Early Clonal Selection of *Hevea Brasiliensis* Based on Latex Physiological Parameters in Cambodia

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Abstract

Since the introduction of new rubber clones from abroad becomes more and more difficult, Cambodian Rubber Research Institute (CRRI) has to consider the possibility to create new clones in Cambodia for improving the rubber yield potential and testing their adaptation to the instability of the environment predicted by climatologists in relation with the climate change. In order to shorten the duration of new clones creation and as hand pollination garden was not developed yet, more than two thousand seeds were collected at random from old seedling trees planted in 1924 in the field 87-A of Sopheak Nika Investment Group Co., Ltd (former Chup rubber plantation) for planting and evaluation in a Seedling Evaluation Trial (SET). All the seeds were germinated and planted in the field with the spacing of 2m x 2m at the CRRI experimental station in 2012, with a total number of 1 230 seedling trees. Early tapping was carried out for 6 months in 2015 in S/2 d3 7d/7. Girth (cm), yield ($g.tree^{-1}$ and $g.tree^{-1}.cm^{-1}$)and latex physiological parameters such as sucrose latex content (Suc, $mM.l^{-1}$), inorganic phosphorus latex content (Pi $mM.l^{-1}$) and latex DRC (%) have been measured. 20 genotypes showing the best trade-off between girth (cm), early production ($g.cm^{-1}.t^{-1}$) and latex sucrose content ($mM.l^{-1}$) have been selected as the 20 most promising clones among the initial seedlings population. These 20 genotypes were characterized with a latex sucrose content increased by more than 40% when compared to the theoretical latex sucrose content deducted from their latex yield, making them candidates for a high latex yield potential, a good response to hormonal stimulation and an improved tolerance to stress.

Keyword: *Hevea Brasiliensis*, growth, yield, latex physiological parameters, sucrose, inorganic phosphorus, clonal selection, seedling evaluation trial,

1. Introduction

The current area under rubber cropping in Cambodia is now estimated at about 389,000 ha, with the production about 126,000 tons in 2015, as a large proportion is still immature. For more than 10 years, the number of rubber tree clones available in Cambodia has been between 40 and 50, with about 20 of them actually cultivated. CRRI has now to consider the possibility to create new clones in Cambodia for improving rubber yield potential and testing their adaptation to the instability of the environment predicted by climatologists in relation with the climate change (higher temperature, higher storm frequency and likely lower water availability).

A network of large scale clone trials still exists and generates regular results. Of course it should be maintained and developed continuously, if possible with the participation of industrial estates which have land available for that. A first experience was gained by CRRI for setting up a small scale clone trial (trial planted in June 2008).For developing early selection, CRRI needs the seeds at the origin of the potential mother-trees of any new clones. Rather than developing hand pollination in Cambodia, and with the agreement of Sopheak Nika Investment Group Co., Ltd, more than two thousand seeds were collected at random from the plot87-A, a seedlings field which was planted in 1924. All the seeds were germinated and planted in the field at the CRRI experimental station in 2012.Their selection would put the base of an original Wickham germplasm in Cambodia. This trial was used to set up a seedling evaluation trial (SET) for selection at 3 years of age (Clément-Demange, 2011).Early tapping was carried out in 2015 in S/2 d/3 7d/7.A crossed selection of genotypes was carried out based on girth, yield and latex physiological parameters (Suc and Pi) and allowed to identify 20 interesting genotypes presenting favorable profiles regarding growth, production and latex sugar loading. The selected genotypes will further be budded in nursery for the implementation of a Small Scale Clone Trial.

This paper describes the method which was used for selection of those potentially high yielding genotypes at an early stage, based on the use of latex physiological parameters.

2. Materials and Methods

2653 seeds were collected randomly from the seedling plot 87-A of Chup plantation, which was planted in 1924. These seeds were germinated in polybag and then planted in the field in 2012, with a spacing of 2 x 2 meters at the experimental station of the Cambodian Rubber Research Institute (latitude 12 °N, longitude 105 °E), in the Tboung Khmum province. Each seedling was coded by its position (number of line + number of row). A first selection was made on the growth and production for the first 3 years (Suhendry *et al.*, 2010).

The trees with a girth higher than 18 cm measured at 1 m height from the ground were selected to be opened for early tapping, resulting in an early selection of 188 genotypes among the 2653 initial ones. The tapping system was S/2 d3 7d/7 with continuous tapping for 50 tappings without stimulation. Cumulated production per tree ($g.tree^{-1}$) was recorded and then converted in production per tree per cm of tapping cut ($g.tree^{-1}.cm^{-1}$) in order to correct and limit the influence of tree girth on the production for further calculations (Gohet *et al*., 1996). Latex physiological parameters as latex sucrose content (Suc, $mM.l^{-1}$) and latex inorganic phosphorus content (Pi, $mM.l^{-1}$) were measured and recorded under tapping without ethephon stimulation (Jacob *et al*., 1988, 1989, 1995, IRRDB 1995). The median of each recorded parameter was calculated in order to classify the values of growth, production, Suc and Pi into 6 different distribution classes (very low/VL, low/L, medium low/ML, medium high/MH, high/H and very high/VH).

3. Results

Detailed results from data recordings are provided in Table 1 (Annex 1).

The girth at opening measured at 1m height from the ground of 188 genotypes ranged from 22 cm (19/8) to 40 cm (77/9) while the length of tapping cut varied from 14.2 cm (69/6) to 26.1 cm (77/9). The cumulated yields expressed in g.tree^{-1}over 50 tappings ranged from 1.5 g (54/7) to 443.7 g (79/10) whereas the yield in g.tree^{-1}.cm^{-1}varied from 0.1 g (54/7) to 23.4 g (79/10). For latex physiological parameters, Suc values ranged from 3.6 mM.l^{-1} (8/5) to 41.3 mM.l^{-1} (77/10) and Pi values ranged from 2.6 mM.l^{-1} (39/9) to 36 mM.l^{-1}(109/3).

The relationship between yield in gram per tree per centimeter (.cm^{-1}) and latex Suc (mM.l^{-1}) was examined according to Gohet *et al.* (1996) (Figure 1). A general regression equation between Suc and yield expressed in g.tree^{-1}.cm^{-1}was established allowing to calculate a predicted value of Suc ($Suc_{predicted}$= -0.325 P (g.tree^{-1}.cm^{-1}) + 12.28), corresponding to the observed yield. The difference between the actual measured Suc value and the Suc value (Delta Suc/gt) predicted from the regression equation was calculated and afterwards expressed as a percentage of the predicted Suc value (a positive percentage meaning that the actual Suc value was found above the predicted Suc value and a negative percentage meaning that the actual Suc value was found below the predicted Suc value). The higher positive percentages (higher positive differences between the actual and the predicted Suc value) were used as indicators for selecting the genotypes regarding their latex sugar loading capacity.

Figure 1 shows a global pattern with a negative relation between Suc and yield (g.tree^{-1}.cm^{-1}), logical as an increased production results in an increased latex sugar consumption for latex regeneration(Gohet *et al.*, 1996, 2003, 2008, Lacote *et al.*, 2010).

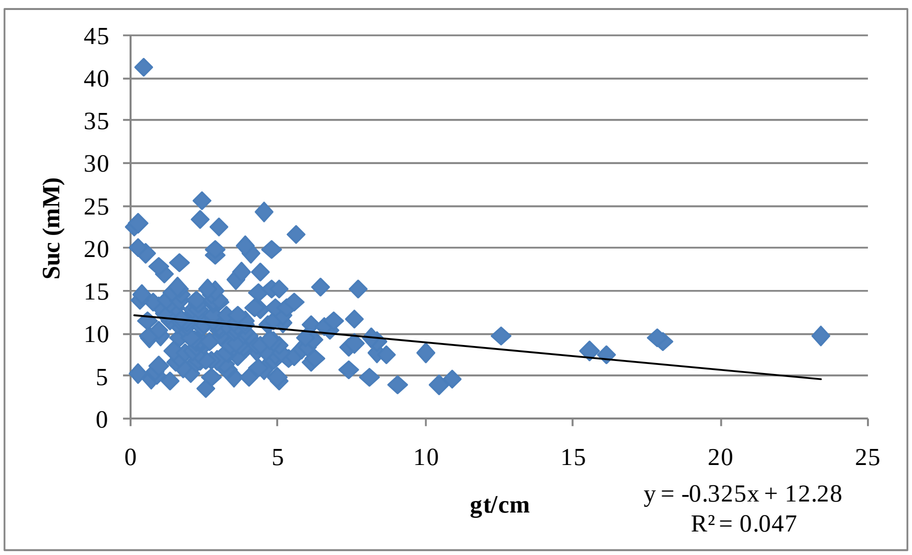

Figure 1. Relationship between latex Suc (mM.l^{-1}) and yield in gram per tree per centimeter.$Suc_{predicted}$=- 0.325P (g.tree^{-1}.cm^{-1}) + 12.28, R^2 =0.047

The relationship between the latex metabolic activity, described by the latex Pi (mM.l^{-1}), and latex Suc (mM.l^{-1}) was examined as well according to Gohet *et al.* (1996) (Figure 2). A general regression equation between Suc and Pi was established allowing to calculate a predicted value of Suc ($Suc_{predicted}$= -0.116 Pi (mM.l^{-1}) + 12.13), corresponding to the observed latex metabolic activity. The difference between the actual measured Suc value and the Suc value predicted from the regression equation (Delta Suc/Pi) was calculated and afterwards expressed as a percentage of the predicted Suc value (a positive percentage meaning that the actual Suc value was found above the predicted Suc value and a negative percentage meaning that the actual Suc value was found below the predicted Suc value). The higher positive percentages (higher positive differences between the actual and the predicted Suc value) were used as indicators for selecting the genotypes regarding their latex sugar loading capacity. However, the results obtained were almost similar to those obtained from the first regression (Figure 1). We therefore suggest that a clonal selection should be first made from the regression Suc = f (Production). The regression Suc = f(Pi) might be used only to check the accuracy of the first selection.

Figure 2 shows a global pattern with a negative tendencybetween Suc and Pi, which is logical asthe latex sugar content decreases with metabolic activation because of its consumption for rubber synthesis (Gohet *et al.*, 1996, 2003, 2008, Lacote *et al.*, 2010).

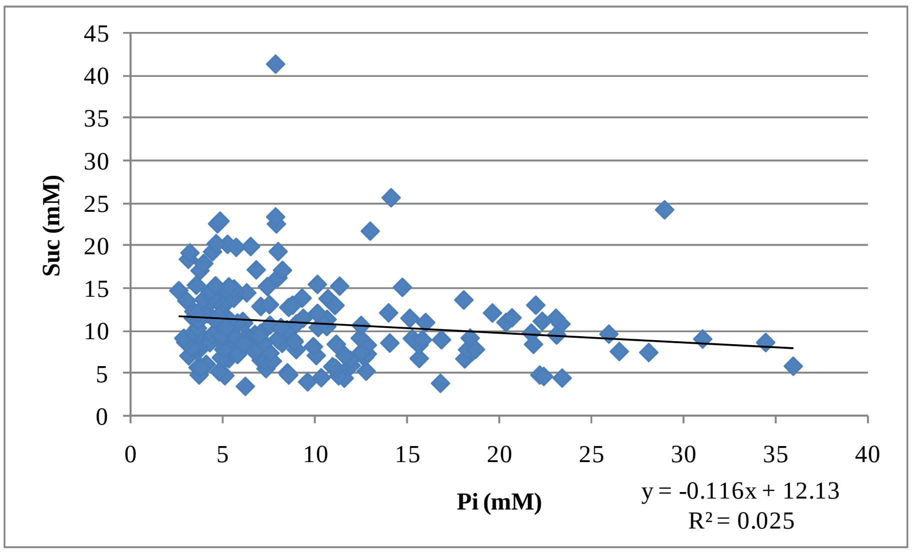

Figure 2. Relationship between latex Suc (mM.l^{-1}) and corresponding latex metabolic activity estimated by latex Pi (mM.l^{-1}).

$Suc_{predicted}$ =- 0.116 Pi (mM.l^{-1}) + 12.13, R^2 =0.025

Figure 3 showsthe repartition of the plant material using the average Pi contentof each genotype and the corresponding yield expressed in g.tree^{-1}.cm^{-1}. This figure shows a logical positive tendencybetween Pi and latex production (latex yield increaseswith metabolic activation). Pi is a biochemical indicator of clonal metabolic activity (Eschbach*et al.* 1984, Jacob *et al*. 1985, 1988a, 1988b, 1995a, 1995b, 1997, 1998, Gohet *et al*. 1991, 1995, 1996, 1997b, 2001, d'Auzac*et al*. 1997), as it is released during the ATP or NAD (P) co-factor turnovers. It is also released during isoprenic anabolism and rubber chain elongation (Lynen, 1969).

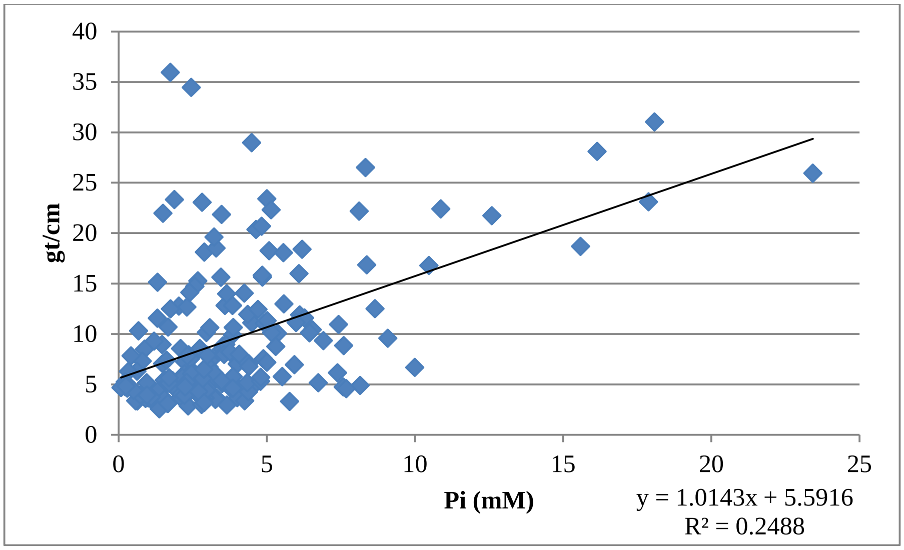

Figure 3. Relationship between latex inorganic phosphorus concentration (Pi) and corresponding yield (g.tree^{-1}.cm^{-1})
P (g.tree^{-1}.cm^{-1}) = 1.0143 Pi + 5.5916 ;R^2 = 0.2488

Genotypes with very low (VL) yield and low (L) yield were discarded from the selection.

Table 2 presentsthe 20 genotypes which were thereafter selected by showing the highest positive differences (Delta Suc/gt) between the actual sucrose and the predicted sucrose, expressed in % of predicted latex Suc; for all these 20 genotypes presenting the best combination of trade-offs between growth, production and latex sugar loading, the difference between actual measured latex Suc and predicted latex Suc was more than 40 % (from +42% for genotype 38/6 to +124% for genotype 120/4).

Table 2. The selected genotypes showing higher delta Suc content by more than 40%.

Trees	Length Cut	gt/cm	Suc bef stim	Suc Predicgt	Delta Suc/gt	Delta Suc%/gt	Pi bef stim	Suc Predic Pi	Delta Suc /Pi	Delta Suc%/Pi	Code Length	Code gtcm	Code Y	Code Suc	CodePi	Cod YxSuc	CodPixSuc
38/6	19.4	4.8	15.2	10.7	4.5	42%	5.3	11.5	3.7	32%	MH	H	YH	H	ML	YHSH	PMLSH
23/7	19.1	18.1	9.1	6.4	2.7	42%	31.0	8.5	0.6	7%	MH	VH	YVH	ML	VH	YVHSML	PVHSML
43/5	18.2	5.0	15.3	10.7	4.7	44%	11.3	10.8	4.5	42%	MH	H	YH	H	H	YHSH	PHSH
47/6	15.4	3.6	16.3	11.1	5.2	46%	8.0	11.2	5.1	45%	VL	MH	YMH	H	MH	YMHSH	PMHSH
30/4	17.8	17.9	9.6	6.5	3.1	48%	23.1	9.4	0.2	2%	ML	VH	YVH	ML	VH	YVHSML	PVHSML
49/5	17.6	6.4	15.5	10.2	5.3	52%	10.1	11.0	4.6	42%	ML	H	YH	H	MH	YHSH	PMHSH
68/5	17.3	3.8	17.2	11.1	6.1	55%	8.2	11.2	6.0	54%	ML	MH	YMH	VH	MH	YMHSVH	PMHSVH
63/6	21.9	7.7	15.3	9.8	5.6	57%	4.6	11.6	3.7	32%	VH	VH	YVH	H	L	YVHSH	PLSH
59/6	21.1	4.4	17.2	10.9	6.4	59%	6.8	11.3	5.9	52%	H	MH	YMH	VH	ML	YMHSVH	PMLSVH
24/8	17.6	2.9	19.2	11.4	7.9	69%	3.2	11.8	7.4	63%	ML	ML	YML	VH	VL	YMLSVH	PVLSVH
65/8	17.7	2.9	20.0	11.4	8.6	76%	6.5	11.4	8.6	75%	ML	ML	YML	VH	ML	YMLSVH	PMLSVH
53/3	20.2	4.1	19.4	11.0	8.4	77%	8.0	11.2	8.2	73%	H	MH	YMH	VH	MH	YMHSVH	PMHSVH
24/10	21.4	3.9	20.3	11.0	9.2	84%	4.6	11.6	8.7	75%	VH	MH	YMH	VH	L	YMHSVH	PLSVH
70/7	18.0	4.8	19.9	10.7	9.1	85%	5.7	11.5	8.4	73%	MH	H	YH	VH	ML	YHSVH	PMLSVH
46/8	21.2	3.0	22.6	11.3	11.3	100%	7.9	11.2	11.4	101%	VH	ML	YML	VH	MH	YMLSVH	PMHSVH
28/5	15.9	2.3	23.4	11.5	11.9	103%	7.8	11.2	12.2	109%	L	ML	YML	VH	MH	YMLSVH	PMHSVH
79/10	18.9	23.4	9.7	4.7	5.0	108%	25.9	9.1	0.6	6%	MH	VH	YVH	ML	VH	YVHSML	PVHSML
49/7	16.1	5.6	21.7	10.5	11.3	108%	13.0	10.6	11.1	105%	L	H	YH	VH	H	YHSVH	PHSVH
84/10	15.2	2.4	25.7	11.5	14.2	123%	14.1	10.5	15.2	145%	VL	ML	YML	VH	H	YMLSVH	PHSVH
120/4	17.9	4.5	24.3	10.8	13.4	124%	29.0	8.8	15.5	177%	MH	MH	YMH	VH	VH	YMHSVH	PVHSVH

4. Discussion and Conclusion

Due to global changes induced by volatility of rubber prices, regular increase of agricultural salaries and possible shortage of skilled tappers, the requirement of implementation of reduced tapping frequencies may be more and more important in the future. Reduction of tapping frequency will require compensation by hormonal ethylene stimulation (ethephon, ethylene) (Gohet *et al*., 1996, Gohet *et al*., 2003, Lacote *et al*., 2010), whose response is itself dependent on an increased latex sugar loading for latex regeneration. Until now, clonal selection of rubber tree has mainly considered early production and early growth, resulting mainly in selection of “quick starter” clones. The method that we propose here consists in introducing the use of physiological parameters, and mainly latex sucrose, from the very early stages of the clonal selection (SET / seedling evaluation trial) together with a less drastic selection on early yield without stimulation resulting in a possible selection of “medium starter” clones and “quick starter” clonestogether with an increased latex sugar content, making them candidates for a high latex yield potential, a good response to hormonal stimulation and an improved tolerance to stress.

The 20 genotypesselected from our method in this SET, and showing together medium to very high growth, medium to very high early yield and a significantly improved latex sugar loading compared to normally expectedand predicted from yield (Suc increased by more than 40% compared to expected predicted Suc values) will be soon multiplied, planted and tested in a grafted seedling evaluation trial (GSET) and a Small Scale Clone Trial (SSCT) simultaneously, with the purpose of saving time and expenses.

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Annex 1.

Table 1. Growth (cm), yield (g) and latex physiological parameters without ethephon stimulation of 188 genotypes

Tree	G.open	G 12 months	Length cut	gtbef stim	gt/cm	Suc bef stim	Suc Predicgt	Delta Suc/gt	Delta Suc%/gt	Pi bef stim	Suc Predic Pi	Delta Suc /Pi	Delta Suc%/Pi
8/5	26.2	38.0	18.5	46.7	2.5	3.6	11.5	-7.9	-69%	6.2	11.4	-7.8	-69%
46/2	24.3	31.0	16.0	10.8	0.7	4.6	12.1	-7.5	-62%	10.3	10.9	-6.3	-58%
11/6	29.0	34.5	18.3	24.0	1.3	4.5	11.9	-7.3	-62%	11.6	10.8	-6.2	-58%
15/3	33.7	40.0	21.3	106.4	5.0	4.6	10.7	-6.1	-57%	23.4	9.4	-4.9	-52%
104/2	25.0	33.0	16.7	14.7	0.9	5.2	12.0	-6.8	-57%	8.5	11.1	-6.0	-54%
112/2	25.0	30.5	16.0	44.0	2.7	4.9	11.4	-6.5	-57%	8.5	11.1	-6.2	-56%
49/3	25.0	30.0	15.9	55.5	3.5	4.8	11.2	-6.3	-57%	5.1	11.5	-6.7	-58%
16/9	24.0	30.2	15.6	3.5	0.2	5.3	12.2	-6.9	-57%	4.8	11.6	-6.3	-54%
85/5	27.7	32.7	17.4	158.4	9.1	4.1	9.3	-5.2	-56%	9.6	11.0	-6.9	-63%
100/7	32.0	36.2	19.7	206.2	10.5	3.9	8.9	-4.9	-56%	16.8	10.2	-6.2	-61%
48/4	33.2	42.5	21.9	87.6	4.0	4.9	11.0	-6.1	-55%	3.7	11.7	-6.8	-58%
95/5	27.2	31.9	17.1	85.2	5.0	4.8	10.7	-5.9	-55%	11.3	10.8	-6.0	-56%
64/9	24.7	31.6	16.3	33.1	2.0	5.4	11.6	-6.3	-54%	12.8	10.6	-5.3	-50%
41/2	27.0	33.0	17.3	13.9	0.8	5.7	12.0	-6.4	-53%	7.3	11.3	-5.6	-50%
109/3	27.8	32.5	17.4	30.4	1.7	5.9	11.7	-5.8	-49%	36.0	8.0	-2.0	-25%
100/1	28.6	36.8	18.9	153.3	8.1	4.9	9.7	-4.7	-49%	22.2	9.6	-4.6	-49%
107/8	27.0	33.0	17.3	16.6	1.0	6.2	12.0	-5.8	-49%	4.1	11.7	-5.5	-47%
44/8	28.8	36.0	18.7	62.0	3.3	5.8	11.2	-5.4	-48%	3.6	11.7	-5.9	-51%
107/6	26.5	31.0	16.6	53.4	3.2	5.8	11.2	-5.4	-48%	3.8	11.7	-5.9	-50%
16/8	24.8	36.0	17.6	78.9	4.5	5.7	10.8	-5.1	-47%	11.1	10.8	-5.2	-48%
47/5	29.3	34.7	18.5	200.9	10.9	4.7	8.8	-4.0	-46%	22.4	9.5	-4.8	-50%
114/4	24.0	32.0	16.2	70.4	4.4	6.0	10.9	-4.8	-45%	11.9	10.7	-4.7	-44%
85/7	30.0	33.5	18.3	27.3	1.5	6.6	11.8	-5.2	-44%	7.1	11.3	-4.7	-41%
37/3	30.3	36.0	19.1	42.7	2.2	6.6	11.6	-5.0	-43%	7.2	11.3	-4.7	-42%
43/4	29.1	35.7	18.7	60.0	3.2	6.5	11.2	-4.7	-42%	7.7	11.2	-4.7	-42%
11/3	30.0	38.3	19.7	46.7	2.4	6.8	11.5	-4.7	-41%	5.3	11.5	-4.7	-41%
97/7	27.0	34.0	17.6	130.7	7.4	5.9	9.9	-4.0	-40%	10.9	10.9	-5.0	-46%
1/2	28.0	34.0	17.9	51.8	2.9	6.8	11.3	-4.5	-40%	18.1	10.0	-3.2	-32%
42/4	28.2	33.0	17.7	47.8	2.7	6.8	11.4	-4.6	-40%	5.1	11.5	-4.7	-41%
42/3	31.0	36.5	19.5	44.9	2.3	7.0	11.5	-4.6	-40%	12.7	10.7	-3.7	-35%
39/3	28.0	32.4	17.4	44.4	2.5	6.9	11.5	-4.5	-39%	4.9	11.6	-4.6	-40%
60/7	30.0	38.0	19.6	32.1	1.6	7.2	11.8	-4.6	-39%	3.1	11.8	-4.6	-39%
105/6	27.0	29.4	16.3	79.1	4.9	6.8	10.7	-3.9	-36%	15.6	10.3	-3.5	-34%
113/4	31.3	42.5	21.3	130.2	6.1	6.7	10.3	-3.6	-35%	11.9	10.7	-4.1	-38%
113/3	29.0	37.0	19.1	68.4	3.6	7.4	11.1	-3.7	-34%	12.8	10.6	-3.3	-31%
70/5	24.2	29.7	15.6	22.8	1.5	7.9	11.8	-3.9	-33%	9.0	11.1	-3.2	-29%
14/3	36.4	46.5	23.9	54.5	2.3	7.7	11.5	-3.8	-33%	5.8	11.5	-3.7	-33%
79/7	34.0	41.0	21.7	39.5	1.8	7.9	11.7	-3.8	-33%	5.4	11.5	-3.6	-32%
12/7	30.0	38.0	19.6	105.3	5.4	7.2	10.5	-3.4	-32%	10.0	11.0	-3.8	-34%
43/6	31.0	34.4	18.9	62.2	3.3	7.7	11.2	-3.6	-32%	18.5	10.0	-2.3	-23%
40/7	24.0	31.0	15.9	33.1	2.1	7.9	11.6	-3.7	-32%	3.7	11.7	-3.8	-32%
90/7	28.0	34.0	17.9	98.9	5.5	7.3	10.5	-3.2	-30%	5.8	11.5	-4.1	-36%
101/3	25.4	34.0	17.1	83.8	4.9	7.5	10.7	-3.2	-30%	7.5	11.3	-3.8	-34%
26/5	25.0	34.0	17.0	55.6	3.3	7.8	11.2	-3.4	-30%	3.5	11.7	-3.9	-33%
24/4	35.5	43.0	22.7	142.2	6.3	7.2	10.3	-3.1	-30%	11.6	10.8	-3.6	-33%
42/8	25.2	31.0	16.2	69.0	4.3	7.9	10.9	-3.0	-27%	3.4	11.7	-3.8	-32%
109/4	29.6	37.5	19.4	89.2	4.6	7.9	10.8	-2.9	-27%	5.0	11.5	-3.6	-32%
1/6	28.0	39.8	19.6	43.5	2.2	8.5	11.6	-3.0	-26%	6.0	11.4	-2.9	-25%
24/6	23.0	27.3	14.5	73.7	5.1	7.9	10.6	-2.8	-26%	18.3	10.0	-2.1	-21%
70/8	24.0	30.0	15.6	60.0	3.8	8.2	11.0	-2.8	-25%	9.9	11.0	-2.8	-25%
87/9	26.5	34.5	17.6	43.0	2.4	8.6	11.5	-2.9	-25%	6.2	11.4	-2.8	-24%
25/5	25.5	29.6	15.9	55.0	3.5	8.4	11.2	-2.7	-24%	15.6	10.3	-1.9	-18%
5/2	29.7	31.2	17.6	43.1	2.5	8.7	11.5	-2.8	-24%	34.5	8.1	0.6	7%

Tree	G.open	G 12 months	Length cut	gtbef stim	gt/cm	Suc bef stim	Suc Predicgt	Delta Suc/gt	Delta Suc%/gt	Pi bef stim	Suc Predic Pi	Delta Suc /Pi	Delta Suc%/Pi
76/4	28.3	34.0	18.0	69.2	3.8	8.4	11.0	-2.6	-24%	12.8	10.6	-2.2	-21%
67/3	29.2	35.0	18.5	64.4	3.5	8.5	11.2	-2.7	-24%	21.8	9.6	-1.1	-11%
16/4	25.2	33.6	17.0	57.4	3.4	8.6	11.2	-2.6	-23%	8.2	11.2	-2.6	-23%
101/1	28.0	36.8	18.7	41.9	2.2	9.0	11.6	-2.6	-22%	3.8	11.7	-2.7	-23%
4/4	30.0	38.5	19.8	47.0	2.4	8.9	11.5	-2.6	-22%	4.8	11.6	-2.6	-23%
16/6	22.5	28.0	14.6	9.1	0.6	9.4	12.1	-2.7	-22%	6.3	11.4	-2.0	-17%
53/8	26.5	33.0	17.2	99.1	5.8	8.1	10.4	-2.3	-22%	3.3	11.7	-3.6	-31%
97/5	22.5	27.3	14.4	33.9	2.4	9.1	11.5	-2.4	-21%	7.9	11.2	-2.1	-19%
92/8	29.0	39.0	19.6	71.8	3.7	8.8	11.1	-2.3	-21%	2.9	11.8	-3.0	-26%
41/6	26.0	31.9	16.7	70.9	4.2	8.7	10.9	-2.3	-21%	14.0	10.5	-1.8	-18%
72/10	32.6	42.0	21.5	50.5	2.3	9.2	11.5	-2.3	-20%	2.8	11.8	-2.6	-22%
24/7	27.0	33.5	17.5	76.5	4.4	8.7	10.9	-2.2	-20%	4.3	11.6	-2.9	-25%
47/8	25.1	29.0	15.6	130.2	8.3	7.7	9.6	-1.9	-20%	26.5	9.1	-1.4	-15%
96/2	29.0	33.7	18.1	38.9	2.1	9.3	11.6	-2.3	-20%	5.7	11.5	-2.2	-19%
90/1	30.0	37.7	19.5	169.1	8.7	7.6	9.5	-1.9	-20%	12.5	10.7	-3.1	-29%
67/1	27.0	37.0	18.5	65.2	3.5	9.0	11.1	-2.2	-20%	8.8	11.1	-2.2	-19%
110/3	26.7	34.5	17.7	47.3	2.7	9.2	11.4	-2.2	-20%	15.3	10.4	-1.2	-11%
32/5	24.8	32.5	16.5	16.6	1.0	9.7	12.0	-2.3	-19%	3.6	11.7	-2.0	-17%
90/2	27.0	33.0	17.3	86.6	5.0	8.7	10.7	-2.0	-19%	7.2	11.3	-2.6	-23%
88/3	25.3	33.5	17.0	10.8	0.6	9.8	12.1	-2.3	-19%	3.4	11.7	-1.9	-16%
68/8	31.3	38.0	20.0	33.4	1.7	9.6	11.7	-2.2	-19%	5.5	11.5	-1.9	-17%
111/3	33.5	41.0	21.5	128.8	6.0	8.5	10.3	-1.8	-18%	11.1	10.8	-2.3	-21%
30/5	27.5	34.5	17.9	36.7	2.0	9.6	11.6	-2.0	-17%	4.4	11.6	-2.0	-17%
27/3	31.2	37.0	19.7	95.4	4.8	9.0	10.7	-1.7	-16%	15.8	10.3	-1.3	-12%
109/8	33.0	40.8	21.3	212.9	10.0	7.7	9.0	-1.3	-15%	6.7	11.4	-3.6	-32%
52/2	24.4	37.0	17.7	54.2	3.1	9.7	11.3	-1.6	-15%	6.7	11.4	-1.7	-15%
81/7	29.0	35.6	18.6	87.7	4.7	9.2	10.8	-1.5	-14%	12.4	10.7	-1.5	-14%
78/6	34.7	39.0	21.3	157.2	7.4	8.5	9.9	-1.4	-14%	6.1	11.4	-2.9	-25%
47/7	29.4	35.2	18.6	17.0	0.9	10.4	12.0	-1.6	-13%	3.6	11.7	-1.3	-11%
6/1	32.2	43.0	21.7	86.9	4.0	9.8	11.0	-1.2	-11%	7.0	11.3	-1.5	-13%
63/7	25.2	29.5	15.8	119.9	7.6	8.8	9.8	-1.0	-10%	8.8	11.1	-2.3	-21%
26/2	27.5	35.7	18.2	69.0	3.8	9.9	11.1	-1.1	-10%	4.6	11.6	-1.7	-14%
33/5	25.3	29.9	15.9	98.7	6.2	9.2	10.3	-1.0	-10%	18.4	10.0	-0.8	-8%
69/6	22.0	27.3	14.2	24.9	1.8	10.7	11.7	-1.0	-9%	12.5	10.7	0.0	0%
106/6	27.0	30.5	16.6	58.4	3.5	10.2	11.1	-0.9	-8%	8.5	11.1	-0.9	-8%
80/8	28.5	35.0	18.3	108.8	5.9	9.6	10.4	-0.8	-8%	7.0	11.3	-1.8	-16%
43/3	25.5	33.3	17.0	50.3	3.0	10.5	11.3	-0.9	-8%	10.1	11.0	-0.5	-4%
61/4	31.0	33.7	18.7	71.9	3.9	10.3	11.0	-0.8	-7%	5.2	11.5	-1.3	-11%
66/4	26.5	36.5	18.2	34.3	1.9	10.9	11.7	-0.8	-7%	23.3	9.4	1.5	15%
112/1	28.0	35.0	18.2	44.1	2.4	10.7	11.5	-0.8	-7%	7.5	11.3	-0.5	-5%
71/9	25.5	30.5	16.2	49.8	3.1	10.6	11.3	-0.7	-6%	10.6	10.9	-0.3	-3%
121/10	27.7	35.3	18.2	64.8	3.6	10.5	11.1	-0.7	-6%	8.1	11.2	-0.7	-6%
72/7	29.0	36.3	18.9	157.8	8.4	9.0	9.6	-0.5	-6%	16.8	10.2	-1.1	-11%
68/10	28.8	36.2	18.8	29.1	1.5	11.1	11.8	-0.7	-6%	5.4	11.5	-0.4	-3%
96/10	30.0	39.0	19.9	59.9	3.0	10.8	11.3	-0.5	-4%	5.2	11.5	-0.7	-6%
85/9	29.8	33.2	18.2	10.5	0.6	11.6	12.1	-0.5	-4%	3.4	11.7	-0.2	-1%
111/8	25.6	29.0	15.8	38.8	2.5	11.2	11.5	-0.3	-3%	6.1	11.4	-0.3	-2%
110/6	29.4	36.1	18.9	24.8	1.3	11.5	11.9	-0.3	-3%	15.1	10.4	1.2	11%
44/7	27.5	34.0	17.8	34.2	1.9	11.4	11.7	-0.3	-3%	4.5	11.6	-0.2	-2%
41/7	23.3	28.0	14.8	24.1	1.6	11.5	11.8	-0.3	-2%	5.0	11.5	-0.1	-1%
74/6	25.3	34.5	17.3	55.6	3.2	11.0	11.2	-0.3	-2%	6.1	11.4	-0.4	-4%
25/7	30.4	39.0	20.0	72.5	3.6	10.9	11.1	-0.2	-2%	9.0	11.1	-0.2	-2%
42/7	30.7	35.0	19.0	154.6	8.2	9.5	9.6	-0.2	-2%	4.9	11.6	-2.1	-18%
67/5	26.0	34.0	17.3	31.5	1.8	11.6	11.7	-0.1	-1%	4.9	11.6	0.0	0%
51/1	24.3	32.0	16.3	47.4	2.9	11.3	11.3	-0.1	-1%	3.7	11.7	-0.4	-4%
120/1	29.0	36.0	18.8	72.6	3.9	11.0	11.0	0.0	0%	5.8	11.5	-0.5	-4%
24/2	27.7	32.7	17.4	29.7	1.7	11.8	11.7	0.1	1%	5.1	11.5	0.3	2%
31/3	30.0	39.4	20.0	69.6	3.5	11.3	11.2	0.1	1%	5.3	11.5	-0.2	-2%
100/4	28.0	34.6	18.1	50.9	2.8	11.5	11.4	0.2	2%	23.1	9.5	2.1	22%
14/7	26.3	34.5	17.6	21.6	1.2	12.1	11.9	0.2	2%	4.2	11.7	0.4	4%

Tree	G.open	G 12 months	Length cut	gtbef stim	gt/cm	Suc bef stim	Suc Predicgt	Delta Suc/gt	Delta Suc%/gt	Pi bef stim	Suc Predic Pi	Delta Suc /Pi	Delta Suc%/Pi
88/4	24.1	32.5	16.3	75.8	4.6	11.1	10.8	0.3	3%	20.3	9.8	1.3	13%
48/9	28.5	37.6	19.1	73.8	3.9	11.4	11.0	0.4	4%	10.6	10.9	0.5	5%
31/7	22.8	27.0	14.4	16.3	1.1	12.4	11.9	0.4	4%	3.4	11.7	0.6	5%
104/1	31.0	40.0	20.5	138.1	6.7	10.5	10.1	0.4	4%	5.2	11.5	-1.1	-9%
22/3	27.3	33.0	17.4	38.7	2.2	12.1	11.6	0.5	5%	3.9	11.7	0.4	4%
65/5	29.0	34.5	18.3	94.3	5.1	11.2	10.6	0.6	5%	22.3	9.5	1.7	17%
99/7	32.0	39.0	20.5	57.8	2.8	12.1	11.4	0.8	7%	3.6	11.7	0.4	4%
8/8	26.5	35.0	17.8	108.1	6.1	11.1	10.3	0.7	7%	16.0	10.3	0.8	8%
91/6	33.0	36.8	20.2	325.4	16.1	7.6	7.0	0.5	7%	28.1	8.9	-1.3	-15%
63/5	33.6	40.6	21.4	140.1	6.5	10.9	10.2	0.8	8%	10.4	10.9	0.0	0%
96/9	26.8	33.8	17.5	56.3	3.2	12.2	11.2	0.9	8%	19.6	9.9	2.3	24%
50/6	27.0	33.0	17.3	83.6	4.8	11.6	10.7	0.9	8%	20.7	9.7	1.9	19%
108/3	35.2	39.0	21.4	333.9	15.6	7.9	7.2	0.7	9%	18.7	10.0	-2.1	-21%
49/4	24.4	28.6	15.3	55.8	3.6	12.2	11.1	1.1	10%	14.0	10.5	1.7	16%
56/4	27.3	35.0	18.0	37.6	2.1	12.8	11.6	1.2	11%	8.5	11.1	1.7	15%
2/5	33.0	42.2	21.7	32.4	1.5	13.1	11.8	1.3	11%	22.0	9.6	3.5	37%
56/7	25.0	34.8	17.3	16.4	0.9	13.3	12.0	1.4	11%	5.2	11.5	1.8	16%
51/7	24.0	30.0	15.6	35.9	2.3	12.9	11.5	1.4	12%	4.9	11.6	1.4	12%
53/6	28.0	34.3	18.0	23.5	1.3	13.5	11.9	1.6	14%	4.3	11.6	1.9	16%
45/10	31.0	40.7	20.7	15.1	0.7	13.7	12.1	1.7	14%	3.9	11.7	2.1	18%
28/7	26.4	33.3	17.2	5.0	0.3	13.9	12.2	1.7	14%	4.6	11.6	2.3	20%
103/2	24.4	29.2	15.5	79.9	5.2	12.1	10.6	1.5	14%	10.1	11.0	1.2	11%
91/3	30.0	37.8	19.6	135.2	6.9	11.6	10.0	1.5	15%	9.3	11.0	0.5	5%
1/9	29.0	39.3	19.7	23.6	1.2	13.9	11.9	2.0	17%	9.3	11.1	2.9	26%
52/8	31.5	39.5	20.5	47.1	2.3	13.6	11.5	2.1	18%	5.2	11.5	2.1	18%
19/8	22.0	32.0	15.6	26.0	1.7	13.9	11.7	2.1	18%	10.7	10.9	3.0	27%
68/2	26.0	32.5	16.9	74.2	4.4	12.9	10.9	2.1	19%	7.0	11.3	1.6	14%
10/7	28.8	38.6	19.5	6.5	0.3	14.5	12.2	2.4	19%	6.3	11.4	3.1	27%
34/7	28.4	37.5	19.0	53.3	2.8	13.6	11.4	2.2	19%	3.0	11.8	1.8	15%
28/6	29.6	32.5	17.9	225.8	12.6	9.8	8.2	1.6	20%	21.7	9.6	0.2	2%
58/6	34.0	39.4	21.2	160.6	7.6	11.8	9.8	2.0	20%	4.7	11.6	0.2	2%
108/9	23.0	29.8	15.2	64.2	4.2	13.1	10.9	2.2	20%	7.5	11.3	1.9	17%
37/10	29.0	38.0	19.3	43.4	2.2	14.0	11.6	2.4	21%	4.7	11.6	2.4	21%
38/8	31.0	38.7	20.1	60.3	3.0	13.7	11.3	2.4	21%	4.7	11.6	2.2	19%
77/9	40.0	50.4	26.1	73.5	2.8	13.9	11.4	2.5	22%	5.6	11.5	2.4	21%
40/6	27.5	33.5	17.6	86.6	4.9	13.1	10.7	2.4	22%	11.1	10.8	2.2	20%
60/2	24.8	30.4	15.9	47.2	3.0	14.0	11.3	2.6	23%	4.4	11.6	2.3	20%
122/2	25.8	33.0	17.0	90.1	5.3	13.1	10.6	2.5	24%	8.8	11.1	2.0	18%
81/8	26.5	34.5	17.6	30.0	1.7	14.6	11.7	2.9	25%	5.6	11.5	3.2	27%
39/9	26.5	34.0	17.5	24.0	1.4	14.8	11.8	2.9	25%	2.6	11.8	3.0	25%
61/6	25.4	34.4	17.3	46.7	2.7	14.7	11.4	3.3	28%	4.3	11.6	3.0	26%
77/6	28.0	34.7	18.1	29.3	1.6	15.3	11.8	3.5	30%	7.4	11.3	4.0	35%
18/8	30.8	38.0	19.9	110.5	5.6	13.7	10.5	3.2	31%	18.1	10.0	3.7	37%
75/5	25.4	32.8	16.8	26.1	1.6	15.4	11.8	3.6	31%	3.5	11.7	3.7	32%
25/2	30.0	37.0	19.3	55.0	2.8	15.0	11.4	3.6	32%	5.6	11.5	3.5	30%
94/4	25.0	34.0	17.0	43.8	2.6	15.2	11.5	3.7	32%	14.7	10.4	4.8	46%
61/5	27.5	31.5	17.0	73.9	4.3	14.9	10.9	4.0	37%	5.2	11.5	3.4	29%
38/6	30.0	37.2	19.4	92.9	4.8	15.2	10.7	4.5	42%	5.3	11.5	3.7	32%
23/7	29.0	37.0	19.1	344.6	18.1	9.1	6.4	2.7	42%	31.0	8.5	0.6	7%
85/10	34.5	42.0	22.1	24.3	1.1	17.1	11.9	5.2	44%	3.7	11.7	5.4	46%
43/5	28.0	35.1	18.2	91.3	5.0	15.3	10.7	4.7	44%	11.3	10.8	4.5	42%
47/6	24.0	29.3	15.4	54.8	3.6	16.3	11.1	5.2	46%	8.0	11.2	5.1	45%
30/4	28.3	33.5	17.8	319.0	17.9	9.6	6.5	3.1	48%	23.1	9.4	0.2	2%
54/10	31.5	40.0	20.6	19.8	1.0	18.0	12.0	6.0	50%	3.9	11.7	6.3	54%
49/5	28.3	32.6	17.6	113.3	6.4	15.5	10.2	5.3	52%	10.1	11.0	4.6	42%
68/5	28.2	31.7	17.3	64.9	3.8	17.2	11.1	6.1	55%	8.2	11.2	6.0	54%
63/6	35.0	40.9	21.9	168.3	7.7	15.3	9.8	5.6	57%	4.6	11.6	3.7	32%
19/6	28.6	34.8	18.3	30.4	1.7	18.5	11.7	6.7	57%	3.1	11.8	6.7	57%
59/6	33.0	40.0	21.1	92.7	4.4	17.2	10.9	6.4	59%	6.8	11.3	5.9	52%
46/9	28.3	33.3	17.8	9.0	0.5	19.3	12.1	7.2	60%	4.4	11.6	7.7	66%

Tree	G.open	G 12 months	Length cut	gtbef stim	gt/cm	Suc bef stim	Suc Predicgt	Delta Suc/gt	Delta Suc%/gt	Pi bef stim	Suc Predic Pi	Delta Suc /Pi	Delta Suc%/Pi
87/1	26.7	34.2	17.6	3.9	0.2	20.2	12.2	8.0	65%	5.2	11.5	8.7	75%
24/8	26.5	34.5	17.6	50.8	2.9	19.2	11.4	7.9	69%	3.2	11.8	7.4	63%
65/8	27.3	34.0	17.7	50.9	2.9	20.0	11.4	8.6	76%	6.5	11.4	8.6	75%
53/3	31.6	38.5	20.2	82.3	4.1	19.4	11.0	8.4	77%	8.0	11.2	8.2	73%
24/10	30.0	44.0	21.4	82.4	3.9	20.3	11.0	9.2	84%	4.6	11.6	8.7	75%
54/7	27.0	34.0	17.6	1.5	0.1	22.6	12.3	10.3	84%	4.7	11.6	11.0	95%
70/7	28.5	34.0	18.0	86.5	4.8	19.9	10.7	9.1	85%	5.7	11.5	8.4	73%
94/10	25.5	35.0	17.5	4.3	0.2	22.9	12.2	10.7	88%	4.8	11.6	11.4	98%
46/8	32.3	41.0	21.2	63.4	3.0	22.6	11.3	11.3	100%	7.9	11.2	11.4	101%
28/5	24.6	30.6	15.9	36.9	2.3	23.4	11.5	11.9	103%	7.8	11.2	12.2	109%
79/10	28.3	37.3	18.9	443.7	23.4	9.7	4.7	5.0	108%	25.9	9.1	0.6	6%
49/7	25.3	30.6	16.1	90.0	5.6	21.7	10.5	11.3	108%	13.0	10.6	11.1	105%
84/10	22.5	30.2	15.2	36.5	2.4	25.7	11.5	14.2	123%	14.1	10.5	15.2	145%
120/4	28.5	33.4	17.9	80.3	4.5	24.3	10.8	13.4	124%	29.0	8.8	15.5	177%
77/10	26.0	36.0	17.9	7.5	0.4	41.3	12.2	29.2	240%	7.8	11.2	30.1	268%