Cross-section modification and branch re-alignment during the growth phase of sympodial bamboos, Binh Duong Province, Viet Nam

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Summary

A simple trial at the Phu An Bamboo Village research station in Binh Duong Province, Viet Nam was set up to investigate the possibility of modifying the cross-section (XS), and re-aligning branches, of sympodial bamboos during their growth phase. XS modifications were trialed on the branch and culm shoots respectively of one unidentified species (UID) and *B. spp*. (Vietnamese name Lồ Ô Vàng). The secondary branch in the trial grew at an average rate of 9.29 cm per day for the fastest 7 days of growth. During the time that the shoots were growing, their lengths were measured daily for 5 weeks. Culm shoot growth for three culms in the trial was much faster than that of the branch, and averaged 26.86 cm per day for the fastest seven days of growth. The UID secondary branch was enclosed in a training form, which slightly changed its cross section (XS), but not greatly. The culm enclosed in a training form had its XS re-shaped into a square-like profile, with rounded corners.

Trials were undertaken to re-align secondary branch shoots of *Bambusa stenostachya* (Vietnamese name Đằng ngà). It was found that branches can be trained to grow straight, and spiral forms are possible by bending young shoots, although training the shoot to grow into the spiral using a guided track might be more effective. A new branch shoot was enclosed in a tube, which prevented tertiary branch development and achieved a straight alignment, but led to fungal development, and is the likely cause of reduced growth. Recommendations are made for further experimental work to investigate the possibilities of re-shaping the XS profile of bamboo culms and branches, and re-aligning branches into desired shapes.

Introduction

A simple trial was set up, whereby forms (or moulds) were used to re-shape growing bamboo shoots into a squarish XS. Sympodial (clumping) bamboo species were selected to investigate the concept. The process is not new and is described briefly by Reubens (2010, p.76). An unidentified branch shoot (UID) was chosen for part of the trial, which sought to impart a square section to the growing shoot. Photographs of the UID, which may aid in its identification, can be found in Attachment 1. Another sympodial bamboo growing at the Bamboo Village, *Bambusa sp.* (Vietnamese name Lồ Ô Vàng), began to develop new culm shoots, and was also selected to trial XS re-shaping.

Square section bamboo grows naturally, in the form of the monopodial (running) bamboo *Chimonobambusa quadrangularis* (Vietnamese name Tre vuông or Trúc vuông) (Fig. 1). This species does not grow to a large diameter however, with a culm thickness in the range of 1 – 4 cm (Stapleton, 2015).

The concept of shaping the XS of bamboo is an interesting one, and particularly so in regard to large diameter species, as the ability to do so would benefit furniture-making, craft-making and possibly construction. Shaping bamboo could produce not only square XSs, but other forms as well.

Figure 1. Square section bamboo, Tre vuông, at the Bamboo Village, Phu An.

Large bamboo can have its XS modified successfully, and this has been demonstrated by a North American nursery, Lewis Bamboo, which has grown large-size square-section bamboo from the temperate monopodial "Moso" (*Phyllostachys heterocycla pubescens*) using a four-sided timber training frame (Lewis Bamboo, Inc., 2016).

Ancillary to the XS modification trial, to gain further understanding about shaping bamboos, secondary branch shoots were trained to be re-aligned into straight forms, two were wound into a spiral, and one was enclosed in poly tube It is possible to re-align quite large bamboos as they grow using forms, and this has been done successfully with *Guadua* bamboo using forms made from car tyres (Erickson, 2011).

Study site

The trial was undertaken on UID, *B. stenostachya* and *B*. spp. 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^{o}35'07"E, 11^{o}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^{o}C in January to 29.0^{o}C in April (climate-data.org, 2015).

Method

UID *secondary branch XS modification*

One newly forming secondary branch of UID was selected from a six-month old culm (Lê Văn Hiên, 2015), and encased in a four-sided frame made of split bamboo pieces each approximately 2.5 cm wide and 40 cm in length (Fig. 2), resulting in an internal dimension of approximately 1cm x 1cm. 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). The frame was held together using packaging tape, and later, light-gauge galvanized tie wire (Fig. 3).

Figure 2. The layout of the split bamboo training frame.

Figure 3. Bamboo training frame taped and wired to the trial secondary branch of UID.

Initially, it was not intended to measure the growth rate of UID, however it was decided to do so once the branch emerged from the training frame. Growth rate was measured over a period of four weeks, and the results compared with those from another study of *B. stenostachya* undertaken simultaneously by the author (Bourne, 2016). Lengths were measured at approximately 9am each day, using the same method as described in Bourne (2016).

After the branch stopped growing and measuring ended, the branch was removed from the culm and cut into sections at the mid-point of each internode, to reveal its cross-section profile within and beyond the encased section. As a control measure, an untrained branch, being the first branch above and on the same axis as the trained branch, was also cut into sections and its cross-sections examined. Another branch, from an adjacent 18 month-old culm (,(Lê Văn Hiên, 2015), was selected as a second control for internode measuring. A tertiary branch of the framed branch was also sectioned, to see if it might have been affected by the secondary branch training.

Bambusa sp. *(Lồ Ô Vàng) culm shoot XS modification*

For the *Bambusa sp.* (Lồ Ô Vàng) trial, one new culm shoot (Fig. 4) was selected from a number of such shoots at various stages of early development. The selected shoot was encased in a four-sided frame made of discarded 73mm x 38mm C-section galvanised steel ranging in length from 142 cm to 232 cm and held together with 4mm Ø synthetic chord and light-gauge galvanised tie-wire (Fig. 5). To maintain the vertical alignment of the culm shoot, it was necessary to tie the encased culm to nearby culms.

Figure 4. The culm shoot selected for training.

Figure 5. The C-section galvanized frame affixed to the culm shoot.

The height of the trial culm shoot was measured from its base, as defined by the top of a bamboo peg driven in to the ground, to the top of the highest culm sheath leaf blade at the shoot apex. To act as controls, and to provide general information on culm shoot growth rates, five other culm shoots were selected for measuring. Lengths were measured at approximately 1pm each day, on consecutive days for a period of 5 weeks, with the data being first entered into a field note book, and then into an Excel spreadsheet. A line chart was created to graphically display the rate of culm shoot growth. Aspects of the trial were photographed over its duration.

The culm shoot bamboo species is non-spikey, unlike UID, and access to the samples was easy at all times. In the early days of the trial a 3m steel pocket tape-measure was used for all measuring. In the latter days of the trial however, the considerable height of three of the new culms made measuring difficult, requiring the use of a length of split bamboo, topped with a wire bracket (Fig. 6). The bamboo split was held vertically next to the culm being measured and the top of the split moved, until it touched the uppermost culm sheath leaf blade. The split was gradually raised, and when the leaf blade stopped moving, its vertical limit had been identified. The level of the base of the split was noted and the height of the culm calculated. Assistance in spotting was very helpful in the latter days of measuring.

Figure 6. The split bamboo pole (top) used for measuring tall culm shoots, and the bracket at its apex (bottom).

Two weeks after measuring ceased the metal form was removed from the culm. Six XSs of the trained culm shoot were measured at approximately the middle of internodes 4 to 9 inclusive to gauge the success or otherwise of the trial. Two XSs of an older control culm were measured at internodes 4 and

6. The age of the latter is not known, however it did display a 60mm x 50mm elliptical lichen growing at internode 1. The trial bamboo culms are part of a collection, therefore it was desirable not to cut the culms to obtain their XSs. XS measuring was achieved using semi-circles of cardboard placed around the middle of the internode, secured in place with clips, and with quick-setting plaster used to fill the seam to obtain an accurate profile (Fig. 7). Packaging tape was first applied to the middle of the measured internodes, to create a non-stick surface for the plaster. Two double-flanges made from small pieces of cardboard were placed on opposite sides of the section, to facilitate the separation of one half from the other. A vertical orientation line had been drawn on the culms and its position was transferred to each XS. Once the plaster had hardened, each section was cut in two at the flanges, removed and re-joined, and the profile traced onto paper on the same alignment.

Figure 7. Cardboard cut-outs to make XS profiles (left), and clipped and plastered in place on the trial culm (right). One pair of flanges can just be seen next to the clip on the left.

Controlling the alignment of young branch shoots

Experiments were undertaken on a very small scale to train the direction of young and pliable *B.stenostachya* branch shoots. Secondary branches were strapped to straight bamboo poles using packaging tape (Fig. 8) and released after 6½ weeks. One thin tertiary branch was wrapped in a spiral around a culm (Fig. 9) and another cut and wound in a spiral around a length of 90mm OD PVC tube, and both released after 12 weeks. A secondary branch was inserted into a length of 18mm ID (27mm OD) polythene tubing (Fig. 10) and released 6 weeks later.

Figure 8. Secondary branches of growing *B. stenostachya* taped to bamboo poles to induce a straight alignment. New branch on left (note the ascending leaf blades near the shoot apex) and an advanced branch, with tertiary and quaternary branches, on right.

Figure 9. Dominant central tertiary branch in a trioramose set, flanked by thorn-like minor branches, orthogonal to its secondary branch (left) and trained in a spiral around another culm (right).

Figure 10. Secondary branch of *B. stenostachya* encased in a length of polythene tubing.

Results

Growth rates – B. stenostachya, UID *and* B. spp*.*

The measurement data for the length of UID branch in the trial appear in Attachment 2, together with the measurement data from the Bourne (2016) study. The data are represented by line plots on the chart in Figure 11. Branches are numbered 1 to 10 with the number of the culm they grew from also indicated (e.g. C1). The trained branch is 10C4.

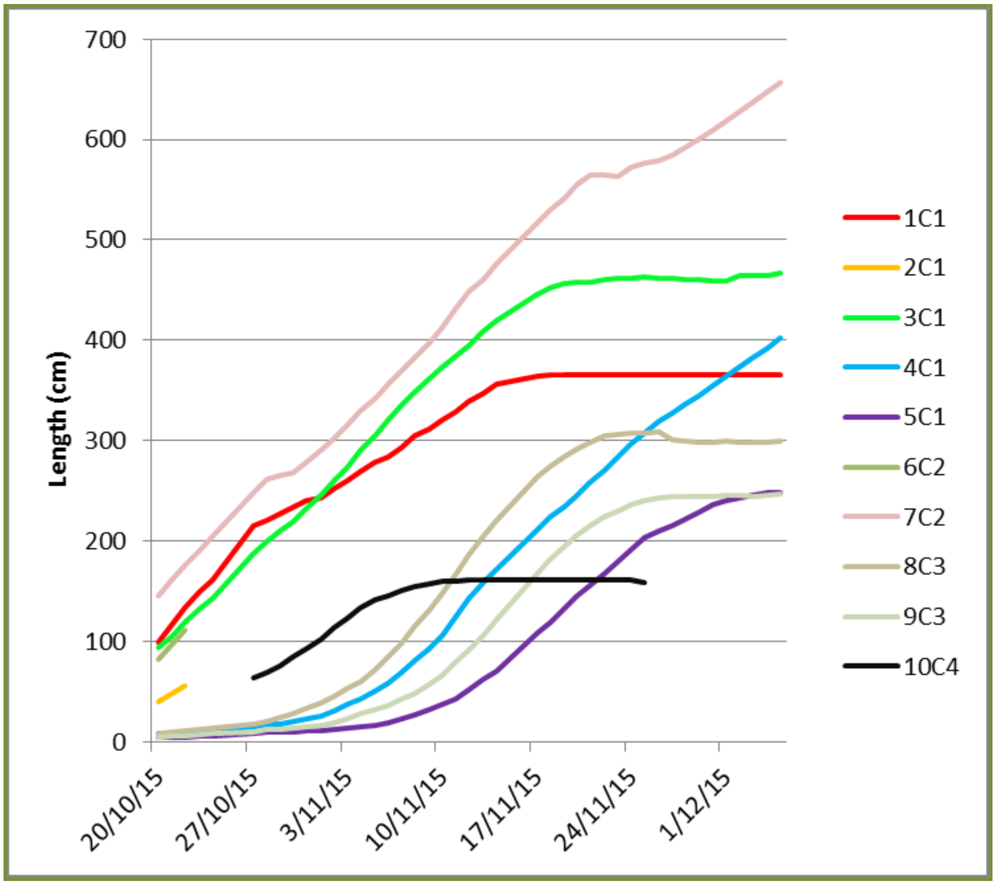

Figure 11. Graphical plot of branch shoot growth over a period of 6½ weeks (from Bourne, 2016). Branch numbers include the number of the culm they grew from (C1 etc.). Branch 10C4 (black line) in the present study was monitored for approximately 4 weeks.

As can be seen from the graph (Fig. 11), the growth of 10C4 was reasonably constant for the first 1½ weeks, then quickly slowed, and had virtually stopped by the end of the second week, possibly due to an injury at the branch apex due to its proximity to a walking track, or as a result of its encasement, or both. Other possible reasons for a slowing of branch growth might be the presence of fungi within the training frame (Fig. 12) or as a consequence of ant habitation (Fig. 13).

Figure 12. Fungal fruiting bodies erupting from the surface of the split bamboo training form.

Figure 13. Black ants and their larvae were found underneath the branch training form.

The fastest 7-day rate of growth for 10C4 was 9.29 cm per day (Table 1), which is however, much less than the average branch growth rate of 14.86 cm per day for other non-trained branches measured in the Bourne (2016) study. The maximum length of 161.5 cm attained by 10C4 was also much less than the 246.5 cm of the shortest branch measured in the Bourne (2016) trial (Attachment 2). The secondary branch on culm C4 immediately above 10C4, and on the same alignment, was measured as a comparison, and its length of 3.56 cm suggests that 10C4 may have increased in length considerably if not damaged or encased in a form.

Table 1. Growth rates for the 7-day period of greatest growth for branch 10C4 of the present study and for the branches measured in Bourne (2016).

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
10C4	29/10 – 5/11	65	9.29
Mean average daily growth of branches 1C1 to 9C3		**104**	**14.86**

The measurements of culm shoot length for *B. spp.* appear in Attachment 3. The data are represented by line plots on the chart in Fig. 12. Culm shoots are numbered 1 to 6, with Shoot 1 being the trained culm.

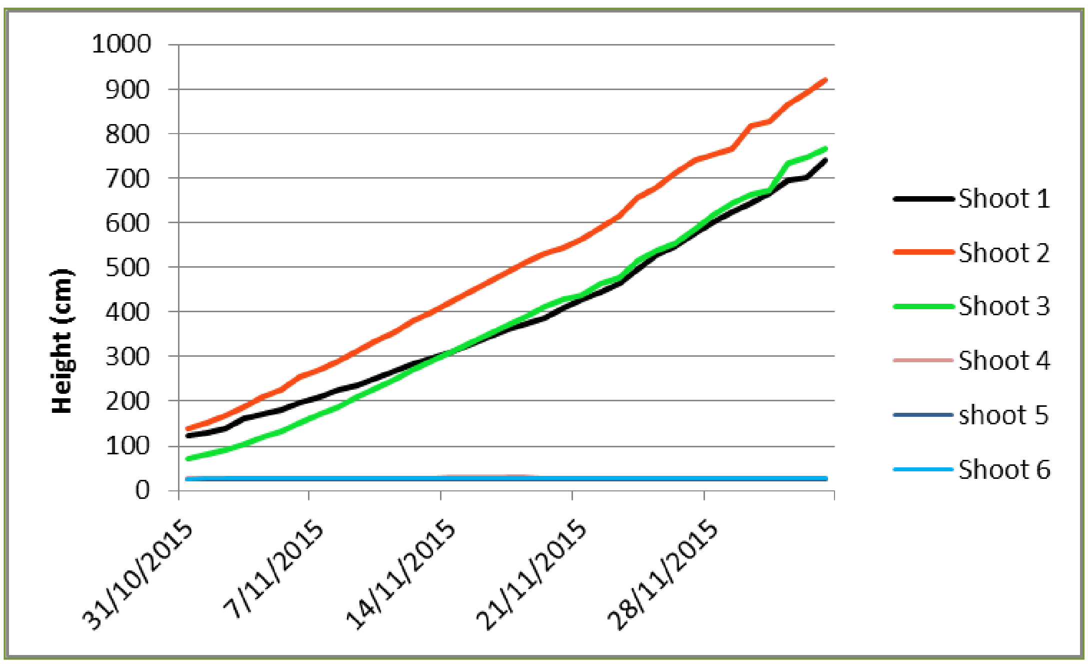

Figure 12. Graphical plot of culm shoot growth over a period of 5 weeks. Shoot 1 (black line) was trialed to alter its XS. Shoots 4, 5 & 6 probably died, as none grew, and with similar heights their plot lines overlap.

A glance at the graph (Fig. 12) reveals that the growth of culm shoots 1, 2 and 3, was very steady, although a careful examination will detect a lesser rate of growth over the first few days of measuring, and a slightly higher rate of growth over the latter half of the measuring period than the first half. Overall growth rates for all shoots, and the one-week period of fastest growth for all shoots, are presented in Table 2. For shoots 1, 2 and 3, their average growth rate for the duration of the trial was 20.52 cm per day. For these shoots, their growth rate over a common one-week period covering the time they grew the most, was 26.86 cm per day.

Table 2. Growth rates of six *B. spp*. bamboo culm shoots for the duration of the trial and for the common week of fastest growth for shoots 1, 2 and 3.

Culm shoot No.	Period 31 Oct to 4 Dec 2015 (34 days)		Period 23 to 30 Nov 2015 (7 days)	
	Growth (cm)	**Rate (cm/day)**	**Growth (cm)**	**Rate (cm/day)**
1	618	18.18	178	25.43
2	782	23.00	200	28.57
3	693	20.38	186	26.57
4	1	Insignificant	0	N/A
5	1	Insignificant	0	N/A
6	2.5	Insignificant	0	N/A
Mean Ave. for shoots 1, 2 & 3	**697.67**	**20.52**	**188**	**26.86**

From Table 2 it can be seen that Shoot 2 was the fastest growing and the trained shoot 1 was the slowest, but not by much. It may be that the training form had a slight negative impact on the growth rate of Shoot 1, however a larger sample size would be required to verify this. The growth rates for *B. spp.* culm shoots in Table 2 are much higher than the 8~15 cm per day for culms of most bamboo species as reported by Yuming & Chaomao (2010, p.25), however they are very close to the 25 cm per day for shoot extension of large bamboos as indicated by Stapleton (2015b).

UID secondary branch XS modification

Prior to cutting the UID secondary branch to obtain XSs, branch internodes were measured, as well as internodes for two control branches. The trial branch 10C4 was located at the 10th node above the culm rhizome. Control branch 11C4 on the same culm was located at the 12th node above the rhizome and the other control branch, on the older culm 12C5, was located at the 9th node above the rhizome. All branches had internodes varying in length (Table 3), which is evident from the chart in Figure 13. Branch 10C4 internodes progressively increased in length to the 11th, then rapidly shortened. The internodes for control branch 11C4 increased continuously for all measured internodes, although the increase tapered off substantially at internode 8. Control branch 12C5 also displayed increasing internode lengths, however a split in internode 12 appears to be the cause of a change in the trend. Overall, all three branches showed a similar trend in internode length increase up to the 7th or 8th. There may be a relationship between length of internode closest to the culm and node number above the rhizome from which a branch grows. For the three branches in the study, internodes closer to the culm are shorter on branches further from the rhizome. Analysis of a larger sample would be required to determine that this is not coincidental.

Table 3. Secondary branch internode length (internode #1 occurs between nodes 1 and 2)

Branch No.	Secondary branch internode number and length (mm) and total branch length (TBL) (cm)																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**TBL**
10C4	58	67	58	76	77	95	103	115	131	133	140	130	129	98	65	49	161
11C4	16	35	67	80	88	102	111	121	122	124	126	132	130	130	135	137	355
12C5	75	77	88	92	102	111	123	125	131	125	96	83	100	122	106	106	

Note: For branch 12C5, internode 12 was split and internode 16 was cut (and allocated the same value as internode 15), hence its TBL is not known.

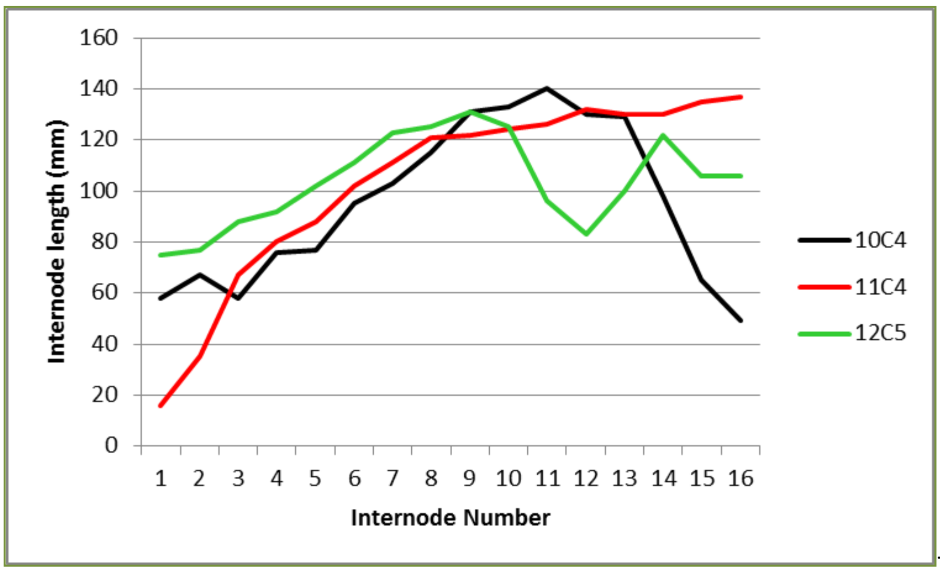

Figure 13. Secondary branch internode lengths (mm).

To determine the success of the trial, the trial branch XS had to be examined for "squareness" and compared with the XS of non-trained branches. Even in the early days of the trial, when the training frame was still in place, the XS for trial branch 10C4 appeared to be becoming "square" (Fig. 14).

Figure 14. The UID branch displayed a "square"-looking XS 3½ weeks after being enclosed.

To obtain the XSs, the trial branch 10C4, and one other secondary branch 11C4, were cut twice in approximately the middle of each internode to form a mountable section (Figs. 15a and 15b respectively). Branch 10C4 had 11 tertiary branches (Fig. 16), and these were sectioned between their 1st and 2nd nodes (Fig. 15c). XSs revealed that all branches were essentially solid and some internodes displayed a sulcate form on one edge.

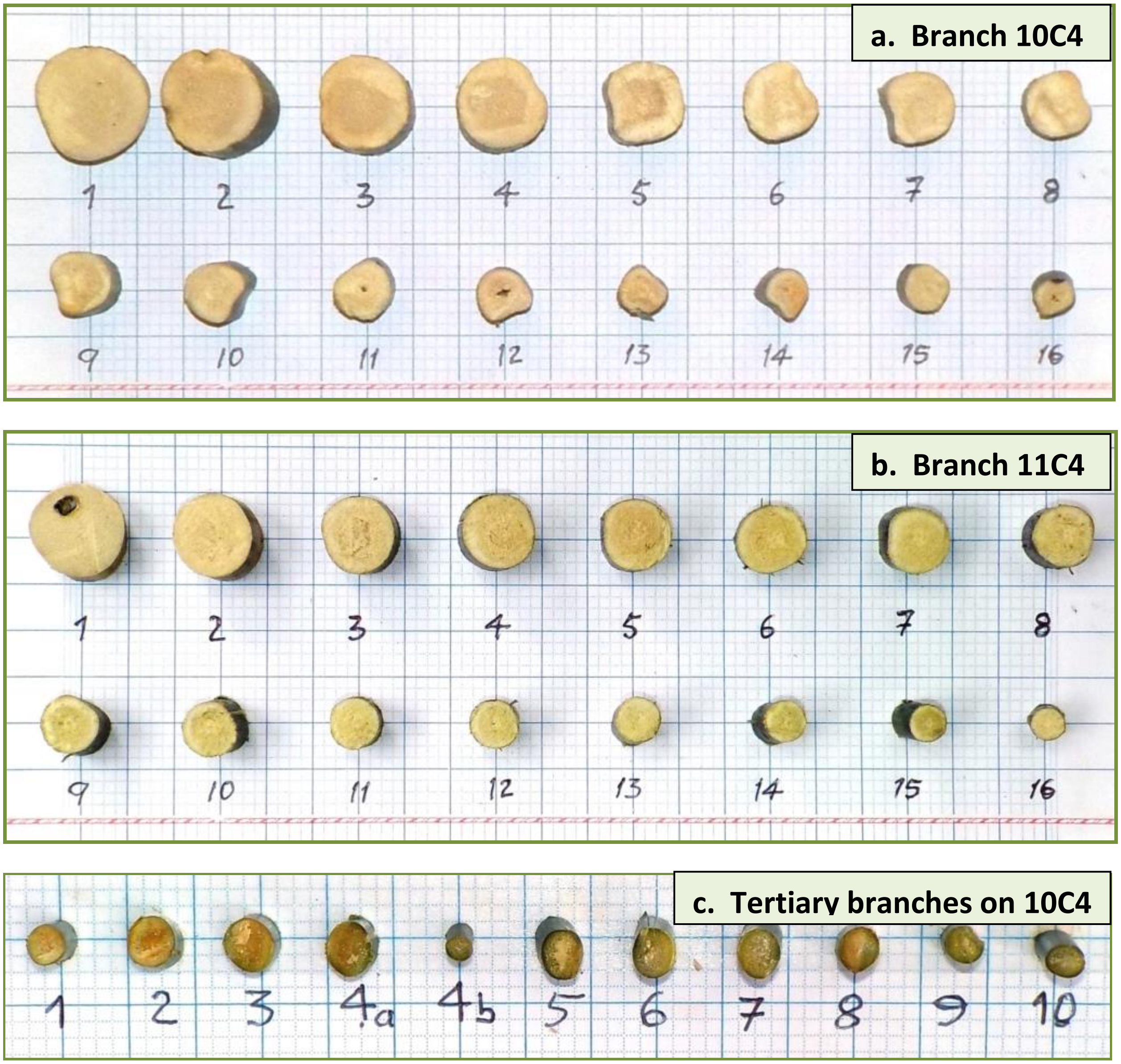

Figure 15. XSs at 16 internodes on secondary branches 10C4 (a) and 11C4 (b) and for 1 internode on all tertiary branches on 10C4 between nodes 1 and 2 (c). Each small square on the graph is 2mm wide.

From Fig. 15 it can be seen that the trained branch 10C4 did show a modified XS tending squarish, particularly evident at internode 5. A sulcate edge can be seen at some XSs on branch 11C4 and was frequently observed on other branches on UID not included in this study.

For the tertiary branches on 10C4, the first occurred at the 4th node, the second at the 9th node (beyond the extent of the training frame on 10C4), and the remaining branches occurred at every node thereafter. From Fig. 15 it can be seen that none of the tertiary branches showed a square XS, however, from branch 4a onwards, they did display a tendency of being oval in XS.

Figure 16. Tertiary branches on secondary branch 10C4. The broken branch apex is in the foreground.

Of the 11 tertiary branches on branch 10C4 (Fig. 16), 8 had developed leaves at and near their apex (Fig. 17 left). For the control branch, 11C4, 15 tertiary branches had grown, with 8 of them displaying leaves (Fig. 17 right).

Figure 17. New terminal leaves on trained secondary branch 10C4 (left) and control branch 11C4 (right).

Bambusa sp. *(Lồ Ô Vàng) culm shoot cross-section modification*

The re-shaping form surrounding the trial *Bambusa sp*. culm was removed 11½ weeks after it had been installed. It was immediately evident that the culm XS had, to some extent, formed into a square shape (Fig. 18) at internodes higher up the culm than where the base of the form had extended to (Fig. 19).

Figure 18. The trained culm clearly showing a modified, and tending square, XS. In the photo the XS forms are clipped and plastered in place.

Figure 19. The training form, pushed-up by the growing culm almost to the 5th node, on the last day of measuring.

The length of the internodes of the trial culm shoot 1, control culm shoot 2 and the older control culm shoot 7, were measured, and the results appear in Table 4.

Table 4. Internode number and lengths for the trial *Bambusa sp*. culm 1 and control culms 2 and 7.

Culm	Culm internode number, length (cm) and height above marker (cm)										Total lgth 10 internodes
	0	1	2	3	4	5	6	7	8	9	
1	19.5	22	30	34	40	46.5	41	39.5	46	51.5	370.0
	19.5	41.5	71.5	105.5	145.5	192	233	272.5	318.5	370	
2	5	29	38	48	54.5	63.5	69.5	76	79	84.5	547.0
	5	34	72	120	174.5	238	307.5	383.5	462.5	547	
7	8	18.5	24	41	50	45	59	67	70	75	457.5
	8	26.5	50.5	91.5	141.5	186.5	245.5	312.5	382.5	457.5	

Note: Internode No. 0 is the distance between the base line marker and the first node.

The results in Table 4 have been displayed in the chart in Figure 20, which clearly shows an increase in internode length for all shoots as the culm is ascended. For the framed culm however, internodes 6 to 8 were shorter than internode 5, and for the older culm 7, internode 5 was shorter than its predecessor.

Over the next few months internode lengths may increase slightly, but only slightly, as culm shoots typically have reached 90% of their full height after two or three months' of growth (Cusack, 1999, p.23).

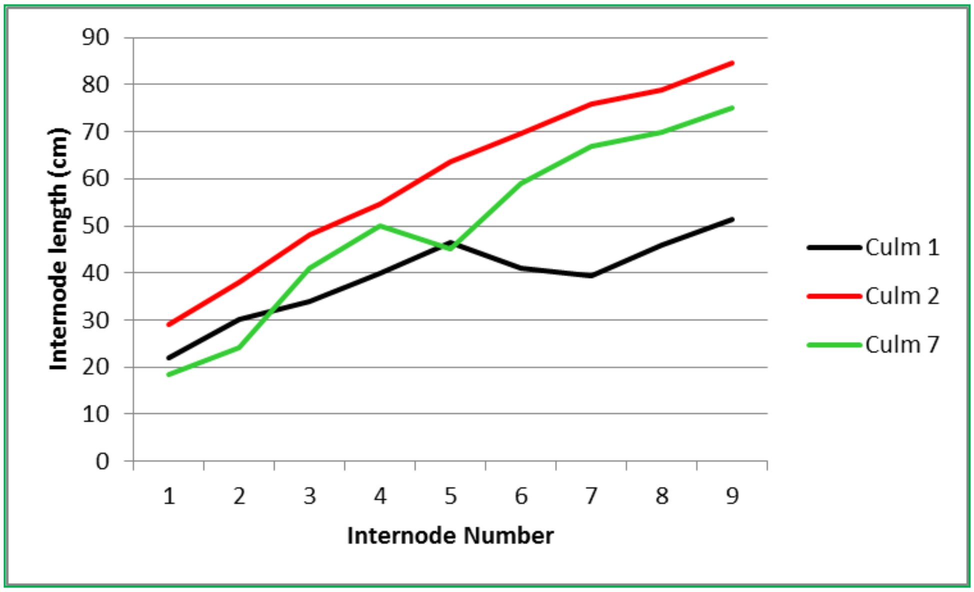

Figure 20. Graphical plot of internode lengths for the trial culm 1 and the two control culms 2 and 7.

The XS profiles taken from shoot 1, and compared with XS profiles from control shoot 7, show the extent to which XS re-forming has been achieved (Fig. 21).

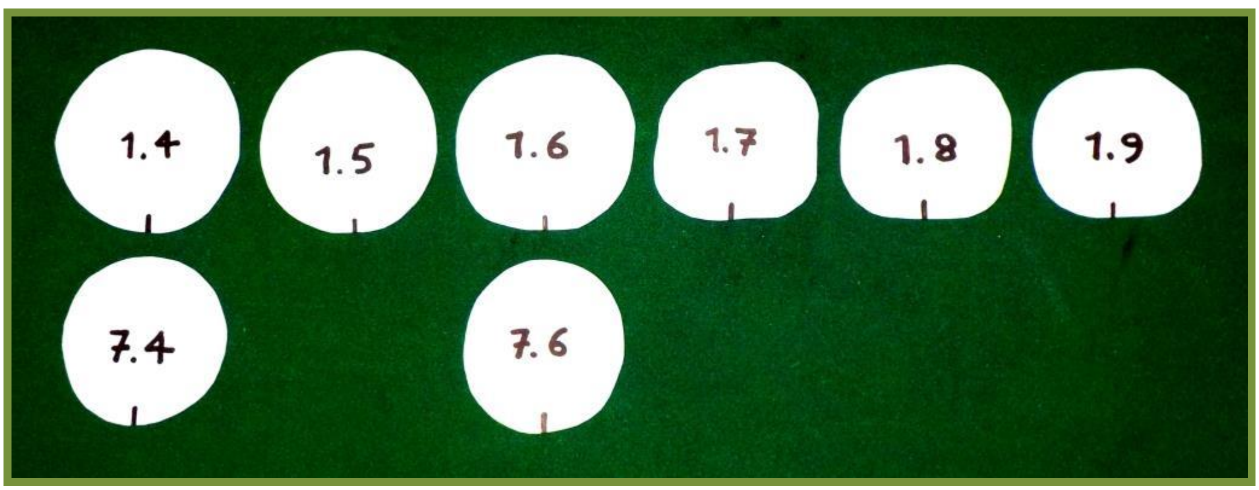

Figure 21. XS profiles of the re-shaped shoot 1 of the trial *Bambusa sp*. (top row) which contrast markedly to the approximately circular XS profiles of the older control culm 7 (bottom row). The first digit in each number is the shoot number and the second digit is the internode number.

The influence of the frame on altering the XSs is clearly evident in Fig. 21, although not for the XSs of internodes 1.4 and 1.5, which were 192 cm off the base line (Table 4). This is not surprising however, as the force of the growing culm pushed up the form until by the last day of measuring it was 131 cm above the base marker (Fig. 19).

Controlling the alignment of young branch shoots

The guiding bamboo poles taped to six secondary branches of *B. stenostachya* were removed 6½ weeks after they were installed. After the guides were removed, all six branches remained straight to some extent, however some had consecutive internodes joining each other at angles when the trial began, and for them, straightening had not been perfect (Fig. 22).

Figure 22. An assortment of re-aligned secondary branches of *B. stenostachya* with guide poles removed 6½ weeks after installation. Although generally straight, most re-aligned branches had internodes off-set to some extent from the general alignment.

All the secondary branches that had been re-aligned had an array of tertiary branches which were re-curved in the direction of the culm (Fig. 23).

Figure 23. Tertiary branches on a re-aligned secondary branch of *B. stenostachya* displaying scythe-like re-curvature towards the culm.

The tertiary branch of *B. stenostachya* which had been wound into a spiral around a nearby culm was cut from its secondary branch source and removed from the culm 12 weeks later. The branch had an extensive array of trioramose quaternary branches, with one being central and dominant, and all being thorn-like. The 286 cm long branch retained a partial spiral shape when removed (Fig. 24), but not as great as when in place around the culm (Fig. 9). Being a tertiary branch, its diameter was quite small, which may explain why it partially unwound upon release. It is possible that a larger diameter secondary branch, if trained into a spiral as it grew, would retain the shape of its form.

Figure 24. Tertiary branch of *B. stenostachya* released from its trained spiral form. Note the thorn-like trioramose quaternary branches.

The tertiary branch which had been cut and wound around the PVC tube was removed from the tube after 12½ weeks. It had dried-out and retained its curvature after removal (Fig. 25).

B. stenostachy has solid branches, which enable them to be curved without crushing, which will not be the case for bamboo species with hollow branch sections.

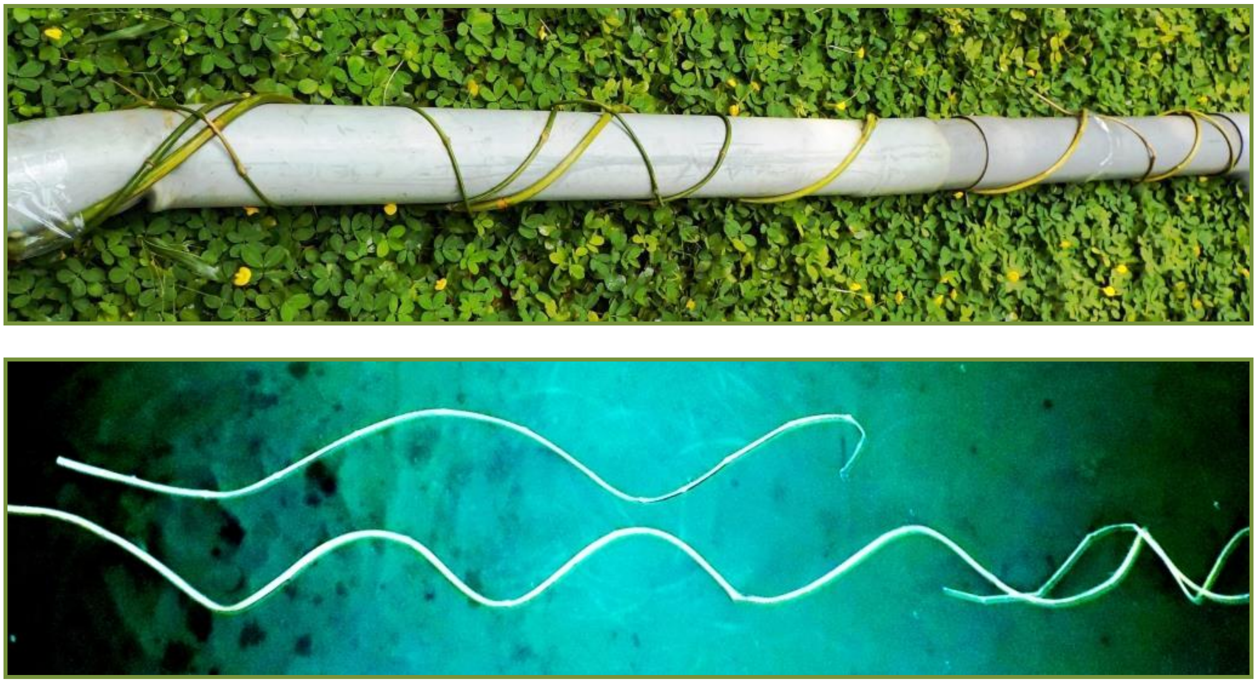

Figure 25. Tertiary branch of *B. stenostachya* cut and wound in a spiral around a length of 90mm OD PVC tube (top), and the same branch, now dry, and released from the tube (bottom).

The new secondary branch shoot of *B. stenostachya* which was guided into a length of polythene tube emerged from the tube but did not grow to be very long. Total length of the branch was 226 cm, made up of 20 cm of unconfined branch near the culm, 196 cm encased in tube and 40 cm of branch tip beyond the tube. The branch was removed 6 weeks after being enclosed. It was very smooth as expected (Fig. 26), it was straight, and tertiary branches had not developed. There was however evidence of a white fungus and sooty mould on the branch sheath surfaces (Fig. 27). The relatively short length of the branch, compared to most secondary branches observed on this clump of *B. stenostachya*, is quite likely a result of its confinement.

Figure 26. Smooth and straight secondary branch of *B. stenostachya* after being released from encasement in a length of polythene tube. Note the absence of tertiary branches.

Figure 27. White fungus (left) and sooty mould (right) on the secondary branch of *B. stenostachya* after its release from encasement in a length of polythene tube.

Conclusions and recommendations

Even though the study employed quite rudimentary materials to modify the XS profile of growing bamboo branches and culms, and to re-align branches, the results were encouraging. The UID branch XSs were altered, however the solid nature of the branches is likely to have made XS change harder to achieve than with a hollow section, such as the culm shoot of *B. sp*.. The *B. sp*. culm shoot trial resulted in significant change to the XS profile. With a more carefully constructed training frame, culm shoots should be able to be re-formed quite easily.

Bamboo branches are easier to re-align the younger (and softer) they are, however care is needed not to damage them. If they are kept in the formed shape until they have sent out their tertiary branches, and preferably until they have grown for long enough to have the strength required for their intended purpose, then cut, and only released from the frame after they have reduced their moisture content, then it is likely they will retain the shape they have been trained to.

The presence of fungi on and beneath training forms may negatively impact on the health of bamboo branches and culms. Moisture from precipitation, condensation and sap discharge, can build up in and under forms, thus creating a good environment for fungal development. Forms therefore should be constructed in ways that discourage fungal development, by the use of materials such as galvanised steel, timber treated with a fungicide or forms which allow air circulation (perforated, slatted, etc.).

The bamboo tertiary branches observed were in alignment with the tips of sheath leaf blades, on opposite sides of alternate nodes. There may be a preferred orientation for training forms, such as, in the case of a square-section form, to place the middle of one side of the form in line with one line of leaf blade tips. Or, it may be preferred to place a corner of the square in line with one line of leaf blade tips. It is recommended to investigate these options.

Training forms for XS profile-forming need to be strong enough to resist the growing forces of the bamboo shoot being trained, and forms should be held in place so that the growing shoot cannot move them. For secondary branch training, a strong strap from the frame around the culm should suffice. For culm shoot XS profile shaping, a way to keep the frame from rising up has to be devised. Perhaps base extensions and weights could work, or using cross-members to strap the frame to nearby culms.

The length of training forms can be trialed. It is possible that very short forms would work, so that the growing shoot is virtually "extruded" from the form. This concept would be worth trialing, to see just how short a training form could be and still be successful.

Experimentation will be required to find out what the XS dimensions of the training form should be for a particular shoot. With sufficient trialing, perhaps a formula can be developed. Lewis Bamboo, Inc. (2016) suggests the use of an adjustable form.

Bamboo hardens with age, and is suitable for timber use after a minimum of three years' growth (less for weaving purposes). Formed bamboo shoots should thus be left uncut for at least three years, unless their intended use is non-structural. Experimentation on earlier harvesting would be worthwhile.

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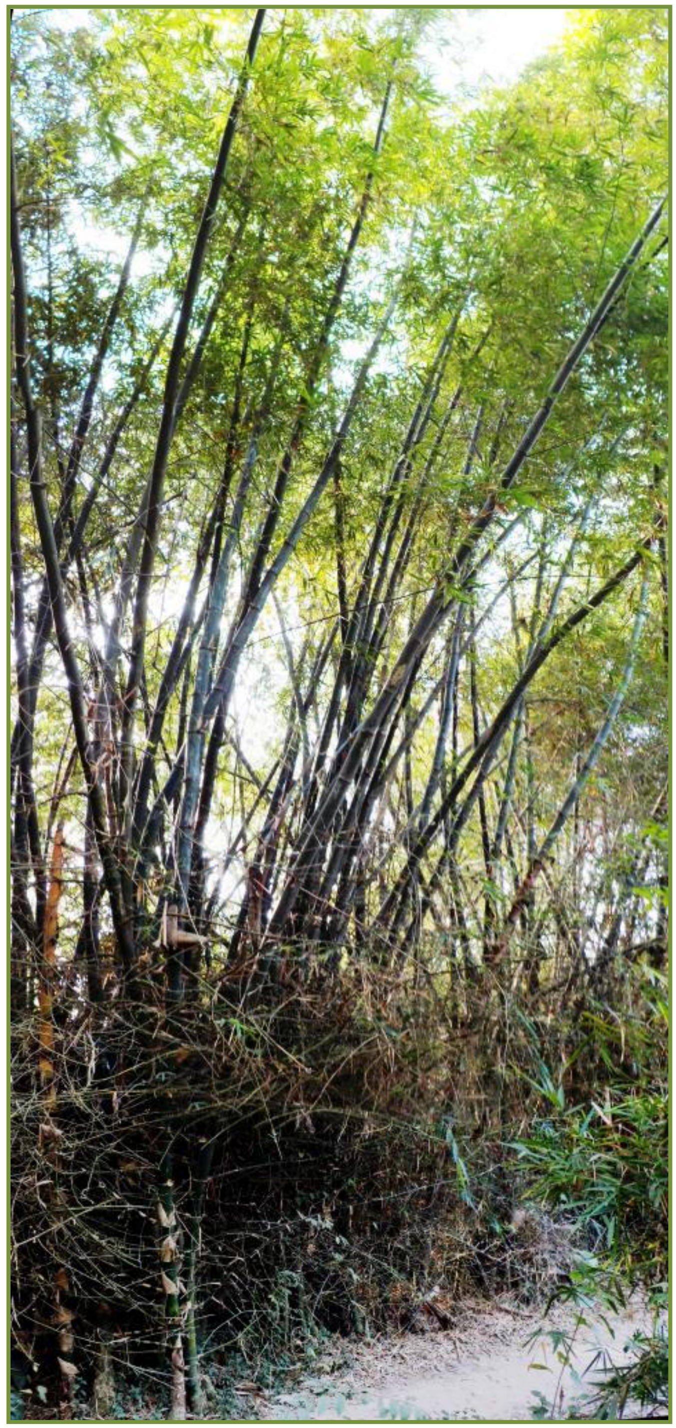
Attachment 1. Features of the unidentified bamboo (UID) selected for branch XS profile modification



Attachment 2. Growth rates of *Bambusa stenostachya (*Đằng ngà*)* branch shoots measured over a 6½ week period and the trained branch 10C4 measured over a 4 week period.

Time	Date	Branch number and length measured (cm)										Rain/ Dry*
		1C1	2C1	3C1	4C1	5C1	6C2	7C2	8C3	9C3	**10C4**	
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	**63.5**	Dry
0900	28/10/15	221		200	17.5	9.5		261	21	12.5	**69.5**	Dry
0900	29/10/15	227.5		210	18	10		265	25	13	**76**	Dry
0900	30/10/15	234.5		220	20	10.5		268.5	28.5	14	**85**	Dry
0900	31/10/15	241		232	22.5	11		278.5	34	15.5	**93**	Rain
0900	1/11/15	243		246	26	11.5		290.5	39.5	17	**102.5**	Dry
0900	2/11/15	252.5		260	30.5	13		303	45.5	19.5	**113.5**	Rain
0900	3/11/15	260		274	37	13.5		315	53	22.5	**123**	Rain
0900	4/11/15	269.5		291	43.5	15		329.5	60.5	28	**133.5**	S/rain
0900	5/11/15	278		305	51	16.5		341.5	72.5	32	**141**	Rain
0900	6/11/15	283.5		320.5	59	19		356	84.5	36	**146**	S/Rain
0900	7/11/15	292.5		335	69.5	23.5		369	98	42.5	**151**	Dry
0900	8/11/15	304.5		348	81	27.5		382.5	115	48.5	**155**	S/Rain
0900	9/11/15	311		361	93	32.5		397	131.5	57	**158**	Dry
0915	10/11/15	320.5		373	106.5	37.5		413.5	148.5	67	**160**	Rain
1015	11/11/15	329		384.5	125	43.5		431	166.5	79.5	**160.5**	S/Rain
0900	12/11/15	339.5		394.5	142.5	52.5		448	186	91	**161**	Dry
0900	13/11/15	346.5		408.5	158.5	62.5		461	204.5	106	**161**	Dry
0900	14/11/15	356.5		419.5	172	70.5		476	220.5	121.5	**161**	Dry
1000	17/11/15	364.5		446.5	211.5	108.5		517	264	167.5	**161**	Dry
0900	18/11/15	365		453	224.5	119		530	275	182	**161**	Dry
0900	19/11/15	365.5		456.5	234.5	133		541	284	194	**161.5**	Dry
0900	20/11/15	365.5		458	245.5	145		555	292	206	**161**	Dry
0900	21/11/15	365.5		458	258.5	156		564	299	216	**161**	Dry
0900	22/11/15	365.5		460.5	271	167.5		564	304.5	224.5	**161.5**	S/Rain

0900	23/11/15	365.5		462	284	180.5		563.5	306.5	230.5	**161**	Rain
0900	24/11/15	365.5		461.5	296.5	192		572	307	236.5	**161**	Dry
0900	25/11/15	365.5		463	307	204		576	307.5	240.5	**159**	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
Mean average maximum length (cm) of un-cut branches 1C1 to 9C3 383.71												
* S/Rain = slightly rainy, drizzle, brief sprinkle												

Note: Branch 10C4 is an unidentified bamboo species.

Attachment 3. Growth rates of *Bambusa sp. (Lồ Ô Vàng)* culm shoots measured over a 5 week period.

Time	Date	Culm number and length measured (cm)						Rain/ Dry*
		1	2	3	4	5	6	
1300	31/10/2015	122	139	72	28	24	25	Rain
1300	1/11/2015	128	152	81	28	25	27	Dry
1400	2/11/2015	140	168	91	28.5	25	27	Rain
1300	3/11/2015	160	186	102	29	25	28	Rain
1300	4/11/2015	172	208	118	29	25	27.5	Srain
1300	5/11/2015	181	227	133	29	25	27.5	Rain
1330	6/11/2015	197	253	153	29	25.5	27.5	S/Rain
1300	7/11/2015	209.5	270.5	170.5	29	25	27.5	Dry
1300	8/11/2015	225	290	188	29	25	27.5	S/Rain
1330	9/11/2015	234	312	208	29	24.5	27.5	Dry
1300	10/11/2015	250	335	228	29	25	27.5	Rain
1300	11/11/2015	267	353	248.5	29	25	27.5	S/Rain
1300	12/11/2015	284	380	270	29	25	27.5	Dry
1300	13/11/2015	297	400	290	29	25	27.5	Dry
1100	14/11/2015	309	422	310	29.5	25.5	28	Dry
1300	17/11/2015	360	490	370	29.5	25.5	28	Dry
1430	18/11/2015	373	511	389	29.5	25.5	28	Dry
1400	19/11/2015	387	531	411	29	25	28	Dry
1300	20/11/2015	409.5	543.5	429	29	25	28	Dry
1300	21/11/2015	428	562	437	29	25	28	Dry
1300	22/11/2015	443	590	462	29	25	28	S/Rain
1300	23/11/2015	465	616	477	29	25	28	Rain
1300	24/11/2015	494	656.5	516	29	25	28	Dry
1300	25/11/2015	528.5	677.5	537	29	25	28	Rain
1300	26/11/2015	547	709.5	555	29	25	28	Rain
1300	27/11/2015	575.5	738.5	584.5	29	25	28	Dry
1300	28/11/2015	600.5	754	618.5	29	25	28	Dry
1300	29/11/2015	623	764.5	644	29	25	28	Dry
1300	30/11/2015	643	816	663	29	25	28	Dry

1300	1/12/2015	665	826	673.5	29	25	28	Dry
1300	2/12/2015	696	865	732.5	29	25	28	S/Rain
1300	3/12/2015	700	890.5	745.5	29	25	27.5	Dry
1330	4/12/2015	740	921	765	29	25	27.5	Dry
Growth rate (cm/day)		**18.18**	**23**	**20.38**				
Mean average growth rate (cm/day)								**20.52**