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Epicormic Shoot Induction on Severed Branches of Selected Native Forest Tree Species with the Potential for Urban Landscaping in the Philippines

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Complete List of Authors:	Piñon, Albert; University of the Philippines Los Banos, Institute of Renewable Natural Resources Tolentino Jr., Enrique; University of the Philippines Los Banos, Institute of Renewable Natural Resources Visco, Roberto; University of the Philippines Los Banos, Institute of Renewable Natural Resources Calderon, Margaret; University of the Philippines Los Banos, Institute of Renewable Natural Resources Navarra, Nappy; University of the Philippines Diliman, College of Architecture
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Abstract

Vegetative propagation can help increase the popularity of native forest tree species (NFTs) in urban landscapes, as it can produce trees with the desired traits (e.g. flowers) faster than the traditional approach. However, rooting success declines with increasing juvenility of cuttings due to maturation. Hence, a low-cost rejuvenation strategy using severed branches of varying diameter sizes (very small, small, medium, and large) was tested for *Pterocarpus indicus* Willd. and *Dillenia philippinensis* Rolfe. After 2 weeks, variations in 80% of shoot parameters were highly significant, which increased to 100% after 3 to 4 weeks. Similar observations were recorded for *D. philippinensis* initially after 7 weeks (70%), but a sharp decline by 30% and 20% was detected after 9 and 11 weeks, respectively. Positive strong, and significant correlations on both species reveal a positive correlative control among shoot traits. However, similar relationships between branch diameter and shoot traits were observed only for *P. indicus* but not in *D. philippinensis*, indicating that while the size of the branches influences the quantity and quality of shoots produced, carbohydrate reserves may vary from species to species. The result of the study could help promote the use of NFTs in the urban landscape by increasing the rooting success through the production of more rejuvenated shoots.

Keywords: Rejuvenation, shoot induction, *Pterocarpus indicus* Willd., *Dillenia philippinensis* Rolfe

Introduction

Native forest trees (NFTs) have numerous advantages compared to exotic species in revegetating the degraded forests and urban landscapes (Davis et al. 2011, Jacobs 2013). However, despite having diverse native genetic reserves, urban greening efforts in the Philippines remain excessively dependent on exotic trees mainly due to the scarcity of native seedlings (Murakami and Palijon 2009, Valle 2018, Jumonong et al. 2021, Bosshard et al.

2021). Apart from being slow-growing, most NFTs have reproductive issues that limits its reproduction ability (ERDB 2012, Aguilon et al. 2019).

The country have alternative seedling production technologies such as tissue culture and rooted cuttings. However, the inherent cost of production, the sophistication of operations, the presence of potential risks, and complicated facilities limit their adoption (Cadiz et al. 2010, ERDB 2012 and 2017, Wu 2017). Fortunately, a low-cost strategy capable to reproduce the NFTs alternatively has been discovered (Cadiz et al. 2014, ERDB 2017, Piñon et al. 2022). The use of young and juvenile cuttings from young seedlings collected from selected stands has been proven effective to mass-produce high quality seedlings (Cadiz et al. 2010, ERDB 2012). However, as true-to-type cloning can capture the genetic blueprint that controls the expression of the desired traits of the mother trees, this offers greater opportunity to produce the desired quality of planting materials for urban greeneries (Ahuja and Libby 1993, Pijut et al. 2011, Zobel and Tabert 2003, Wendling et al. 2014).

True-to-type cloning can mass-produce trees in massive quantities. Such a strategy relies on vegetative parts, hence continuous supply of seedlings is guaranteed than those originated from seeds (Ahuja and Libby 1993, Zobel and Talbert 2003, Piñon et al. 2021). However, success of this technique varies among trees, hence, the cloning protocol for one species may not be applicable to others (Ahuja and Libby 1993, Zobel and Talbert 2003). For instance, rooting induction using stem cuttings collected directly from mature trees is possible for *Aquilaria cumingiana* (Decne.) Ridl. but not in other trees (Stuepp et al. 2014, Nascimento et al. 2018, Piñon et al. 2021, Piñon et al. 2023, Ashwath et al. 2023). Several factors are in play, but "maturation" seems to be the major reason why rooting induction of cuttings from mature trees is both hard and challenging (Pijut et al. 2011, Wendling et al. 2014). As a result, majority of previous studies used cuttings derived from young and juvenile seedlings but limited from mature trees (Pollisco 2006, Cadiz et al. 2010, ERDB 2012, ERDB 2017, Piñon et al. 2021).

Maturation is a developmental change with increasing age in woody plants (Ahuja and Libby 1993, Wendling et al. 2014). Cellular and biochemical changes may affect this phenomenon but experts believe that the most prevalent could be reflected in the changes and amount in their DNA methylation (5-deoxycytidines) (Baurens et al. 2004, Irish and McMurray 2006, Pijut et al. 2011). This changes affects the maturation and juvenility transition and indicated the possibility of reversing the physiological state of cuttings known as "rejuvenation" (Irish and McMurray 2006, Wendling et al. 2014). Some used strategies such as pruning, hedging, and serial grafting to control or delay this transition from mature to juvenile state (Talbert et al. 1993, Leakey 2004, Wendling et al. 2015). Others believed that epicormic shoot production using severed branches from mature trees could be the most practical and efficient way of rejuvenation because it captures the fully expressed traits of the desired trees (Stuepp et al. 2014, Wendling et al. 2015, Nascimento et al. 2018, Piñon et al. 2021, Ashwath et al. 2023).

Pterocarpus indicus Willd. and *Dillenia philippinensis* Rolfe are promising species for urban greening. The former is locally known as narra from the family Fabaceae (Joker 2000, Orwa et al. 2009). It is recognized as among the most important NFTs due to its numerous economic and environmental relevance, which widely planted as street trees in the country (Pulhin et al. 2006, Pansit 2015, ERDB 2017, Tutor et al. 2017, Valle 2018, Piñon et al. 2021). The latter, meanwhile, is known locally as katmon from the Dilleniaceae family with unique features (e.g., flower) and morphology (Quisumbing 1978, Ansari et al. 2021).

As such, this study was carried out to test the response of *P. indicus* and *D. philippinensis* in epicormic shoot production using severed branches derived from mature trees.

Materials and Methods

Description of the Study Site

The epicormic shoot induction experiments were conducted at the Forest and Agroforest Nursery Learning Laboratory, located at the Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of the Philippines, Los Baños, Laguna. Renovation of this facility was conducted to be used as an improvised clonal nursery facility (Fig. 1a to b). The construction of cemented surface beds for epicormic shoot induction was among the renovations applied. The experiments were undertaken between May to December 2023. Meanwhile, planting materials used in this study were collected from selected mother trees growing within the Mt. Makiling Forest Reserve.

[Here the Fig. 1]

Planting Materials

Epicormic shoots sprouting from the stem or branches that are located near the ground surface root easily with the best quality (Wendling et al. 2014). As such, the first 2 to 3 growing branches in this location were collected from 4 and 3 mother trees of *P. indicus* and *D. philippinensis*, respectively (Fig. 1c to f). Coordinates and other relevant morphometric measurements of these trees were presented in Table 1 and 2.

[Here the Tab. 1]

[Here the Tab. 2]

Epicormic Shoot Induction

For standardization purposes, the study used an equal length (1 m) and 4 diameter classes of branches that were measured in the central part of each branch. For *P. indicus*, these were very small (VS – 17.08 mm $\pm$ 0.16), small (S – 25.74 mm $\pm$ 0.55), medium (M – 38.35 mm $\pm$ 1.03), and large (L – 75.78 mm $\pm$ 1.26). While for *D. philippinensis*, the diameter classes were very small (VS – 23.83 mm $\pm$ 0.65), small (S – 32.70 mm $\pm$ 0.38), medium (M – 45.53 mm $\pm$ 0.78), and large (L – 66.51 mm $\pm$ 1.66). The methods of epicormic shoot production for vegetative propagation of hard-to-root plants were adapted from the study of Byrne (1996). Branches were sterilized by soaking in Dithane M-45 fungicide solution (Dow AgroSciences, USA), composed of 1 tablespoon of fungicide powder mixed with 8 L of water. Sterilized branches were then air-dried for 5 minutes. Each branch was then laid out horizontally, with about half of the diameter of each branch submerged in the formulated growth medium composed of screened topsoil and partially decomposed rice hull in a 1:1 ratio installed in the improvised clonal nursery facility. Once clumps of epicormic shoots were observed, they were mist-sprayed with foliar fertilizer (Agrowell Liquefied Foliar Fertilizer), with 8 tbsp per 16 liters of water once a week using a 16-L stainless knapsack sprayer (Golden Golden Agin Tungho, SA). Mist-watering was applied using the same knapsack sprayer on the branches' exposed surface once daily (7:00 to 8:00 am or 5:00 to

6:00 pm). Data collection on various shoot parameters was initiated after 17 days and 48 days for *P. indicus* and *D. philippinensis*, respectively.

Experimental Design and Data Analysis

A complete randomized design was employed in the shooting induction study for *P. indicus* and *D. philippinensis.* Treatments were the branches of 4 different diameter classes. Ten parameters were collected such as the number of clumps (NC – total number of clumps of shoots produced per branch), the average number of shoots per clump (ANSC – the average number of shoots produced per clump), average shoot length (ASL - the average length of produced shoots per branch, measured using a ruler), length of the longest shoot (LLS – longest shoot produced per branch, measured using a ruler), number of shoots (NS – total number of shoots produced per branch), average shoot diameter (ASD – average diameter of shoot produced per branch, measured by a digital vernier caliper), diameter of the biggest shoot (DBS – diameter of the biggest shoot, measured by a digital vernier caliper), average number of node (ANN – the average number of nodes produced per shoot), highest number of node (HNN – the highest number of nodes produced per shoot), and percent shooting (PS – total number of shoots produced over the total number of branches planted per treatment). For correlation analysis, two shoot traits were added. These are the HNSC – the highest number of shoot per clump and BD - branch diameter. Treatment effects were assessed 2 to 4 weeks for *P. indicus* and 7 to 11 weeks for *D. philippinensis* after setting up the branches in the improvised rooting chamber. Collected data were arranged, organized, and transformed (square root) for normality distribution using Microsoft Excel Office 365 before calculating the analysis of variance (ANOVA). Statistical analysis such as the ANOVA and comparison of the means using the Duncan Multiple Range Test (DMRT) were performed using the "easyanova" packages in R version 4.3.2 (R Core Team 2023). Moreover, correlation analysis was also computed in 2 and 4 weeks (*P. indicus*), while 7 and 11 weeks (*D. philippinensis*) to identify the relationships among shooting parameters using the "metan", "ggplot2", and "lares" packages in R-statistics.

Results and Discussion

Effect of varying sizes of branches on shooting success

P. indicus

All shooting parameters used differed significantly (*P=0.0026 – P<0.001*), 2 to 4 weeks after setting up the shoot induction experiment (Fig. 2 to 4). Eighty percent of the shooting parameters used were highly significant after 2 weeks. This increased to 100% after 3 and 4 weeks. From the 10 shoot traits analyzed, only the ASL (*28.56 mm*, *P=0.0012*) and LLS (*51.36 mm, P=0.0026*) have registered the lowest significant levels after 2 weeks and increased their significance (*P<0.001*) after 3 to 4 weeks. This implies that varying sizes of branches tend to influence the induced shoots differently, and the degree of variation increases with increasing planting duration, particularly after 3 to 4 weeks (Fig. 5). A comparison of the means using the DMRT revealed that all branch sizes were significantly affecting all shoot parameters differently aside from ASL and LLS, 2 weeks after planting establishment. In these shoot traits, all branch sizes have similar effects on shoot length aside from large-size branches, suggesting that the bigger the size of branches, the longer the shoots induced will produced. Meanwhile, after 3 weeks, small-size and medium-size branches had similar effects on all shoot traits, but not after 4 weeks where all branch sizes significantly influenced the ten shoot traits differently. These findings may suggest that the presence of variable amounts of food reserves stored in severed branches causes differences in mechanisms that control the quantity and quality of epicormic shoots produced (Hartmann et al. 2010).

The average number of epicormic shoots produced using detached live branches in *P. indicus* after 4 weeks is 3.06. Variable results, however, were discovered in other studies. For instance, no reported number of epicormic shoots produced in severed branches of *Pawlonia fortunei var. Mikado* (Seem.) Hemsl after 45 days, 4.70 in *Ilex paraguariensis* A.St.Hil. after 42 weeks, and 18.83 after 14 weeks in *Tectona grandis* L.f. (Stuepp et al. 2014, Nascimento et al. 2018, Ashwath et al. 2023). Meanwhile, the ASL obtained from the present study after 2 weeks (28.56 mm), after 3 weeks (59.57 mm), and after 4 weeks (97.21 mm) were greater than those reported in *I. paraguariensis* after 30 weeks (5 mm), 36 weeks (3 mm), and 42 weeks (9 mm) (Nascimento et al. 2018). These finding suggest that variations in the quantity and quality of epicormic shoot produce by different species could be the result of varying degree of maturation due to their genetic differences, hence, rejuvenation strategy that is effective to a certain tree may not necessarily applicable to other (Zobel and Talbert 2003, Leakey 2004, Wendling et al. 2014). Additionally, note that apart from varying quantity and quality of shoots produced, these studies also reported some differences in the durations of epicormic shoot induction. These suggest that aside from technical considerations, these differences may also have some financial implications as the cost of production increases with increasing duration of shooting induction. As such, more studies should be done, perhaps to include also the financial analysis of epicormic shoot production.

[Here the Fig. 2]

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[Here the Fig. 4]

[Here the Fig. 5]

D. philippinensis

Seventy percent of the shooting parameters differed significantly (*P = 0.041 – P = 0.005*), 7 and 8 weeks after setting up the experiment (Fig. 6 and 7). The degree of significance decreased by 30% and 20% after 9 weeks (*P = 0.04 – P = 0.0124*) and 11 weeks (*P = 0.0458 – P = 0.0136*) (Fig. 8 and 9)**.** Among four (4) weeks of epicormic shoot assessment periods, the ANN (0.19 pcs, *P = 0.0059*) out of ten shoot traits had recorded the highest level of significance after 7 weeks. Similar observations were detected only in the ASD in the next consecutive weeks. These results may imply that while variation in height growth, as indicated by the average number of nodes is more pronounced 7 weeks after planting, the differences in diameter growth of newly induced shoots tend to be stronger than the other shooting traits with increasing shooting duration, particularly after 8 weeks (*P = 0.005*). Generally, the comparison of the means as per DMRT revealed that better quantity and quality of the epicormic shoots are produced with increasing diameter of branches. Within 4 weeks of assessments, the DMRT showed non-significant differences between small-sized-diameter branches (very small and small) but consistently differed significantly with the other sizes, indicating that big branch diameter sizes do matter in epicormic shoot production of the *P. indicus* and *D. philippinensis* (Fig. 10).

The degree of significant differences decreased by 30% and 20% after 9 and 11 weeks of the shooting induction study of *D. philippinensis.* In contrast, despite having a much shorter shooting induction period, the same observation was found otherwise in *P. indicus*, which increased from 80% (2 weeks) to 100% (3 and 4 weeks). Additionally, significant variation was detected only in the ANN after 7 weeks, while only in the ASD in the succeeding assessment periods for *D. philippinensis.* However, variable observations were observed in other species. For example, in the present study, all shoot parameters used in *P. indicus* varied significantly, particularly after 3 and 4 weeks. However, after nearly 13 weeks, different rates of significance were discovered in the shooting parameters of detached branches of *Ilex paraguariensis* when subjected to various shooting induction techniques (Nascimento et al. 2018). Variable results were also noticed using severed branches of *Tectona grandis* after 14 weeks (Ashwath et al. 2023). These differences in response to epicormic shoot production were further verified after comparing the shooting productivity in various trees. In *D. philippinensis*, the overall mean percent shooting increased steadily from 13.67% (7 weeks) to 16.02% (9 weeks), before it declined slightly after 11 weeks (15.63%). A similar trend was also discovered in *P. indicus*, although the overall mean percent shooting [40.36% (2 weeks), 47.17% (3 weeks), and 42.63% (4 weeks)] was relatively greater than those recorded in *D. philippinensis*. In contrast, an opposite trend was observed when coppicing was applied in trees that remained planted on the ground, instead of using severed branches that were partly submerged in a growth medium to induce the epicormic shoots. For instance, a consistent increase in the average shoot productivity per mother plant from 6 to 14 months was recorded after coppicing treatment in *Calophyllum brasiliense* Cambess. (Kratz et al. 2016). Several studies have indicated that these variations are caused by varying auxins, cytokinins, and strigolactones in plants (Domagalska and Leyser 2011, Mason et al. 2014). However, while many studies have proved the role of plant hormone (e.g. auxin) in the adventitious root formation in cuttings, it appears that sugars or carbohydrate reserves have a greater influence on shooting induction in severed branches as sugars act as signals that regulate bud growth (Mason et al. 2014, Gao et al. 2024, Liu et al. 2024). This coincides with the total nonstructural carbohydrate (TNC) reserves evaluation in many temperate tree species, wherein branches revealed the highest TNC concentration and significantly increased with interbranch position from the base to the top (Barbaroux et al 2003, Furze et al. 2018). As the branch sizes normally get bigger from the base to the top of a tree or from the base to the tip of the branch, this would indicate an increasing carbohydrate content with increasing diameter size of the branches.

[Here the Fig. 6]

[Here the Fig. 7]

[Here the Fig. 8]

[Here the Fig. 9]

[Here the Fig. 10]

Associations among Shoot Traits and between Shoot Parameters and Branch Sizes

P. indicus

All calculated correlations were positive and significant after 2 weeks ($r = 0.35 – 1.00, P<0.01 – P<0.001$) and 4 weeks ($r = 0.47 – 1.00, P<0.001$) (Fig. 11). The strongest associations after 2 weeks were established between ASD vs. DBS ($r = 0.97, P<0.001$), while between DBS vs. HNN ($r = 0.98, P<0.001$) after 4 weeks. On the other hand, regardless of duration, the weakest relationships among 66 established associations, although still positive and significant were detected between branch diameter and shoot traits, particularly after 2 weeks. Specifically, these relationships were identified between the BD vs. ANN ($r = 0.35, P<0.01$) and between BD vs. LLS ($r = 0.35, P<0.001$) after 2 weeks. Interestingly, not only in terms of significance but such associations between branch diameter and shoot traits had increased in strength after 4 weeks. This emphasized the higher probability of producing epicormic shoots with a greater quantity and quality when using bigger-diameter branches that are planted horizontally and partially submerged in the formulated growth medium for a much longer period[1].

Numerous studies were undertaken that determine the relationships among shoot architectural traits and branch characteristics (e.g. shoot size vs. branching patterns; stem length vs. leaf area vs. stem weight) but none have tried investigating the existence of

[1] Four (4) weeks for *P. indicus*.

associations among shoot traits of artificially induced epicormic shoot until recently (Johnson and Lakso 1985, Yagi 2011, Walker and Bennett 2018). The study obtained positive, significant with moderately strong to very strong associations among 10 shoot traits and branch diameter (Fig. 11). Also, highly significant with positive and increasing strength of relationships were detected among shoot traits and branch size from 2 to 4 weeks. These findings may suggest the existence of correlative controls in the subject native tree. Correlative controls pertain to the ability of one plant part to regulate the growth of another (Walker and Bennett 2018). Therefore, large-diameter branches should be used to ensure the production of epicormic shoots with higher quantity and better quality.

[Here the Fig. 11]

D. philippinensis

Correlation analysis for *D. philippinensis* was undertaken during the first (7 weeks) and last (11 weeks) data collection only. All correlations among shoot traits and between shoot traits and branch sizes were positive and significant ($r = 0.33 – 1.00, P<0.01 – P<0.001$) after 7 weeks (Fig. 12). Similar relationships were calculated after 11 weeks aside from associations between the BD and HNSC ($r = 0.21, P>0.05$) and between the BD vs. HNN ($r = 0.16, P>0.05$). The strongest associations after 7 weeks was between ASD vs. DBS ($r = 0.98$). The same findings were computed after 11 weeks, although with the addition of the relationships between the ANSC vs. ANN ($r = 0.98$), which tied with the correlation between ASD vs. DBS. All of these associations were highly significant ($P<0.001$). On the other hand, the weakest correlations in both assessments were detected between shoot traits and branch sizes. In fact, all associations between these traits, although positive and mostly significant, were found weak in both periods. Specifically, such weakest relationship was detected between the BD and NC ($r = 0.33, P<0.01$) after 7 weeks, while between the BD and HNN ($r = 0.16, P>0.05$) after 11 weeks. These findings emphasized the positive, strong, and significant relationships among shooting traits but not between shoot traits and branch sizes.

The results of correlation analysis among shoot traits of *D. philippinensis* are in agreement with those of *P. indicus,* but not in terms of the relationships between shoot traits and branch sizes. While weak relationships between branch sizes and shoot traits of the former were generated, stronger associations were detected in the latter. These findings would indicate the existence of variable correlative control[2] among different tree species (Walker and Bennett 2018). However, since very limited similar studies have been conducted so far that look into the relationships among the traits of artificially induced epicormic shoots in trees, more investigations are needed to understand the dynamics of epicormic shoots induced using severed branches, not only to increase the shoot productivity but also their rooting ability.

[Here the Fig. 12]

Conclusion and Recommendation

An increasing percentages in significant variations from 80% after 2 weeks to 100% after 3 to 4 weeks were observed in shooting parameters of *P. indicus.* In contrast, a decreasing percentages of significant differences from 70%, 30%, and 20% after 7 to 8 weeks, 9 weeks, and 11 weeks, respectively for *D. philippinensis*. These suggest that different species may respond to epicormic shoot induction differently due to varying carbohydrate reserves that depend on the sizes of branches. The results of DMRT for *P. indicus* suggested that the larger the diameter of the branches, will more likely produce longer epicormic shoots. For *D. philippinensis*, the DMRT showed non-significant differences between small-sized-diameter branches (very small and small) but consistently varied significantly with bigger diameter sizes, indicating that the diameter of the branches does matter in epicormic shoot production of trees.

Positive, strong, and significant correlations among shoot traits of *P. indicus* and *D. philippinensis* were detected, but not in terms of the relationships between shoot traits and branch sizes. While mostly strong and significant relationships between branch sizes and shoot traits of *P. indicus* were generated, the opposite was observed in the majority of these relationships for *D. philippinensis*. These findings would indicate the existence of variable correlative control among different tree species.

[2] The ability of one plant part to regulate the growth of another (Walker and Bennett 2018)

As such, it is recommended to conduct further investigation on epicormic shoot induction to enhance the production efficiency by testing the other factors (e.g. different branch length, auxin application, etc.). Moreover, bigger diameter branches should be used when conducting epicormic shoot production, particularly if the intention is to use a mature tree.

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Table 1: Characteristics of the four identified mother trees of *P. indicus*.

Tree Number	GPS Reading	DBH (cm)	MH (m)	TH (m)	No. of Major Branches	Crown Spread (m)	
						NS	EW
1	N 14° 08' 19.5" E 121° 13' 56.6"	64.87	3.2	52.1	13	17.4	12.5
2	N 14° 08' 19.2" E 121° 13' 54.2"	90.82	8.4	68.4	4	21.5	16.3
3	N 14° 08' 20.2" E 121° 13' 53.5"	97.78	8.8	53.5	6	18.7	18.2
4	N 14° 08' 48.3" E 121° 13' 52.4"	87.03	7.2	61.7	7	15.2	18.3

DBH – diameter at breast height; MH – merchantable height; TH – total height; NS – north-south crown; EW – east-west crown.

Table 2: Characteristics of the three identified mother trees of *D. philippinensis*.

Tree Number	GPS Reading	DBH (cm)	MH (m)	TH (m)	No. of Major Branches	Crown Spread (m)	
						NS	EW
1	N 14° 07' 55.08" E 121° 12' 53.0"	31.65	5.1	15.5	4	4.2	3.5
2	N 14° 07' 55.08" E 121° 12' 53.0"	53.80	6.8	18.7	4	9.5	5.3
3	N 14° 07' 50.6" E 121° 12' 55.8"	50.63	3.2	16.5	6	10.3	8.1

DBH – diameter at breast height; MH – merchantable height; TH – total height; NS – north-south crown; EW – east-west crown.

Figure 1: Renovations of the makeshift nursery facilities (a to b); branches collection in the mother trees of *P. indicus* (c to d) and *D. philippinensis* (e to f).

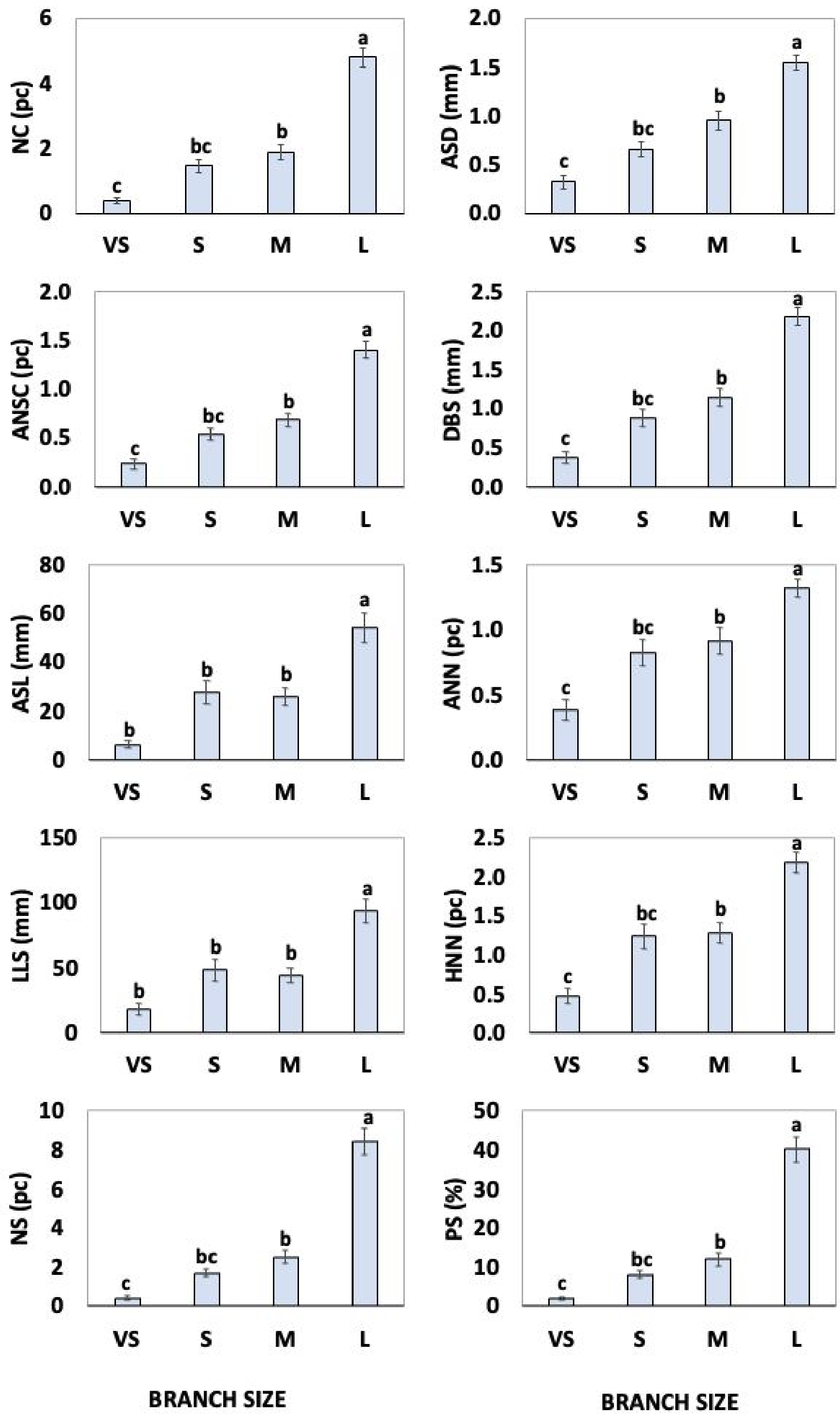

Figure 2: Effect of varying sizes of branches in the shooting induction of *P. indicus*, 2 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

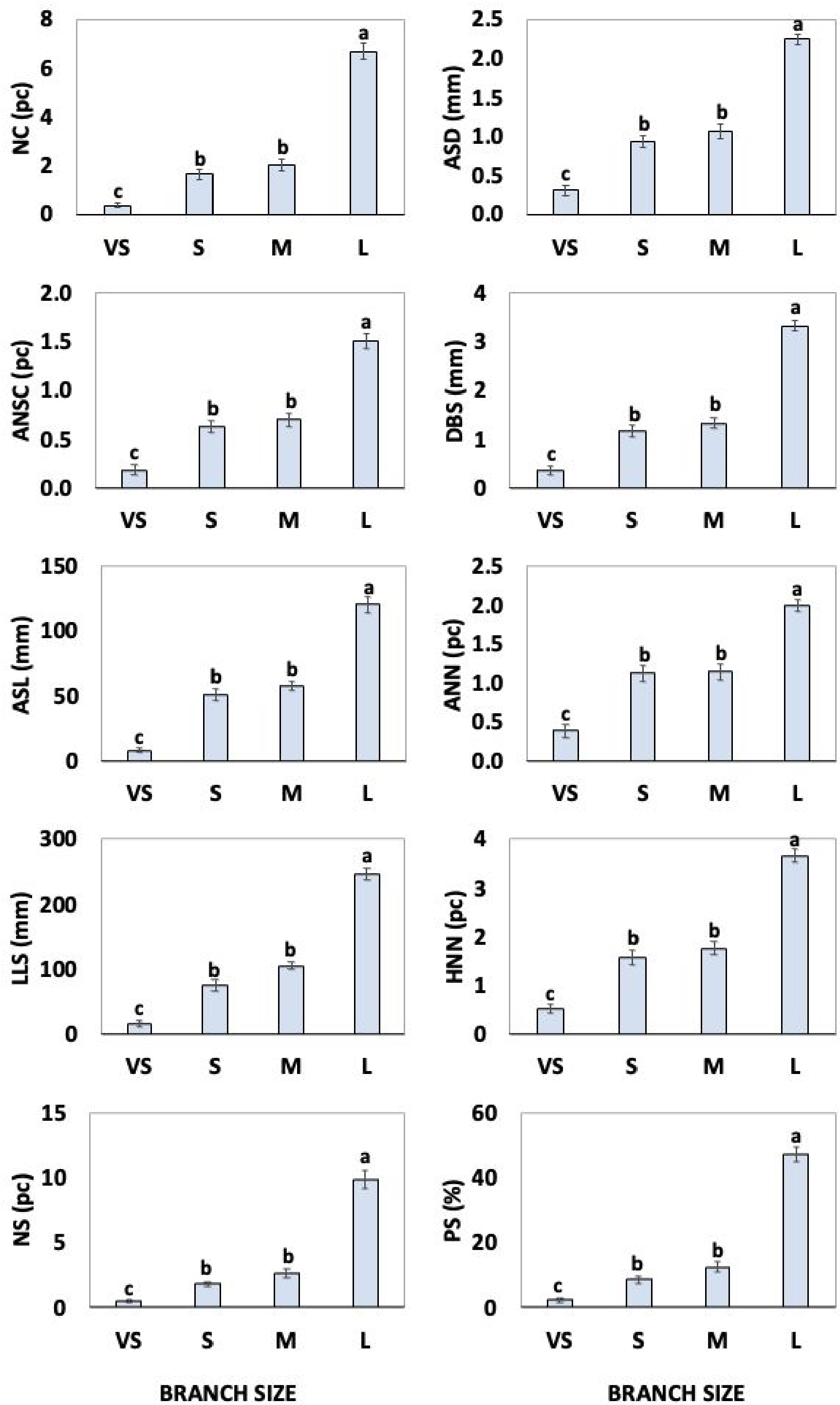

Figure 3: Effect of varying sizes of branches in the shooting induction of *P. indicus*, 3 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

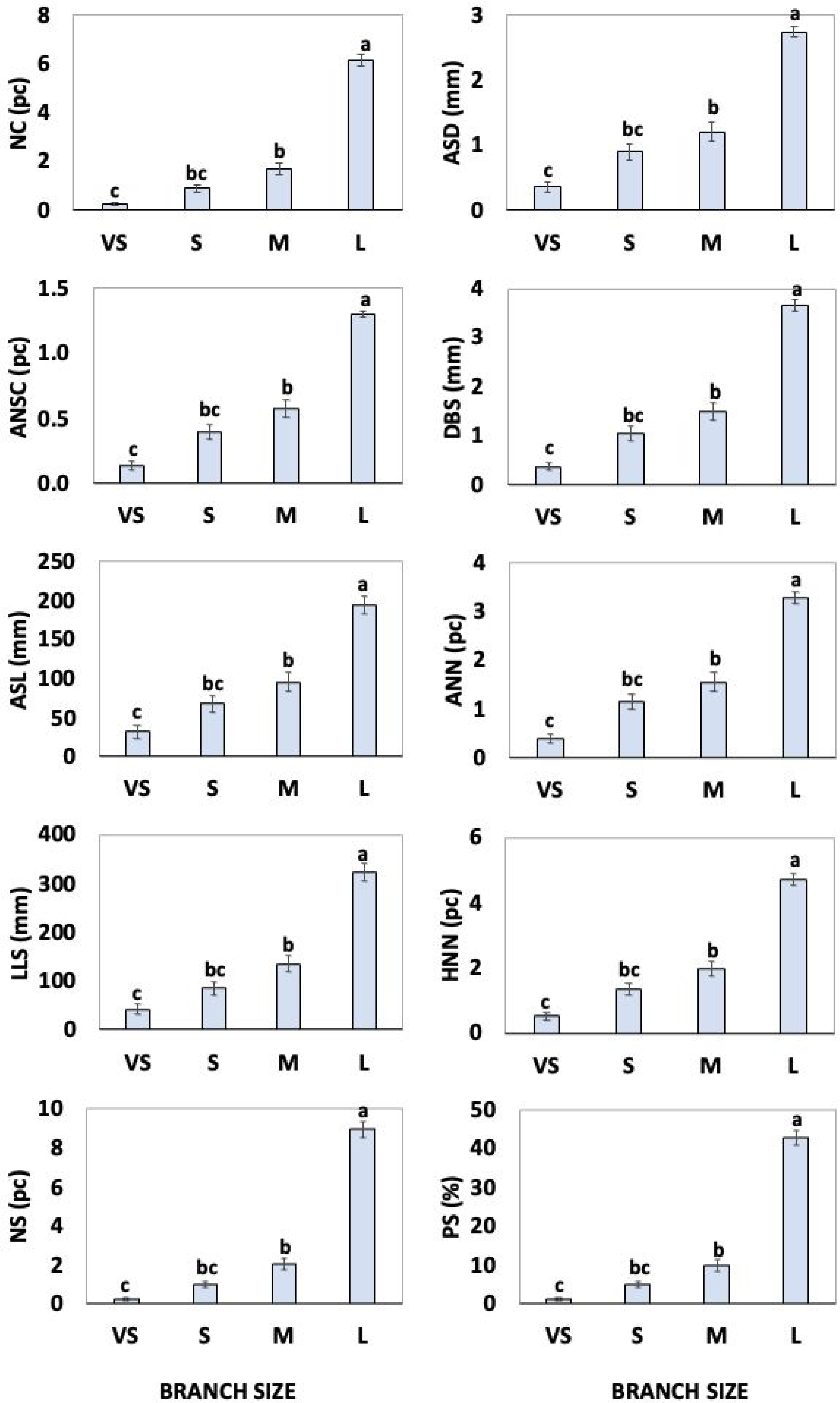

Figure 4: Effect of varying sizes of branches in the shooting induction of *P. indicus*, 4 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

Figure 5: Shoots induced rom branches of *P. indicus* after 1 week (a), 2 weeks (b), and 4 weeks (c). Some branches produced roots after 10 weeks (d to h). Note the callus formation at the base of severed branches where adventitious roots are produced.

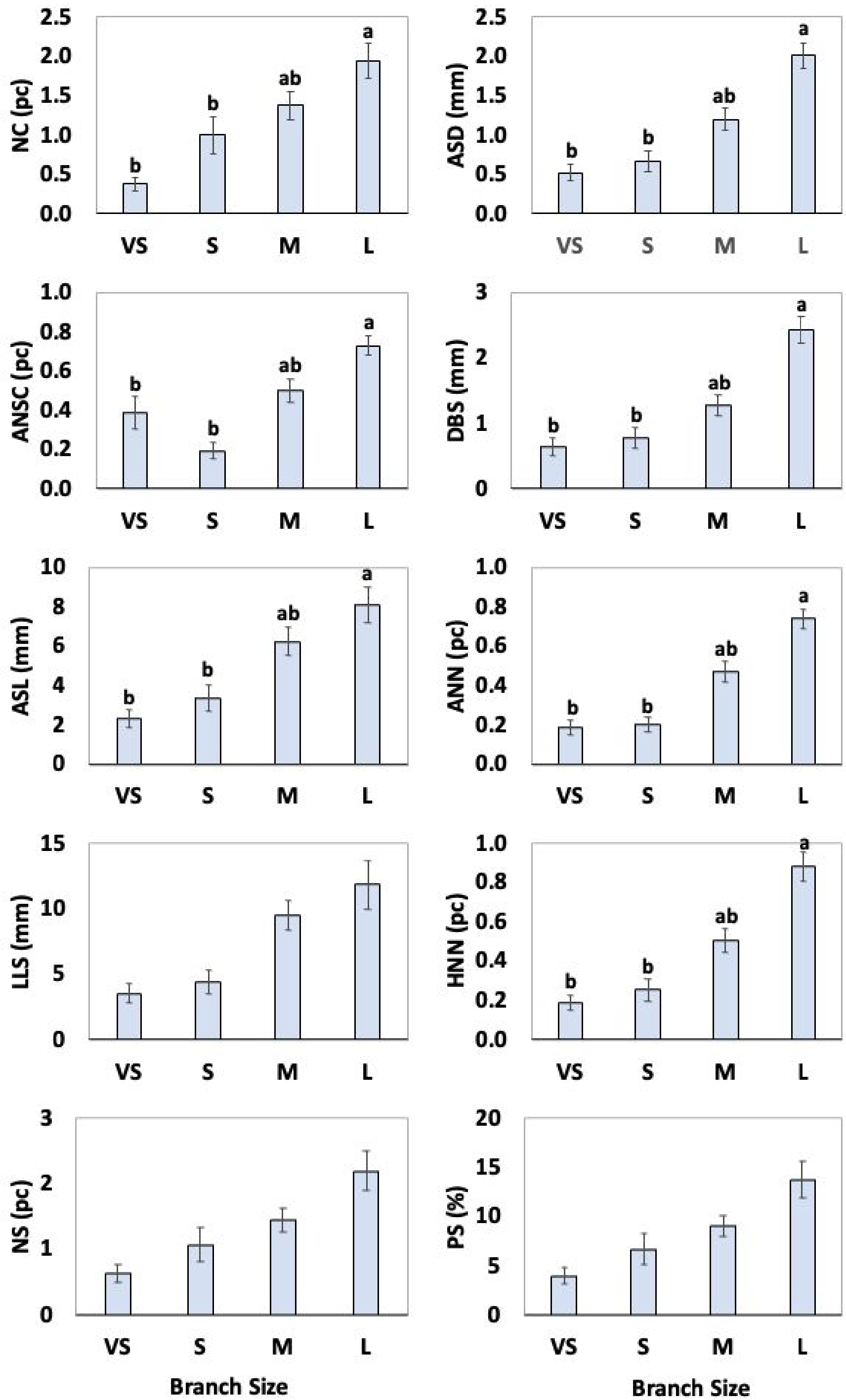

Figure 6: Effect of varying sizes of branches in the shooting induction of *D. philippinensis*, 7 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

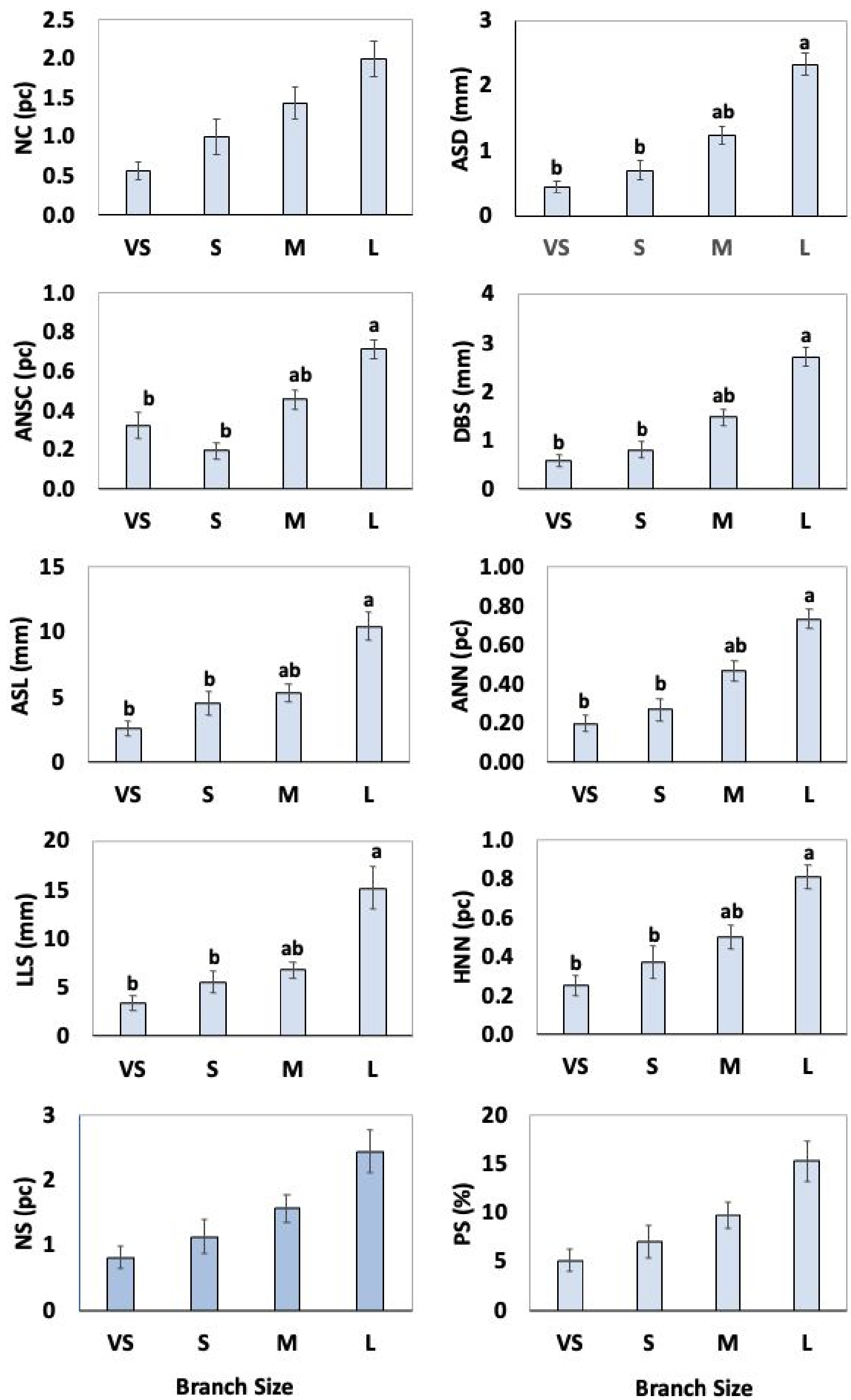

Figure 7: Effect of varying sizes of branches in the shooting induction of *D. philippinensis*, 8 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

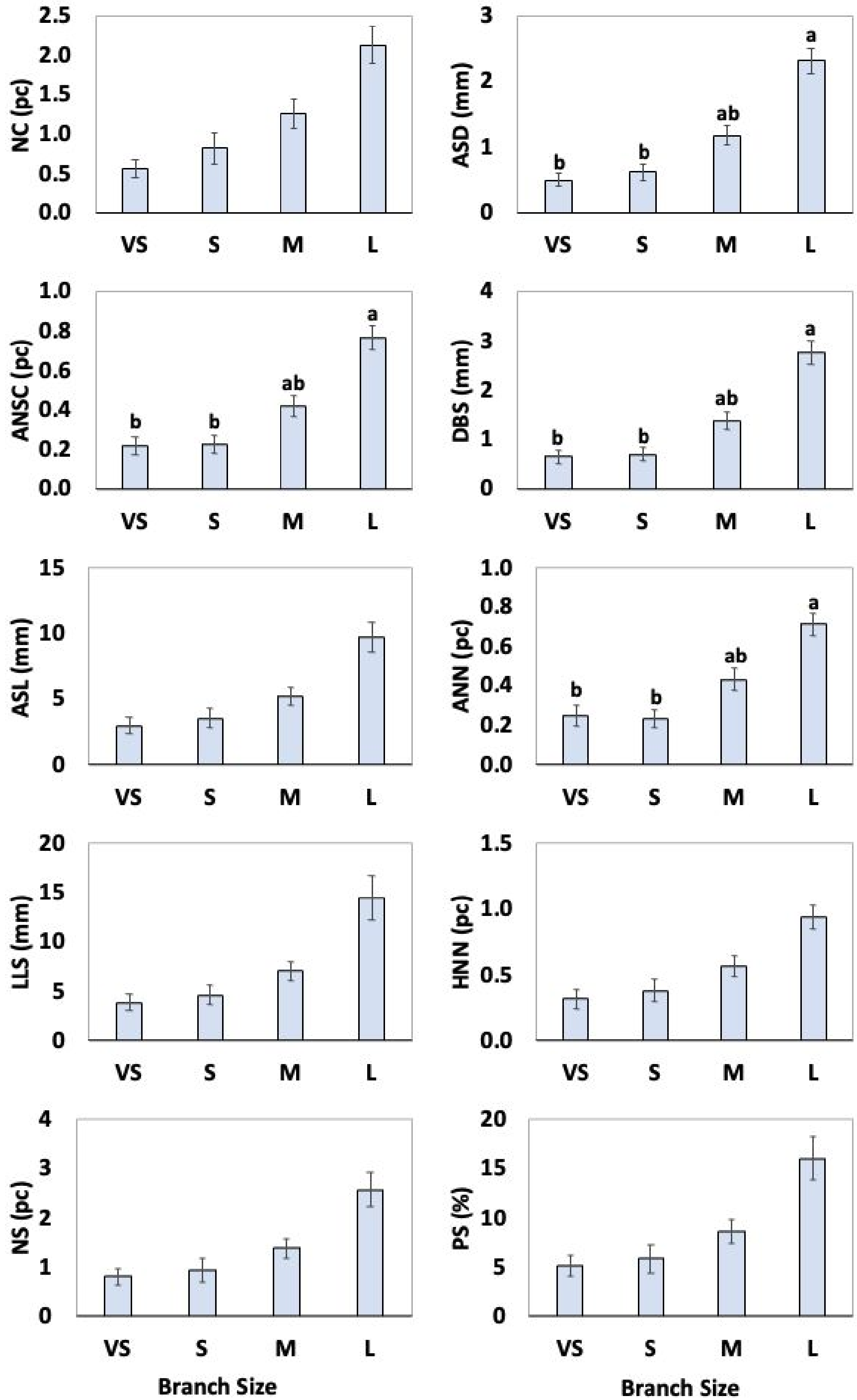

Figure 8: Effect of varying sizes of branches in the shooting induction of *D. philippinensis*, 9 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

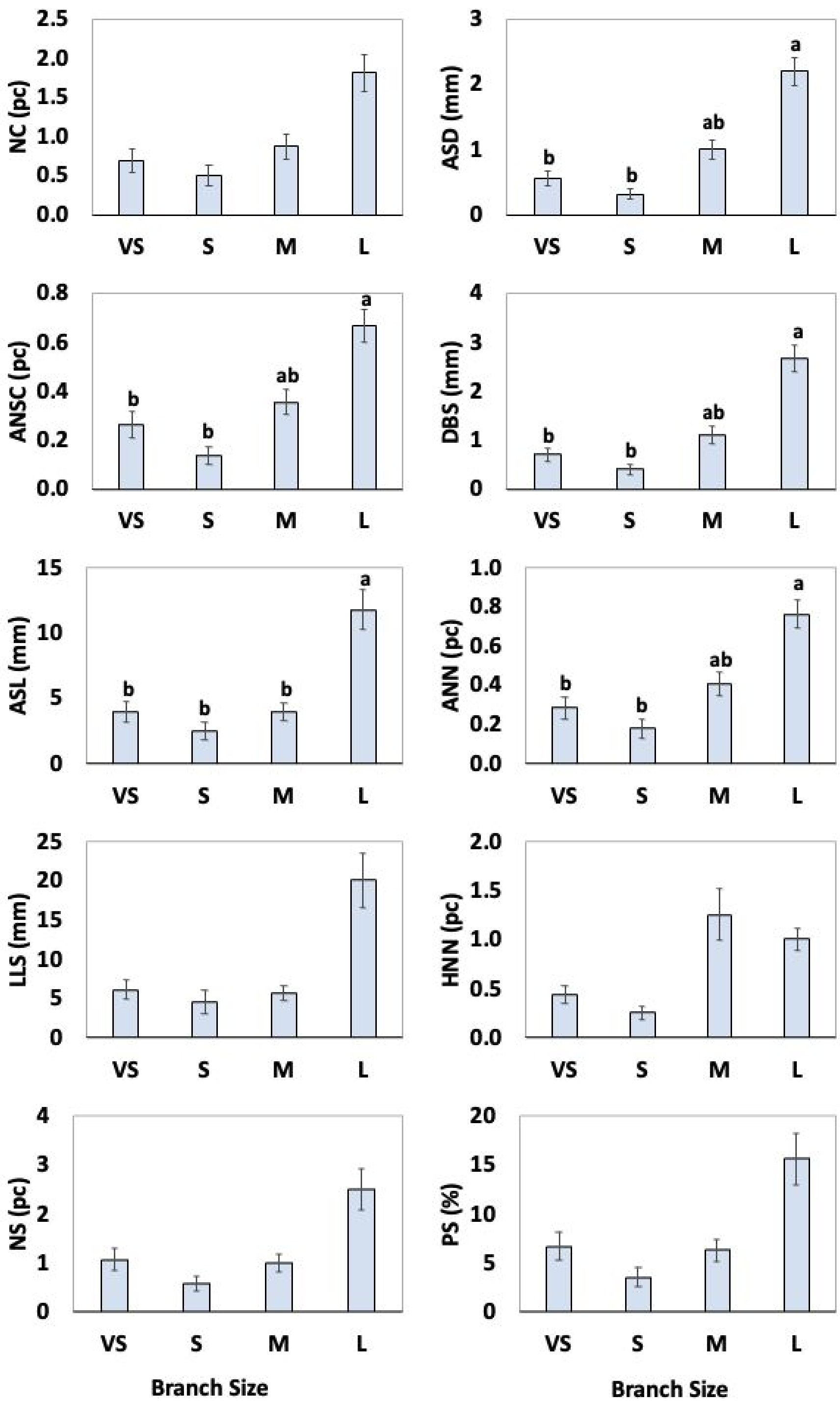

Figure 9: Effect of varying sizes of branches in the shooting induction of *D. philippinensis*, 11 weeks after planting. Error bars represent the standard error. Means followed by the same letter(s) are not significantly different at the 5% level based on the DMRT.

Figure 10: Epicormic shoot production (a to e) and rooting induction (f) of *D. philippinensis*. Note the wilting of newly sprouted epicormic shoots (d to e) and planted cuttings with necrotic leaves for the rooting induction experiment (f).

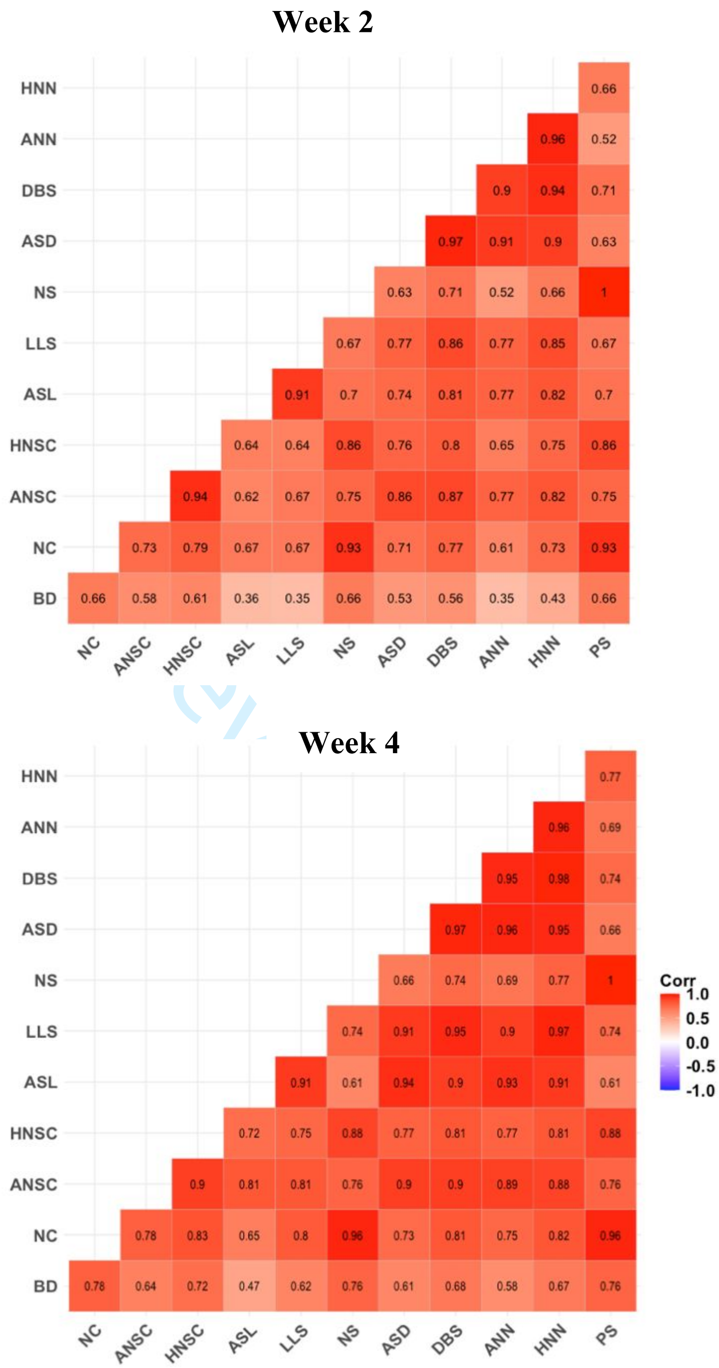

Figure 11: Correlations among shoot traits and branch sizes of *P. indicus* after 2 and 4 weeks of planting establishment.

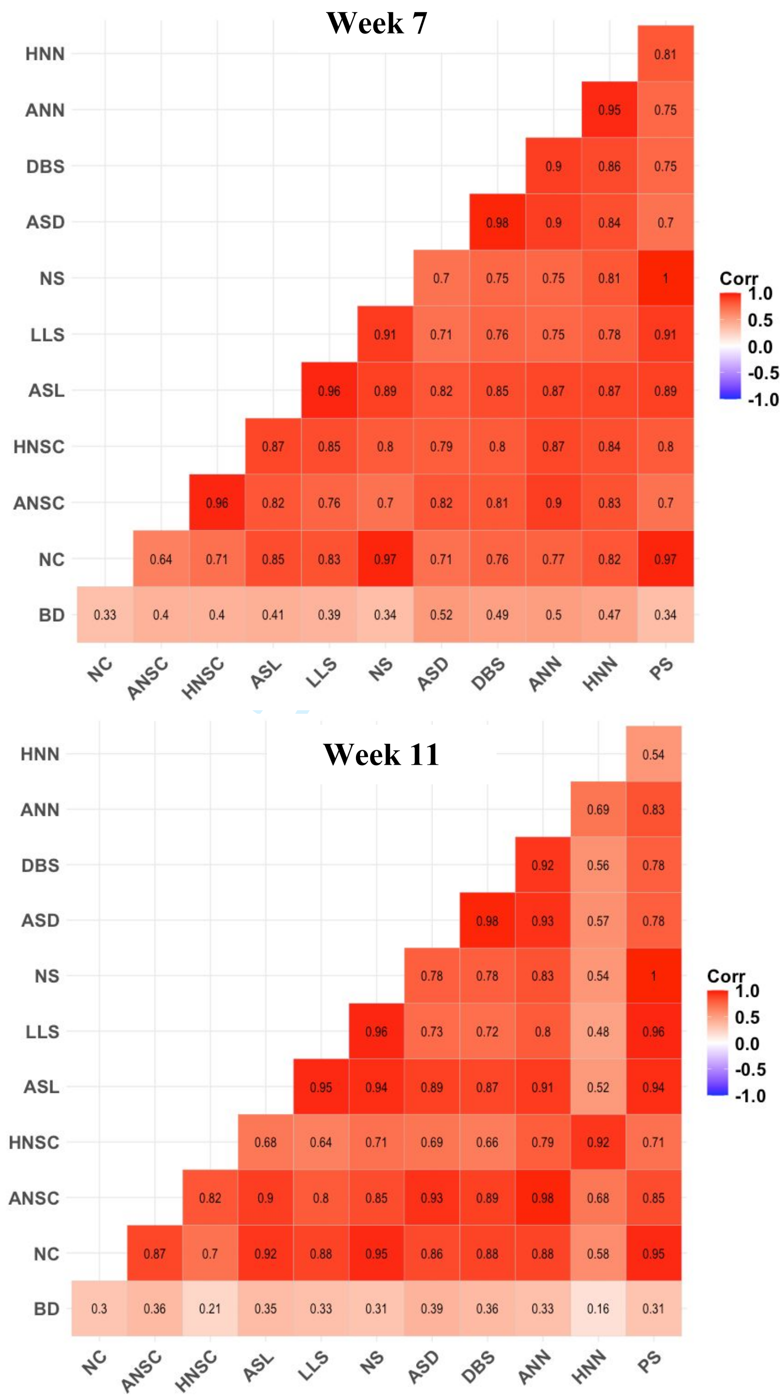

Figure 12: Correlations among shoot traits and branch sizes of *D. philippinensis* after 7 and 11 weeks of planting establishment.