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EARLY BUD EMERGENCE AND GROWTH OF RUBBER (*Hevea brasiliensis* Muell Arg.) BUDDED STUMPS AS INFLUENCED BY CUT-BACK HEIGHT AND INDUCTION METHODS

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ABSTRACT

Early bud emergence of rubber (*Hevea brasiliensis* Muell Arg.) guarantees uniform plant growth leading to vigorous plants, escape from diseases, saves time, resources and increase in production. The field experiment carried out at Rubber Research Institute of Nigeria, Akwete Substation, Abia State, Nigeria was aimed at determining the interactive effect of cut-back height and bud induction methods on bud emergence and the growth of *Hevea*-budded stumps. The trial was laid out in a 3 x 3 factorial arrangement using the randomised complete block design with three replications. The factors were cut-back height ($\geq 7.0 \leq 7.5$ cm, $\geq 7.5 \leq 8.0$ cm and $\geq 8.0 \leq 8.5$ cm) and induction methods (control, notching and ringing). Plant traits assessed were days to first and 50 per cent bud emergence, percentage survival at 3 months after transplanting (MAT), shoot length, stem girth, leaf stalk length, number of leaves/plant, leaf area and sturdinessquotient at 2 and 5 MAT. Results showed that induction method significantly affected the tested traits except days to first bud emergence, leaf area and stem girth at 5 MAT, percentage survival at 3 MAT and sturdiness quotient at 2 MAT. Cut-back height significantly affected stem girth, number of leaves/plant, leaf stalk length, leaf area and sturdinessquotient. The interaction effect of cut-back height and induction method was significant for shoot length, number of leaves/plant, leaf area and leaf stalk length. Correlation analysis indicated that number of leaves per plant exhibited significant ($p \leq 0.05$) and positive association with leaf stalk length with correlation coefficient of r = 0.72 and leaf area (r = 0.57) at 2 MAT as well as with shoot length (r = 0.83) at 5 MAT, which implied increased photosynthetic ability and high latex production. The other variables exhibited different degrees of correlation amongst themselves.

Key words: Bud emergence; percentage survival; induction method; cut-back height; correlation
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INTRODUCTION

Para rubber (*Hevea brasiliensis* Mull Arg.) is propagated by vegetative method mainly through budding techniques, which leads to the production of planting materials of known pedigree (Atminingsih and Andriyanto, 2020). In rapid and mass production of certified high-quality rubber planting materials, early healthy root and shoot formation enhance better establishment, uniform growth, survivability, early tapping ability and productivity of the plant, especially during the off-seasons. They also provide the platform for genetic engineering research. Brown-*Hevea*-budded plants prepared for planting with pruned stem and roots known as brown-budded stumps are normally cut back above the upper end of the bud patch, downward slight at 45^{o} from the side of the bud to the opposite side. Several authors have reported varying cut-back heights of budded rubber to be about 7.5 cm (Marattukalam and Mercykutty, 2000), 4 cm (Aghughu and Oghide, 2012), 2.5 – 3.0 cm (Sagay, 2001) from the bud union which could also depend on the budding height. According to Ishfaq *et al*. (2015), low budding height invites pathogen. Though it takes about 3 - 4 weeks for brown bud to break after transplanting, sprouting may be delayed for some months when budded stock seedlings are left in the nurseries longer than one month before they are cut back and transplanted. Such delay is attributed to overgrowth of callus. Delay in early shooting could result to diseased infestation especially during wet periods and reduction in plant yield and sometimes uneven plant growth especially in the field (Udayakumara and Seneviratne, 2005). Moreso, too long a portion of the stock seedling above the bud patch may delay sprouting, leading to formation of numerous off- shoots (Punnoose and Lakshmanan, 2000).

Several studies have been reported on the chemical induction of shoots and roots in plants (Webster, 1989; Nor Mayati and Jamnah, 2014; Darwesh *et al*., 2017; Kuntagol *et al*., 2018; Ling *et al*., 2018; Naing *et al*., 2019). Also, coating the *Hevea* -budded stump bud patch with molten paraffin wax at a temperature of 85 ^{o}C in a water-bath with a brush enhanced bud-break and induced uniform sprouting (Ramanathan *et al*., 1991). Seneviratne *et al*. (1996) reported that spraying a two-per cent solution of thiourea (Thiocarbamide–CH_4N_2S) on buds increased the percentage of bud sprouting and early uniformity in budded *Hevea*. According to Marattukalam and Mercykutty (2000), undue delay in *Hevea* bud sprouting could be reduced by certain minor mechanical horticultural techniques which are normally carried out above the bud, on the bud patch or above the bud patch on the stock stem.

The four techniques adopted for this act are pricking, notching, ringing and arching. Pricking is performed with the pointed end of a knife just above the bud without causing any damage to the bud. The notching is done about 5 mm above the bud, with a horizontal cut below and an oblique cut above to remove a thin slice of bark above the dormant bud. Ringing and arching methods are carried out above the bud. Ringing is done by making a circular wound all around the stock just above the bud patch with a sharp knife (Edgar, 1958). Arching involves making of a wound above and on the two sides of the bud patch in the shape of an arch or inverted U (Marattukalam and Mercykutty, 2000). Across these four methods, the wound is deep up to the wood to cause a complete severing of the conducting vessels.

The stimulus of the wounding and the accumulation of nutrients below the wound initiate bud formation and development. Furthermore, Tswanya and Olaniyi (2017) observed that pinched plants produced higher yield than un-pinched plants. Kamanga *et al*. (2017) reported that pruning, lopping/cripping or cutting half way through the rootstock would break apical dominance and encourage budded buds to grow. Xue-wei *et al*. (2013) reported the significant effect of integrated method of bud-notching, twisting shoot and removing terminal shoot together with shoot-bending on flower bud development, increase of yield and corresponding decrease in vegetative growth of fuji apple. These operations are advisably carried out under wet conditions to avoid loss of latex and moisture from the tissues. Although these methods can be a tedious operation, it is immensely rewarding. Similarly, the combined effects of cultural and chemical techniques in improving branching effect, increased percentage bud-break and proportions of shoot have been reported in cherry trees (Bennewitz *et al*., 2010), apple (Quellette *et al*., 1996) and lemon (McArtney and Obermiller, 2015).

Considering that chemical root and shoot induction techniques are expensive and economic capacity of most rubber farmers is low, this study was aimed at investigating the interactive cultural effects of shoot induction methods and cut-back height on bud emergence and on the growth of rubber-budded stumps.

MATERIALS AND METHODS

Description of the experimental site

The rainfed experiment was conducted during the 2018/2019 cropping season at Rubber Research Institute of Nigeria, Akwete Sub-Station, Abia State (latitude 4^0 50′ and 4^0 65′ N and Longitude 7^0 00′ and 7^0 19′E, 122 metres above sea level) (Kamalu *et al*., 2014) in the south east agro-ecological zone of Nigeria. Ten-year mean rainfall is 2,352.23 mm (Nuga *et al*., 2016) with minimum and maximum temperatures of between 20^0C and 32^0C, respectively. The soil was classified in USDA soil taxonomy as Fluvaquentic Dystrudept (Ugwa *et al*., 2017). Rubber (*Hevea brasiliensis*) and oil palm are two prominent permanently cultivated crops in the area.

Experimental materials, designs, field operation and data management

Brown budding was carried out using *Hevea* clone Nigeria 800 (NIG 800) on vigorously growing rubber seedlings in the rootstock nursery. After first and second openings, harvested selected budded stumps were cut back at 3 heights above the bud patch ($\geq 7 \leq 7.5$ cm, $\geq 7.5 \leq 8$ cm and $\geq 8 \leq 8.5$ cm) with three shoot inducement techniques (ringing, notching and control). The stumps were then arranged in a randomised complete block design fitted in 3x3 factorial combinations in three replicates. The field was maintained accordingly. Quantitative data were recorded on number of days to first and 50 % bud emergence, shoot length, number of leaves per plant, stem girth, leaf area, leaf stalk length, sturdinessquotient at 2 and 5 months after transplanting (MAT) and percentage establishment at 3 MAT. The data were subjected to analysis of variance and means were compared using the least significant difference (LSD). The Genstat (2011) statistical package was used. Correlation analysis was carried out to determine the inter-relationships among the studied traits using SPSS for Windows, Version 17.0 (SPSS, 2010).

RESULTS

Table 1 shows that induction method had no significant effect on days to first bud emergence and percentage establishment of rubber-budded stumps at 3 months after transplanting except days to 50 % bud emergence. The main effect (cut-back height) and the interaction between induction method (*I*) and cut-back height (*C*) had no significant ($p<0.05$) effect on all the three tested variables. The effect of induction method on days to 50 % bud emergence indicated that the control method (24.65) was higher than ringing (21.39) and notching (24.54) by 13.23 and 0.45 per cent, respectively, indicating significant difference between control and the ringing method.

Table 1: Effects of induction method and cut-back height on days to first bud emergence, days to 50 % bud emergence and % establishment of rubber-budded stumps

Treatments	Days to first bud emergence	Days to 50 % bud emergence	Percentage establishment of budded-rubber at 3 months after transplanting(%)
I			
C	20.67	24.65	74.10
N	20.00	23.54	88.90
R	21.33	21.39	81.50
LSD (0.05%)	3.70	3.00	21.14
F Sig.	Ns	*	Ns
C			
1	19.89	22.56	74.10
2	20.56	24.87	88.90
3	21.56	23.14	81.50
LSD (0.05%)	3.67	2.95	21.14
F Sig.	Ns	Ns	Ns
I x C			
C x 1	21.33	24.50	77.8
C x 2	20.30	26.78	77.8
C x 3	20.33	22.67	66.7
N x 1	19.70	19.83	66.7
N x 2	19.67	24.17	100.00
N x 3	24.67	20.17	100.00
R x 1	18.67	23.36	77.80
R x 2	22.00	23.67	66.70
R x 3	19.67	26.60	100.00
LSD (0.05%)	6.37	5.11	36.62
F Sig	Ns	Ns	Ns
CV (%)	17.8	12.5	12.00

I = Induction method: C = Control, N= Notching, R=Ringing. *C* = Cutback height: 1 = ≥ 7 ≤ 7.5, 2 = ≥ 7. 5 ≤ 8, 3 = ≥ 8 ≤ 8.5, * = Significant at 0.05 %,
Ns = not significant.

Table 2: Effects of induction method (*I*) and cut-back height (*C*) on shoot length, stem girth, leaf stalk length, number of leaves/plant, leaf area and sturdinessquotient of rubber-budded stumps

Treatment	Shoot length (L) (cm)		Stem girth (G) (cm)		Leaf stalk length (cm)		Number of leaves plant-^{1}		Leaf area (cm^{2})		Sturdiness quotient L(cm)/G(mm)	
	Months after transplanting (MAT)											
I	2	5	2	5	2	5	2	5	2	5	2	5
C	38.63	69.80	2.30	4.04	19.85	21.04	39.17	69.40	79.40	78.20	1.86	1.83
N	33.26	48.00	1.89	3.66	19.22	19.56	27.89	39.70	83.40	82.50	1.91	1.35
R	36.56	69.30	1.88	3.85	14.55	15.14	32.93	60.20	71.2	76.10	2.14	1.82
LSD (0.05%)	5.00	14.57	0.20	0.50	3.00	2.99	3.22	17.00	10.00	7.87	0.50	0.47
F Sig.	*	*	***	Ns	*	*	***	*	*	Ns	Ns	*
C												
1	36.31	58.8	2.61	4.53	19.10	19.85	34.39	66.70	91.7	96.9	1.41	1.37
2	36.78	64.6	2.01	3.60	19.57	20.05	33.28	50.40	77.6	83.4	1.93	1.80
3	35.36	63.6	1.46	3.42	14.95	15.84	32.31	52.20	63.7	56.6	2.57	1.83
LSD (0.05%)	4.80	15.00	0.20	0.52	2.99	2.99	3.20	17.00	9.65	7.90	0.47	0.47
F Sig	Ns	Ns	***	***	*	*	Ns	*	***	***	***	*
I x C												
LSD (0.05%)	8.32	25.25	0.35	0.90	5.20	5.19	5.58	29.45	16.71	13.62	0.81	0.81
F Sig.	*	*	**Ns**	*	*******	***	***	*	***	***	**Ns**	**Ns**
CV (%)	13.30	23.40	9.90	13.50	16.80	16.20	9.70	30.1	12.4	10.00	23.80	28.10

I = Induction method: C = Control, N= Notching, R=Ringing. *C* = Cut-back height; 1= ≥ 7 ≤ 7.5, 2= ≥ 7. 5 ≤ 8, 3= ≥ 8 ≤ 8.5, *, *** = Significant at 0.05 % and 0.001 %, respectively, Ns = not significant.

Table 2 shows that except stem girth and leaf area at 5 MAT and sturdinessquotient at 2 MAT, induction method significantly ($p < 0.05$) affected all the tested variables at the sampling dates (shoot length, stem girth, leaf stalk length and number of leaves per plant, leaf area and sturdinessquotient). Similarly, cut-back height of the rubber-budded stumps significantly ($p < 0.05$) affected stem girth, leaf stalk length, leaf area, sturdinessquotient at 2 and 5 MAT and number of leaves/plant at 5 MAT. Except stem girth at 2 MAT and sturdinessquotient at 2 and 5 MAT, the interaction between induction method (*I*) and cut-back height (*C*) significantly affected shoot length, stem girth, leaf stalk length, number of leaves per plant and leaf area at the different sampling dates.

Table 3: Number of leaves/plant, leaf stalk length, leaf area, stem girth and sturdinessquotient of rubber-budded stumps as influenced by the interactive effect of induction method and cut-back height

Inducement Method (*I*) x	Cut back height (*C*) (cm)	Shoot length (L) (cm)		Number of leaves plant $^{-1}$		Leaf stalk length (cm)		Leaf area (cm^2)		Stem Girth (G)(cm)		Sturdiness quotient (L_{cm} /G_{mm})	
		Months after transplanting											
		2	**5**	**2**	**5**	**2**	**5**	**2**	**5**	**2**	**5**	**2**	**5**
C	1	39.17	61.20	45.67	71.20	23.33	24.65	97.60	103.70	2.77	4.96	1.41	1.23
C	2	35.80	86.40	41.17	86.00	19.52	20.15	77.80	79.50	2.46	3.82	1.46	2.26
C	3	40.92	61.70	30.67	51.20	16.71	18.31	62.80	51.40	1.67	3.52	2.45	1.75
N	1	36.33	63.00	16.33	63.30	8.76	9.52	56.00	68.00	2.51	3.92	1.45	1.61
N	2	35.17	60.00	32.17	43.20	20.39	20.57	89.40	96.70	1.78	3.75	1.98	1.60
N	3	38.17	84.10	35.17	74.20	14.49	15.32	68.40	63.60	1.36	3.87	2.81	2.17
R	1	33.42	52.20	41.17	65.50	25.20	25.38	121.50	119.00	2.54	4.72	1.31	1.11
R	2	39.37	46.70	26.50	22.2	18.80	19.42	68.60	73.90	1.78	3.22	2.21	1.45
R	3	27.01	45.10	31.11	31.30	13.67	13.89	60.00	54.70	1.36	3.03	1.99	1.49
SED	3. 92	3. 92	11.91	2.634	13. 89	2.45	2.50	7.88	6.43	0.16	0.43	0.38	0.40
$LSD_{(0.05)}$	8.32	8.32	25.24	29.45	29.45	5.197	5.20	16.71	13.63	0.34	0.90	0.81	0.81
CV (%)	13.30	13.30	23.4	9.7	30.1	16.8	16.2	12.40	10.00	9.90	13.5	23.80	28.1
Mean		36.15	62.30	33.33	56.40	17.87	18.58	78.00	78.90	2.03	3.85	1.90	1.63

I = Inducement method: C = Control, N= Notching, R=Ringing, *C* = Cut-back height; 1= ≥ 7 ≤ 7.5, 2= ≥ 7. 5 ≤ 8, 3= ≥ 8 ≤ 8.5

Table 3 shows that induction method and cut-back height interaction resulted in shoot length that ranged from 27.01 to 40.92 cm and 45.1 to 86.4 cm at 2 and 5 months after transplanting, respectively. The use of ringing inducement method at ≥ 8.0 ≤ 8.5 cm cut-back height resulted in the shortest shoot length relative to the other interactive treatments at the two sampling dates, respectively. The interaction between inducement method and cut-back height resulted in the highest number of leaves per plant at 2 months after transplanting under the control plot at ≥ 7 ≤ 7.5 cm cut-back height (45.67) compared to notching induction method at the same cut-back height (16.33). The highest number of leaves per plant at 5 months after transplanting was observed under the interaction of control plot at ≥ 7.5 ≤ 8cm cut back height (86.0).

The longest leaf stalk length was obtained with ringing method at ≤ 7.5 cm cut-back height at the sampled periods (25.20 cm and 25.38 cm at 2 and 5 MAT, respectively) while the shortest leaf stalk length was observed under notching at ≥ 7 ≤ 7.5 cm (8.76 cm and 9.52 cm at 2 and 5 MAT, respectively). A similar trend was observed in leaf area at the sampling dates. The interaction effect of induction method and cut-back height on stem girth at 2 MAT was not significant. At 5 MAT, it showed that the lowest stem girth was observed with ringing method at ≥ 8 ≤ 8.5 cm cut-back height which was 38.9 % less than the highest stem girth observed in the control plants at ≥ 7 ≤ 7.5 cm cut-back height. The correlation matrix of the variables at 2 months after transplanting (MAT) indicated significant (p≤ 0.05) and positive correlation relationship between number of leaves per plant and leaf stalk length and between number of leaves per plant and leaf area. The correlation between number of leaves per plant and shoot length, stem girth and leaf stalk length as well as stem girth and leaf area was positive and significant at 5 MAT. Also, high and significant positive correlations were observed between leaf area and stem girth as well as stalk length at both sampling periods. Similarly, positive and negative correlations were observed between sturdinessquotient with days to first emergence, shoot length and days to 50 % emergence, percentage establishment, stem girth, leaf stalk length and leaf area, respectively. The existence of strong positive correlation between number of leaves per plant and leaf area indicated that photosynthetic ability will be enhanced which will invariably improve early *Hevea* fruit, seed formation and latex production. The other variables exhibited different degrees of correlation amongst themselves at both sampling dates (Tables 4).

Table 4: Correlation matrix between different agronomic traits of rubber budded stumps as influenced by induction method and cut back height at 2 and 5 months after transplanting

Traits	MAT	Days to first emerg-ence	Days to 50 % emerg-ence	% Establish-ment at 3 MAT	Number of leaves plant-[1]	Stem girth (cm)	Shoot length (cm)	Leaf stalk length (cm)	Leaf area (cm^2)	Sturdi-ness quotient **(L_{cm}/G_{mm})**
Days to first Emergence		1.00								
Days to	2	-0.29^{ns}	1.00							
50 % emergence	5	-0.29^{ns}	1.00							
	2	-0.17^{ns}	0.31^{ns}	1.00						
%-establishment at 3 MAT	5	-0.17^{ns}	0.31^{ns}	1.00						
	2	0.06^{ns}	0.32^{ns}	-0.24^{ns}	1.00					
Number of leaves/plant	5	0.00^{ns}	-0.17^{ns}	-0.45*	1.00					
	2	-0.21^{ns}	0.08^{ns}	-0.16^{ns}	0.26^{ns}	1.00				
Stem girth (cm)	5	-0.05^{ns}	0.06^{ns}	-0.13^{ns}	0.33^{ns}	1.00				
	2	0.28^{ns}	-0.21^{ns}	-0.21^{ns}	0.06^{ns}	0.06^{ns}	1.00			
Shoot length (cm)	5	0.13^{ns}	-0.24^{ns}	-0.28^{ns}	0.83**	-0.01^{ns}	1.00			
	2	-0.12^{ns}	0.33^{ns}	0.02^{ns}	0.72**	0.36^{ns}	0.19^{ns}	1.00		
	5	-0.13^{ns}	0.32^{ns}	-0.07^{ns}	0.08ns	0.50**	-0.19^{ns}	1.00		
Leaf stalk length (cm)										
	2	-0.07^{ns}	0.16^{ns}	-0.11^{ns}	0.57**	0.45*	0.02^{ns}	0.81**	1.00	
Leaf area (cm^2)	5	-0.24^{ns}	0.11^{ns}	-0.11^{ns}	0.23^{ns}	0.66**	-0.04^{ns}	0.65**	1.00	
	2	.320	-.165	-.069	-.134	-.838**	.413*	-.237	-.378	1.00
Sturdiness quotient **(L_{cm}/G_{mm})**	5	.102	-.183	-.145	.575**	-.448*	.880**	-.393*	-.343	1.00

*, ** = Correlation is significant at 0.05 and 0.01 level of probability, respectively; Ns = not significant.
MAT = months after transplanting.

DISCUSSION

The treatments and the interactions had no significant effect on number of days to first bud emergence and percentage survival except the induction method, which affected days to 50 % bud emergence. The observed significant effect of induction method on days to 50 % bud emergence corroborated the report of Marattukalam and Merckutty (2000) that minor horticultural manipulations of *Hevea* stumps could induce early bud emergence at cut-back height of about 7.5 cm. This could be attributed to stimulus and accumulation of nutrients below the wounding area. The non-significant effect of treatment on percentage establishment could be attributed to genetic variation of the clone as well as environmental influence. The variation was obvious with the ringing method compared with others. The reports of Bennewitz *et al*. (2010) in cherry trees, Quellette *et al*. (1996) in apple and McArtney and Obermiller (2015) in lemon showed that the effects of manual and chemical combinations influenced various growth responses including percentage bud-break and proportion of shoot amongst other traits.

Variations in the number of leaves per plant, leaf area, bud stick length, leaf stalk length and stem girth (though not consistent throughout the sampling period among all the treatments in each factor) showed that induction method and cut-back height had significant effect on rubber growth and development. This result is in agreement with previous findings of Kamanga *et al*. (2017), who reported that pruning, lopping/cripping or cutting half way through the rootstock could break apical dominance and encourage budded buds to grow. Similarly, Xue-wei *et al*. (2013) reported the significant effect of integrated method of bud-notching, twisting shoot and removing terminal shoot together with shoot-bending on flower bud development, increase of yield and corresponding decrease in vegetative growth of fuji apple. The sturdinessquotient values obtained as influenced by induction method and cut-back height were within the recommended range of ≤ 6.0, a desired sturdy characteristic of high quality seedlings in tropical system (Jaenicke 1999; Kamanga *et al*., 2017). According to Edralin and Mercado (2010), a sturdinessquotient of 6.0 shows that the seedlings have a greater height relative to stem diameter, meaning that they are weak, lanky and are unlikely to survive in a windy and dry environment (Dey and Parker, 1997; Gregorio *et al*., 2005). Mexal and Landis (1990) and Ivetic *et al*. (2016) showed that sturdinessquotient correlated with seedling survival and initial growth in the field. This is, however, contrary to the results obtained especially with the percentage establishment and other traits, which could vary with species.

The existence of a strong positive correlation between shoot length and number of leaves per plant is an indication that photosynthetic ability will be enhanced which will invariably improve early *Hevea* fruit, seed formation and latex production. The non-significant correlation between number of days to 50 % bud emergence and most of the traits studied is an indication that they are likely not suitable criteria for uniform growth in budded rubber in this ecology.

CONCLUSION

It can be concluded from this study that higher leaf area, leaf stalk length, stem girth and number of leaves/plant were obtained with ringing method at ≥ 7 ≤ 7.5 cm cut-back height. Also, earliest days (21.39) to 50 % bud emergence obtained with ringing method compared with other responses could lead to uniformity in rubber budded stumps and less dependent on weather and soil conditions for early growth performances.

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