding to isopropenyl $-C(CH_3)=CH_2$ group (Ivan *et al.*, 1993).

CONCLUSION

Important properties, which are related to the qualities of latex and rubber were studied in 13 clones of *Hevea brasiliensis*. The impact of clonal and seasonal variations on these parameters were observed to be significant. The interactive influence of clone to season was also sound.

DRC was medium to high for all the clones studied except PB 310 and PB 312. The highest DRC was observed for the clones KRS 128 and RRII 105. In terms of plasticity, most of the clones gave medium to hard rubbers. Clone RRII 105 could be graded to the higher viscosity range. KRS 163 had the lowest P_0, Mooney viscosity and gel content, whereas the highest values were observed for clone PB 255. The clone PB 255 showed the lowest value for ASHT while KRS 163, the highest. Ash content and PRI were not affected by clonal and seasonal factors. Good correlation was obtained between Mooney viscosity and P_0 for all the clones. Correlation between P_0 and ASHT was also

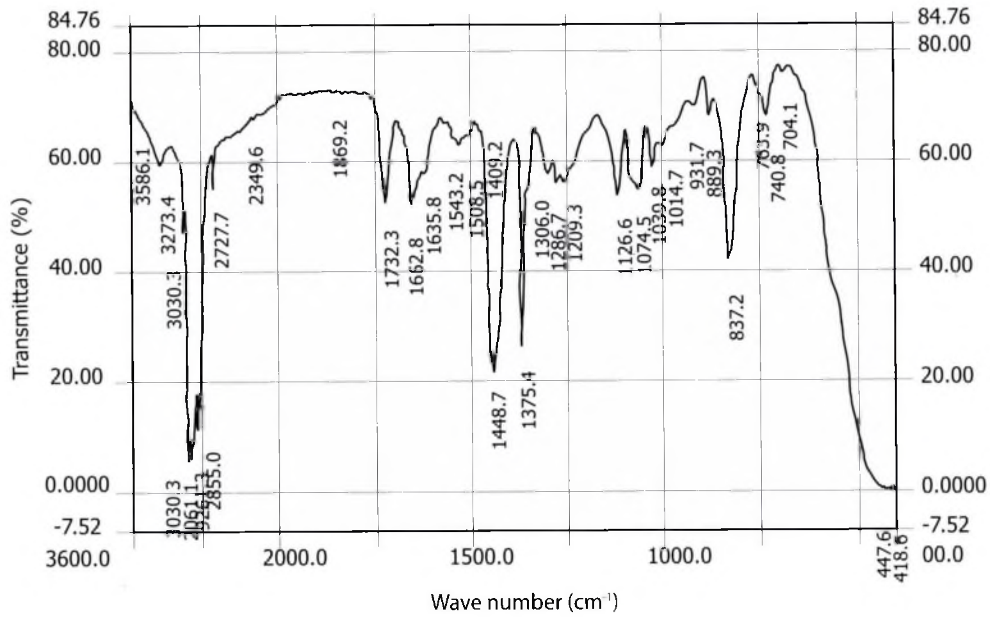

Fig. 3. IR spectrum of the rubber film from the clone RRII 105

significant. ASHT and gel content showed significant indirect relationship. Rubber from all the clones showed similar degradation pattern during thermogravimetric analysis. Characteristics including molecular weight distribution for all the clones were almost uniform. Little difference could be traced in the IR spectrum of all the clones. The data generated could provide a comparative assessment of the latex of different clones, though some variations are expected under different soil and environmental conditions.

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