AGRONOMICAL PERFORMANCE AND PROFITABILITY OF EXPLOITATION SYSTEMS IN FOUR RUBBER TREE CLONES IN SÃO PAULO STATE (1)

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ABSTRACT

The exploitation or tapping of the rubber tree, *Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell. Arg. is one of the most important cultural practices in determining useful life, yield and accounts for a major part of the total production costs in rubber farming. The objective of this work was to evaluate yield performance and economic aspects of rubber tree clones submitted to diverse tapping systems. The trial was placed in Guararapes city, São Paulo State, Brazil, in a randomized block design with split-plot in time. The plots consisted of the IAN 873, PR 261, RRIM 600 and RRIM 701 clones. The tapping systems consisted the subplots, where: ½S = tapping of half spiral cut; d/2, d/3, d/4, d/5 and d/7 = tapping every 2, 3, 4, 5 and 7 days, respectively; 11 m/y = tapping during eleven months per year; ET = ethephon (stimulant); Pa = panel application; La = lace application; 8/y = eight applications per year. The five experimental years were the sub-subplots and the ½S d/2 system was used as control. The analyzed variables were girth, dry rubber yield, tapping panel dryness and economic profitability. The ½S d/3 ET 2.5% and ½S d/4 ET 2.5% tapping systems provide the highest yield and profitability per hectare per year for the RRIM 600 and PR 261 clones. For the IAN 873 and RRIM 701 clones the yield superiority occurs in high tapping frequency; however the best profitability is obtained in the ½S d/7.ET 2.5% system.

Key words: *Hevea brasiliensis*, natural rubber, tapping, ethephon, tapping panel dryness.

RESUMO

DESEMPENHO AGRONÔMICO E RENTABILIDADE DE SISTEMAS DE SANGRIA EM QUATRO CLONES DE SERINGUEIRA NO ESTADO DE SÃO PAULO

A explotação ou sangria da seringueira *Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell. Arg. é uma das práticas culturais mais importantes que determina a vida útil, a produtividade, sendo responsável por maior parte dos custos totais do seringal. O objetivo deste trabalho foi avaliar o desempenho produtivo e aspectos econômicos de clones de seringueira, em diferentes sistemas de sangria. O experimento foi instalado no município de Guararapes, Estado de São Paulo, em delineamento de blocos ao acaso com parcelas subdivididas no tempo. As parcelas constituíram dos clones IAN 873, PR 261, RRIM 600 e RRIM 701. As subparcelas foram constituídas por nove sistemas de sangria: ½S = sangria em meio espiral; d/2, d/3, d/4, d/5 e d/7 = sangria a cada 2, 3, 4, 5 e 7 dias, respectivamente; 11 m/y = sangria durante onze meses por ano; ET = ethephon (estimulante); Pa = aplicação no painel; La = sobre a canaleta; 8/y = oito aplicações por ano. Os cinco anos experimentais foram as sub-

(1) Received for publication in September 14, 2009 and accepted in March 11, 2010.
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subparcelas e o sistema ½S d/2 foi utilizado como testemunha. As variáveis estudadas foram: perímetro do caule, produtividade de borracha seca, secamento do painel e rentabilidade econômica. Os sistemas ½S d/3.ET 2,5% e ½S d/4.ET 2,5%, proporcionam maior produtividade e rentabilidade por hectare ao ano para os clones RRIM 600 e PR 261. Para os clones IAN 873 e RRIM 701 o melhor rendimento ocorre em sistemas de alta frequência de sangria, mas a melhor rentabilidade é obtida no sistema ½S d/7.ET 2,5%.

Palavras-chave: *Hevea brasiliensis*, borracha natural, sangria, ethephon, seca do painel.

1. INTRODUCTION

Hevea brasiliensis (Willd. ex Adr. de Juss.) Muell.-Arg., a deciduous perennial tree of the Euphorbiaceae family, is the prime source of commercial rubber. Natural rubber is the strategic raw material for more than 40,000 products including 400 medical devices (Mooibroek and Cornish, 2000). The current trends toward increased production costs and shortened labor availability have led to a continued search for methods to reduce production costs of rubber plantations (Rajagopal et al., 2004).

The exploitation or tapping is fundamental in determining the useful life and yield of rubber tree plantations, accounting for a major part of the total production costs. It consists of a systematic wounding of the bark to extract latex. In many rubber-producing countries, the widely adopted exploitation system is the 'half-spiral, alternate-day' (½S d/2) tapping. However, the tapper requirement is high in this system and is a problem in several rubber-producing countries, such as Malaysia, Sri Lanka and Brazil, due to of the shortage of skilled tappers and high labor wages. A possible solution is to tap at lower frequencies, but that may not extract the proper maximum volume of latex from the tree (Gunasekara et al., 2007). In an attempt to overcome this limitation, rubber-growing countries are investigating the use of yield stimulants, such as ethephon, in combination with lower frequencies of tapping (Nugawela et al., 2000). Ethylene is a plant hormone with numerous mechanisms of action at the laticiferous cells, including biochemical modifications inducing metabolism activation. Hence, upon ethylene stimulation, the *in situ* latex regeneration is activated after tapping, improving latex flow and extends its duration there after (Jacob et al., 1992).

Another major economic impact impairing rubber yield is the onset of the Tapping Panel Dryness (TPD) disease, caused by extensive tapping, chemical stimulation and other stresses as well (Silva et al., 2007a,b). The TPD can cause partial or total and irreversible reduction of the latex yield in rubber tree plantations.

The objective of this work was to evaluate yield and economic aspects of four rubber tree clones submitted to several tapping systems, aiming at identifying the best exploitation systems suitable to these clones.

2. MATERIAL AND METHODS

The experiment was conducted in a rubber growing area near Guararapes city (21º 20'S, 50º 50'W), São Paulo State, Brazil. According to Köppen's climatic classification, the climate of this region is an Aw type, with average annual temperature of 26.7 ºC and average annual precipitation of 1,271 mm. The temperatures in the experimental area are considered suitable for crops that should be at 28 ± 2º C (Jiang, 1988; Gonçalves et al., 2001). The rainfall is lower than the optimum levels for rubber tree plantations, which should range from 2,000 to 4,000 mm per year (Gonçalves et al., 2001). However, the rubber tree has adaptability to low water availability, because under such condition the plant can absorb water as deep as 3 m or more, as well as water previously stocked in the trunk (Rao and Vijakumar, 1992).

The soil in the experimental growing rubber area is a eutrophic Red Argissol, according to the Brazilian Soil Taxonomy and Classification System (Embrapa, 1999). In chemical analysis, it was characterized as: pH 4.2; 1.8 g kg^{-1} organic matter; P = 9 mg cm^{-3} (resin method); K, Ca, Mg and H+Al = 1.8, 21.0, 5.0 and 13.0 mmol 100 dm^{-3}, respectively. All management practices were performed following standard technical recommendation for rubber tree plantations in São Paulo State, according to Gonçalves et al.; (2001).

In 1992, the four studied clones were planted in the field using the 8 x 2.5 m spacing. The tapping started seven years after the planting, when girth was higher than 45 cm in all rubber trees. The tapping panel management was of five years on the same panel.

The experiment was designed as randomized blocks with split-plot in time, with four replicates. The main treatments were the IAN 873, PR 261, RRIM 600 and RRIM 701 rubber tree clones, in plots of 0.25 ha (totalizing 1 ha). The secondary treatments comprised 12 trees, except for the control with 24 trees, and consisted of nine tapping systems (Table 1). The international notation system was used, where ½S = tapping of half spiral cut; d/2, d/3, d/4, d/5 and d/7 = tapping every 2, 3, 4, 5 and 7 days, respectively; 11 m/y = tapping during eleven months per year; ET = ethephon (stimulant); Pa = panel application; La = lace application; 8/y = eight applications of the stimulant per year. Regarding ethephon stimulated treatments; stimulation

Table 1. Tapping systems applied to four rubber tree clones in a five-year evaluation period at a Brazilian rubber-growing region, in Guararapes SP. Cut length: half spiral (½S). Tapping periodicity: eleven months per year (11 m/y). Tapping frequencies: between 2 to 7 days (d/). Type of stimulant: ethephon (ET). Method of ET application: panel and lace application (Pa, La). ET application frequency: eight applications per year (8/y)

Tapping systems	Tapping frequency	Ethephon concentration
1 (1)	d/2	-
2	d/3	2.5 %
3	d/3	5.0 %
4	d/4	2.5 %
5	d/4	5.0 %
6	d/5	2.5 %
7	d/5	5.0 %
8	d/7	2.5 %
9	d/7	5.0 %

(1) Control.

was performed using 1 g of commercial formulation previously diluted with water (2-chloroethylphosphonic acid 10%) per tree per stimulation (i.e. 25 or 50 mg a.i. per tree per stimulation).The ½S d/2 traditional system was used as control.

The rubber yield was evaluated monthly and the income was assayed by weighing the coagulated latex in plastic cups. In rainy days, 5% acetic acid was added to the latex for coagulation, in order to avoid losses. The monthly total mass of each exploitation system was divided by the total number of tapping, and the results were expressed in grams of dry rubber per tapping per tree. The dry rubber content (DRC) of 53% was considered, following the standard methodology overall accepted for this kind of experiment. As for rubber yield estimates extrapolated to hectare per year, stands of 240, 340, 380 and 400 trees per hectare were evaluated within the tapping treatments respectively in the first, second, third, fourth and fifth year (Embrapa, 1987). In addition, the tapping was done in a total of 140, 104, 78, 62 and 52 days per year for the d/2, d/3, d/4, d/5 and d/7 tapping treatments, respectively.

In the fifth year of evaluation, the trees with tapping panel dryness (TPD) were counted and appraised for each clone, within each of the exploitation systems. The incidence of diseased trees was calculated according to the stand in the exploitation systems.

In the plots, girth averages were measured annually in order to estimate vigor of the rubber trees. Girth measurements of five trees from each plot were recorded at 1.20 m from the highest point of the bud union.

Economical analysis comprised evaluations of gross income, wages, inputs and agricultural materials. Data were used to estimate the effective operational cost (EOC) in the production, the net income and the profitability for each clone within each exploitation treatment. The effective operational costs referred to the period of the tapping and not to the crop, because implantation costs were not included in the estimates since they were common to all clones and exploitation systems (Toledo and Ghilardi, 2000). Annual expenses with inputs, such as ethephon and acetic acid, agricultural materials in eventual replacements and wages (salary and social tax) were logged considering that one worker is responsible for tapping 800 trees a day. The net income corresponded to the difference between the gross income and the effective operational cost. The profitability of each exploitation system in each clone was calculated in relation to the control and expressed in percentage.

The data on yield were submitted to the analysis of variance, for the F test at 1% probability. The analysis of the interaction clones vs. tapping systems was performed and submitted to the test of Tukey at 1% probability. In the split-plot in time design, the plots consisted of the rubber tree clones, the tapping systems were the subplots, and the experimental years were the sub-subplots.

3. RESULTS AND DISCUSSION

There were significant ($p<0.01$) differences among clones at the third production year and afterwards (Table 2). As for the interaction clone vs. tapping systems, the dry rubber yield of the four clones, in all years. The coefficients of variation are in agreement with previous data reported (Gonçalves et al., 2000).

In all clones, during the five years of evaluations, the yield per tree was highest in the d/7 tapping treatment. This result indicated that the longest intertap period allowed the most suitable regeneration of the latex in the vessel rows (Figures 1, 2, 3 and 4). In the western region of Africa, a four-day intertap interval was reported to be necessary for a proper reconstitution of the latex content in the vessel rows (irca, 1987). In that region, intertap intervals shorter than four days resulted in fast increase of total solids, while the yield was quickly decreased in intervals longer than seven days. Tapping frequencies of 4 or 5 days may enable better use of the production factors, but the reduction of cuts can decrease productivity to no economical levels (Virgens Filho et al., 1986). Consequently, clones that show good response to stimulation and provide high and sustainable yield are preferred alternatively to lower tapping frequencies (Gireesh et al., 2005).

Regarding yield per hectare per year, the highest response of the IAN 873, RRIM 600 and RRIM 701 clones was in the ½S d/3.ET 2.5% treatment, in most years (Figures 1, 3 and 4). The results of the IAN 873 and RRIM 600 clones were similar to those found by Bernardes et al.

Table 2. Mean squares of the analysis of variance for dry rubber yield per tree per tapping, and yield per hectare per year, of four rubber tree clones submitted to nine tapping systems in five consecutive years in Guararapes, SP, Brazil

Sources of variation	D.F.	Mean Squares					
		1st year	2nd year	3rd year	4th year	5th year	average
Blocks	3	143.87^{ns} (46935.93^{ns})	285.03^{ns} (182962.13^{ns})	272.01^{ns} (216025.50^{ns})	268.80^{ns} (239329.41^{ns})	538.74^{ns} 484312.05^{ns}	280.30^{ns} (204091.28^{ns})
Clones (A)	3	127.22^{ns} (40580.01^{ns})	844.69^{ns} (591688.05^{ns})	1132.58** (1113059.94**)	719.36** (856753.53**)	483.79** (575878.75**)	437.07** (452748.73**)
Error (*a*)	9	71.67 (23062.63)	146.45 (92676.07)	119.04 (95153.34)	114.43 (101237.75)	7.55 (7047.00)	36.87 (23430.71)
Tapping systems (B)	8	1476.30** (89786.88**)	3475.72** (360242.86**)	2988.51** (262144.74**)	2950.75** (269317.38**)	2638.79** (581760.60**)	2521.22** (152945.58**)
A x B	24	13.92** (4942.63**)	41.79** (36628.25**)	63.56** (96488.00**)	80.29** (113390.79**)	48.97** (76711.51**)	27.20** (44503.70**)
Error (*b*)	96	0.71 (48.81)	1.68 (219.40)	1.48 (257.43)	1.49 (284.43)	1.30 (378.89)	0.81 (105.78)
Total	143						
General means		36.51 (656.63)	51.74 (1304.87)	48.14 (1357.37)	47.56 (1415.07)	45.59 (1336.90)	45.91 (1220.17)
CV % (A)		7.73 (7.71)	7.80 (7.78)	7.55 (7.58)	7.50 (7.50)	2.01 (2.05)	4.41 (4.18)
CV % (B)		2.31 (1.06)	2.51 (1.14)	2.53 (1.18)	2.57 (1.19)	2.50 (1.42)	1.95 (0.84)

^{ns}; **: not significant and significant at $p< 0.01$ respectively.
Data between parentheses refer to yield per hectare per year (kg ha^{-1} year^{-1}).

Table 3. Means for girth and its increments in four rubber tree clones submitted to tapping, in a five-year period at a rubber-growing region in Guararapes, SP, Brazil

Year	Girth				Increment			
	IAN 873	PR 261	RRIM 600	RRIM 701	IAN 873	PR 261	RRIM 600	RRIM 701
	cm				%			
1	55.40	50.00	50.80	48.50	-	-	-	-
2	57.60	51.60	53.80	50.00	3.97	3.20	5.91	3.09
3	58.60	52.60	55.20	52.25	1.74	1.94	2.60	4.50
4	59.60	54.00	56.40	53.25	1.71	2.66	2.17	1.91
5	62.60	56.80	58.80	57.25	5.03	5.19	4.26	7.51
Means	58.76	53.00	55.00	52.25	3.11	3.25	3.73	4.25
Standard deviation	2.65	2.58	2.98	3.36				

First year corresponds to the panel opening.

(2000), who recommended the ½S d/3.ET 2.5% system for these two clones, although this recommendation was associated with four stimulant applications per year.

In the ½S d/3.ET 5% treatment, the yield per hectare per year of all clones was high in the first year, but there was a tendency of yield decrease in the subsequent years. In the IAN 873, RRIM 600 and RRIM 701 clones, the yield per hectare per year was highest in the first and second years (Figures 1, 3, 4a and 1, 3, 4b) with a substantial decrease afterwards (Figures 1, 3 and 4c). As for the PR 261 clone, the yield per hectare decreased in the fifth year (Figure 2e). These results indicate that a combination of high tapping frequencies with high concentration of ethephon can cause significant yield losses along the years.

Data on rubber yield per tree per tapping showed, in the first three years of evaluations, an evident high yield upon the stimulation with 5% ethephon, mainly in the RRIM 600 and RRIM 701 clones. In the subsequent years, however, this stimulation caused yield decrease in all tapping treatments (Figures 3 and 4). A tendency of yield increased per hectare in all years for the PR 261 clone submitted to the ½S d/4.ET 2.5% treatment, which is in agreement with the Irca (1989) recommendation for this clone.

Averages of the annual girth and their increment during the five years of evaluation showed largest girths in the IAN 873 clone, followed by the RRIM 600 clone (Table 3). However, in the fifth year, the percentage of girth increment was the smallest (3.11%) for the IAN 873

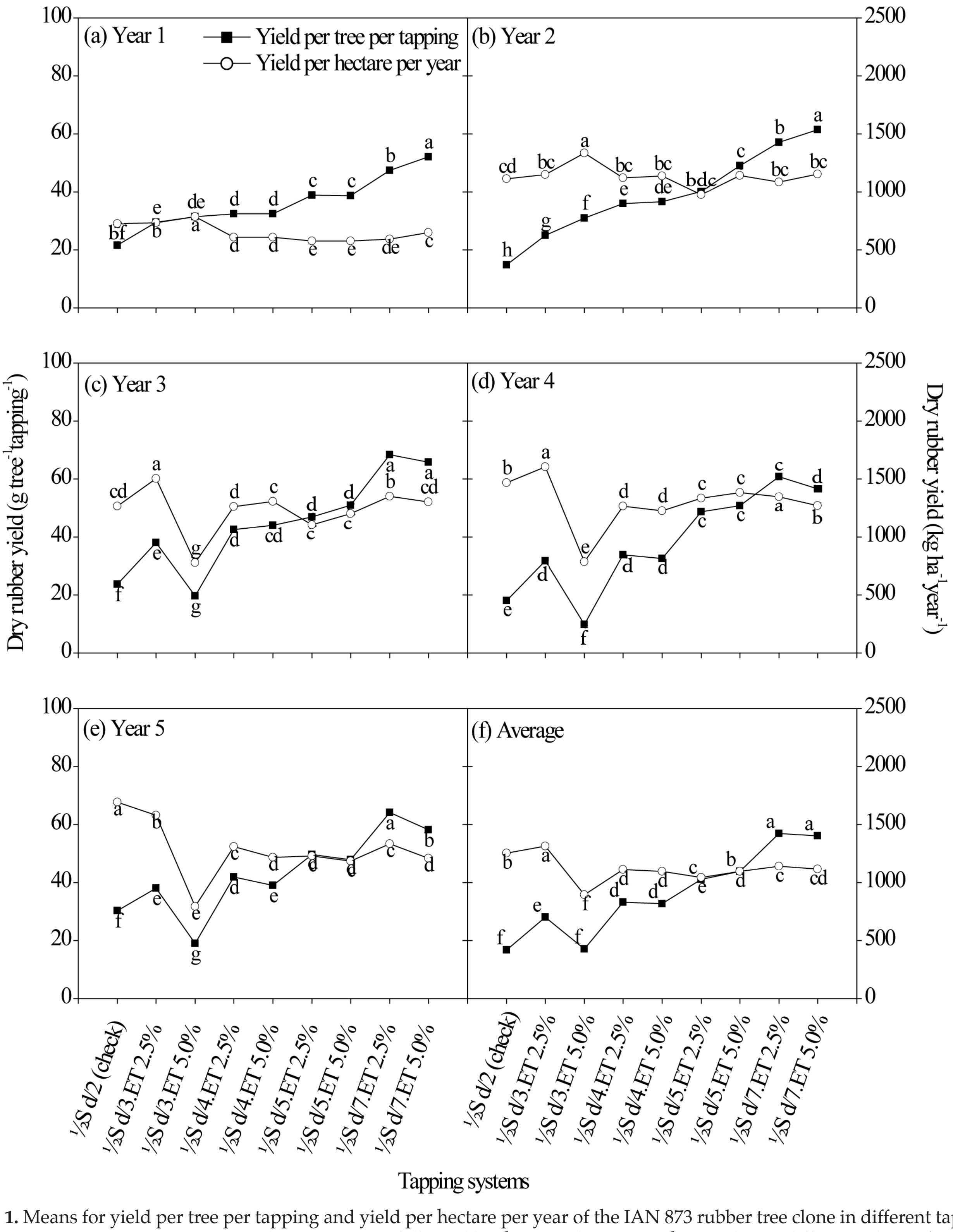

Figure 1. Means for yield per tree per tapping and yield per hectare per year of the IAN 873 rubber tree clone in different tapping systems in Guararapes city São Paulo State. Means followed by the same letter in each year do not differ at Tukey 1%.

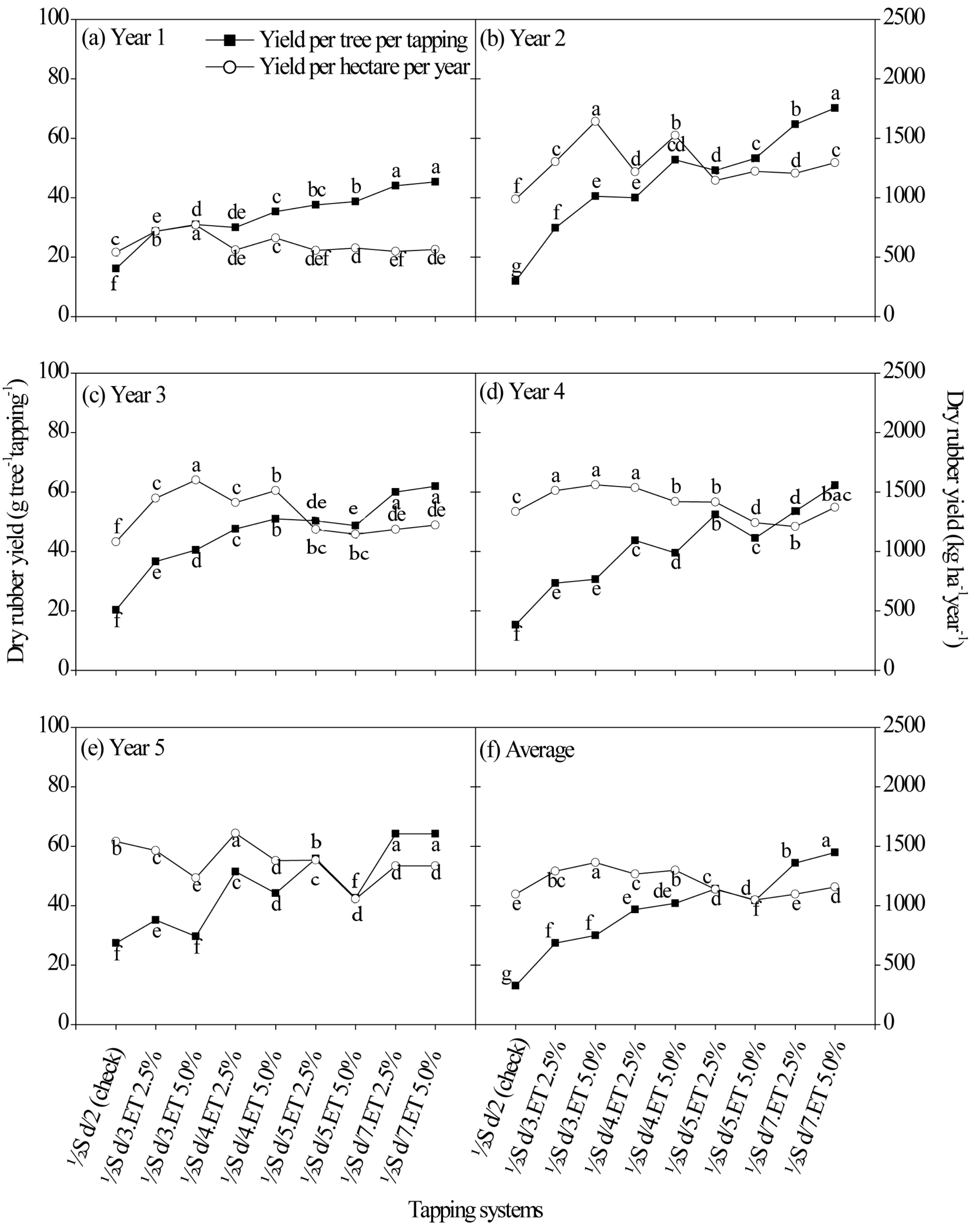

Figure 2. Means for yield per tree per tapping and yield per hectare per year of the PR 261 rubber tree clone in different tapping systems in Guararapes city São Paulo State. Means followed by the same letter in each year do not differ at Tukey 1%.

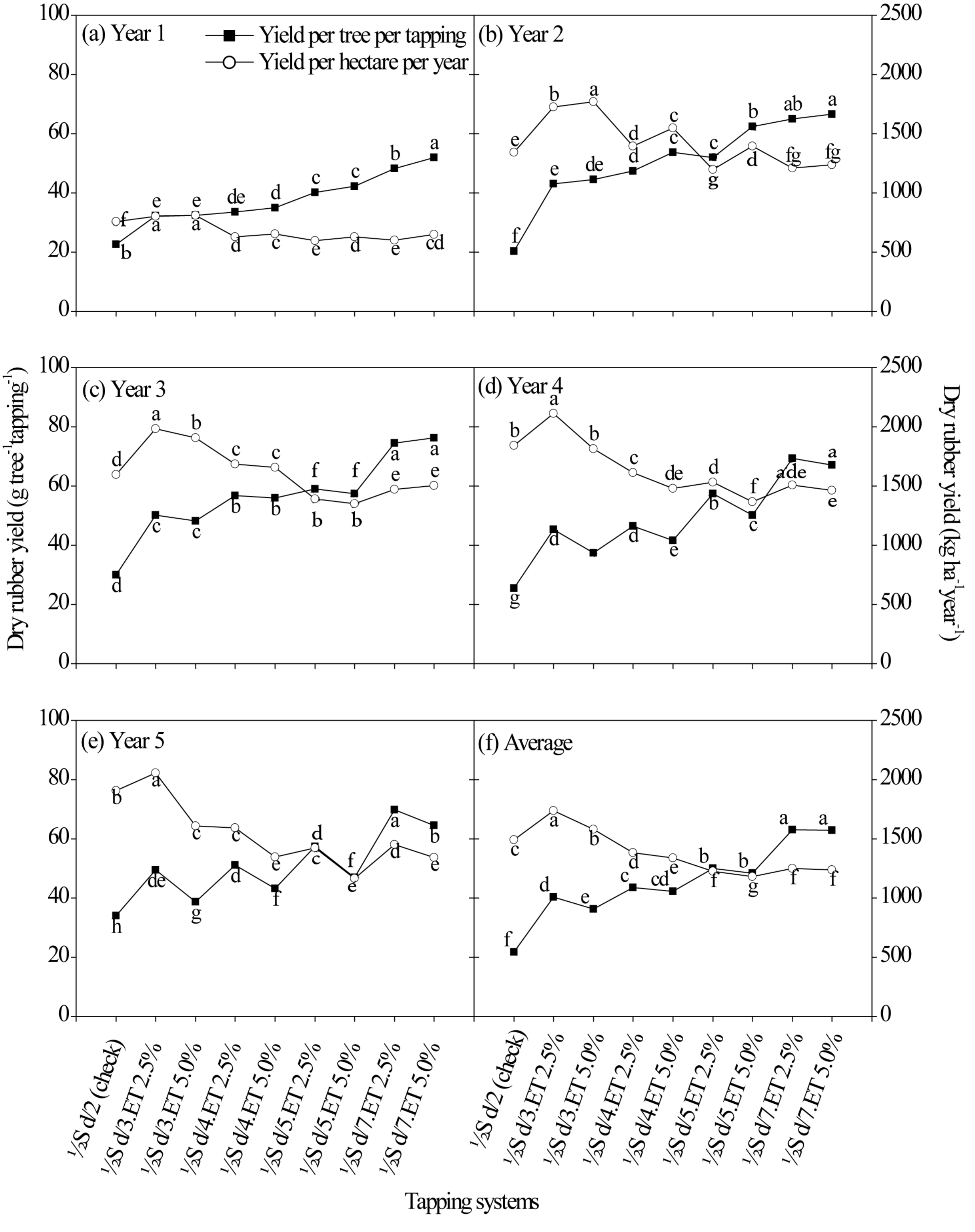

Figure 3. Means for yield per tree per tapping and yield per hectare per year of the RRIM 600 rubber tree clone in different tapping systems in Guararapes city São Paulo State. Means followed by the same letter in each year do not differ at Tukey 1%.

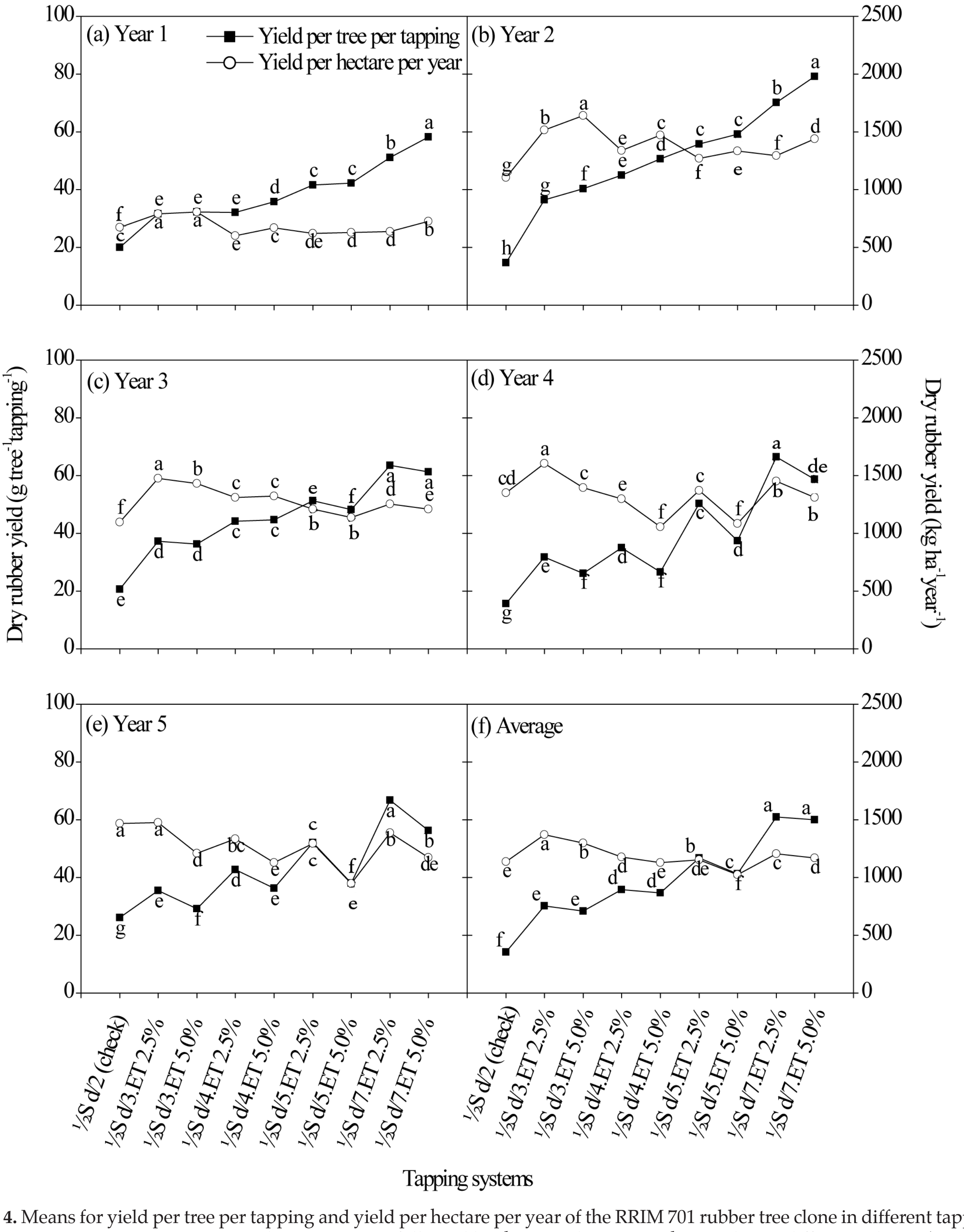

Figure 4. Means for yield per tree per tapping and yield per hectare per year of the RRIM 701 rubber tree clone in different tapping systems in Guararapes city São Paulo State. Means followed by the same letter in each year do not differ at Tukey 1%.

clone and the highest (4.25%) for the RRIM 701 clone. These results are quite meaningful because, according to Gonçalves et al. (2006), the growth of clones in the tapping period is indicative for the capability of continued yield performance and less susceptibility to wind damage. The interclonal variability regarding rubber yield is directly related to the girth of the tree. The rubber yield is increased when the tree girth is large at opening, due to the longer tapping cut, as observed by Obouayeba et al. (2002). An inverse correlation exists between latex extraction and girth increment, because both of them depend on a common pool of assimilates from photosynthesis (Obouayeba et al., 2002; Gunasekara et al., 2007). Silpi et al. (2006) evidenced that the tapping impact on growth was much stronger in the second year of tapping than in the first, whereas latex production increased significantly between the first and the second year. Moreover, as expected, ethylene significantly increased latex production in the first two years, but it had no effect on the growth rates of tapped trees.

Table 4. Incidence of tapping panel dryness (TPD) in four rubber tree clones submitted to nine tapping systems, evaluated at the fifth year in Guararapes, SP, Brazil

Tapping systems	Number of trees in tapping				Percentages of tapping panel dryness (1)			
	IAN 873	PR 261	RRIM 600	RRIM 701	IAN 873	PR 261	RRIM 600	RRIM 701
½S d/2 (control)	96	92	94	84	1.0	1.1	4.1	14.3
½S d/3.ET 2.5%	48	37	47	41	3.9	17.8	2.1	16.3
½S d/3.ET 5.0%	48	38	48	41	5.9	29.6	7.7	21.2
½S d/4.ET 2.5%	48	46	46	41	4.0	4.2	2.1	16.3
½S d/4.ET 5.0%	47	37	45	37	2.1	14.0	8.2	21.3
½S d/5.ET 2.5%	45	44	46	47	0.0	6.4	0.0	13.0
½S d/5.ET 5.0%	48	42	47	44	2.0	17.6	2.1	22.8
½S d/7.ET 2.5%	46	45	46	43	0.0	6.3	0.0	6.5
½S d/7.ET 5.0%	45	46	45	46	4.3	2.1	0.0	6.1

(1) The percentage of tapping panel dryness is in relation to the total number of trees in each subplot.

Table 5. Economical evaluation of nine diverse tapping systems of two rubber tree clones, based on the average of yield during five consecutive years in Guararapes, SP, Brazil

Clones	Tapping systems	Yield	Gross income (1)	Wages (2)	Inputs	Agricultural materials	Effective operational cost	Net income (3)	Profitability (4)
		kg ha^{-1} year^{-1}	US$						%
IAN 873	½S d/2 (control)	1254	2632	1265	7	21	1292	1340	100
	½S d/3.ET 2.5%	1315	2760	843	76	21	940	1821	136
	½S d/3.ET 5.0%	896	1881	843	145	21	1009	871	65
	½S d/4.ET 2.5%	1113	2338	633	76	21	729	1609	120
	½S d/4.ET 5.0%	1099	2307	633	145	21	798	1509	113
	½S d/5.ET 2.5%	1045	2194	506	76	21	603	1591	119
	½S d/5.ET 5.0%	1097	2304	506	145	21	672	1632	122
	½S d/7.ET 2.5%	1143	2399	422	76	21	518	1881	140
	½S d/7.ET 5.0%	1117	2345	422	145	21	588	1758	131
PR 261	½S d/2 (control)	1097	2301	1265	7	21	1292	1010	100
	½S d/3.ET 2.5%	1289	2707	843	76	21	940	1767	175
	½S d/3.ET 5.0%	1362	2859	843	145	21	1009	1850	183
	½S d/4.ET 2.5%	1268	2662	633	76	21	729	1933	191
	½S d/4.ET 5.0%	1300	2729	633	145	21	798	1931	191
	½S d/5.ET 2.5%	1138	2389	506	76	21	603	1787	177
	½S d/5.ET 5.0%	1049	2201	506	145	21	672	1529	151
	½S d/7.ET 2.5%	1097	2304	422	76	21	518	1786	177
	½S d/7.ET 5.0%	1158	2431	422	145	21	588	1843	182

(1) The product was marketed as dry rubber in March 2006, at US$ 2.10 per kg.
(2) The wage was US$ 389, including 30% of social responsibilities by tapper a month, considering that in the system d/2 each tapper accounts for 1600 trees, in d/3 for 2400 trees, in d/4 for 3200 trees, in d/5 for 4000 trees and in d/7 for 5600 trees.
(3) Net income = Gross income – Effective operational cost.
(4) The profitability percentage of each clone was estimated in relation to the control (½S d/2).

Table 6. Economical evaluation of nine diverse tapping systems of two rubber tree clones, based on the average of yield during five consecutive years in Guararapes, SP, Brazil

Clones	Tapping systems	Yield	Gross income (1)	Wages (2)	Inputs	Agricultural materials	Effective operational cost	Net income (3)	Profitability (4)
		kg ha^{-1}year^{-1}	US$						%
RRIM 600	½S d/2 (control)	1490	3129	1265	7	21	1292	1837	100
	½S d/3.ET 2.5%	1736	3646	843	76	21	940	2706	147
	½S d/3.ET 5.0%	1582	3323	843	145	21	1009	2314	126
	½S d/4.ET 2.5%	1383	2905	633	76	21	729	2176	118
	½S d/4.ET 5.0%	1337	2809	633	145	21	798	2010	109
	½S d/5.ET 2.5%	1228	2578	506	76	21	603	1975	108
	½S d/5.ET 5.0%	1181	2480	506	145	21	672	1808	98
	½S d/7.ET 2.5%	1249	2622	422	76	21	518	2104	115
	½S d/7.ET 5.0%	1240	2604	422	145	21	588	2016	110
RRIM 701	½S d/2 (control)	1138	2390	1265	7	21	1292	1098	100
	½S d/3.ET 2.5%	1372	2882	843	76	21	940	1942	177
	½S d/3.ET 5.0%	1297	2724	843	145	21	1009	1715	156
	½S d/4.ET 2.5%	1176	2469	633	76	21	729	1740	159
	½S d/4.ET 5.0%	1131	2375	633	145	21	798	1577	144
	½S d/5.ET 2.5%	1153	2420	506	76	21	603	1818	166
	½S d/5.ET 5.0%	1025	2153	506	145	21	672	1482	135
	½S d/7.ET 2.5%	1206	2532	422	76	21	518	2014	183
	½S d/7.ET 5.0%	1171	2459	422	145	21	588	1871	170

(1) The product was marketed as dry rubber in March 2006, at US$ 2.10 per kg.
(2) The wage was US$ 389.22, including 30% of social responsibilities by tapper a month, considering that in the system d/2 each tapper accounts for 1600 trees, in d/3 for 2400 trees, in d/4 for 3200 trees, in d/5 for 4000 trees and in d/7 for 5600 trees.
(3) Net income = Gross income – Effective operational cost.
(4) The profitability percentage of each clone was estimated in relation to the control (½S d/2).

The percentage of TPD incidence ranged from 0 to 29.6% in the four rubber tree clones, differing in the diverse clones (Table 4). The differences could be explained by possible resistance diversity among the clones and by undetermined factors intrinsic and extrinsic to the plant (Gonçalves et al., 2000; Nair et al., 2004). The RRIM 701 clone was the most susceptible to TPD, with incidences above 5% in all tapping systems. Further studies are necessary to evaluate different combinations of stimulant concentration with application frequency for the RRIM 701 clone, in the d/7 tapping, where small incidence of TPD was observed. In the PR 261, RRIM 600 and RRIM 701 clones, the TPD incidence was highest in the treatments including 5% ethephon stimulation, except in the seven-day (d/7) frequency. Possibly, the high concentration of ethylene increased plant susceptibility to TPD. In the d/7 tapping with 5% ethephon, the TPD incidence was smaller in all clones, varying from 0 to 6.5 % what can be explained by the theory that lower tapping frequencies reduce the possibility of occurrence of TPD. In India, the yield in smallholding areas reaches less than half of its potential limit, mainly because of the intensive exploitation of trees leading to tapping panel dryness (Nair et al., 2004).

Data on the economical evaluation of the tapping systems applied to each clone are shown in Table 5 and Table 6. There was 67% labor reduction in the d/7 tapping frequency compared with the d/2 (control). These results were evident because in the lowest tapping frequency (d/7) each tapper is responsible for approximately 5,600 trees while in d/2 each tapper is responsible for 1,600 trees. According to Bernardes et al. (2000), because the rubber tree tapping is done during the entire productive period and accounts for the largest portion of the rubber production costs, it is considered the most important cultural practice. The tapping accounts for approximately 60% of the total rubber costs, just considering labor expenses (Gonçalves et al., 2000). The profitability of the IAN 873 and RRIM 701 clones was highest in the ½S d/7.ET 2.5% system, consisting respectively of 40% and 83% in comparison with the ½S d/2 system (control). In the RRIM 600 clone, the highest gain (47%) was obtained in the ½S d/3.ET 2.5% treatment. As for the PR 261 clone, 91% of profitability was achieved in the ½S d/4.ET 2.5% and in the ½S d/4.ET 5.0% systems, compared with the control. However, in the treatment with 5% ethephon stimulation the incidence of TPD was so high, that this tapping system was unfeasible from the agronomic point of view.

The data presented herein are potentially useful for the development of future guidelines aiming at both better rubber yield and profitability from the studied clones cultivated in the evaluated rubber growing region or at comparable regions in the world.

4. CONCLUSIONS

1. The ½S d/3 ET 2.5% and ½S d/4 ET 2.5% tapping systems provide the highest yield and profitability per hectare per year and lower TPD incidence compared with 5% ethephon treatments for the RRIM 600 and PR 261 clones.

2. For the IAN 873 and RRIM 701 clones the yield superiority occurs in the ½S d/3.ET 2.5% system of high tapping frequency; however the best profitability is obtained in the ½S d/7.ET 2.5% a system of lower tapping frequency.

3. Plant vigor in the IAN 873 clone is the most affected by tapping with consequent lower girth increment.

4. The stimulation of latex production with 5% ethephon shows a tendency to decrease the yield per hectare per year and favors high TPD incidence.

ACKNOWLEDGEMENTS

The authors are grateful to Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for a scholarship to the first author, and to the employees of Santa Gilda rubber plantation and of Rodobens Agrícola e Pecuária group for their collaboration during the development of this work.

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