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The physiological and biochemical regulation of yield in clones of *Hevea brasiliensis*

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ABSTRACT

The intrinsic capacity of a clone to synthesize rubber is different in different clones of *Hevea*. While factors influencing rubber regeneration and latex flow are related to intrinsic characteristics of a particular clone, they are also modified by the prevailing environmental factors. The present study was conducted with the objective to understand the role of physiological and biochemical parameters in regulating the yield. The yield in ten different *Hevea* clones at three different seasons of the year was studied to assess clonal and seasonal variations in yield. The observed variations in yield were then related to the physiological and biochemical parameters that regulate the *in situ* regeneration of rubber and flow of latex.

Introduction

The intrinsic rubber synthesis capacity is different in different clones of *Hevea*[1]. Similarly, the various physiological parameters that regulate the flow of latex are also different in different clones. Both *de nova* synthesis, or regeneration of rubber between sucessive tappings, and latex flow are important in determining the rubber yield of a clone[2,3].

While factors influencing rubber regeneration and latex flow are related to intrinsic characteristics of a particular clone, they are also modified by the prevailing environmental factors. For example, factors influencing total flow such as initial flow rate (IFR), plugging index (PI), turgor pressure (TP) etc are sensitive to the prevailing environment[3]. Similarly, the biochemical composition of the latex such as the dry rubber content (drc) and the concentration of thiols, total solid content (TSC) etc may also depend on the environment.

The present study was conducted with the objective to understand the role of physiological and biochemical parameters in regulating the yield. The yield of ten different *Hevea* clones was studied at three different seasons of the year to assess clonal and seasonal variations in yield. The observed variations in yield were then related to the physiological and biochemical parameters that regulate the *in situ* regeneration of rubber and flow of latex.

Materials and methods

The study was conducted at the Central Experiment Station, Chethackal, Kerala, India at a latitude of 9.22° N 76.9° E and an altitude of 100m above mean sea level. The clones investigated were RRII 300, PB 235, RRII 105, RRIM 600, GT1, PR 107, RRIM 501, RRII 118, RRIM 703, and RRIM 612. The experimental trees were planted in 1981 and were tapped using the 1/2S d/2 6d/7 tapping system. Yield was measured by the cup coagulation method during January 1993, September 1993 and July 1994; of these January was a dry month and the other two were wet (data not shown). Measurements were recorded separately on four trees of each clone. Physiological parameters such as initial flow rate (IFR), plugging index (PI) and turgor pressure (TP) were determined as described previously[3]. Dry rubber content was determined by the gravimetric method after acid coagulation. For the determination of TSC one gram of latex sample was dried to constant weight. Sucrose, thiols, inorganic phosphate (Pi) and Magnesium (Mg^{++}) were extracted from a known amount of latex with 2.5% trichloroacetic acid. Thiols were measured by the Taussky and Short method[4]. Magnesium was estimated by the atomic absorption spectrometry method[5]. The method of Scott and Melvin[6] was followed for the estimation of sucrose. Bursting index was calculated from measurements of phosphatase activity as given by Ribaillier[7].

For the sake of clarity, only seasonal variation data of two clones (RRII 105 - the highest yielder and RRIM 612 - the lowest yielder) are shown. The yield of the other clones fell between these two. Data were analysed for statistical significance by employing an independent "t" test. In order to understand the general relationship between the various parameters, linear correlation was done by pooling data from all ten clones studied.

Results

Significant difference in yield was noticed between clones RRII 105 and RRIM 612 during all of the three seasons studied (Figure 1A). Yield was less in the dry month of January 1993 than in the wet months of September 1993 and July 1994 for both clones.

Bursting Index showed significant difference between the two clones only during the dry season and not during the wet season (Figure 1B). Pooling data from all ten clones, a clear negative correlation was observed between yield and BI (Figure 4C). Initial flow rate (IFR) was positively correlated with yield (Figure 4A). Clone RRII 105 had a higher IFR than RRIM 612 (Figure 1C). When all clones are compared there was a weak negative correlation between yield and the sucrose content of latex (Figure 4D). Sucrose content was higher in RRIM 612 than RRII 105 in all seasons studied (Figure 2A). Thiol content of latex was inversely related to rubber yield (Figure 4E). Comparing RRII 105 with RRIM 612, the former had lower latex thiol levels than the latter during wet months. During the dry season, the latex thiols content increased and was comparable in both clones (Figure 2B). Dry rubber content exhibited exactly the opposite trend to thiols (Figure 2C) and TSC (Figure 2D) in the two clones. Dry Rubber Content was positively related to yield (Figure 5A). While Mg^{++} was positively related to yield (Figure 5B), Pi showed a very weak association with yield (Figure 4F). However, when RRII 105 is compared with RRIM 612, both Pi and Mg were markedly higher in RRII 105 compared to RRIM 612 in all seasons (Figures 3A and 3B). Turgor pressure (Figure 3C) was greater and PI was lower (Figure 3D) in RRII 105 compared to RRIM 612. While BI was negatively related to Mg^{++}, it was positively correlated with thiol and PI (Figures 6A, 6B and 6C). Sucrose content showed a negative correlation with phosphate but it was positively related to thiols and PI (Figures 6D, 6E and 6F).

Discussion

In the present study with ten *Hevea* clones, there were clear clonal differences in yield and yield components which were altered by the environment.

Of the various parameters, yield was more strongly related to BI ($r = -0.67$) and thiols ($r = -0.58$). Bursting index is a measure of the integrity of the lutoid particles and as they become less and less stable, the fast and easy flow of latex becomes restricted due to the bursting of the lutoids and the ensuing plugging of the laticiferous vessels. While the negative association between yield and BI is well known[8,9], our results on the correlation of thiols with yield do not agree with some published studies[9].

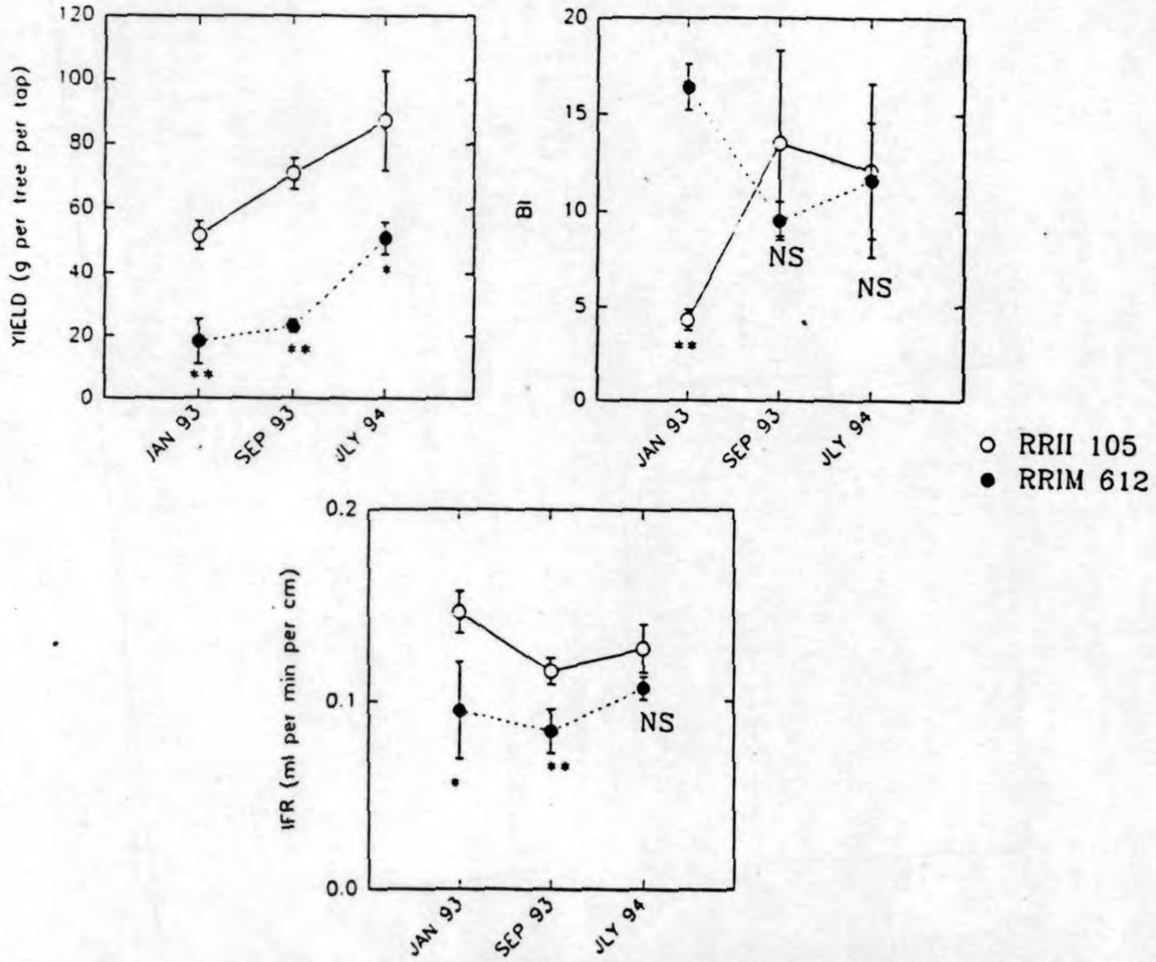

Figure 1 *Seasonal variations in yield (A), BI (B) and IFR (C) in RRII 105 and RRIM 612*

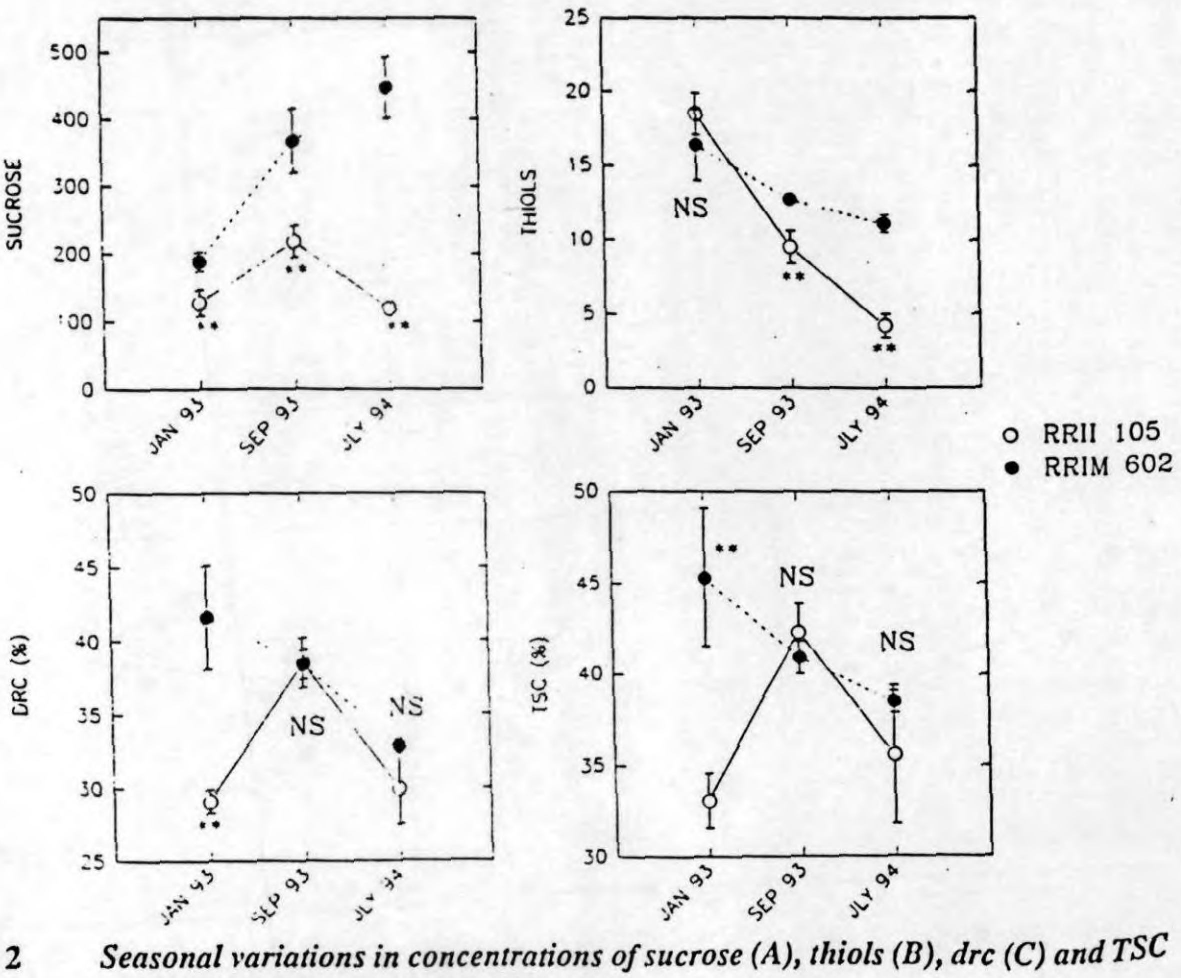

Figure 2 *Seasonal variations in concentrations of sucrose (A), thiols (B), drc (C) and TSC (D) in RRII 105 and RRIM 612*

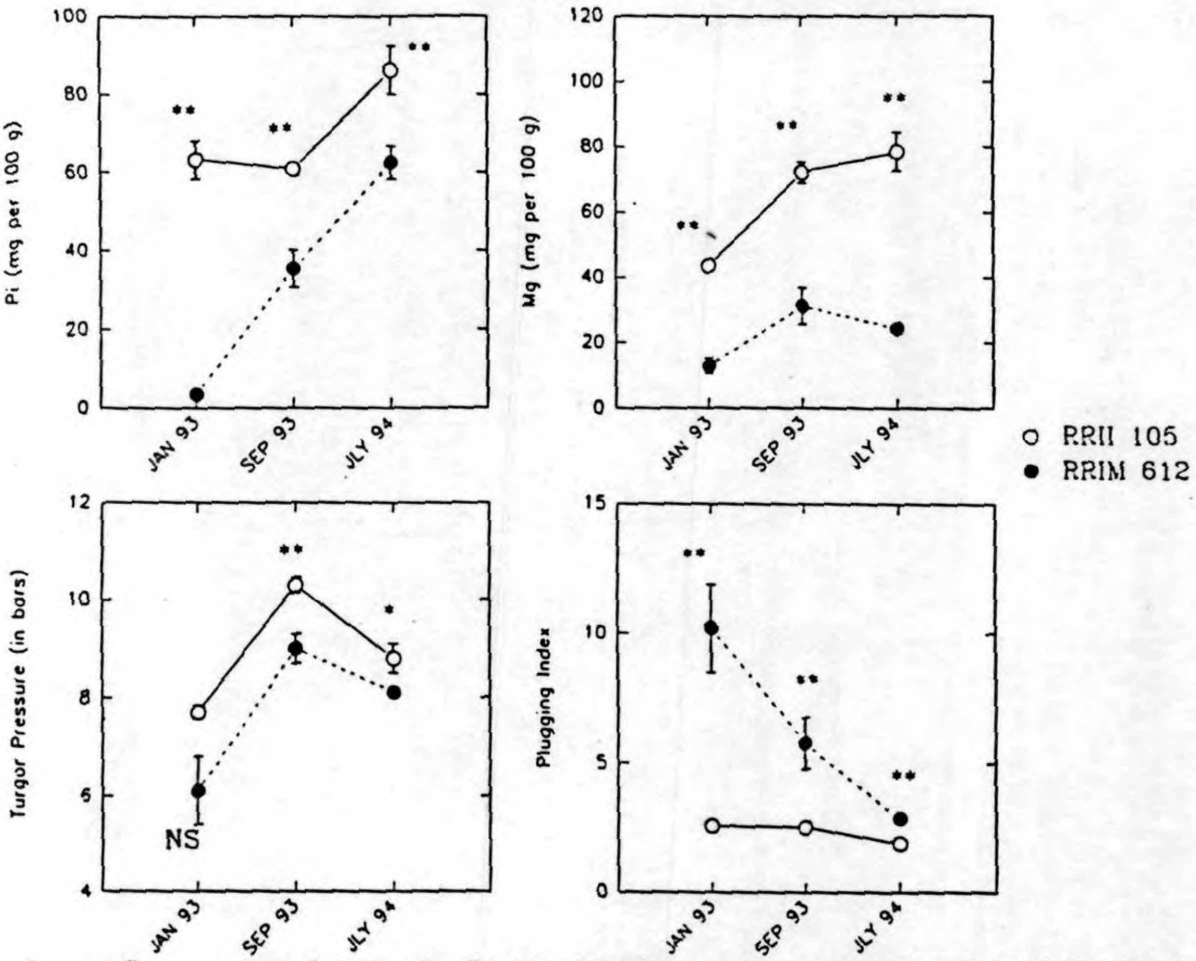

Figure 3 ***Seasonal variations in Pi (A), Mg (B), turgor pressure (C) and PI (D) in RRII 105 and RRIM 612***

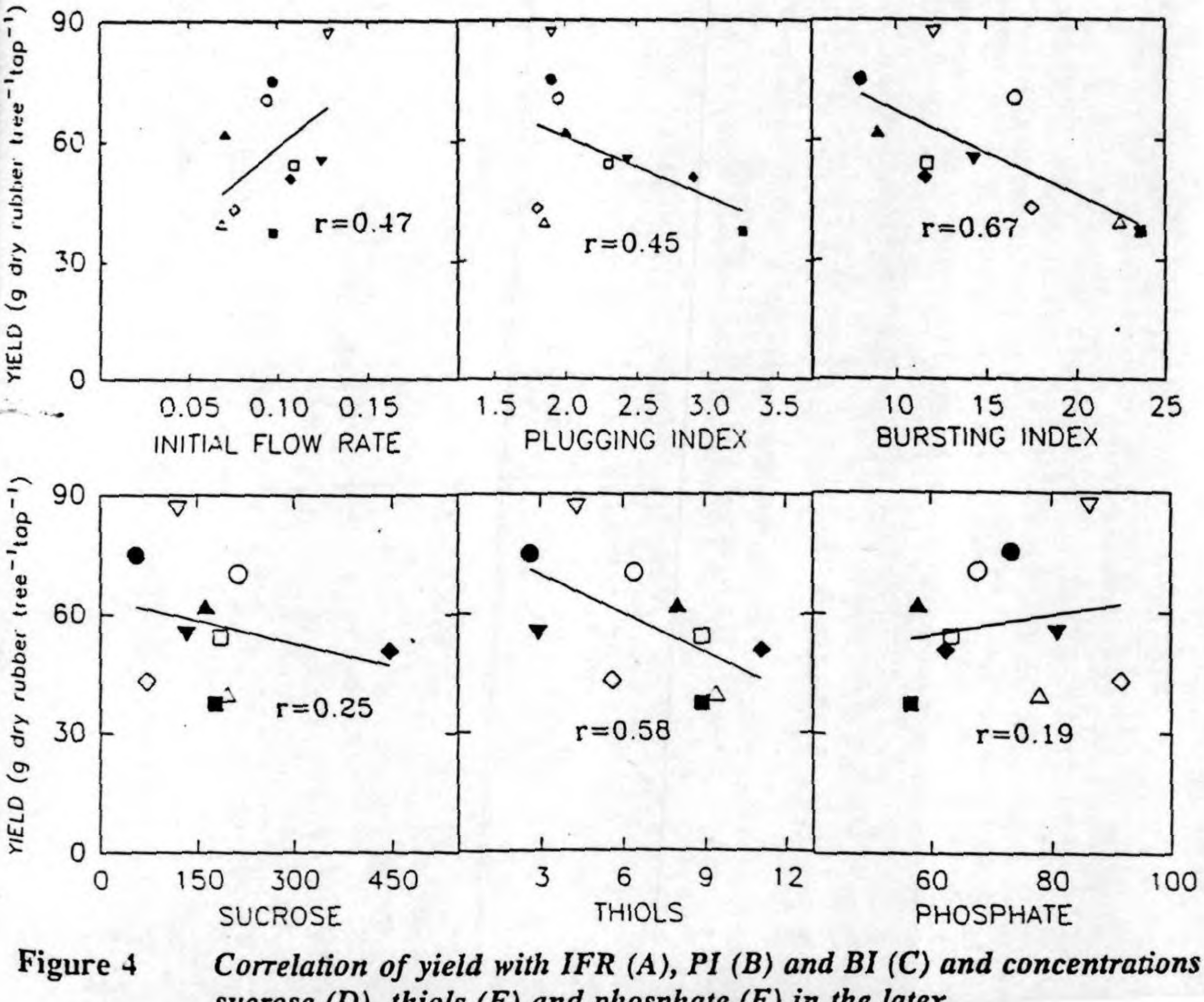

Figure 4 ***Correlation of yield with IFR (A), PI (B) and BI (C) and concentrations of sucrose (D), thiols (E) and phosphate (F) in the latex***

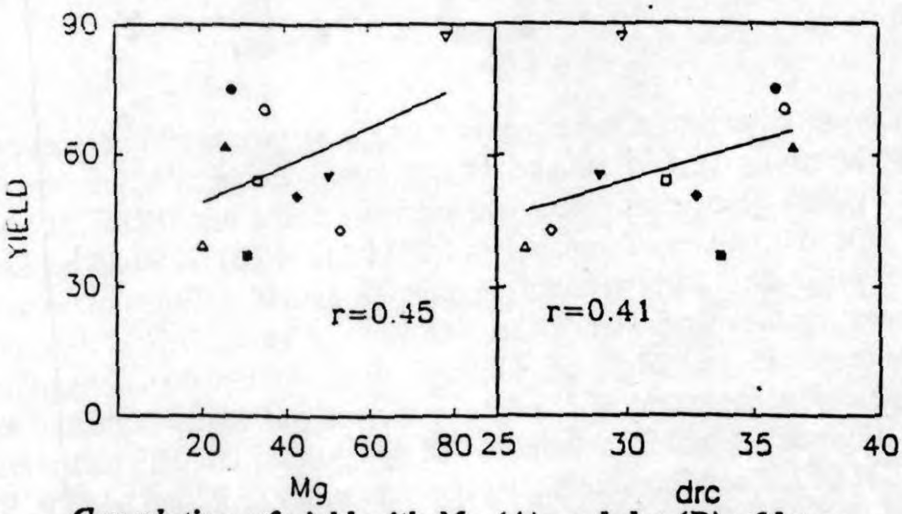

Figure 5 *Correlation of yield with Mg (A) and drc (B) of latex*

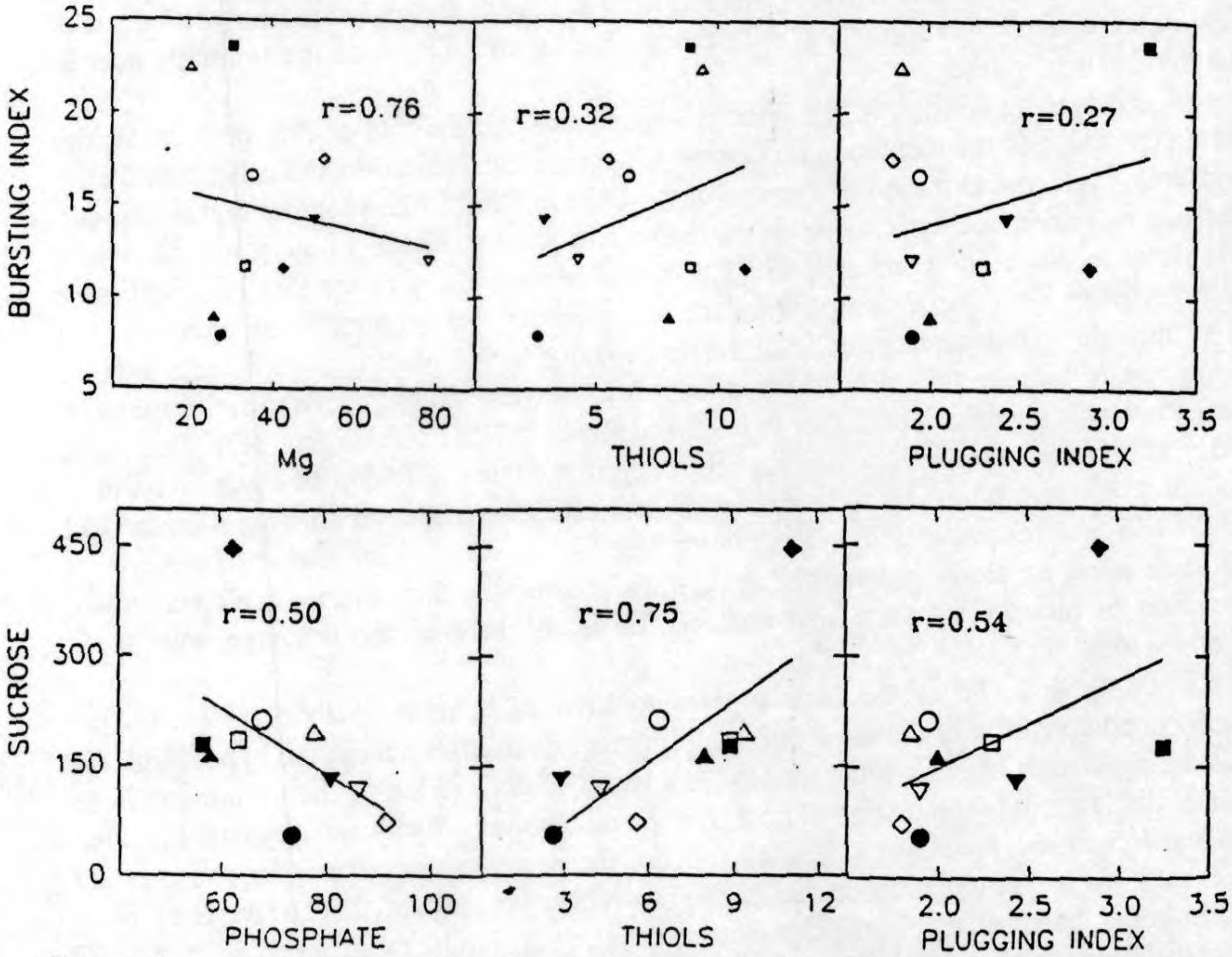

Figure 6 *Correlation of bursting index with Mg (A), thiols (B) and PI (C) and sucrose content of latex with phosphate (D), thiols (E) and PI (F).*

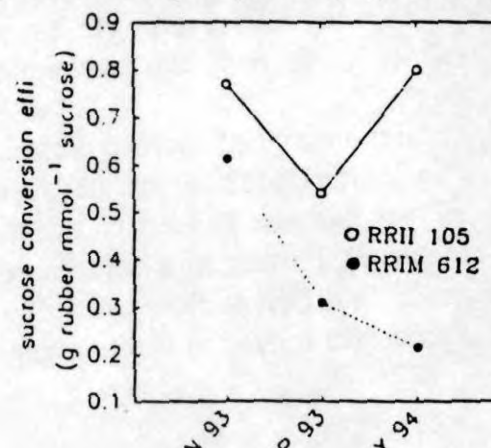

Figure 7 *Seasonal variations in the sucrose conversion efficiency in the high yielding clone (RRII 105) and the low yielding clone (RRIM 612)*

Thiols, which are known to activate enzymes such as invertase[8] and scavenge toxic oxygen species produced by certain surface bound lutoid enzymes[10], are shown to be positively related to yield[9]. The present study shows that a clone like RRIM 612 with high latex thiol content is a low yielder. Compared to RRIM 612, RRII 105 had a lower thiols content and a higher yield during wet seasons (Figures 2B and 1A). Thiols increased during the dry season suggesting that its content is an indication of stress. While thiol content is related to stress, sucrose, Pi and Mg^{++} are closely related to the metabolism of rubber regeneration. Inorganic phosphate and Mg^{++} contents were significantly higher in RRII 105 than in RRIM 612 (Figures 3A and 3B). It should be noted that RRII 105 had significantly more yield than RRIM 612. Therefore, the higher concentrations of Pi and Mg^{++} in RRII 105 were directly related to the high yield of this clone. Inorganic phosphate plays an important role in the energetics of any actively metabolising cell such as the laticiferous cell through its role in the phosphorylation of ADP for the production of ATP which is essentially needed in the synthesis of rubber.

Sucrose concentration in the latex is dependent upon the rate of flux of sucrose into the drainage area and the metabolic utilization of sucrose for respiration and rubber synthesis. Therefore, a high concentration of sucrose in the latex of RRIM 612 suggests that the supply of sucrose was adequate and/or one or more steps in the conversion of sucrose into rubber was limiting in this clone compared to RRII 105. Alternatively, a factor that inhibited latex flow in RRIM 612 may be responsible for the relatively large concentration of sucrose in the latex of this clone independent of its intrinsic capacity for converting sucrose into rubber. That appears to be true since PI, which is known to be very strongly related to termination of latex flow, was significantly higher in RRIM 612 than in RRII 105 (Figure 3D). Therefore, it is logical that the increased sucrose concentration in the latex of RRIM 612 was an indirect consequence of rapid plugging and termination of latex flow. It appears that the increased PI in RRIM 612 was related to a low TP (Figure 3C). This is a direct indication of the crucial role of bark water relations in determining the flow of latex and thus altering the biochemical composition of latex. However, what controls TP in the bark of the drainage area needs further investigation.

Thus, the low TP of the bark appears to have an indirect feedback effect on the biochemical composition of the latex through plugging. Even if we accept the hypothesis that a feedback regulation of latex biochemistry as a result of high PI led to the accumulation of sucrose in the latex, it is interesting to note that the metabolic pathway was regulated in such a way that it was the precursor (sucrose) and not the economically important end product (rubber) that was accumulated in the latex. The dry rubber content and TSC of the latex were similar in both clones (except in the dry season) despite the significant differences in their PI or TP. This suggests that the preferential accumulation of sucrose over the end product, or any intermediate of the rubber synthesis pathway, in the latex of RRIM 612 was not a direct consequence of faster plugging of the laticiferous cells resulting in a more concentrated latex, but rather that this may be the result of more complex biochemical regulation of the metabolism of the laticiferous cells.

The concentration of rubber per unit amount of sucrose present in the latex, termed the sucrose conversion efficiency, is an indirect estimate of the overall regulation of the metabolic conversion of sucrose into rubber. Sucrose conversion efficiency was remarkably higher in RRII 105 than RRIM 612 (Figure 7). Further studies are needed to understand the difference in sucrose conversion efficiency in different clones and how this is regulated by various physiological and biochemical processes related to *in situ* regeneration of rubber and latex flow.

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