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Modification of Crown Development of Hevea brasiliensis *Muell. Arg. by Cultural Practices. I. Pruning*

W. LEONG and P.K. YOON

This paper describes the effect of pruning on crown development of RRIM 600 and GT 1. The pruning treatments were estate pruning, controlled pruning, controlled pruning plus branch induction and estate pruning low. Crown development was discussed in terms of crotch height, crown width, crown length, crown area, crown volume, crown fullness ratio, crown percent, degree of crown spread and crown projection ratio. Methods to measure and derive these parameters were described.

The pruning treatments affected crotch height, crown length, crown area, crown volume and crown percent. They had little effect on the other crown parameters.

The effect of different pruning treatments on the rubber tree *(Hevea brasiliensis* Muell. Arg.) has been studied[1]. The treatments affected the frequency and quality of branching, tree height, tree girth, dry matter production and canopy density. Most cultural practices are successful only to the extent to which they improve the physiological processes such as photosynthesis, translocation, assimilation, respiration and transpiration in trees. As crown size and form are important factors influencing photosynthesis through their effect on light interception within the crown, it is the objective of this paper to study the effect of pruning on these factors.

MATERIALS AND METHODS

Crown development of the rubber tree (*Hevea brasiliensis* Muell. Arg.) was studied in four experiments, *GHS/1, GHS/2* and GHS/10 with RRIM 600 and *GHS/6a* with GT 1. The details of these experiments have been reported in a previous paper[1]. The pruning treatments were:

- *Treatment EP (Estate pruning).* All branches below 2.4 m were removed regularly at two- to three-month intervals to duplicate as closely as possible estate practice. This served as the control.
- *Treatment CP (Controlled pruning).* Pruning of branches to 1.7 m but removal of the branches was delayed. The general criteria used were that the diameter of the branch must reach approximately half that of the trunk diameter and that the branch had at least three or four flushes of leaves. In some cases, pruning was delayed till about eight to nine flushes of leaves were on the branch.
- *Treatment CPBI (Controlled pruning plus branch induction where necessary).* Similar to *Treatment CP* except that the trees had no branches, they were induced artificially at about 2.0-2.4 m from the ground

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with the double-blade ring cut device. The application of the device followed the procedures outlined elsewhere[2].

- *Treatment EPL (Estate pruning low).* This treatment was similar to *Treatment EP* except that the pruning height was 1.7 m instead of 2.4 metres.

Tree height and crotch height were measured with a 'Haga' hyposometer and the difference between these measurements gave the crown length. The crown width was measured with a crown meter made in accordance with the specifications given by Sheppard[3]. The mean of two crown widths measured along the inter-row and between-row directions were taken as the width. Thirty-six to sixty trees per treatment were used for the measurement.

From the measurements of crown width, crown length and tree height, assessments of crown areas and volume and descriptions of crown form were obtained. Their formulae[4] are given in *Table 1*. The crown percent and degree of crown spread indicate the relative crown length and crown width to tree height respectively. Crown fullness ratio indicates the degree of roundness of the crown and the crown projection ratio indicates the relative size of the crown width to trunk diameter. In the absence of sufficient information on the geometrical shape of the *Hevea* crown, it is assumed in this study to be conical with circular base.

RESULTS

Crotch Height

Pruning influenced crotch height. In *Experiment GHS/10*, the crotch height of RRIM 600 was significantly higher in *Treatment EP* than in *Treatment EPL* at two, three and four years after treatment *(Table 2)*. Among the *Treatments EPL, CP* and *CPBI,* there was no crotch height difference between trees in *Treatments CP* and *CPBI* but these two treatments resulted in lower crotch height of the trees than in *Treatment EPL.* In *Treatments GHS/1* and *2* where the crotch height was measured at six years after treatment, trees under *Treatment EP* had higher crotch height than trees in the other treat-

TABLE 1. CHARACTERS MEASURED OR DERIVED

Characters	Abbreviation	Formula
Tree height	h	–
Trunk diameter	d	–
Crotch height	c	–
Crown length	l	–
Crown width	w	–
Crown percent	Cp	$1/h \times 100$
Degree of crown spread	Cs	$w/h \times 100$
Crown fullness ratio	Cf	w/l
Crown projection ratio	Cpr	$w/d \times 100$
Crown cross-section area	Ca	$w^2 \times 0.7854$
Crown surface area	Csa	$0.7854w\sqrt{41^2 + w^2}$
Crown volume	Cv	$1/3w^2 \times 0.7854$

ments although only in *Experiment GHS/2* was the difference significant. The pruning treatments affected GT 1 similarly. The crotch height of GT 1 in *Experiment GHS/6a* was significantly higher in *Treatment EP* than in *Treatments CP* and *CPBI* at three, four and five years after treatment *(Table 2)*.

Crown Size

Crown with. The crown width was not influenced by the pruning treatments. With the exception in *Experiment GHS/10* where trees in *Treatment EP* had significantly narrower crown than trees in *Treatments CP* and *CPBI* at two years after treatment, results from other years and other experiments showed no significant difference in crown width among trees in the pruning treatments *(Table 3)*.

Crown length. The crown length of RRIM 600 in *Experiment GHS/10* was significantly different between the pruning treatments during the three years of observation. *Treatments CP* and *CPBI* had resulted in longer crowns than *Treatment EPL* where crown length was longer than

TABLE 2. EFFECT OF PRUNING ON CROTCH HEIGHT

Experiment	Clone	Years after treatment	Crotch height (m) EP	EPL	CP	CPBI	SE(±)	LSD ($P < 0.05$)
GHS/10	RRIM 600	2	3.26	2.78	2.57	2.30	0.113	0.34
		3	3.24	2.70	2.38	2.25	0.100	0.30
		4	3.80	3.17	2.71	2.61	0.124	0.37
GHS/1	RRIM 600	6	3.54	3.44	3.61	2.60	0.235	NS
GHS/2	RRIM 600	6	3.51	NA	2.73	2.35	0.132	0.46
GHS/6a	GT 1	3	3.40	NA	2.36	2.14	0.129	0.51
		4	3.54	NA	2.52	2.35	0.184	0.72
		5	3.89	NA	2.72	2.58	0.071	0.28

NA = treatment not available in experiment

TABLE 3. EFFECT OF PRUNING ON CROWN WIDTH

Experiment	Clone	Years after treatment	Crown width (m) EP	EPL	CP	CPBI	SE(±)	LSD ($P < 0.05$)
GHS/10	RRIM 600	2	3.42	3.91	4.13	4.13	0.170	0.51
		3	4.87	4.82	5.00	5.04	0.076	NS
		4	5.19	5.18	5.13	5.38	0.084	NS
GHS/1	RRIM 600	6	7.22	7.28	7.06	7.20	0.159	NS
GHS/2	RRIM 600	6	6.89	NA	6.74	7.08	0.170	NS
GHS/6a	GT 1	3	3.83	NA	4.48	4.14	0.275	NS
		4	4.78	NA	5.30	5.09	0.029	NS
		5	5.56	NA	6.05	5.71	0.303	NS

NA = treatment not available in experiment

TABLE 4. EFFECT OF PRUNING ON CROWN LENGTH

Experiment	Clone	Years after treatment	Crown length (m) EP	EPL	CP	CPBI	SE(±)	LSD (P < 0.05)
GHS/10	RRIM 600	2	4.23	4.65	5.10	5.15	0.124	0.37
		3	7.68	8.00	8.82	8.38	0.221	0.67
		4	9.41	9.36	10.19	10.33	0.264	0.79
GHS/1	RRIM 600	6	14.81	15.53	14.90	15.94	0.321	NS
GHS/2	RRIM 600	6	12.88	NA	14.44	14.54	0.264	0.73
GHS/6a	GT 1	3	5.62	NA	6.59	6.57	0.492	NS
		4	7.70	NA	9.09	8.85	0.420	NS
		5	9.31	NA	11.72	10.18	0.353	1.39

NA = treatment not available in experiment

TABLE 5. EFFECT OF PRUNING ON CROWN CROSS-SECTIONAL AREA AND CROWN SURFACE AREA

Experiment	Clone	Years after treatment	Treatment EP	EPL	CP	CPBI	SE(±)	LSD (P < 0.05)
			Crown cross-sectional area (m^2)					
GHS/10	RRIM 600	2	10.2	12.3	13.6	13.8	0.92	2.8
		3	18.9	18.5	20.0	20.3	0.60	NS
		4	21.8	21.6	21.2	23.0	0.74	NS
GHS/1	RRIM 600	6	41.3	42.1	39.5	41.0	1.82	NS
GHS/2	RRIM 600	6	37.7	NA	36.3	40.0	1.87	NS
GHS/6a	GT 1	3	11.8	NA	16.1	13.7	1.86	NS
		4	18.4	NA	22.4	20.8	2.37	NS
		5	24.9	NA	29.2	26.2	2.82	NS
			Crown surface area (m^2)					
GHS/10	RRIM 600	2	25.7	31.7	36.3	36.7	1.69	5.1
		3	62.0	64.1	72.8	69.8	2.04	6.2
		4	80.6	80.1	85.7	90.2	2.64	NS
GHS/1	RRIM 600	6	173.2	183.1	170.2	185.3	5.26	NS
GHS/2	RRIM 600	6	144.8	NA	158.0	166.9	5.09	NS
GHS/6a	GT 1	3	36.5	NA	49.7	45.1	5.46	NS
		4	61.6	NA	79.6	74.5	7.35	NS
		5	86.1	NA	115.3	95.3	7.11	NS

NA = treatment not available in experiment

in *Treatment EP (Table 4)*. The crown length of RRIM 600 was also significantly longer in *Treatments CP* and *CPBI* than in *Treatment EP* in *Experiment GHS/2*. In Experiment GHS/1 no significant difference was detected *(Table 4)*. *Treatments CP* and *CPBI* also increased the crown length of GT 1 in *Experiment GHS/6a* although the difference reached significant level only at five years after treatment *(Table 4)*.

Crown area. Pruning affected crown cross-sectional area and crown surface area in RRIM 600 at the second year after treatment in *Experiment GHS/10*. *Treatments CP* and *CPBI* had resulted in significantly larger crown areas than *Treatment EP (Table 5)*. In the third year after treatment, only crown surface area responded to the treatments and in the fourth year after treatment, no differential effect of the treatments on crown areas were observed. In the six years after treatment in *Experiments GHS/1* and *GHS/2* there were also no significant differences in crown areas among the pruning treatments *(Table 5)*. In *Experiment GHS/6a* GT 1 trees receiving *Treatments CP* and *CPBI* had higher values of crown cross-sectional areas and crown surface area than in *Treatment EP (Table 5)*.

Crown volume. The treatments affected the crown volume as they affected the crown surface area. The crown volume was less in *Treatment EP* than in *Treatments CP* and *CPBI* in *Experiment GHS/10* at two and three years after treatment. No significant affect was observed at four years after treatment in *Experiment GHS/10* and at any other time in *Experiments GHS/1, GHS/2* and *GHS/6a (Table 6)*.

Crown Form

Crown fullness ratio. The treatments did not have strong effects on the crown fullness ratio of RRIM 600 and GT 1. Only in *Experiment GHS/2* on RRIM 600 was the treatment effect significant. *Treatment EP* resulted in rounder crowns than *Treatments CP* and *CPBI*. This trend was observed in the other experiments although the responses did not reach significant levels *(Table 7)*.

Crown percent. The crown percent was significantly affected by pruning. *Treatments CP* and *CPBI* had resulted in higher crown percent than *Treatment EP* in *Experiments GHS/1, GHS/2* and *GHS/10* for RRIM 600 and in *Experiment GHS/6a*

TABLE 6. EFFECT OF PRUNING ON CROWN VOLUME

Experiment	Clone	Years after treatment	Crown volume (m^3) EP	EPL	CP	CPBI	SE(±)	LSD ($P < 0.05$)
GHS/10	RRIM 600	2	14.5	19.9	23.9	24.4	1.61	4.9
		3	48.8	50.5	59.8	57.3	1.27	6.9
		4	69.5	68.9	73.5	78.9	3.21	NS
GHS/1	RRIM 600	6	204.0	219.2	196.5	218.4	9.95	NS
GHS/2	RRIM 600	6	162.3	NA	176.3	194.4	9.80	NS
GHS/6a	GT 1	3	22.8	NA	36.4	30.3	5.45	NS
		4	48.7	NA	69.1	62.5	9.33	NS
		5	79.3	NA	114.1	89.3	11.10	NS

NA = treatment not available in experiment

TABLE 7. EFFECT OF PRUNING ON CROWN FULLNESS RATIO AND CROWN PERCENT

Experiment	Clone	Years after treatment	Treatment EP	EPL	CP	CPBI	SE(±)	LSD ($P < 0.05$)
			Crown fullness ratio					
GHS/10	RRIM 600	2	0.85	0.87	0.83	0.81	0.048	NS
		3	0.64	0.61	0.58	0.61	0.017	NS
		4	0.56	0.57	0.51	0.53	0.018	NS
GHS/1	RRIM 600	6	0.49	0.47	0.48	0.45	0.015	NS
GHS/2	RRIM 600	6	0.54	NA	0.47	0.49	0.015	0.95
GHS/6a	GT 1	3	0.71	NA	0.69	0.64	0.041	NS
		4	0.63	NA	0.58	0.58	0.019	NS
		5	0.61	NA	0.52	0.57	0.024	NS
			Crown percent					
GHS/10	RRIM 600	2	56.6	62.4	66.3	68.9	1.32	4.0
		3	70.2	74.7	78.4	78.8	1.05	3.2
		4	71.3	74.4	78.8	79.6	0.98	3.0
GHS/1	RRIM 600	6	80.7	81.9	80.4	86.0	1.18	4.1
GHS/2	RRIM 600	6	78.5	NA	84.1	86.0	0.82	2.8
GHS/6a	GT 1	3	61.8	NA	73.5	75.2	2.14	8.4
		4	68.3	NA	78.3	78.9	1.49	5.9
		5	70.2	NA	81.0	79.7	0.75	3.0

NA= treatment not available in experiment

TABLE 8. EFFECT OF PRUNING ON DEGREE OF CROWN SPREAD AND CROWN PROJECTION RATIO

Experiment	Clone	Years after treatment	Treatment EP	EPL	CP	CPBI	SE(±)	LSD ($P < 0.05$)
			Degree of crown spread					
GHS/10	RRIM 600	2	47.0	52.7	53.8	55.4	2.16	NS
		3	44.7	45.4	44.8	47.5	0.98	NS
		4	39.4	41.7	39.8	42.0	1.03	NS
GHS/1	RRIM 600	6	39.6	38.4	38.3	38.9	1.17	NS
GHS/2	RRIM 600	6	42.2	NA	39.3	42.1	1.11	NS
GHS/6a	GT 1	3	42.9	NA	50.1	47.9	1.70	NS
		4	42.6	NA	45.7	45.4	0.81	NS
		5	42.4	NA	42.3	45.0	1.84	NS
			Crown projection ratio					
GHS/10	RRIM 600	2	48.4	53.7	52.8	53.8	2.40	NS
		3	46.0	46.0	45.7	46.4	0.69	NS
		4	41.8	42.3	40.5	41.3	0.64	NS
GHS/1	RRIM 600	6	41.1	40.2	39.6	39.4	0.96	NS
GHS/2	RRIM 600	6	39.2	NA	36.9	38.2	0.89	NS
GHS/6a	GT 1	3	38.2	NA	38.3	36.5	0.75	NS
		4	42.1	NA	41.7	41.5	0.75	NS
		5	40.4	NA	40.6	39.0	0.57	NS

NA = treatment not available in experiment

for GT 1 *(Table 7)*. Trees in *Treatment EPL* also had higher crown percent than trees in *Treatment EP*.

Degree of crown spread. The degree of crown spread was not significantly affected by pruning. None of the experiments showed significant treatment effects *(Table 8)*. However, there was a tendency for trees in *Treatments CP, CPBI* and *EPL* to have a greater degree of crown spread than trees in *Treatment EP* at the early years of treatment when the trees were younger.

Crown projection ratio. The crown projection ratio was not significantly different among the pruning *Treatments EP, EPL, CP* and *CPBI (Table 8)*. Clones RRIM 600 and GT 1 were similarly affected and there was a tendency for the crown projection ratio to decrease with tree age.

DISCUSSION AND CONCLUSION

All branches on the tree below the height of 1.7 m from the ground were pruned off in *Treatments CP, CPBI* and *EPL* while in *Treatment EP*, the branches below the height of 2.4 m from the ground were pruned off. This differential pruning height obviously would result in different crotch height and the significant effect of the pruning treatments on crotch height was expected. What was not expected however, was that trees in *Treatment EPL* had higher crotch height than trees in *Treatments CP* and *CPBI*. The difference could be caused by the methods employed to remove the lower branches. In *Treatment EPL*, branches below 1.7 m from the ground were regularly removed as soon as they appeared whereas in *Treatments CP* and *CPBI*, the branches below 1.7 m from the ground were not removed until they had grown to substantial size with four to six flushes of leaves. The delayed removal of branches could have encouraged the initiation of more branches above 1.7 m or that the regular removal of branches could have inhibited or reduced the frequency of branching at 1.7 m above the ground.

General observations show that in young buddings, in the absence of any external factors such as pruning, branches developed from the auxillary buds. Their formation seems to be synchronised with the rhythmic apical growth. Rhythmic growth of trees had been reported in *Hevea brasiliensis* by Halle and Martin[5] and in *Theobroma cacao* by Greathouse *et at*[6]. Thus it is conceivable that the different methods of branch removal may influence branch formation by the desynchronisation of the rhythmic growth. *Treatments CP* and *CPBI* caused less desynchronisation than *Treatment EPL*.

The differences in crotch height between pruning treatments became less apparent with age. After canopy closure, the light levels under the canopy would become less and may be below the light compensation point for leaves on the lower branches. Such branches would be shedded and the initial height difference would not be sustained.

Generally, *Treatments CP, CPBI* and *EPL* resulted in larger crown size than *Treatment EP*. Their main effect was on crown length. This was the result of their lower pruning heights. Crown size differences among pruning treatments were most noticeable on younger trees where the intercrown competition had not set in. In *Experiments GHS/10* at two years after treatment, trees in *Treatments CP* and *CPBI* had about 20% longer crown length than those in *Treatment EP* and this difference was reduced to less than

10% at four years after treatment. As the trees became older and intercrown competition commenced the crown size differences among the pruning treatments became less evident. This trend explains the absence of significant differences in crown size among the treatments in most of the older trees in *Experiments GHS/1, GHS/2* and *GHS/6a.*

Among the four descriptions of crown form, only crown percent was affected significantly by pruning. This was the result of the significant effect of the treatments on crown length. Trees in *Treatments CP, CPBI* and *EPL* had higher crown percent than those in *Treatment EP.*

The pruning treatments investigated have been shown to affect crown development. *Treatments CP, CPBI* and *EPL* have increased crown size and crown percent. These increases could have contributed to the better tree growth observed in these treatments[1].

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Rubber Research Institute of Malaysia
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