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Clonal Nursery Studies in Hevea III. Correlations between Yield, Structural Characters, Latex Constituents and Plugging Index

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Girth, number of latex vessel rings and plugging index are the important characters determining the yield of young rubber plants. These characters are unrelated and contribute independently to yield of nursery buddings. The average distance between consecutive rings and latex d.r.c. are also related, but less closely, to yield of young buddings.

The first paper of this series (Ho *et al.*, 1973) indicated the desirability of establishing multiple regressions between yield of mature trees and certain measurable characters of nursery plants, particularly characters which are independent of each other. This paper discusses the relationships between the yield of nursery plants and certain structural features, the d.r.c. and mineral constituents of the latex, and the plugging index (MILFORD *et al.*, 1969). The main objectives are to seek information concerning the extent these nursery characters are independent of each other and to establish if the factors determining yield in nursery plants are the same as those affecting mature trees also.

EXPERIMENTAL

relationship of yield to structural characters was studied over eighty clones, the measurements involved being already described (Ho *et al.*, 1973):

- Y_1 Yield (gram per tree per six tappings) thirty-three months after budding
- Y_2 Yield (gram per tree per four tappings) fifty-six months after budding
- G_1 Girth (cm) at thirty-three months from budding
- G_2 Girth (cm) at fifty-six months from budding
- B Bark thickness (mm) measured from bark samples collected for latex vessel determination thirty-three months after budding
- n Total number of latex vessel rings (normal and disorganised) thirty-three months after budding
- d Average distance (mm) between consecutive latex vessel rings (based on all rings) thirty-three months after budding
- d_1 Distance (mm) between the second and fourth ring thirty-three months after budding
- f Density of latex vessels per 5 mm per ring, averaged over all rings thirty-three months after budding
- D_1 Diameter (μ) of latex vessels thirty-three months after budding
- D_2 Diameter (μ) of sieve tubes thirty-three months after budding
- R Latex d.r.c. (%) of samples collected
- N Nitrogen (% of latex)
- P Phosphorus (% of serum)
- K Potassium (% of serum)
- Mg Magnesium (% of serum)
- Ca Calcium (p.p.m. of serum)
- I Plugging index (mean of four collections sixty-seven months after budding)

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RESULTS AND DISCUSSION

Yield, Structural Characters and Plugging Index

Table 1a shows the means, standard leviations and coefficients of variation of rield, plugging index and structural chaacters of the eighty clones studied. Yield ınd plugging index show the greatest variaion, and latex vessel and sieve-tube dianeters, girth and bark thickness the least. *Table 1b* shows the means, standard deviaions and coefficients of variation between lones for the d.r.c. and mineral contents of latex. The coefficients for magnesium ınd calcium contents are large (25 to 30%) compared to those of the other mineral onstituents.

Simple Correlations

Table 2 shows the simple correlations etween yield, girth and the various structural haracters. Yields on both sampling occaions are positively correlated with girth, ark thickness and the total number of latex vessel rings *(Figures 1a, 1b* and *1c)* but negatively correlated with densit *(Figure 1d)*. Yield is also positively correlated with the average distance betweer latex vessel rings *(Figure 1e)* and negatively correlated with the distance between the second and fourth ring. The diameter of

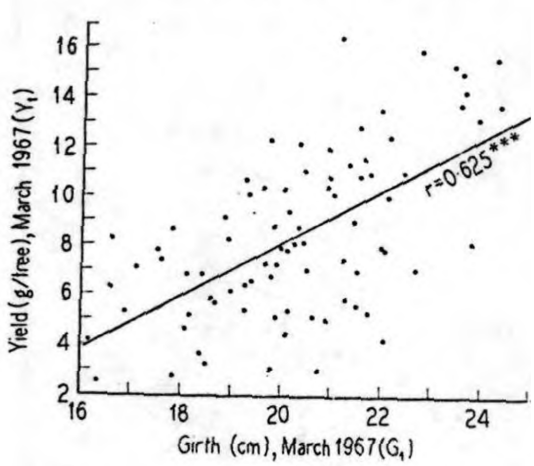

Figure 1a. Relationship between yield (Y_1) and girth (G_1) over eighty clones (March 1967).

TABLE 1A. MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION OF YIELD, PLUGGING INDEX AND STRUCTURAL CHARACTERS

Character	Months after budding	Symbol	No. of clones	Mean	S.D.	C.V.(%)
ield (g/tree/6 tappings)	(33 months)	Y_1	80	8.42	3.42	40.6
ield (g/tree/4 tappings)	(56 months)	Y_2	80	16.74	6.04	36.1
irth (cm)	(33 months)	G_1	80	20.30	1.94	9.6
irth (cm)	(56 months)	G_2	80	26.01	3.43	13.2
ark thickness (mm)	(33 months)	B	80	3.39	0.32	9.4
o. of LV rings	(33 months)	n	80	6.7	1.1	16.4
istance (mm) between consecutive LV rings	(33 months)	d	80	0.213	0.034	16.0
istance (mm) between 2nd and 4th LV rings	(33 months)	d_1	80	0.538	0.170	31.6
V density per 5mm per ring (over all rings)	(33 months)	f	80	59.9	10.0	16.7
iameter (μ) of						
latex vessels	(33 months)	D_1	80	17.3	1.7	9.8
sieve tubes	(33 months)	D_2	80	19.0	1.3	6.8
lugging index	(67 months)	I	23	9.08	4.21	46.3

TABLE 1B. MEANS, STANDARD DEVIATOINS AND COEFFICIENTS OF VARIATION OF D.R.C. AND MINERAL CONSTITUENTS OF LATEX

Character		Symbol	No. of clones	Mean	S.D.	C.V. (%)
d.r.c. (%)	(56 months)	*R*	80	32.9	2.4	7.4
N		*N*	80	0.210	0.021	10.1
P		*P*	80	0.067	0.009	14.0
K		*K*	80	0.270	0.022	8.0
Mg		*Mg*	80	0.011	0.003	24.1
Ca		*Ca*	80	30.8	9.2	29.8

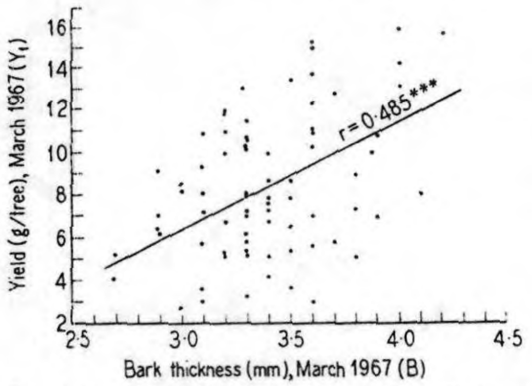

Figure 1b. Relationship between yield (Y_1)*and bark thickness (*B*) over eighty clones (March 1967).*

latex vessels and sieve tubes shows no correlation with yield.

The yields and girths at the two sampling periods are closely correlated; $r = 0.794$ and 0.956 for yield and girth respectively.

Girth is highly correlated with bark thickness and to a lesser extent with the number of latex vessel rings. Girth is positively correlated with the average distance between latex vessel rings, but not with the distance between the second and fourth ring. Girth is not correlated with the diameter of latex vessels or sieve tubes.

Bark thickness is positively correlated with the number and average distance between latex vessel rings, but not with the diameter of latex vessels or sieve tubes or with the distance between the second and fourth LV ring.

The number of LV rings is negatively correlated with their density, positively correlated with the diameter of the sieve-tubes, and negatively correlated with the distance between the second and fourth LV ring.

The density of latex vessels is positively correlated with the distance between the second and fourth ring, but not with the average distance between rings or their diameter. The average distance between rings is not related to the diameter of the latex vessels.

Partial Correlations

Table 3 shows the partial correlations of different orders between yield and structural

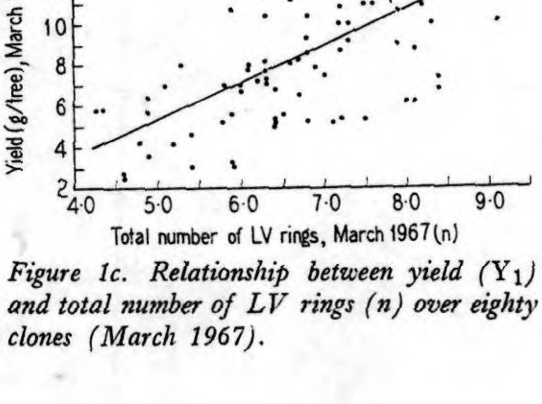

Figure 1c. Relationship between yield (Y_1*) and total number of LV rings (n) over eighty clones (March 1967).*

TABLE 2. LINEAR CORRELATION COEFFICIENTS BETWEEN YIELD AND VARIOUS STRUCTURAL CHARACTERS

Character	Symbol	Y_1	G_1	B	n	d	d_1	f	D_1	D_2
Yield	Y_1	1.000	0.624***	0.485***	0.595***	0.273*	— 0.239*	— 0.195 ($P<0.1$)	— 0.011	0.118
Girth	G_1		1.000	0.735***	0.244*	0.421***	0.016	— 0.148	0.109	— 0.026
Bark thickness	B			1.000	0.293**	0.434***	0.011	— 0.121	0.005	0.047
No. of LV rings	n				1.000	— 0.173	— 0.709***	— 0.302**	0.004	0.209 ($P<0.1$)
Distance between consecutive rings	d					1.000	—	0.065	— 0.042	0.192 ($P<0.1$)
Distance between 2nd & 4th LV ring	d_1						1.000	0.322**	0.024	— 0.015
LV density per 5 mm of ring	f							1.000	— 0.163	— 0.119
Diameter of latex vessels	D_1								1.000	— 0.076
Diameter of sieve tubes	D_2									1.000
		Y_2	G_2	B	n	d	d_1	f	D_1	D_2
Yield	Y_2	1.000	0.730***	0.577***	0.506***	0.182 ($P<0.1$)	— 0.229*	— 0.274*	0.019	0.058
Girth	G_2		1.000	0.700***	0.174	0.402***	0.086	— 0.121	0.118	— 0.054

*** $P < 0.001$ ** $P < 0.01$ * $P < 0.05$

TABLE 4. SIMPLE AND PARTIAL CORRELATI

Girth and bark thickness		Girth and LV ring number		Girth and average distance between LV rings		Gi
r_{G_1B}	0.735***	r_{G_1n}	0.244*	r_{G_1d}	0.421***	r_{G_1f}
$r_{G_1B.n}$	0.716***	$r_{G_1n.B}$	0.044	$r_{G_1d.B}$	0.167	r_{G_1f}
$r_{G_1B.d}$	0.676***	$r_{G_1n.d}$	0.355**	$r_{G_1d.n}$	0.485***	r_{G_1f}
$r_{GB_1.f}$	0.730***	$r_{G_1n.f}$	0.212 ($P<0.1$)	$r_{G_1d.f}$	0.436***	r_{G_1f}
$r_{G_1B.nd}$	0.622***	$r_{G_1n.Bd}$	0.110	$r_{G_1d.Bn}$	0.195 ($P<0.1$)	r_{G_1f}
$r_{G_1B.nf}$	0.716***	$r_{G_1n.Bf}$	0.020	$r_{G_1d.Bf}$	0.181	r_{G_1f}
$r_{G_1B.df}$	0.665***	$r_{G_1n.df}$	0.318**	$r_{G_1d.nf}$	0.488***	r_{G_1f}
$r_{G_1B.ndf}$	0.621***	$r_{G_1n.Bdf}$	0.085	$r_{G_1d.Bnf}$	0.199 ($P<0.1$)	r_{G_1f}

LV ring number and average distance between LV rings		LV ring number and LV density		Average distance between LV rings and LV density		L\
r_{nd}	— 0.173	r_{nf}	— 0.302**	r_{df}	0.065	r_{d_1G}
$r_{nd.G_1}$	— 0.313**	$r_{nf.G_1}$	— 0.277*	$r_{df.G_1}$	0.142	r_{d_1G}
$r_{nd.B}$	— 0.348**	$r_{nf.B}$	— 0.281*	$r_{df.B}$	0.131	r_{d_1G}
$r_{nd.f}$	— 0.161	$r_{nf.d}$	— 0.296**	$r_{df.n}$	0.014	r_{d_1G}
$r_{nd.G_1B}$	— 0.361**	$r_{nf.G_1B}$	— 0.278*	$r_{df.G_1B}$	0.149	r_{d_1G}
$r_{nd.G_1f}$	— 0.288*	$r_{nf.G_1d}$	— 0.247*	$r_{df.G_1n}$	0.061	r_{d_1G}
$r_{nd.Bf}$	— 0.327**	$r_{nf.Bd}$	— 0.253*	$r_{df.Bn}$	0.037	r_{d_1G}
$r_{nd.G_1Bf}$	— 0.336**	$r_{nf.G_1Bd}$	— 0.243*	$r_{df.G_1Bn}$	0.054	r_{d_1G}

***$P<0.001$ **$P<0.01$ *$P<0.05$

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Bark thickness	B			1.000	0.293**	0.434***	0.011	— 0.121	0.005	0.047
No. of LV rings	n				1.000	— 0.173	— 0.709***	— 0.302**	0.004	0.209 ($P<0.1$)
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LV density per 5 mm of ring	f							1.000	— 0.163	— 0.119
Diameter of latex vessels	D_1								1.000	— 0.076
Diameter of sieve tubes	D_2									1.000
		Y_2	G_2	B	n	d	d_1	f	D_1	D_2
Yield	Y_2	1.000	0.730***	0.577***	0.506***	0.182 ($P<0.1$)	— 0.229*	— 0.274*	0.019	0.058
Girth	G_2		1.000	0.700***	0.174	0.402***	0.086	— 0.121	0.118	— 0.054

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$r_{GB_1.f}$	0.730***	$r_{G_1n.f}$	0.212 ($P<0.1$)	$r_{G_1d.f}$	0.436***	r_{G_1f}
$r_{G_1B.nd}$	0.622***	$r_{G_1n.Bd}$	0.110	$r_{G_1d.Bn}$	0.195 ($P<0.1$)	r_{G_1f}
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$r_{G_1B.df}$	0.665***	$r_{G_1n.df}$	0.318**	$r_{G_1d.nf}$	0.488***	r_{G_1f}
$r_{G_1B.ndf}$	0.621***	$r_{G_1n.Bdf}$	0.085	$r_{G_1d.Bnf}$	0.199 ($P<0.1$)	r_{G_1f}

LV ring number and average distance between LV rings		LV ring number and LV density		Average distance between LV rings and LV density		LV
r_{nd}	— 0.173	r_{nf}	— 0.302**	r_{df}	0.065	r_{d_1G}
$r_{nd.G_1}$	— 0.313**	$r_{nf.G_1}$	— 0.277*	$r_{df.G_1}$	0.142	r_{d_1G}
$r_{nd.B}$	— 0.348**	$r_{nf.B}$	— 0.281*	$r_{df.B}$	0.131	r_{d_1G}
$r_{nd.f}$	— 0.161	$r_{nf.d}$	— 0.296**	$r_{df.n}$	0.014	r_{d_1G}
$r_{nd.G_1B}$	— 0.361**	$r_{nf.G_1B}$	— 0.278*	$r_{df.G_1B}$	0.149	r_{d_1G}
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$r_{nd.G_1Bf}$	— 0.336**	$r_{nf.G_1Bd}$	— 0.243*	$r_{df.G_1Bn}$	0.054	r_{d_1G}

***$P<0.001$ **$P<0.01$ *$P<0.05$

TABLE 3. SIMPLE AND PARTIAL CORRELATIONS BETWEEN YIELD AND OTHER STRUCTURAL CHARACTERS

Girth		Bark thickness		No. of LV rings		Average distance between consecuture LV rings		Distance between 2nd and 4th LV ring		Density of LV per 5 mm of ring	
$^{r}Y_1G_1$	0.624***	$^{r}Y_1B$	0.485***	$^{r}Y_1n$	0.595***	$^{r}Y_1d$	0.273*	$^{r}Y_1d_1$	— 0.239*	$^{r}Y_1f$	— 0.195 (P<0.1)
$^{r}Y_1G_1.B$	0.451***	$^{r}Y_1B.G_1$	0.050	$^{r}Y_1n.G_1$	0.584***	$^{r}Y_1d.G_1$	0.015	$^{r}Y_1d_1.G_1$	— 0.319**	$^{r}Y_1f.G_1$	— 0.133
$^{r}Y_1G_1.n$	0.614***	$^{r}Y_1B.n$	0.404***	$^{r}Y_1n.B$	0.542***	$^{r}Y_1d.B$	0.079	$^{r}Y_1d_1.B$	— 0.279*	$^{r}Y_1f.B$	— 0.157
$^{r}Y_1G_1.d$	0.583***	$^{r}Y_1B.d$	0.423***	$^{r}Y_1n.d$	0.678***	$^{r}Y_1d.n$	0.475***	$^{r}Y_1d_1.n$	0.323**	$^{r}Y_1f.n$	— 0.020
$^{r}Y_1G_1.f$	0.614***	$^{r}Y_1B.f$	0.474***	$^{r}Y_1n.f$	0.574***	$^{r}Y_1d.f$	0.292**	$^{r}Y_1d_1.f$	— 0.190 (P<0.1)	$^{r}Y_1f.d$	— 0.222*
$^{r}Y_1G_1.Bn$	0.509***	$^{r}Y_1B.G_1n$	— 0.064	$^{r}Y_1n.G_1B$	0.585***	$^{r}Y_1d.G_1B$	0.005	$^{r}Y_1d_1.G_1B$	— 0.319**	$^{r}Y_1f.G_1B$	— 0.132
$^{r}Y_1G_1.Bd$	0.446***	$^{r}Y_1B.G_1d$	0.048	$^{r}Y_1n.G_1d$	0.620***	$^{r}T_1d.G_1n$	0.256*	$^{r}Y_1d_1.G_1n$	0.200 (P<0.1)	$^{r}Y_1f.G_1n$	0.037
$^{r}Y_1G_1.Bf$	0.444***	$^{r}Y_1B.G_1f$	0.048	$^{r}Y_1n.G_1f$	0.575***	$^{r}Y_1d.G_1f$	0.034	$^{r}Y_1d_1.G_1f$	— 0.294**	$^{r}Y_1f.G_1d$	— 0.137
$^{r}Y_1G_1.nd$	0.499***	$^{r}Y_1B.nd$	0.211 (P<0.1)	$^{r}Y_1n.Bd$	0.609***	$^{r}Y_1d.Bn$	0.340**	$^{r}Y_1d_1.Bn$	0.222 (P<0.1)	$^{r}Y_1f.Bn$	, 0.006
$^{r}Y_1G_1.nf$	0.615***	$^{r}Y_1B.nf$	0.404***	$^{r}Y1n.Bf$	0.525***	$^{r}Y_1d.Bf$	0.102	$^{r}Y_1d_1.Bf$	— 0.244*	$^{r}Y_1f.Bd$	— 0.169
$^{r}Y_1G_1.df$	0.565***	$^{r}Y_1B.df$	0.402***	$^{r}Y_1n.df$	0.657***	$^{r}Y_1d.nf$	0.475***	$^{r}Y_1d_1.nf$	0.331**	$^{r}Y_1f.nd$	— 0.030
$^{r}Y_1G_1.Bnd$	0.480***	$^{r}Y_1B.G_1nd$	— 0.145	$^{r}Y_1n.G_1Bd$	0.629***	$^{r}Y_1d.G_1Bn$	0.286*	$^{r}Y_1d_1.G_1Bn$	0.217 (P<0.1)	$^{r}Y_1f.G_1Bn$	0.039
$^{r}Y_1G_1.Bnf$	0.510***	$^{r}Y_1B.G_1nf$	— 0.065	$^{r}Y_1n.G_1Bf$	0.576***	$^{r}Y_1d.G_1Bf$	0.025	$^{r}Y_1d_1.G_1Bf$	— 0.295**	$^{r}Y_1f.G_1Bd$	0.134
$^{r}Y_1G_1.Bdf$	0.436***	$^{r}Y_1B.G_1df$	0.042	$^{r}Y_1n.G_1df$	0.611***	$^{r}Y_1d.G_1nf$	0.254*	$^{r}Y_1d_1.G_1nf$	0.197 (P<0.1)	$^{r}Y_1g.G_1nd$	0.022
$^{r}Y_1G_1.ndf$	0.499***	$^{r}Y_1B.ndf$	0.210 (P<0.1)	$^{r}Y_1n.Bdf$	0.594***	$^{r}Y_1d.Bnf$	0.340**	$^{r}Y_1d_1.Bnf$	0.227*	$^{r}Y_1f.Bnd$	— 0.020
$^{r}Y_1G_1.Bndf$	0.480***	$^{r}Y_1B.G_1ndf$	— 0.145	$^{r}Y_1n.G_1Bdf$	0.621***	$^{r}Y_1d.G_1Bnf$	0.285*	$^{r}Y_1d_1.G_1Bnf$	0.214 (P<0.1)	$^{r}Y_1f.G_1Bnd$	0.025

***P<0.001 **P<0.01 *P<0.05.

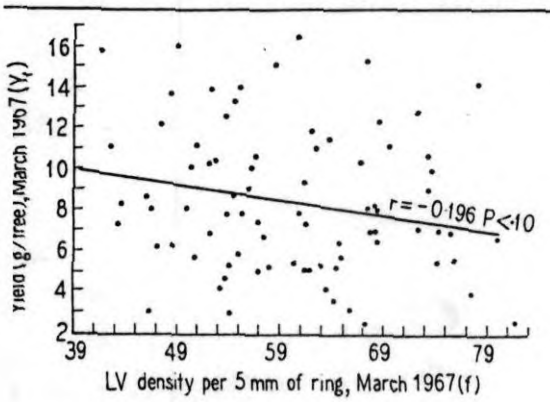


Figure 1d. Relationship between yield (Y_1) *and density of latex vessels per 5 mm of ring* (f) *over eighty clones (March 1967).*

factors (excluding the diameter of latex vessels and sieve tubes). The simple correlation between Y_1 and G_1 is not much influenced by the other structural factors. The correlation between Y_1 and B is considerably reduced if G_1 is kept constant, but is not affected by *n*, *f* or *d*.

The correlation between Y_1 and *d* becomes insignificant if either G_1 or *B* is fixed, but is enhanced if *n* or *f* is kept constant. The correlation between Y_1 and d_1 is also not affected by G_1 or *B*, but is considerably affected if *n* is kept constant. The negative correlation between Y_1 and *f* becomes nonsignificant if G_1, *B* or *n* is kept fixed but is not affected by keeping *d* constant.

Table 4 shows partial correlations of different orders between the structural characters. The simple correlation between G_1 and *B* is unaffected if other factors are kept constant, but the correlation between G_1 and other factors is considerably reduced if *B* is held constant. The correlation between G_1 and *n* is enhanced by keeping *d* constant and is little affected by *f*. Similarly the correlation between G_1 and *d* is little affected by *n* or *f*. There is no correlation between G_1 and *f* whether the other factors are held constant or not.

The simple correlation between *B* and *n* is considerably reduced by keeping G_1 constant, and is enhanced by keeping *d* constant. Similarly the correlation between *B* and *d* is reduced slightly by keeping G_1 constant, but increased by keeping *n* constant. The density *(f)* has no effect on r_{Bd}, and there is no correlation between *B* and *f*. The value of r_{nd} is considerably decreased if G_1 or *B* is kept constant, while *f* has no effect on this correlation. The negative correlation between *n* and *f* is unaffected by the other factors. There is no correlation between *f* and *d*.

The non-significant simple correlation between d_1 and G_1 or between d_1 and *B* becomes significant when *n* is kept constant. The value of r_{d_1n} is unaffected by G_1, *B* or *f*.

The correlation between d_1 and *f* is not affected by keeping G_1 or *B* constant, but is considerably reduced if *n* is kept constant.

Since latex vessel density *(f)* has little effect on yield or on the interrelationship of yield and other structural factors, it is not considered further. Similarly, since the correlation with yield of the average distance *(d)* between latex vessel rings and of the distance (d_1) between the second and fourth ring are similar when the structural factors G_1, *B* and *n* are constant, d_1 is also not considered further.

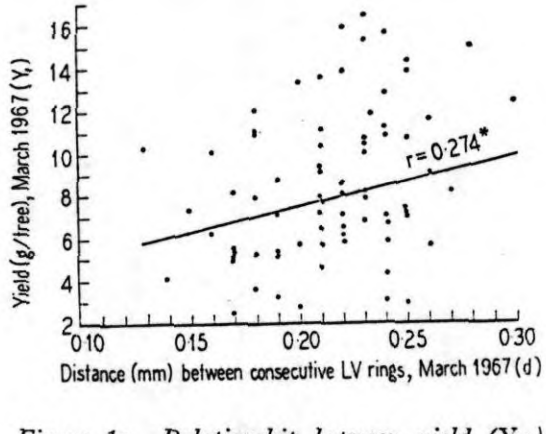


Figure 1e. Relationship between yield (Y_1) *and distance between consecutive LV rings*(d) *over eighty clones (March 1967).*

ONS BETWEEN VARIOUS STRUCTURAL CHARACTERS

rth and LV density		Bark thickness and LV ring number		Bark thickness and average distance between LV rings		Bark thickness and LV density	
	— 0.148	^rBn	0.293**	^rBd	0.434***	^rBf	— 0.121
$.B$	— 0.088	$^rBn.G_1$	0.173	$^rBd.G_1$	0.203 ($P<0.1$)	$^rBf.G_1$	— 0.018
$.n$	— 0.080	$^rBn.d$	0.415***	$^rBd.n$	0.515***	$^rBf.n$	— 0.036
$.d$	— 0.194 ($P<0.1$)	$^rBn.f$	0.271*	$^rBd.f$	0.446***	$^rBf.d$	— 0.166
$.Bn$	— 0.079	$^rBn.G_1d$	0.254*	$^rBd.G_1n$	0.275*	$^rBf.G_1n$	0.032
$.Bd$	— 0.112	$^rBn.G_1f$	0.175	$^rBd.G_1f$	0.208 ($P<0.1$)	$^rBf.G_1d$	— 0.048
$.nd$	— 0.099	$^rBn.df$	0.388***	$^rBd.nf$	0.516***	$^rBf.nd$	— 0.050
$.Bnd$	— 0.088	$^rBn.G_1df$	0.250*	$^rBd.G_1nf$	0.274*	$^rBf.G_1nd$	0.016

/ distance and girth		LV distance and bark thickness		LV distance and LV ring number		LV distance and LV density	
$_1$	0.016	^rd_1B	0.011	^rd_1n	— 0.709***	^rd_1f	0.322**
$_1.B$	0.012	$^rd_1B.G_1$	— 0.001	$^rd_1n.G_1$	— 0.735***	$^rd_1f.G_1$	0.328**
$_1.n$	0.276*	$^rd_1B.n$	0.324**	$^rd_1n.B$	— 0.745***	$^rd_1f.B$	0.326**
$_1.f$	0.068	$^rd_1B.f$	0.053	$^rd_1n.f$	— 0.678***	$^rd_1f.n$	0.160
$_1.Bn$	0.067	$^rd_1B.G_1n$	0.189 ($P<0.1$)	$^rd_1n.G_1B$	— 0.746***	$^rd_1f.G_1B$	0.328**
$_1.Bf$	0.043	$^rd_1B.G_1f$	0.005	$^rd_1n.G_1f$	— 0 710***	$^rd_1f.G_1n$	0.191 ($P<0.1$)
$_1.nf$	0.294**	$^rd_1B.nf$	0.334**	$^rd_1n.Bf$	— 0.720***	$^rd_1f.Bn$	0.182
$_1.Bnf$	0.083	$^rd_1B.G_1nf$	0.186	$^rd_1n.G_1Bf$	— 0.722***	$^rd_1f.G_1Bn$	0.189 ($P<0.1$)

TABLE 4. SIMPLE AND PARTIAL CORRELATIONS BETWEEN VARIOUS STRUCTURAL CHARACTERS

Girth and bark thickness		Girth and LV ring number		Girth and average distance between LV rings		Girth and LV density		Bark thickness and LV ring number		Bark thickness and average distance between LV rings		Bark thickness and LV d…	
…$_{1}B$	0.735***	r_{G_1n}	0.244*	r_{G_1d}	0.421***	r_{G_1f}	−0.148	r_{Bn}	0.293**	r_{Bd}	0.434***	r_{Bf}	−0.121
…$_{1}B.n$	0.716***	$r_{G_1n.B}$	0.044	$r_{G1d.B}$	0.167	$r_{G_1f.B}$	−0.088	$r_{Bn.G_1}$	0.173	$r_{Bd.G_1}$	0.203 (P<0.1)	$r_{Bf.G_1}$	−0.018
…$_{1}B.d$	0.676***	$r_{G_1n.d}$	0.355**	$r_{G_1d.n}$	0.485***	$r_{G_1f.n}$	−0.080	$r_{Bn.d}$	0.415***	$r_{Bd.n}$	0.515***	$r_{Bf.n}$	−0.036
…$B_1.f$	0.730***	$r_{G_1n.f}$	0.212 (P<0.1)	$r_{G_1d.f}$	0.436***	$r_{G_1f.d}$	−0.194 (P<0.1)	$r_{Bn.f}$	0.271*	$r_{Bd.f}$	0.446***	$r_{Bf.d}$	−0.166
…$_{1}B.nd$	0.622***	$r_{G_1n.Bd}$	0.110	$r_{G_1d.Bn}$	0.195 (P<0.1)	$r_{G_1f.Bn}$	−0.079	$r_{Bn.G_1d}$	0.254*	$r_{Bd.G_1n}$	0.275*	$r_{Bf.G_1n}$	0.032
…$_{1}B.nf$	0.716***	$r_{G_1n.Bf}$	0.020	$r_{G_1d.Bf}$	0.181	$r_{G_1f.Bd}$	−0.112	$r_{Bn.G_1f}$	0.175	$r_{Bd.G_1f}$	0.208 (P<0.1)	$r_{Bf.G_1d}$	−0.048
…$_{1}B.df$	0.665***	$r_{G_1n.df}$	0.318**	$r_{G_1d.nf}$	0.488***	$r_{G_1f.nd}$	−0.099	$r_{Bn.df}$	0.388***	$r_{Bd.nf}$	0.516***	$r_{Bf.nd}$	−0.050
…$_{1}B.ndf$	0.621***	$r_{G_1n.Bdf}$	0.085	$r_{G_1d.Bnf}$	0.199 (P<0.1)	$r_{G_1f.Bnd}$	−0.088	$r_{Bn.G_1df}$	0.250*	$r_{Bd.G_1nf}$	0.274*	$r_{Bf.G_1nd}$	0.016

LV ring number and average distance between LV rings		LV ring number and LV density		Average distance between LV rings and LV density		LV distance and girth		LV distance and bark thickness		LV distance and LV ring number		LV distance and LV den…	
…d	−0.173	r_{nf}	−0.302**	r_{df}	0.065	$r_{d_1G_1}$	0.016	r_{d_1B}	0.011	r_{d_1n}	−0.709***	r_{d_1f}	0.322**
…$d.G_1$	−0.313**	$r_{nf.G_1}$	−0.277*	$r_{df.G_1}$	0.142	$r_{d_1G_1.B}$	0.012	$r_{d_1B.G_1}$	−0.001	$r_{d_1n.G_1}$	−0.735***	$r_{d_1f.G_1}$	0.328**
…$d.B$	−0.348**	$r_{nf.B}$	−0.281*	$r_{df.B}$	0.131	$r_{d_1G_1.n}$	0.276*	$r_{d_1B.n}$	0.324**	$r_{d_1n.B}$	−0.745***	$r_{d_1f.B}$	0.326**
…$d.f$	−0.161	$r_{nf.d}$	−0.296**	$r_{df.n}$	0.014	$r_{d_1G_1.f}$	0.068	$r_{d_1B.f}$	0.053	$r_{d_1n.f}$	−0.678***	$r_{d_1f.n}$	0.160
…$d.G_1B$	−0.361**	$r_{nf.G_1B}$	−0.278*	$r_{df.G_1B}$	0.149	$r_{d_1G_1.Bn}$	0.067	$r_{d_1B.G_1n}$	0.189 (P<0.1)	$r_{d_1n.G_1B}$	−0.746***	$r_{d_1f.G_1B}$	0.328**
…$d.G_1f$	−0.288*	$r_{nf.G_1d}$	−0.247*	$r_{df.G_1n}$	0.061	$r_{d_1G_1.Bf}$	0.043	$r_{d_1B.G_1f}$	0.005	$r_{d_1n.G_1f}$	−0.710***	$r_{d_1f.G_1n}$	0.191 (P
…$d.Bf$	−0.327**	$r_{nf.Bd}$	−0.253*	$r_{df.Bn}$	0.037	$r_{d_1G_1.nf}$	0.294**	$r_{d_1B.nf}$	0.334**	$r_{d_1n.Bf}$	−0.720***	$r_{d_1f.Bn}$	0.182
…$d.G_1Bf$	−0.336**	$r_{nf.G_1Bd}$	−0.243*	$r_{df.G_1Bn}$	0.054	$r_{d_1G_1.Bnf}$	0.083	$r_{d_1B.G_1nf}$	0.186	$r_{d_1n.G_1Bf}$	−0.722***	$r_{d_1f.G_1Bn}$	0.189 (P

***P<0.001 **P<0.01 *P<0.05

Multiple Regression and Correlations

Table 5a shows the multiple linear regression equations of yield (Y_1) on the four variables G_1, B, n and d, taken singly, two or three at a time and all together. The coefficients of the independent variables are termed the partial regression coefficients. With four variables, the coefficient for G_1 denoted by $bY_1G_1.Bnd$ (0.880) measures the increase in Y_1 per unit increase in G_1, with the other variables constant. The partial regression coefficients have been standardised by expressing each of the variables (inclduing the dependent variable) in standard measure; the standard multiple linear regression equations are given in *Table 5b*. In standardised form the partial regression coefficients are independent of the units of measurement and comparison of the different coefficients indicates approximately the relative importance of the independent variables. Thus if one coefficient (G_1') is twice another (say B'), then the first (G_1') is twice as important as the second (B') in determining yield. The test of significance of the partial (and also of the standard partial) regression coefficients and the corresponding partial correlations are identical. The multiple correlation coefficients of yield with the different variables are also given in *Table 5a.*

Taken singly, G_1 shows the highest correlation with Y_1; for variables taken two at a time, G_1 and n show the highest correlation, n and d the next, and B and n the third highest. For three variables at a time, G_1, n and d have independently significant effects on yield estimation; the other combination showing significance in all the three variables is B, n and d. When G_1, B and n are considered, the coefficient for B does not show significance; however,

TABLE 5A. MULTIPLE REGRESSION EQUATIONS BETWEEN YIELD AND VARIOUS STRUCTURAL CHARACTERS

Regression of yield (Y_1) on	$Y_1 =$	Multiple correlation coefficient *(R)*
G_1	− 13.88 + 1.099*** G_1	0.625
B	− 9.01 + 5.141***B	0.485
n	− 3.87 + 1.845***n	0.596
d	2.62 + 27.262* d	0.274
G_1 and B	− 14.42 + 1.027*** G_1 + 0.591B	0.626
G_1 and n	− 19.49 + 0.896*** G_1 − 1.459*** n	0.774
G_1 and d	− 13.96 + 1.089*** G_1 + 1.246 d	0.625
B and n	− 14.01 + 3.598*** B + 1.536*** n	0.678
B and d	− 9.45 + 4.783*** B + 7.750 d	0.490
n and d	− 13.49 + 2.053***n + 38.693*** d	0.708
G_1, B and n	− 18.97 + 0.974*** G_1 — 0.667 B + 1.482*** n	0.775
G_1, B and d	− 14.43 + 1.025***G_1 + 0.579 B + 0.427 d	0.626
G_1, n and d	− 21.31 + 0.732*** G_1 + 1.631***n + 18.877* d	0.791
B, n and d	− 16.66 + 1.923 ($P < 0.1$) B + 1.839*** n + 29.656** d	0.723
G_1, B, n and d	− 20.44 + 0.880*** G_1 — 1.487B + 1.711*** n + 21.841* d	0.796

* $P < 0.05$.   ** $P < 0.01$ *** $P < 0.001$

TABLE 5B. STANDARD MULTIPLE REGRESSION EQUATIONS OF YIELD ON VARIOUS STRUCTURAL CHARACTERS

Regression of yield (Y_1') on	Y_1' =
G_1' and B'	$0.584^{***} G_1' + 0.056 B'$
G_1' and n_1'	$0.511^{***} G_1' + 0.471^{***} n'$
G_1' and d'	$0.620^{***} G_1' + 0.012 d'$
B' and n'	$0.342^{***} B' + 0.496^{***} n'$
B' and d'	$0.454^{***} B' + 0.078 d'$
n' and d'	$0.663^{***} n' + 0.387^{***} d'$
G_1', B' and n'	$0.554^{***} G_1' - 0.063 B' + 0.479^{***} n'$
G_1', B' and d'	$0.583^{***} G_1' + 0.055 B' + 0.004 d'$
G_1', n' and d'	$0.417^{***} G_1' + 0.527^{***} n' + 0.189^{*} d'$
B', n' and d'	0.183 ($P < 0.1$) $B' + 0.594^{***} n' + 0.297^{**} d'$
G_1', B', n' and d'	$0.501^{***} G_1' - 0.141 B' + 0.553^{***} n' + 0.218^{*} d'$

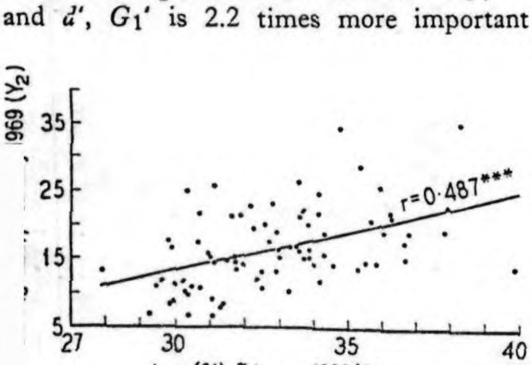
Standard partial regression coefficients are the partial regression coefficients when each variable is expressed *in standard measure. The standardised variables are indicated by dashes (Y_1', G_1' etc.).*

$$Y_1' = (Y_1 - \overline{Y_1})/(SY_1), \qquad (G_1' = G_1 - \overline{G_1})/SG_1), \text{ etc.}$$

the multiple correlation coefficient is higher than if B, n and d are chosen.

Both G_1' and n' are equally important in determining yield *(Table 5b)*, whereas n' is about 1.5 times more important than B' and about 1.75 times more important than d'.

Considering the three variables G_1', n' and d', G_1' is 2.2 times more important than d', and n' is 2.8 times more important than d' in the estimation of yield. With B', n' and d', n' is twice as important as d' and 3.2 times more important than B'; d' is 1.6 times more important than B'.



igure 2. Relationship between yield (Y_2) id d.r.c. (R) over eighty clones (February 969).

The linear multiple regression equations of Y_2 with G_2 are given in *Table 6a*, and selected standard multiple regression equations in *Table 6b*. The values of G_2 and n together account for about 68% of the variation in yield between clones, compared with 60% of the variations in Y_1 being accountable to G_1 and n. The relative importance of G_2 and n in determining Y_2 is somewhat different from the corresponding Y_1 relationship, possibly because the number of LV rings relates to measurements made much earlier in growth than the data of yield and girth. G_2' is about 1.7 times more important than n' in the estimation of Y_2', while both factors are equally important in estimating Y_1'. The loss of significance of the third order partial

TABLE 6A. MULTIPLE REGRESSION EQUATIONS OF YIELD ON VARIOUS STRUCTURAL CHARACTERS

Regression of yield (Y_2) on	$Y_2 =$	Multiple correlation coefficient *(R)*
G_2	$-16.72 + 1.286^{***} G_2$	0.730
B	$-19.93 + 10.813^{***} B$	0.577
n	$-1.73 + 2.772^{***} n$	0.506
d	$9.92 + 32.073 (P < 0.1) d$	0.182
G_2 and n	$-27.87 + 1.167^{***} G_2 + 2.140^{***} n$	0.825
G_2, n and B	$-27.77 + 1.171^{***} G_2 + 2.144^{***} n - 0.070 B$	0.825
G_2, n, B and d	$-27.41 + 1.178^{***} G_2 + 2.103^{***} n + 0.108 B - 4.111 d$	0.826

TABLE 6B. STANDARD MULTIPLE REGRESSION EQUATIONS OF YIELD ON VARIOUS STRUCTURAL CHARACTERS

Regression of Yield (Y_2') on	$Y_2' =$
G_2' and n'	$0.663^{***} G_2' + 0.392^{***} n'$
G_2', n' and B'	$0.665^{***} G_2' + 0.392^{***} n' - 0.004 B'$
G_2', n', B' and d'	$0.669^{***} G_2' + 0.385^{***} n' + 0.006 B' - 0.023 d'$

regression coefficient of d in the estimation of Y_2 may also be due to the early measurements of structural characters.

Correlation between Yield (Y_2) and d.r.c.

Table 7 shows the simple correlations between yield (Y_2), d.r.c. and the mineral content of the latex. Yield is positively correlated with d.r.c., *N*, *P* and *K*, but not with *Mg* or *Ca*. The d.r.c. is positively correlated with *N* and *P*, and slightly so with Ca. *N* is correlated with *K* and *Ca*; *P* is slightly correlated with *K* while *Mg* and *Ca* are positively correlated.

The correlation between yield (Y_2) and d.r.c. is not affected by keeping any of the

TABLE 7. SIMPLE CORRELATIONS BETWEEN YIELD (Y_2), D.R.C. *(R)* AND MINERAL CONTENT OF LATEX

Character	Y_2	*R*	*N*	*P*	*K*	*Mg*	*Ca*
Y_2	1.000	0.487***	02.46*	0.324**	0.231*	0.019	0.139
R		1.000	0.238*	0.358**	0.180	0	0.218 ($P < 0.1$)
N			1.000	0	0.328**	0	0.332**
P				1.000	0.197 ($P < 0.1$)	0	0.054
K					1.000	0	0.104
Mg						1.000	0.231*
Ca							1.000

mineral characters constant. However, the partial correlations between yield (Y_2) and the mineral characters are considerably reduced if the d.r.c. is kept constant $^rY_2N.R$ = 0.153, $^rY_2P.R$ = 0.184, $^rY_2K.R$ = 0.167, all being insignificant). Thus it can be said that these mineral characters are related to yield through d.r.c.

The significant simple correlation between d.r.c. and N is reduced to insignificance if Ca is kept constant ($^rRN.Ca$ = 0.180), while the correlation between d.r.c. and P is not affected by any of the other mineral characters ($^rRP.NKMgCa$ = 0.351). The correlations between *N* and *K*, *N* and *Ca* and *Mg* and *Ca* are not affected by keeping the other mineral factors constant.

Correlations between Plugging Index and Yield and Structural Factors

The data for plugging index and the correlations between the plugging index, yield and other structural factors are available for only twenty-three clones. The relationships studied were between girth, the number of LV rings, the average distance between consecutive rings, the density of the rings, and yield.

Clonal differences in plugging index are apparent. *Table 8a* shows the simple and partial correlations of plugging index with yield and the four structural characters. The plugging index is negatively correlated with yield *(Figure 3)* on both recording occasions. The correlation is not affected by keeping the girth or average distance between consecutive LV rings constant, but is much reduced if either the number of latex rings or their density is held constant. Even where all four structural factors are kept constant, the correlation between plugging index and yield remains significant, indicating that the plugging index is related

TABLE 8A. SIMPLE AND PARTIAL CORRELATIONS BETWEEN YIELD AND PLUGGING INDEX, WITH FOUR STRUCTURAL CHARACTERS CONSTANT

^rY_1I	— 0.431*	^rY_2I	— 0.451*
$^rY_1I.G_1$	— 0.537**	$^rY_2I.G_2$	— 0.518**
$^rY_1I.n$	— 0.257	$^rY_2I.n$	— 0.284
$^rY_1I.f$	— 0.314	$^rY_2I.f$	— 0.369 ‡
$^rY_1I.d$	— 0.552**	$^rY_2I.d$	— 0.550*
$^rY_1I.G_1n$	— 0.398 †	$^rY_2I.G_2n$	— 0.377 †
$^rY_1I.G_1f$	—0.395 †	$^rY_2I.G_2f$	— 0.429 †
$^rY_1I.G_1d$	— 0.514*	$^rY_2I.G_2d$	— 0.443*
$^rY_1I.nf$	— 0.259	$^rY_2I.nf$	— 0.326
$^rY_1I.nd$	— 0.478*	$^rY_2I.nd$	— 0.467*
$^rY_1I.fd$	— 0.430 †	$^rY_2I.fd$	— 0.454*
$^rY_1I.G_1nf$	— 0.360	$^rY_2I.G_2nf$	— 0.420 †
$^rY_1I.G_1nd$	— 0.482*	$^rY_2I.G_2nd$	— 0.416 †
$^rY_1I.G_1fd$	— 0.414 †	$^rY_2I.G_2fd$	— 0.401 †
$^rY_1I.nfd$	— 0.436 †	$^rY_2I.nfd$	— 0.467*
$^rY_1I.G_1nfd$	— 0.437 †	$^rY_2I.G_2nfd$	— 0.444 †

*05 P < 0. ** P < 0.01 *** P < 0.001 ‡ P < 0.1

TABLE 9A. MULTIPLE REGRESSION EQUATIONS OF YIELD ON STRUCTURAL CHARACTERS, D.R.C. AND PLUGGING INDEX

Regression of yield		Y =	Multiple correlation coefficient
	$G_1\ n\ d$	$-23.34 + 0.827^{*} G_1 + 1.515^{***} n + 21.804\ d$	0.837^{***}
Yield Y_1 on	$G_1\ n\ d\ R$	$-22.07 + 0.851^{*} G_1 + 1.585^{**} n + 24.759\ d - 0.086\ R$	0.839^{***}
	$G_1\ n\ d\ \ I$	$-19.70 + 0.737^{*} G_1 + 1.304^{**} n + 29.931^{\ddagger} d - 0.238^{*} I$	0.877^{***}
	$G_1\ n\ d\ R\ I$	$-20.32 + 0.714^{*} G_1 + 1.242^{**} n + 28.473^{\ddagger} d + 0.058\ R - 0.254^{*} I$	0.878^{***}
	$G_2\ n\ d$	$-28.98 + 1.109^{**} G_2 + 2.269^{**} n + 8.712\ d$	0.862^{***}
Yield Y_2 on	$G_2\ n\ d\ R$	$-33.16 + 1.076^{**} G_2 + 2.056^{**} n - 0.418\ d + 0.254\ R$	0.869^{***}
	$G_2\ n\ d\ \ I$	$-24.12 + 0.969^{**} G_2 + 2.034^{**} n + 24.792\ d - 0.343^{*} I$	0.888^{***}
	$G_2\ n\ d\ R\ I$	$-30.87 + 0.831^{**} G_2 + 1.463^{*} n + 12.637\ d + 0.551^{*} R - 0.506^{**} I$	0.914^{***}

TABLE 9B. STANDARD MULTIPLE REGRESSION EQUATIONS OF YIELD ON STRUCTURAL CHARACTERS, D. R. C. AND PLUGGING INDEX

Regression of yield		Y' =
	$G_1'\ n'\ d'$	$0.418^{*} G_1' + 0.591^{***} n' + 0.222\ d'$
Yield Y_1' on	$G_1'\ n'\ d'\ R'$	$0.431^{*} G_1' + 0.619^{**} n' + 0.253\ d' - 0.079\ R'$
	$G_1'\ n'\ d'\ \ I'$	$0.373^{*} G_1' + 0.509^{**} n' + 0.305^{\ddagger} d' - 0.294^{*} I'$
	$G_1'\ n'\ d'\ R'\ I'$	$0.361^{*} G_1' + 0.485^{**} n' + 0.290^{\ddagger} d' + 0.053\ R' - 0.314^{*} I'$
	$G_2'\ n'\ d'$	$0.590^{**} G_2' + 0.504^{**} n' + 0.051\ d'$
Yield Y_2' on	$G_2'\ n'\ d'\ R'$	$0.572^{**} G_2' + 0.457^{**} n' - 0.002\ d' + 0.132\ R'$
	$G_2'\ n'\ d'\ \ I'$	$0.516^{**} G_2' + 0.452^{**} n' + 0.114\ d' - 0.242^{*} I'$
	$G_2'\ n'\ d'\ R'\ I'$	$0.442^{**} G_2' + 0.325^{*} n' + 0.073\ d' + 0.287^{*} R' - 0.356^{**} I'$

Relationships are based on twenty-three clones.

*** $P < 0.001$ ** $P < 0.01$ * $P < 0.05$ ‡ $P < 0.1$

TABLE 8B. SIMPLE AND PARTIAL CORRELATIONS BETWEEN PLUGGING INDEX AND FOUR STRUCTURAL CHARACTERS

Plugging index and girth		Plugging index and LV number		Plugging index and LV density		Pluagging index and average LV distance	
r_{IG_1}	— 0.048	r_{In}	— 0.402 ‡	r_{If}	0.480*	r_{Id}	0.281
$r_{IG_1.n}$	0.038	$r_{In.G_1}$	— 0.401 ‡	$r_{If.G_1}$	0.481*	$r_{Id.G_1}$	0.381 †
$r_{IG_1.f}$	— 0.054	$r_{In.f}$	— 0.185	$r_{If.n}$	0.337	$r_{Id.n}$	0.176
$r_{IG_1.d}$	— 0.272	$r_{In.d}$	— 0.343	$r_{If.d}$	0.423*	$r_{Id.f}$	0.131
$r_{IG_1.nf}$	— 0.009	$r_{In.G_1f}$	— 0.177	$r_{If.G_1n}$	0.336	$r_{Id.G_1n}$	0.209
$r_{IG_1.nd}$	— 0.120	$r_{In.G_1d}$	— 0.248	$r_{If.G_1d}$	0.376 **	$r_{Id.G_1f}$	0.212
$r_{IG_1.fd}$	— 0.176	$r_{In.fd}$	— 0.169	$r_{If.nd}$	0.309	$r_{Id.nf}$	0.106
$r_{IG_1.nfd}$	— 0.114	$r_{In.G_1fd}$	— 0.102	$r_{If.G_1nd}$	0.308	$r_{Id.G_1nf}$	0.156

* $P < 0.05$ ** $P < 0.1$

to yield independently of the structural factors considered.

The simple and partial correlations of plugging index with the four structural characters are given in *Table 8b*. The plugging index is not correlated with girth or the average distance between consecutive LV rings, whether or not the other structural factors are held constant. The plugging index and the number of LV rings are negatively correlated. The correlations between plugging index and both density and the number of LV rings lose significance if either correlated factor is held constant.

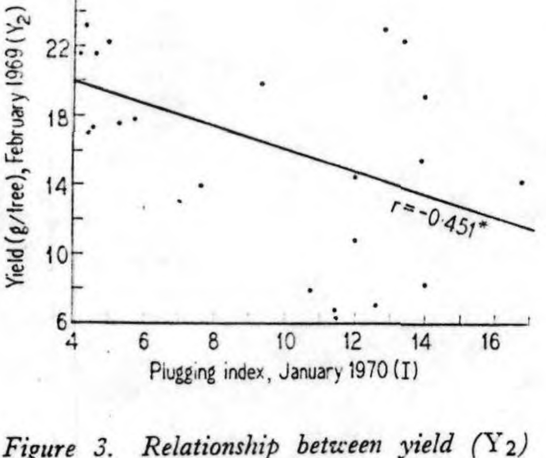


Figure 3. Relationship between yield (Y_2) and plugging index (I) over twenty-three clones.

Multiple Regressions of Yield on Girth and Other Factors

Linear multiple regression equations between yield and plugging index, d.r.c., girth, number of LV rings and the average distance between rings are given in *Table 9a* and their standardised forms in *Table 9b*. All three structural factors, as well as the plugging index (I), are important in estimating yield (Y_1), while only two structural factors (G_2 and n) together with I and d.r.c. are important in the determination of yield (Y_2). In estimating Y_1, n is more important than the other factors, whereas G_2 is most important in estimating Y_2. About 80% of the variation in yield of the nursery stage is accounted for by the factors G, n, I and d.

CONCLUSIONS

The correlation studies show that girth, number of LV rings and the plugging index are important in determining yield of young rubber plants grown in the nursery. This finding agrees with similar studies on mature rubber (Ho, 1972; NARAYANAN *et al.*, 1973).

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Stem Galls of Hevea brasiliensis

W.C. LIM[1]

Galls of up to 50 cm diameter were found on the trunks and branches of trees of RRIM 612 on an estate in Selangor. The galls were formed by proliferation of the outer parts of the branch or trunk, probably as a result of enhanced manufacture of growth substances. No pathogens were found associated with gall tissue. Galls can be easily removed and are of little economic cosequence.

Stem galls were first reported on *Hevea brasiliensis* in Malaysia in 1965 (RUBBER RESEARCH INSTITUTE OF MALAYA, 1965) in a 14-acre field of eight-year-old trees of clone RRIM 612 in Selangor. Galls were first noticed on the trunks and branches a few years after planting the clone and, at the time of examination in 1970, they ranged in size from 2 – 50 cm in diameter *(Figures 1 – 3)*, some almost circumscribing the trunk. Gall-bearing trees were distributed at random in the 14 acres, about 5% of trees being affected. Such gall-bearing trees were otherwise healthy and of normal girth. Adjacent trees of clones RRIM 603 and 605 were unaffected.

DISCUSSION

The surface texture of a gall depends on its age and rate of growth; the bark of rapidly-growing galls flakes from the surface *(Figure 1)*, whereas the surfaces of

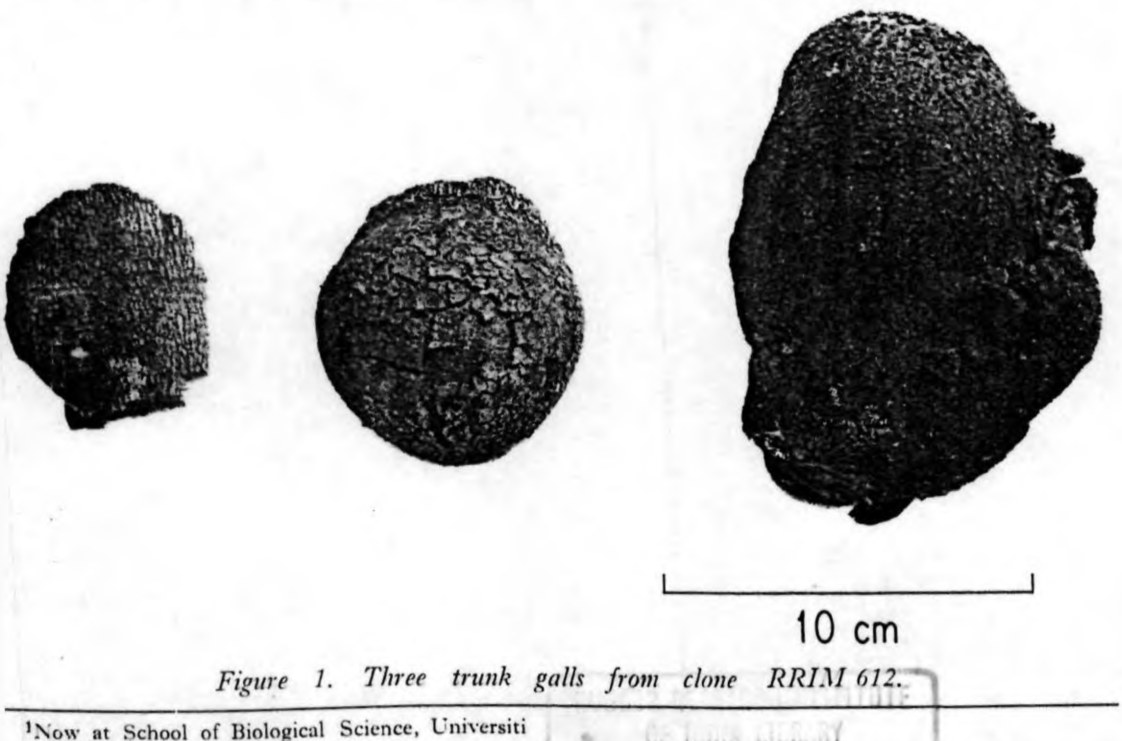

Figure 1. Three trunk galls from clone RRIM 612.

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The average distance between consecutive LV rings and latex d.r.c. have varying associations with young nursery buddings. The major mineral constituents of latex (*N*, *P* and *K*) are related to yield through d.r.c.

Partial correlations indicate that girth, number of LV rings and the plugging index are not correlated with each other and contribute towards yield of young buddings independently.

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