Observations of branch growth in a sympodial bamboo, *Bambusa stenostachya* (Đằng ngà), in Binh Duong Province, Viet Nam

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Summary

To gain insight into the rate of branch growth of the sympodial (clumping) bamboo, *Bambusa stenostachya* (Vietnamese name Đằng ngà) nine secondary branches were selected from three culms growing at the Phu An Bamboo Village research station in Binh Duong Province, Viet Nam, and measured daily for 6½ weeks. After a slow start, branch growth increased to an average rate of 14.86 cm per day for their fastest 7 days of growth, and over the time it took to grow 2m, averaged 13.3 cm per day, consistent with the culm growth rate for most bamboos. Branches developed tertiary branches, and in some cases quaternary branches and the pattern of their development, and internode features, are described. Sap was observed exuding from young branches in the mornings, likely the result of overnight root pressure, and two species of ant were observed foraging on branches.

Introduction

Bamboo has been described as the fastest-growing woody plant on earth (Karoshi & Nadagoudar, 2012), and when one year old culms of *B. stenostachya* situated at the Bamboo Village began to develop branches, an opportunity was presented to investigate their growth rate, for comparison with culms. *B. stenostachy* is known in Viet Nam as Đằng ngà (name tag at Bamboo Village) and Tre gai nhỏ, Tre hóa and Tre nhà (Vietnam Plant Data Center, 2016).

Study site

Branch measurements were taken from *B. stenostachya* growing at the Bamboo Village research station. The Bamboo Village is located at Phu An in Ben Cat town, Binh Duong Province, Viet Nam, and is 35km NNW from downtown Ho Chi Minh City. Google Earth coordinates for the site are: 106°35’07”E, 11°03’58.6”N. The site is flat, with an elevation of 18m (Google Earth 30 January 2015 image), and lies 1.8 km NE of the Saigon River. Soils are sandy loam. Rainfall averages 1900 mm per year for nearby Thủ Dầu Một, and is typically northern hemisphere tropical, occurring in a prominent wet season from May to October, and temperatures range from 25.6°C in January to 29.0°C in April (climate-data.org, 2015).

Method

Nine secondary branches were selected from three culms of one-year old (Lê Văn Hiên, 2015) *B. stenostachya*, with 5, 2 and 2 branches each and their lengths measured at 9am daily on consecutive days for 6½ weeks. Times varied occasionally and a small number of days were missed. Four days into the study, branches 2C1 and 6C2 were cut off by a new employee not familiar with the study. Measurements were taken using a 3m steel pocket tape-measure by placing the tape end firmly against the culm (Fig. 1), after removing any culm sheath parts, and taking the reading at the terminal node of the branch (Fig. 2). A secondary branch is the first branch growing from a bamboo culm, as the culm is the primary branch which grows from the rhizome (Yuming & Chaomao, 2010, p.16).

Figure 1. Using a pocket steel tape measure to measure branch shoot length.

Figure 2. A new branch displaying ascending sheath-leaf blades, terminal node and foraging black ants.

In the early stages of the trial measuring was easy, as branches were short and access was good. As the branches grew, and particularly after they began to develop tertiary branches in threes, with two of the latter becoming thorny, the task of measuring became increasingly difficult and great care was necessary to avoid injury.

Measurement data, and rain events, were recorded in a field notebook and subsequently entered into an Excel spreadsheet. A line chart was created to graphically display the rate of branch growth.

Observations were made regarding tertiary and quaternary branch development, and general matters of interest. Photographs were taken of various aspects of the study.

Results

The measurements of branch length for the trial period appear in Attachment 1 and are represented by line plots on the chart in Figure 3. Branches are numbered 1 to 9 with the number of the culm they grew from also indicated (e.g. C1). Plots for branches 2C1 and 6C2 are very short due to their early loss.

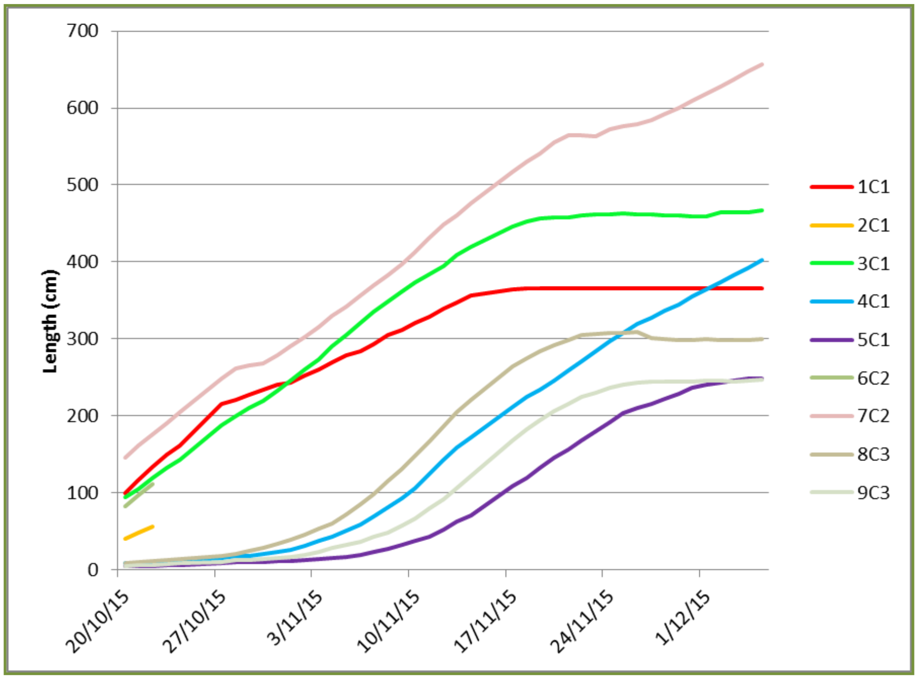

Figure 3. Graphical plot of branch shoot growth over a period of 6½ weeks. Branch numbers include the number of the culm they grew from (C1 etc.).

As can be seen from the graph (Fig. 3), growth of new (short) branches began slowly, until the beginning of the growth spurt, and after approximately one week, attained their highest rate until they peaked, then for most, abruptly stopped growing. Branch 7C2 suffered an injury at 564 cm of growth, but continued to grow at a slower rate. Branch 1C1 also suffered a slight injury early into the study, which explains its reduced growth rate. The presence or absence of rain events (Attachment 1) were perhaps too insignificant to be reflected in growth rates. For all branches, the average rate for the fastest 7 days of growth for each over the trial period was 14.86 cm per day (Table 1).

Table 1. Growth rates for the 7-day period of greatest growth for each branch.

Branch No.	Period	Growth (cm)	Rate (cm/day)
1C1	20/10 – 27/10	115.0	16.43
3C1	21/10 – 28/11	95.0	13.57
4C1	10/11 – 17/11	105.0	15.00
5C1	18/11 – 25/11	85.0	12.14
7C2	20/10 – 27/10	102.5	14.64
8C3	7/11 – 14/11	122.5	17.50
9C3	12/11 – 19/11	103.0	14.71
Mean average daily growth		**104**	**14.86**

Growth rates were also calculated for approximately 2m of branch growth beginning at a length of approximately 1m (Table 2). Average growth rate for the 2m of growth for the five branches assessed was 13.3 cm per day. These growth rates seem to be quite high, however they are consistent with the growth rate of 8~15 cm per day for culms of most bamboo species (Yuming & Chaomao, 2010, p.25).

Table 2. Branch growth rates for approx. 2m of length starting from a length of approx. 1m

Branch No.	Period	No. of days	Growth (cm)	Rate (cm/day)
1C1	20/10–8/11	18	204.5	11.36
3C1	21/10–5/11	14	200.0	14.29
4C1	10/11–25/11	15	200.5	13.37
7C2*	20/10–6/11	16	210.0	13.13
8C3	7/11 –21/11	14	201.0	14.36
Mean average daily growth rate				**13.30**

* For branch 7C2, measurements began at a length of 146 cm.

During the trial it was observed that when branches of *B. stenostachya* are young they are tightly wrapped with smooth sandy to pale green-coloured sheath leaves with ascending blades (Fig. 2). As the branches mature, sheaths wither and peel away from the branch and some are discarded, revealing branch internodes which are initially light green in colour, progressing to dark green, and commonly displaying a white film which can be easily wiped off (Figs. 5 & 6).

As the branches continue to grow they become more rigid, and at some distance from the culm, a tertiary branch will appear at a node, and further along a pair of tertiary branches, then three tertiary branches, two being lesser and which harden into thorns, and the prominent and central branch lengthening and growing quaternary branches in similar fashion (Figs. 4, 5 and 6).

Figure 4. A secondary branch shoot developing tertiary branch shoots.

Figure 5. Three tertiary branch shoots (left), one prominent and two lesser and thorny, and secondary parent branch 1C1 (right).

Figure 6. Tertiary branch of branch 1C1 from which three quaternary branches are developing, one prominent and two lesser and thorny.

The development of the branches creates an increasingly dense and difficult-to-penetrate thorny thicket (Fig. 7), making measuring more difficult, and requiring much care to avoid injury.

Figure 7. Branches 3C1, 8C3, 9C3 and one other branch creating a tangle of internodes and thorns.

Branch development is sequential, and secondary branches are well-grown before they develop tertiary branches, and likewise for the development of quaternary branches. By the end of the trial, secondary branches had grown very long tertiary branches, with one tertiary branch on 7C2 measured at 3.25m in length. Secondary branches in the study are initially monoramose (1 branch) in the lower section of the culm, beginning at approximately the 8th culm node above the rhizome. Not until approximately the 26th node above the rhizome do secondary branches become bioramose (2 branches) or trioramose (3 branches). In the secondary branches studied, tertiary branch monoramose branches occur at approximately the 7th node from the culm, bioramose branches at approximately the 9th node and with trioramose branching at approximately the 11th node (Table 3). This relationship trend is similar for quaternary branches.

Table 3. Secondary branch node at which tertiary branch types occur and short internode location.

Branch type	**Branch No. and node of occurrence (from culm)**										
	1C1	2aC1	2bC1	3C1	4C1	5C1	6C2	7C2	8C3	9C3	**Ave.**
Mono	7	-	4	5	7	8	5	8	6	6	**7**
Bi	9	5	-	10	11	9	6	10	8	8	**9**
Tri	10	6	5	12	16	12	9	12	9	9	**11**
Shortest internode between nodes	2/3	2/3	2/3	2/3	3/4	2/4	2/3	3/4	2/3	2/4	**2/3 2/4 equal**

Note: Branches 2aC1, 2bC1 and 6C2 have sprouted from where the initial secondary branch was cut off.

Branches 2C1 and 6C2, although having been cut off early in the study, grew new shoots at the wound (Fig. 8.). Branch 2C1 grew two new secondary branches at the cut, while Branch 6C2 grew one new secondary branch.

Figure 8. Branch 2C1 has been cut off, and bioramose branching has occurred at the wound.

For the two cut branches, it can be seen from Table 3 that tertiary bioramose and trioramose branches formed at the 5th and 6th nodes respectively of 2aC1, monoramose and bioramose branches formed at the 4th and 5th nodes respectively of 2bC1 and monoramose, bioramose and trioramose branches formed at the 5th, 6th, and 9th nodes respectively of 6C2 (Table 3).

On secondary and tertiary branches, at nodes where branches are absent, buds are none-the-less evident. From the parent branch to the first branching, these buds progressively develop into thorn-like cusps, with tips clear of the branch surface (Fig. 9). Because of this characteristic, sliding one's hand along the internode in the direction of the culm will result in injury.

Figure 9. Branch 5C1 showing a thorn-like bud at the 6th node.

The length of secondary branch internodes in the study displayed considerable shortening between nodes 2 and 3, 3 and 4 or 2 and 4 (measured from the culm) (Table 3 and Fig. 10). The shortened internodes are very pronounced in the un-cut branches in the study, whereas those for the sprouting cut branches 2aC1, 2bC1 and 6C2 are less so. Tertiary branches also display shortened internodes in the region between nodes 2 and 5, however the extent of shortening is much less than for the un-cut secondary branches.

Figure 10. Secondary branches in the study had very short internodes either between nodes 2 and 3, 3 and 4, or 2 and 4 (counted from the culm), as the internodes between nodes 2 and 4 on branch 5C1 shows (the sheath has been peeled back to the first node).

When measurements were being taken at 9am each day during the course of the study, and particularly during the early growth stage of the branches, sap was observed to be exuding from the edges of the sheath leaves, in a process known as guttation (Fig. 11). It is likely that the exudate is a result of positive root pressure overnight. In a study of the bamboo *Guadua angustifolia*, it was found that sap flow in developed culms (i.e. juvenile and mature) was predominantly nocturnal and concentrated between 23:00 and 09:00, suggesting that positive root pressure served as the chief mechanism for sap movement (Marine, 2009). A survey of root pressure in 53 Asian species of bamboo made reference to the occurrence of "bamboo rain" caused by guttation. The study revealed that all 53 bamboos (*B.*

stenostachya was not in the study) possessed root pressure, and in some species root pressure was high enough to cause guttation of liquid from leaves at predawn (Wang *et al*., 2011). On some mornings, the author experienced bamboo rain, in the form of droplets of liquid falling from *B. stenostachya*.

Figure 11. Sap expressed from branch shoots, possibly as a result of overnight root pressure.

During the course of the study, and particularly in its early stages when branch shoots were young, numerous black ants were observed on the shoots. On close inspection, very small black and cream coloured ants were co-existing with the black ants (Fig. 12).

Figure 12. Ants foraging on new branch shoots.

During the compilation of this report, and five weeks after branch measurements ceased, leaves had begun to appear at the terminal end of some of the tertiary branches in the trial (Fig. 13).

Figure 13. New leaves at the terminal end of a tertiary branch on secondary branch 3C1.

Conclusion

This short study of *B. stenostachya* has provided information on secondary branch growth rate, tertiary and quaternary branch occurrence and characteristics, relative branch internode spacing, sap exudation and ant associations, which may benefit others researching similar features of bamboo.

Acknowledgements

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Attachment 1. Growth rates of *Bambusa stenostachya* branch shoots measured over a 6½ week period.

Time	Date	Branch number and length measured (cm)									Rain/Dry*
		1C1	2C1	3C1	4C1	5C1	6C2	7C2	8C3	9C3	
0900	20/10/15	100	40	94	8	4.5	83	146	9	4.5	Dry
0900	21/10/15	117	47.5	105	9	5	97.5	161.5	10	6	S/Rain
0900	22/10/15	133.5	55.5	119.5	9.5	5	112	176	11	6.5	S/Rain
1000	23/10/15	149.5		133	10.5	6		191	12	7	Rain
0900	24/10/15	161.5		143	11	6.5		205	13.5	8	Dry
1200	27/10/15	215		187.5	15.5	8.5		248.5	18	10.5	Dry
0900	28/10/15	221		200	17.5	9.5		261	21	12.5	Dry
0900	29/10/15	227.5		210	18	10		265	25	13	Dry
0900	30/10/15	234.5		220	20	10.5		268.5	28.5	14	Dry
0900	31/10/15	241		232	22.5	11		278.5	34	15.5	Rain
0900	1/11/15	243		246	26	11.5		290.5	39.5	17	Dry
0900	2/11/15	252.5		260	30.5	13		303	45.5	19.5	Rain
0900	3/11/15	260		274	37	13.5		315	53	22.5	Rain
0900	4/11/15	269.5		291	43.5	15		329.5	60.5	28	S/rain
0900	5/11/15	278		305	51	16.5		341.5	72.5	32	Rain
0900	6/11/15	283.5		320.5	59	19		356	84.5	36	S/Rain
0900	7/11/15	292.5		335	69.5	23.5		369	98	42.5	Dry
0900	8/11/15	304.5		348	81	27.5		382.5	115	48.5	S/Rain
0900	9/11/15	311		361	93	32.5		397	131.5	57	Dry
0915	10/11/15	320.5		373	106.5	37.5		413.5	148.5	67	Rain
1015	11/11/15	329		384.5	125	43.5		431	166.5	79.5	S/Rain
0900	12/11/15	339.5		394.5	142.5	52.5		448	186	91	Dry
0900	13/11/15	346.5		408.5	158.5	62.5		461	204.5	106	Dry
0900	14/11/15	356.5		419.5	172	70.5		476	220.5	121.5	Dry
1000	17/11/15	364.5		446.5	211.5	108.5		517	264	167.5	Dry
0900	18/11/15	365		453	224.5	119		530	275	182	Dry
0900	19/11/15	365.5		456.5	234.5	133		541	284	194	Dry
0900	20/11/15	365.5		458	245.5	145		555	292	206	Dry

0900	21/11/15	365.5		458	258.5	156		564	299	216	Dry
0900	22/11/15	365.5		460.5	271	167.5		564	304.5	224.5	S/Rain
0900	23/11/15	365.5		462	284	180.5		563.5	306.5	230.5	Rain
0900	24/11/15	365.5		461.5	296.5	192		572	307	236.5	Dry
0900	25/11/15	365.5		463	307	204		576	307.5	240.5	Rain
0900	26/11/15	365.5		462	319.5	210.5		579	309	242.5	Rain
0900	27/11/15	365.5		461.5	327	216		584.5	301.5	244	Dry
0900	28/11/15	365.5		460.5	336	222		592	300	245	Dry
0900	29/11/15	365.5		460	345	228.5		599.5	299	245	Dry
0900	30/11/15	365.5		459	355.5	236		609	299	245	Dry
0900	1/12/15	366		459.5	364	240		618	299.5	245.5	Dry
0900	2/12/15	365.5		464	373	243		627.5	299	245.5	S/Rain
0900	3/12/15	365.5		464	382.5	245.5		637	299	245	Dry
0930	4/12/15	365.5		464	392.5	248		647.5	299	246	Dry
0900	5/12/15	365.5		466.5	402	249		657	299.5	246.5	Dry
* S/Rain = slightly rainy, drizzle, brief sprinkle											