

Production of *Dipteryx odorata* (Aubl.) Willd seedlings with high Quality Standard, making Possible Environmental Valorization

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Abstract— The species *Dipteryx odorata* (Aubl.) Willd. – Fabaceae) is distributed in the Amazon and produces noble wood used for different means; moreover, its seeds are used in the perfume and cosmetics industry, and as medication in folk medicine. Luminosity and substrate affect growth and quality before planting when seedlings are produced in plant nursery. Thus, wood particles of *Ochroma pyramidale* (Cav. ex Lamb.) Urban in substrate supplemented with macro- and micronutrients at 0%, 30%, 50% and 70% shading were used to replace chicken manure in the production with high-quality *D. odorata* seedlings. The experiment was installed in the plant nursery of Tropical Forestry Experimental Station of INPA, in Manaus – AM. It was based on substrates composed of clay soil, sand and chicken manure at ratio 3:1:1/2 of *O. pyramidale* particles to replace manure at ratios 3:1:1/2; 3:1:1 and 3:1:2. The completely randomized design was adopted, to enable factorial (4x4) analysis through ANOVA; means were compared through Tukey test at 5% at 306 days. Height, neck diameter, number of leaves, leaf area and, root, stem, leaf and total dry matter were measured; the survival was evaluated and, quality standard, assessed through the height/neck diameter ratio and Dickson Quality Index. The substrate with half part of *O. pyramidale* particles at 70% shading led to higher growth of *D. odorata* seedlings, to higher quality standards and better survival than chicken manure, allowing environmental valorization through the use of wood and residues of *O. pyramidale* from plantations in the Amazon.

Keywords— Plant nursery, Biometry, Shading and Allocation of assimilates.

I. INTRODUCTION

The forest tree species *Dipteryx odorata* (Aubl.) Willd. – Fabaceae, known as ‘cumaru’, belongs to the climax ecological group and is distributed in the entire

Amazonian region; it is a large-sized plant native to mainland dry forests [1], and can reach 40m high and 150cm DBH [2]. The species is not classified as endangered; it is possible finding three individuals per hectare in natural forests [3].

D. odorata wood is used in civil and naval construction, in lampposts, furniture, laminated wood joinery and railway sleepers due to its life span and because it does not crack due to exposure to sunlight [2] and [4]; overall, logging takes place in natural populations. It is one of the most used woods in the Brazilian Amazon to secondary forest enrichment [5], as well as in Agroforestry Systems [6], besides having high potential to recover degraded areas by itinerant farming [7], and by extensive livestock [8], still fruiting early at 4 years of age [2].

The nuts of *D. odorata* fruits has coumarin, which is a substance used in the perfume and tobacco industries [9], and is used (in small drops) as perfume in moisturizers and shampoos by the cosmetics industry. It is also applied in the manufacture of liqueurs, whisky and vermouth [10]. Folk medicine uses it as diaphoretic or sweaty to treat respiratory and heart issues, to fight intestinal worms and the oil of its nuts is applied to heal mouth ulcer, otitis and scalp issues [2]. It becomes toxic to leaf-cutting ants due to increased coumarin concentration [11], and inhibits the oxidative metabolism of rabbits' neutrophils [12]. Yet, the American Food and Drug Administration (FDA) agency classified this plant as toxic and prohibited its use in food [13]; however, there is poor evidences of its toxicity to human beings in therapeutic doses (1900 higher than the doses acquired through food and cosmetic sources) [14]. In 2014, Pará State was responsible for 87.4% of the national production: 103 tons of *D. odorata* nuts [15]. Given the high potential of the species wood and seeds in planting, or in recovering degraded areas, the production of high-quality standard seedlings is an important factor for forestry development in the region.

Luminosity conditions, and substrate, affect growth in the production of forest species seedlings and cause morphological and physiological changes in interactions with the environment [16]. *D. odorata* seedlings adapt either to sunlight or to partial shading; therefore, they are an option for reforestation and agroforestry systems [9]. On the other hand, the substrate is one of the important inputs directly influencing plant performance in the field [17]; each species prefers a certain combination of substrates [18]. A good substrate must make plants more resistant, mainly at initial planting phases [19].

The use of particles of balsa wood (*Ochromapyramidale* (Cav. ex Lamb.) Urban – Malvaceae (PB) to compose the substrates in the present study was based on the physical-mechanical features and use-diversity of the species, as well as on its fast growth and on the fact that it is native to the Amazon. Seedlings of this species reached approximately 6m high in the first year of plantings focused on recovering areas degraded by itinerant agriculture [20]. Seed production started eight months after planting and it did not present integumentary numbness [21]. Wood can be used in paper and cellulose manufacturing, in boat construction and as ceiling linings [22], in the production of boxes for perishable products, besides being a good thermal isolation [23]. Cellulose nanofibers of the species were obtained [24]. This species has been cultivated by the paper industry in commercial planting in Brazil, in São Paulo State [25]. The planted area in Mato Grosso State covers 7,900 hectares and is in constant expansion [26].

O. pyramidale particles supplemented with macro- and micronutrients were used in the present experiment to allow better use of timber-industry waste and to provide more sustainability to pure and mixed planting, since the branches and stems deriving from thinning and pruning can be used as part of the substrate in seedling production; they can also replace the chicken manure added to substrates used in plant nursery. This manure often has different origins, composition and cure stages, fact that causes heterogeneity and unsafety to the survival and quality of seedlings produced in large scale in the Amazonian region.

The aim of the present study was to find technological alternatives to the production of *D. odorata* seedlings given the potential use of this species wood and seeds in the timber and cosmetics industries, as well as its use in folk medicine in the region. The quality of the seedlings identified through a new substrate with *O. pyramidale* particles, can provide more homogeneity and more sustainable in seedling production of these species appropriate to recover degraded areas, for use in the timber industry and for the production of forestry seeds in pure and mixed planting.

II. MATERIALS AND METHODS

The experiment was installed in the forest nursery of the Tropical Forestry Experimental Station of the National Research Institute of the Amazon, Manaus – AM, which is located in BR-174 Road, Km 43, at geographic coordinates 2°35'00" S and 60°20'00" W (GPS/SAD 69 DATUM).

D. odorata fruits were collected under the canopy of matrix trees in EEST, broken in order to remove the seeds, washed in running water, horizontally sown at 1cm deep in germination boxes filled with washed sand and at the same day.

After germination, seedlings presenting developed first leaf and perfect roots were selected; their root system was thinned 7cm from the root cap in order to standardize root size and to make transplanting easier. Seedlings were transplanted to plastic bags (28x16 cm) with drainage holes on the sides. The bags were filled with different substrate types, which were composed of 3 parts of clay soil (horizon b), 1 part of sand and half part of chicken manure (CM) – dry and pulverized (3:1: ½ PB; 3:1:1 PB and 3:1:2 PB). Chicken manure in the other substrates was replaced by *O. pyramidale* (PB) particles at ratios 3:1: ½ PB; 3:1:1 PB and 3:1:2 PB.

The particles of *O. pyramidale* stems and branches, from plantation to recover degraded areas, were obtained through grinding in wood grinder (Nogueira DPM 4 with 15mm sieve). The stems and branches were sun-dried, immersed in nutritional solution in 1m³ plastic boxes and daily revolved for 3 months. The nutritional solution was composed of macronutrients (N₂: 4%, P₂O₅: 14% and K₂O: 8%) and micronutrients (Ca: 20.6%, S: 3.2%, B: 0.160%, Cu: 0.280%, Mn: 0.320% and Zn: 0.200%) to dilute 3Kg of mineral fertilizer/1000L of water. Subsequently, the particles were once again left to dry in the shade for 30 days in covered shed, without side walls.

D. odorata seedlings were transplanted, but their root caps were kept at substrate level, 1cm below the edge of the plastic bag. After the transplantation, seedlings remained in cover sheds for 30 days; they were subjected to sprinkle irrigation for 5 minutes, twice a day. Next, they were exposed to 30%, 50% and 70% shading treatments in plant nursery covered with black polyolefin Sombrite® screens on the top and sides. The control-treatment garden was subjected to 0% shading and it did not have Sombrite® screen.

Each experimental plot was composed of 35 seedlings, they were distributed in 5 rows with 7 single border seedlings each. In total, 5 seedlings (repetitions) were randomly removed in each evaluation and the remaining ones were rearranged in order to keep the same distance between plants in the useful area and the single border.

Treatments were called T1 – (0% shading at 3:1: ½ CM), T2 – (0% shading at 3:1: ½ PB), T3 – (0% shading at 3:1:1 PB), T4 – (0% shading at 3:1:2 PB), T5 – (30% shading at 3:1: ½ CM), T6 – (30% shading at 3:1: ½ PB); T7 – (30% shading at 3:1:1 PB), T8 – (30% shading at 3:1:2 PB), T9 (50% shading at 3:1: ½ CM), T10 – (50% shading at 3:1: ½ PB), T11 – (50% shading at 3:1:1 PB), T12 – (50% shading at 3:1:2 PB), T13 (70% shading at 3:1: ½ CM), T14 – (70% shading at 3:1: ½ PB), T15 – (70% shading at 3:1:1 PB), T16 – (70% shading at 3:1:2 PB).

The statistical design used to data analysis was entirely randomized at 306 days. The data were analyzed in a factorial scheme (4 x 4), through analysis of variance (ANOVA) and, the means, compared by the Tukey test at 5% probability.

The effects of the treatments on seedling growth were assessed through total height (TH), neck diameter (ND),

number of leaves (NL), leaf area (LA), root dry matter weight (RDW), stem dry matter weight (SDW), leaf dry matter weight (LDW) and total dry matter weight (TDW) measurements. The quality of the seedlings was determined through the Dickson's Quality Index (DQI) ($DQI = TDW / ((H/ND) + (GPDM/RDW))$). GPDM (dry matter of the above ground part) = stem dry matter weight – (SDW) + leaf dry matter weight (LDW)[28]; TH/ND ratio [29] and, through survival at the end of the experiment.

The chemical analyses applied to the substrates were conducted at the beginning, and at the end of experiment [30].

III. RESULTS

3.1 The effects of shading on the growth of *D. odorata* seedlings

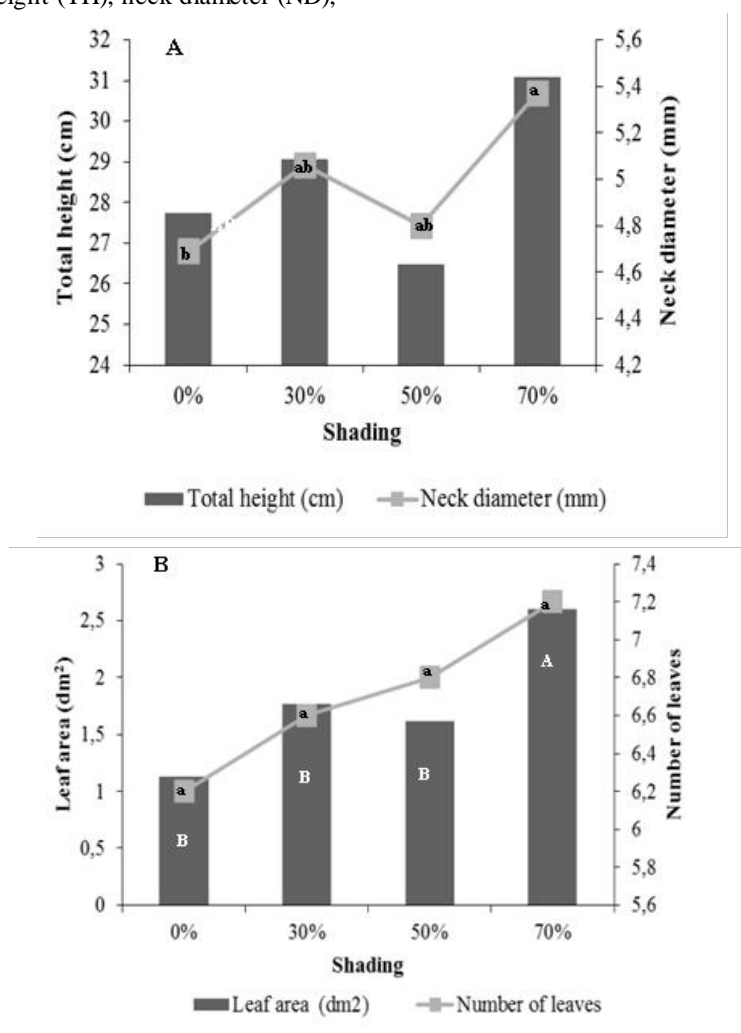


Fig.1: A) Total height and Neck diameter. B) Leaf area and Number of leaves of seedling *Dipteryx odorata* (Aubl) Willd. at 306 days in the nursery in different shading. Means followed by the same capital letter comparing height and leaf area, or followed by the same lower case, comparing stem diameter and number of leaves, did not differ significantly from each other by the Tukey test at 5 % probability

Seedling height at 306 days in nursery did not present variation proportional to the tested shading levels. Height was higher in the treatment at 70% shading than in the one at 50% shading, but treatments at 0% and 30% shading did not record significant differences in comparison to all shadings (Fig. 1A). However, neck diameter at 70% shading was only bigger than that recorded for the treatment at 0% shading; differences

were not significant in treatments with intermediate shading (30% and 50%) (Fig. 1A).

Leaf area had more regular response to the tested shadings; it was significantly larger at 0%, 30% and 50%, whereas the number of leaves did not record differences among all shading conditions (Fig. 1B), but it interacted with the different types of tested substrates (Table 1).

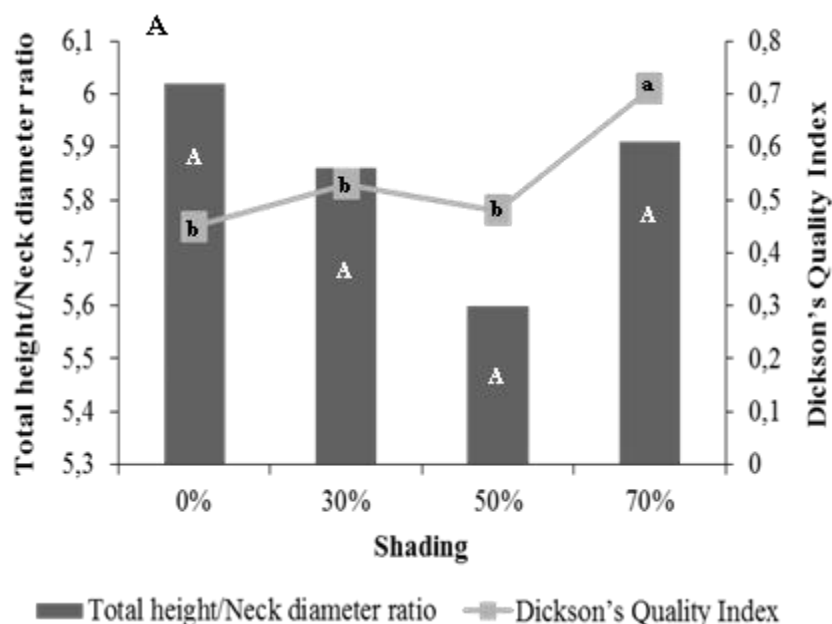
Table 1: Interaction between shading and substratum in the number of leaves of *Dipteryx odorata* (Aubl.) Willd. seedlings at 306 days in nursery.

| Days in nursery | Shading (%) | Substrate | | | |
|-----------------|-------------|-----------|-----------|-----------|----------|
| | | 3:1: ½ CM | 3:1: ½ PB | 3:1:1 PB | 3:1:2 PB |
| 306 | 0 | 5,40 a B | 8,80 a A | 6,20 a AB | 4,40 b B |
| | 30 | 6,20 a AB | 9,20 a A | 6,00 a AB | 5,00 b B |
| | 50 | 4,20 a B | 6,80 a AB | 7,60 a A | 8,60 a A |
| | 70 | 4,00 a B | 8,20 a A | 7,80 a A | 8,80 a A |

Means values followed by different lowercase letters in columns and by uppercase in rows, differ from each other by Tukey test at 5% probability. CM: Chicken manure and PB : Ochromapiramide.

The interaction has shown that there was larger number of leaves at 0% shading in the substrate with half part of *O. pyramidale* (3:1:1/2 PB), and different at 3:1:1 PB. The highest values at the highest shadings (50% and 70%) were observed in substrates with more *O. pyramidale* particles (3:1:1 PB and 3:1:2 PB), although all substrates with *O. pyramidale* particles at 70% shading recorded larger number of leaves than the substrate with chicken manure (Table 1).

Values of the height/neck diameter ratio did not record differences between shadings (Fig. 2A), due to balanced height and diameter growth at significantly shading differences (Fig. 1A). There was no neck diameter difference in the treatment recording the shortest height (50%) in comparison to the treatment at 70% shading. There was also no height difference in the treatment recording the smallest diameter (0%) in comparison to the treatment at 70% shading (Fig. 1A).



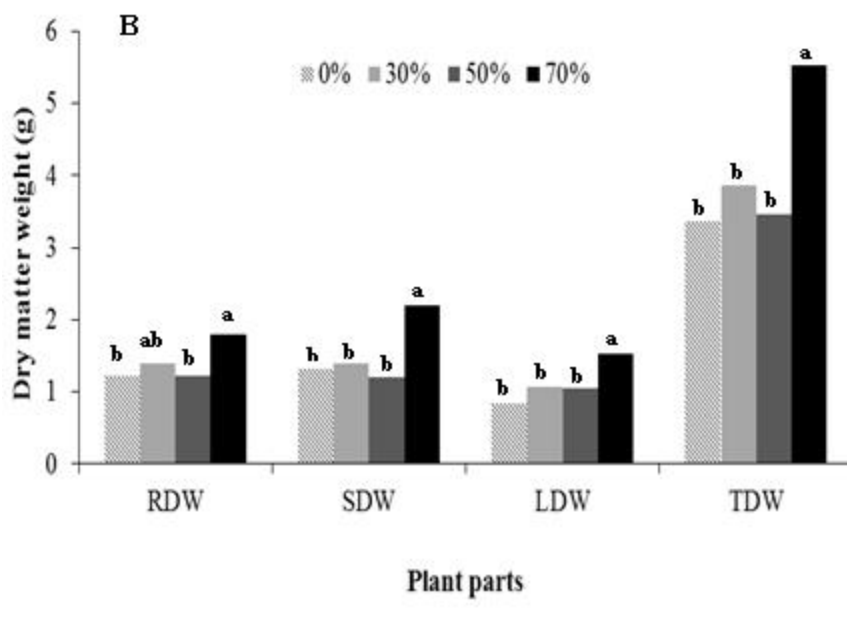
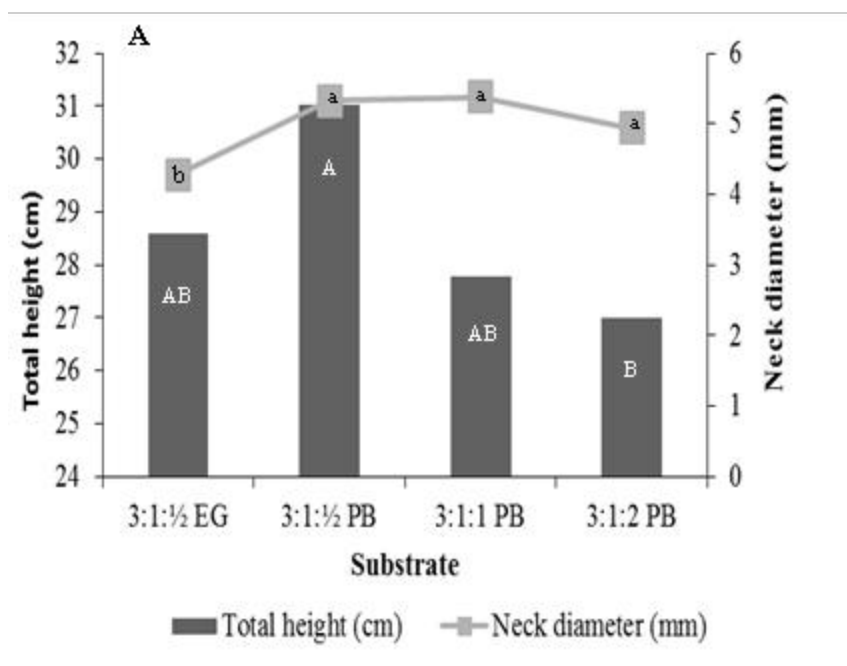


Fig.2: A) Height/Neck diameter ratio (H/ND) and Dickson's Quality Index (DQI). B) Weight dry matter of root (DRW), Stem (DSW), Leaf (DLW) and Total (TDW) of *Dipteryx odorata* (Aubl.) Willd. seedling at 306 days in nursery in different shading. Means followed by the same capital letter compare H/ND ratio, or followed by the same lowercase letter comparing DQI and shading in the dry matter weight, did not differ significantly from each other by the Tukey test at 5% probability.

The highest DQI (0.71) was recorded for the treatment at 70% shading (Fig. 2A), which has resulted from the highest values recorded for dry root, stem, leaf and total dry matter (Fig. 2B), as well as from the non-significant differences between shadings in the H/ND ratio (Fig. 2A). This ratio is one of the components in the formula applied to calculate the index used to evaluate the quality of forest seedlings.

3.2 Effects of substrates on the growth of *D. odorata* seedlings

The highest height in substrate 3:1: ½ PB diminished as the number of *O. pyramidale* particles and chicken manure increased, it was only different from 3:1:2 PB. However, the neck diameter in all substrates with *O. pyramidale* particles was larger than the treatments with chicken manure (Fig. 3A).



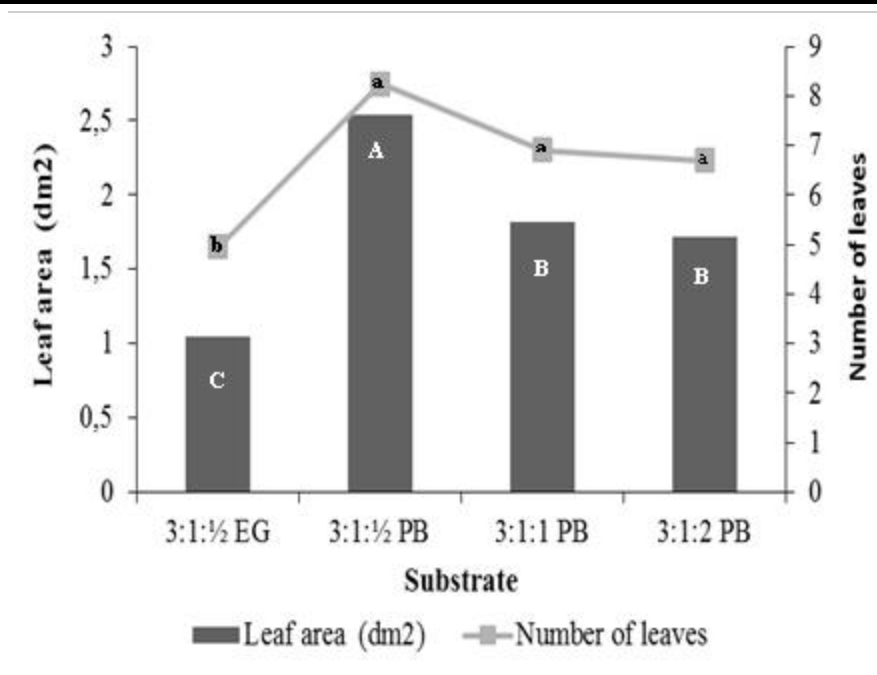
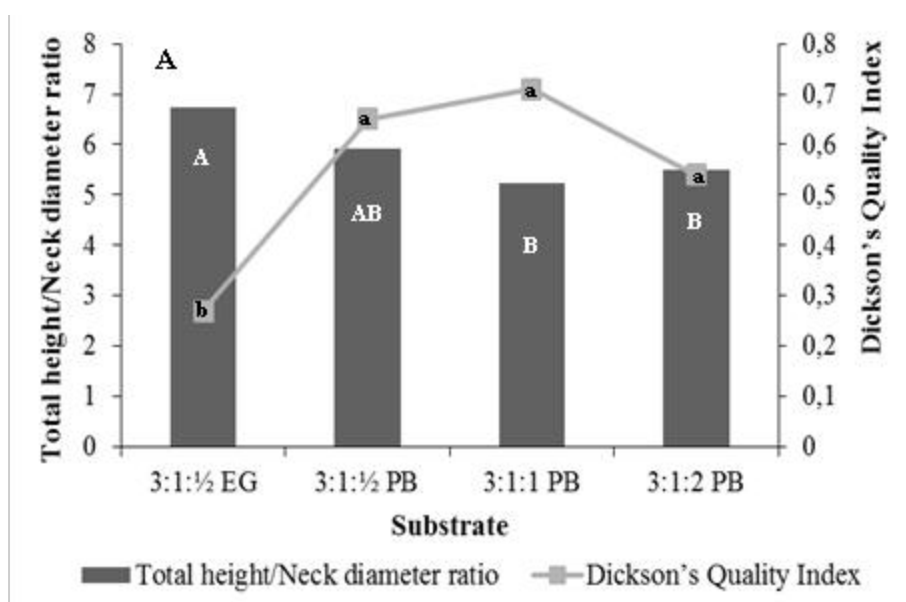


Fig.3: A) Total height and Neck diameter. B) Leaf area and Number of leaves of seedling *Dipteryx odorata* (Aubl) Willd. at 306 days in the nursery in different shading. Means followed by the same capital letter comparing Total height and Leaf area, or followed by the same lower case, comparing Stem diameter and Number of leaves, did not differ significantly from each other by the Tukey test at 5 % probability.

Leaf area in the substrate 3:1: ½ PB with 2.54 dm² was bigger than that in the substrates with *O. pyramidale* particles: mean value 1.77 dm². This value was also higher than that recorded for substrates with chicken manure: mean value 1.05 dm². However, the number of leaves in all substrates with *O. pyramidale* particles recorded mean number 7.28, besides being larger than that recorded for the substrate with chicken manure (Fig. 3B). Each leaf recorded 0.31 dm² in substrate 3:1: ½ PB, on average; in substrates 3:1: 1 PB

and 3:1: 2 PB, both recorded 0.26 dm², and 0.21 dm² in the substrate with chicken manure.

The H/ND ratio recorded the highest value in the substrate with chicken manure, but the value was not different from that of the substrate with less *O. pyramidale* particles (3:1: ½ PB). However, values were lower and significantly different than that of the substrate with chicken manure as the amount of *O. pyramidale* increased (Fig. 4A).



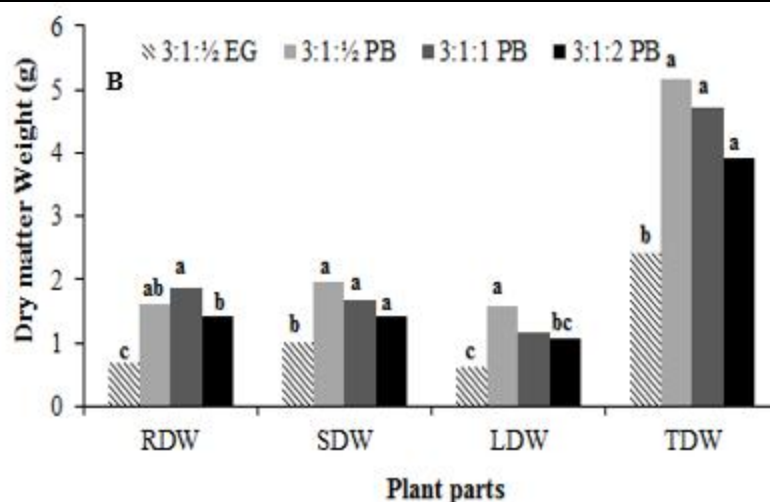


Fig.4: A) Total height/Neck diameter ratio(H/ND) and Dickson Quality Index (IQD). B) Weight of dry matter of root (MSR), Stem (MSC), Leaves (MSF) and Total (MST) of *Dipteryx odorata* (Aubl.) Willd. seedlings, at 306 days in the nursery. Means followed by the same capital letter comparing H/ND ratio, or followed by the same lower case compare IQD and substrates in dry matters did not differ significantly from each other by the Tukey test at 5 % probability.

The Dickinson's Quality Index of *D. odorata* seedlings grown in substrates with *O. pyramidale* particles recorded mean value 0.63 and it was even higher than that with chicken manure: mean value 0.27 (Fig.4A). The substrate 3:1: 1/2 PB stood out among substrates with *O. pyramidale* particles recording the highest DQI values, since there was more growth balance between shoot and root parts. The highest height value was followed by the largest diameter, and the leaf area was followed by the number of leaves (Figs. 3A and 3B). The highest root and leaf dry matter values were observed in 3:1:1 PB, and the dry stem and total matter were higher in substrates with *O. pyramidale* particles (Figs. 4A and 4B).

The lowest DQI value in the substrate with chicken manure mainly resulted from the smallest neck diameter (Fig. 3A), which influenced the height/diameter ratio recording the highest value (Fig. 4A), as well as the lowest values recorded for the roots, stem, leaves and total dry matter (Fig. 4B).

3.3 Effects of shadings and substrates on the survival of *D. odorata* seedlings

Table.2: Chemical characteristics of substrates under 70% shading. In the beginning and end of the experiment at 306 days *.

| Component | 70%/3:1: 1/2 EG | | 70%/3:1: 1/2 PB | | 70%/3:1:2 PB | |
|---|-----------------|------|-----------------|------|--------------|-------|
| | Beginning | End | Beginning | End | Beginning | End |
| OM (g/kg) | 15.72 | 9.02 | 8.10 | 7.41 | 7.65 | 12.25 |
| P (mg/dm ³) | 1016 | 752 | 205 | 22 | 34 | 45 |
| K (mg/dm ³) | 270 | 40 | 60 | 10 | 40 | 17 |
| Ca (cmol _c /dm ³) | 2.32 | 2.37 | 0.58 | 0.54 | 0.56 | 0.74 |
| Mg (cmol _c /dm ³) | 1.68 | 1.66 | 0.11 | 0.10 | 0.13 | 0.13 |
| CEC (cmol _c /dm ³) | 5.12 | 4.36 | 0.93 | 0.96 | 1.03 | 1.06 |

Legend: OM – Organic Matter. CEC - Cations Exchange Capacity.

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The lowest survival rate of cumaru seedlings at all shadings reached 76.8%; it was recorded in substrates with chicken manure and in those with two parts of *O. pyramidale*. On the other hand, the highest mean survival rates were observed in substrates with half, and one part of *O. pyramidale* particles: 90.5% and 93.5%, respectively. However, the 70% shading produced the best quality of *D. odorata* seedlings in the substrate with half part of *O. pyramidale*: 82% survival.

3.4 Chemical characteristics of substrates with chicken manure and *O. pyramidale* particles at 70% shadings at the beginning, and at the end, of the experiment.

The Table 2 shows that, overall, the organic matter (OM) in the substrate with chicken manure recorded higher values at the beginning, and at the end of the experiment based on treatments with *O. pyramidale*, except for that with two parts of *O. pyramidale*. This treatment recorded higher value at the end of the experiment (12.25 g/kg) than that recorded for the substrate with chicken manure (9.02 g/kg).

Values observed for the treatment with one part of *O. pyramidale* particles (3:1:1 PB) were not shown in Table 1, because they did not show differences in the assessed variables in comparison to the other treatments with *O. pyramidale* particles. Phosphorus (P) and organic matter (OM) values in substrate with chicken manure, and half part of *O. pyramidale* particles, diminished in the final evaluation, but they increased from 7.65 to 12.25 g/kg, and from 34 to 45 mg/dm³, respectively, in the substrate with two parts of particles. Potassium (K) diminished in all treatments. Calcium (Ca) and Magnesium (Mg) values, and the ability to effectively exchange cations (CTCt) had little, or no, variation between the beginning and the end of the experiment.

IV. DISCUSSION

4.1 Effects of shading

The height variation in *D. odorata* seedlings was not proportional to the levels of tested shading at 306 days in nursery, and this outcome evidences the species adaptation to more shaded environments. The evaluations conducted at 81 days showed that the 50% shading only generated higher heights than the 0% shading. Based on the evaluation at 201 days, the 70% shading recorded higher heights than the 30% one and, at the 306 days, height at 70% shading was only higher than at 50% shading [31]. Thus, height growth at the highest shading rate (70%) got more intense with time, whereas seedlings under lower shading returned to the same height values. The effects of shading on the height of *D. odorata* seedlings were also observed in seedlings of other climatic forest species. However, *Copaifera langsdorffii* (copaiba) seedlings had growing linear response in variable 'height' due to increased shading [16], which is a characteristic result for climax species.

Height is the most often used parameter to assess plant growth responses to intense lighting, since plants grow faster under shading - an adaptation mechanism and valuable strategy to escape shading [16]. Height growth must be related to neck diameter when it comes to express growth balance and to determine quality standards, but it must be followed by other morphological and physiological parameters [29].

Neck diameter growth in *D. odorata* seedling at 306 days grown in nursery was proportional to shading increase, but there were differences in values recorded for treatment without shading (0%) and the one using the highest shading rate (70%). Therefore, the highest height (31.10cm) and the largest diameter (5.37cm) were recorded for *D. odorata* seedlings at 70% shading, which also allowed better growing balance and quality standards. Better growth balance can determine higher quality standards before planting [29]. Moreover, forest

species seedlings presenting height ranging from 20 to 35cm, and diameter between 5 and 10mm, have good quality [32].

The height/neck diameter ratio (H/ND) in *D. odorata* seedlings have changed and tended to get steady due to height and neck diameter growth, mainly at 70% shading. This shading rate only generated larger diameter than the 0% shading; however, height was lower at 50% shading and the diameter did not show significant difference between shadings. Values recorded for the H/ND ratio ranged from 5.60 to 6.02. The variation recorded for *Pinus taeda* ranged from 5.4 to 8.1 and this outcome expresses growth balance; therefore, it can be used to determine the quality standards before planting, although it must be followed by other morphological and physiological parameters [29].

Among other morphological parameters, the leaf area was higher at 70% shading in comparison to other shading rates. However, as the number of leaves did not show differences between shadings, it is possible saying that the higher the shading the bigger the leaves and, consequently, the higher the dry mass weight, which evidences that leaf expansion resulted from cell multiplication. The strong effects of higher shading were also observed in the integration between shadings and substrates, mainly when the number of leaves did not change at higher shading in all substrates with *O. pyramidale* particles, although the number was larger than that recorded for plants grown in substrates with chicken manure. The number of leaves in *Cassia grandis* seedlings in the interaction between shading at 50% and substrates with soil+bovine manure (2:1) and with soil+sand+bovine manure (1:2:1) was larger than that in the substrate with soil+sand (1:1) [33].

The leaf expansion under low lighting is a frequent response, and it indicates that plants compensate, or inflict better use, under such conditions [34], and somehow, they invest more photo-assimilates in area expansion in order to maximize light capture by thin leaves, since they have larger area and lower density [35]. Leaf area in cumaru seedlings at 70% shading grew more proportionally than the dry leaf mass weight: mean specific leaf area 1.70 cm²/g.

The number of leaves was lower in *Hymenaea courbaril* and *Enterolobium contortisiliquum* seedlings under full sunlight than that of seedlings grown on the shade [36]. The number of leaves is an important indicator of this strategy, as well as biomass allocation in the leaves [37]. Shading also caused morphological and physiological changes in *H. courbaril* seedlings in order to increase light absorption and to maximize carbon gains [36].

The highest root, stem and leaf dry mass values recorded for *D. odorata* seedlings prevailed at 70% shading, and

the same outcome was observed in height and neck diameter. These numbers corroborate the statements by [38], about the existing relation among root biomass, neck diameter and root growth, and the interdependence to shoot growth. Similar results were observed in *Copaiferalangsdorffii* seedlings, which recorded more root dry mass at higher shadings [16]. The root dry mass in *Swieteniamacrophylla* seedlings at 50% was higher than that recorded for plants at 0% shading [39].

By taking into account the minimal value for [40], it is possible saying that the higher the value, the better the quality of the seedlings [41]. The highest value recorded for seedlings of climax species *D. odorata* (0.71) concerned 70% shading, this outcome indicates that the production of higher quality *D. odorata* seedlings depends on high shading levels. *Simarouba amara* seedlings – which is a species belonging to an initial intermediate ecological succession group – recorded DQI 0.69 at 50% shading [43]. This outcome evidences that DQI reflects, and follows, the characterization of the ecological group the species is classified in.

Accordingly, *D. odorata* seedlings can be recommended for nursery cultivation at any of the tested shadings, but these seedlings recorded higher dry biomass and growth balance between shoot and root at 70% shading.

4.2 Effects of the substrates

The highest height recorded for *D. odorata* seedlings was observed in the substrate 3:1:½ PB; it was only higher than that recorded for the substrate 3:1:2 PB. This outcome evidenced that only half part of *O. pyramidale* particles is the sufficient physical and nutritional condition to keep this variable growing in nursery; moreover, this value can be compared to the substrate with chicken manure. But, height growth must be related to neck diameter in order to express growth balance and to determine the quality standards; besides, it must be followed by other morphological and physiological parameters [29].

Neck diameter in substrates with *O. pyramidale* particles was larger than that recorded for substrates with chicken manure. This outcome also evidences that these substrates allow more balanced growth in *D. odorata* seedlings. By taking into account that forest species seedlings must measure from 5 to 10mm [32], it is possible saying that *D. odorata* seedlings were within this interval: 5.2mm in 1:½ PB, and 5.38mm in 3:1:1 PB. *T. impetiginosa* seedlings recorded neck diameter 6mm in the substrate with organic compounds and climax species, and their heights were higher in the substrate with underground sand and organic composites than seedlings treated with manure (22.5%) [45].

The highest leaf area growth was observed in the substrate 3:1: ½ PB, which was followed by the number of leaves, whereas the other substrates with *O. pyramidale* particles recorded leaf number growth relatively higher than the growth recorded for leaf area. This outcome evidences that each leaf had smaller leaf area. Substrate 3:1:½ PB led to more leaf expansion, i.e., bigger leaves with higher dry mass, which shows that expansion resulted from cell reproduction and helped generating higher shoot dry mass at the allocation of assimilates.

Leaf area and number of leaves in *Mimosa caesalpiniaefolia* seedlings were higher in substrates with coconut powder, it reached 77.2cm² leaf area and 16.8 leaves in the substrate with soil+coconut powder [46]. *Calophyllum brasiliense* seedlings recorded the largest leaf areas in the substrate with 101 Kg.m⁻³ of bovine manure, which was 18.9% higher in the substrate without manure; 24.8% in the in substrates with 175 Kg.m⁻³ manure and 47.1% in the substrate with 229 Kg.m⁻³ [45]. The addition of bovine manure to the substrate used for *Caesalpinia ferrea* also allowed larger leaf area [47].

The relative diameter higher than the height growth in the substrates with *O. pyramidale* particles made the H/ND ratio in substrates 3:1:1 PB and 3:1:2 PB adopted for *D. odorata* lower than that recorded for substrate 3:1: ½ EG; however, substrate 3:1:½ PB did not show results different from those of the other substrates, and it resulted in proportional diameter and height growth.

Although height growth was followed by diameter growth in substrate 3:1:½ PB, leaf area and number of leaves also showed proportional growth, as well as the highest relative values recorded for root, stem, leaf and total dry masses. This outcome expresses higher growth balance between shoot and root and evidences higher-quality forest seedlings. These results corroborate indication by [29], about height growth, which must be related to neck diameter, and followed by other morphological and physiological parameters in order to express growth balance and to determine the quality standards of forest species seedlings. Thus, these outcomes showed that the H/ND ratio must not be taking into consideration alone, as well as record the lowest value in order to classify, or determine, the quality standards of forest seedlings.

The H/ND ratio ranged from 6.13 to 8.73 in *Araucaria angustifolia* in the mixture with Plantmax, sieved organic compound and vermiculite (mean particle size) added with slow-release fertilizer doses (Basacote®) in the base substrate. The highest value in the highest Basacote® value ranged from 5.34 to 6.39 in *Ocotea odorifera* [48]. The value in the substrate 3:1:½ PB was 5.92 in *D. odorata* seedlings.

The Dickinson's Quality Index in *D. odorata* seedlings, and in the substrates with *O. pyramidale* particles, had mean value 0.63, it was higher than that of the substrate with chicken manure (0.27) at 70% shading, at 306 days, in nursery. This outcome indicates higher quality seedlings when one takes into account that the minimal value suggested by [40] is 0.20 and that, the higher this value, the better the quality of the seedlings [41]. The highest growth balance in the seedlings of forest species reflects the accumulation of reserves, and assures higher resistance and better fixation in the soil by reducing plant tipping, death or deformation that can compromise the forestry value of the seedlings [49].

Phosphorus and potassium had positive effect on [50], in *Eucalyptus grandis* seedlings grown in the substrate with 80% organic composite and 20% fertilized coal mill with, or without, nitrogen. DQI was higher in *Caesalpinia ferrea* seedlings (0.50) under full sunlight and grown in substrates with bovine manure in comparison to the sloppy substrate (soil from granite and gneisses with partially decomposed minerals – sandy or silty, with low clay content) [47].

Substrate 3:1:½ PB was composed of less *O. pyramidale* particles in the present experiment. It could be cheaper and promising to *D. odorata* seedlings presenting higher standard quality to replace chicken manure, besides providing environmental gains by enabling more wood use and wood waste from sawmills, thinning and pruning in pure, or mixed, planting focused on recovering degraded areas. It happens because since this species has high forestry potential for such means, based on [7] and [8].

D. odorata seedlings also recorded higher survival rates in the treatments with the highest shading (70%) and lowest shading (0%), as well as in substrates with chicken manure and with two parts of *O. pyramidale* particles (3:1:2 PB). However, they recorded longer survival in the substrate with half (3:1:½ PB), and with one, part of (3:1:1 PB) *O. pyramidale* particles. This outcome evidences that the most balanced growth leads to higher quality standards and longer survival. The survival of *Copaifera langsdorffii* seedlings – climax species – also recorded shorter survival under full sunlight; however, it was higher at 50% shading, but there were no significant differences between the tested substrates [16].

With regard to the composition of the substrates, the increase or maintenance of pH, organic matter (OM), phosphorus (P), Calcium (Ca), Magnesium (Mg), sum of bases (SB), ability to effectively exchange cations (CTC – 1) and the ability to exchange cation at pH 7.0 (CTC – T), in the substrate with two parts of *O. pyramidale* (3:1:2 PB), and at the highest shading (70%), was observed between evaluations at the beginning, and the end, of the

experiment. It likely resulted from the highest composition of particles (two parts), and from their highest decomposition, through the 306 days in the nursery, which generated more organic matter in the environment with higher shading. Consequently, the content and composition of these components in *O. pyramidale* particles, so far not decomposed, were released as decomposition took place. On the other hand, and by taking into account the absorption of nutrient by *D. odorata* seedlings, the leaching throughout the experimental period also led to the accumulation of these components in the substrate. However, the interaction between shading and the chemical composition of the substrate did not allow higher growth of *D. odorata* seedlings showing higher quality standards in comparison to the substrate with half part of *O. pyramidale* particles (3:1:½ PB).

However, the treatment with half part of *O. pyramidale* particles (3:1:½ PB) at 70% shading generated the seedlings with the highest quality standards. The contents of pH, organic matter and Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sum of bases (SB), Ability to Effectively Exchange Cation (CTC – t) and Ability to Exchange cation at pH 7.0 (CTC – T) decreased between the beginning, and the end, of the experiment due to the possible higher ability to absorb nutrients. Besides, thus treatment allowed leaching, and produced higher growth throughout the assessed period, as well as high quality standards. Yet, at the end of the experiment, pH, organic matter, Phosphorus (P), Calcium (Ca) and Magnesium (Mg) contents in this treatment were higher than the ones observed in the soil solution 40-60cm down into the ground, and the in the mainland dry forests subjected to selective wood extraction in Central Amazon [51].

V. CONCLUSIONS

D. odorata seedlings grew with better balance between shoot and roots, higher quality standards for forest species in the nursery and high survival, on the substrate with 3 parts of clay soil (Horizon b), 1 part of sand and half part of *Ochroma pyramidale* particles (3:1:½ PB) supplemented with macro- and micronutrients at 70% shading. Under these conditions, this substrate replaced the chicken manure (3:1:½ CG) to produce *D. odorata* seedlings, besides allowing environmental valorization through the use of wood and residues of *O. pyramidale* from plantations to recovery degraded areas or production in the Amazon.

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