Reflective material in the formation of *Dipteryx alata* seedlings

Material refletor na formação de mudas de *Dipteryx alata*

Material reflectante en la formación de plántulas *Dipteryx alata*

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Abstract

The study aimed to evaluate the influence of reflective materials on the cultivation bench and the use of rice husks over the substrate in the formation of *Dipteryx alata* seedlings. The experiment was carried out in the experimental area of the Mato Grosso do Sul State University, in Cassilândia-MS, from November 1st, 2016 to January 26th, 2017. A completely randomized design in a 5 x 2 factorial scheme was used, with five replications and five plants per plot. Four reflective material for the cultivation bench and treatment without reflective material (control), combined with or without rice husks over the substrate (0.5 cm layer), were evaluated. Laminated paper tray, mirror, reflective fabric (known as “fake sequin fabric”), and aluminum foil were used as reflective materials. The reflecting materials did not differ in the reflectance of photosynthetically active radiation. However, the mirror and the aluminum foil reflected more than the control. The use of rice husk over the substrate did not increase the *Dipteryx alata* seedlings' quality. The mirror as a reflective material produced *Dipteryx alata* seedlings of higher quality than the system without material reflector called control.

Keywords: Baru; Photosynthetically active radiation; Mirror.

Resumo

O estudo teve como objetivo avaliar materiais refletores sobre a bancada de cultivo e a proteção do substrato com palha de arroz na formação de mudas de *Dipteryx alata*. O experimento foi conduzido na área experimental da Universidade Estadual de Mato Grosso do Sul, em Cassilândia, no período de 01 de novembro de 2016 a 26 de janeiro de 2017. Foi utilizado o delineamento inteiramente casualizado em esquema fatorial de 5 x 2, com cinco repetições e cinco plantas por parcela. Quatro materiais reflexivos sobre a bancada e um tratamento sem material reflexivo (controle), combinados com e sem cascas de arroz sobre o substrato (camada de 0,5 cm). Os materiais refletores utilizados foram a bandeja de papel laminado, o espelho, um tecido denominado de “falso paetê” e o papel alumínio. Os materiais refletores não diferiram entre si na reflectância da radiação fotossinteticamente ativa, contudo, o espelho e o papel alumínio refletiu mais que o controle. O uso de casca de arroz sobre o substrato não aumentou a qualidade das mudas de *Dipteryx alata*. O espelho como material refletor produziu mudas de *Dipteryx alata* de maior qualidade que o sistema sem refletor material, denominado controle.

Palavras-chave: Baru; Radiação fotossinteticamente ativa; Espelho.

Resumen

El estudio tuvo como objetivo evaluar la influencia de los materiales reflectantes en el banco de cultivo y el uso de cáscaras de arroz sobre el sustrato en la formación de plántulas de *Dipteryx alata*. El experimento se llevó a cabo en el área experimental de la Universidade Estatal de Mato Grosso do Sul (UEMS), en Cassilândia-MS, del 1 de noviembre de 2016 al 26 de enero de 2017. Un diseño completamente al azar en una factorial de 5 x 2 esquema fue utilizado, con cinco repeticiones y cinco plantas por parcela. Se evaluaron cuatro materiales reflectantes en el banco de cultivo y tratamiento sin material reflectante (control), combinado con o sin cáscaras de arroz sobre el sustrato (capa de 0,5 cm). Bandeja de papel laminado, un espejo, tela reflectante (conocida como "fake sequin fabric"), y se utilizó una lámina de aluminio como materiales reflectantes. Los materiales reflectantes no diferían en la reflectancia de la radiación fotosintéticamente activa, sin embargo, el espejo y la lámina de aluminio reflejaban más que el control. El uso de cáscara de arroz en el sustrato no aumentó la calidad de las plántulas de *Dipteryx alata*. El espejo como material reflectante produjo plántulas *Dipteryx alata* de mayor calidad que el sistema sin material reflector, llamado control.

Palabras clave: Baru; Radiación fotosintéticamente activa; Espejo.

1. Introduction

Among the plant species of the Cerrado biome, *Dipteryx alata* Vogel, known as Baru, is one of eight fruit trees of interest for sustainable use in the short term (Vieira et al., 2016). This tree species produce a nutritious nut, appreciated in natural or processed, with high commercial value (Paglarini et al., 2018), can be used in the reforestation of degraded areas, and its presence contributes to the return and maintenance of the biome’s fauna. *Dipteryx alata* seedlings are obtained via seed that promotes high germination, emergence, and field survival, thus being a promising species for commercial cultivation or use in the recovery of degraded areas (Oliveira et al., 2019, Silva et al., 2019).

Many studies have shown that seedlings with high quality can be obtained according to appropriate choices of specific techniques or technologies, among them the following can be highlighted: the use of suitable substrate (Gomes & Freire, 2019), the percentage of shading that the species best adapts (Felsemburgh et al., 2016), the sowing depth (Montanha et al., 2018), the volume of the cultivation container (Miranda et al., 2018), the protection of the substrate with some type of coverage (Tsukamoto Filho et al., 2013).

According to the reports by Salles et al. (2017), as well as those by Santos et al. (2017), the use of material increase the quality of seedlings that reflect the photosynthetically active radiation (PAR) by placing reflective structures on the cultivation bench. These can enlarge the reflection of radiation used by the plant physiology and enable the increase of biomass. However, it is necessary to study for each plant species, due to the morphophysiological variation linked to the genetic characteristic concerning taking advantage of the photosynthetic radiation made possible by the reflective material.

Given the above, this study aimed to evaluate the use of reflective materials on the cultivation bench, and with or without rice husk over the substrate in the formation of *Dipteryx alata* seedlings.

2. Material and Methods

The experiment was carried out in the experimental area of the Mato Grosso do Sul State University (UEMS), in Cassilândia-MS, from November 1st, 2016 to January 26th, 2017. A protected environment (agricultural greenhouse) was used, with a galvanized steel structure, 8.00 m wide by 18.00 m long and 4.00 m high, covered with 150-micron low-density polyethylene film and thermo-reflective screen (Aluminet®) with 50% shading under the film.

A completely randomized design in a 5 x 2 factorial scheme was used, with five replications and five plants per plot. Four reflective materials on the cultivation bench and treatment without reflective material (control), combined with or without rice husks over the substrate, were evaluated. Laminated paper tray, mirror, reflective fabric (known as “fake sequin fabric”), and aluminum foil were used as reflective materials, each one with 1.2 m^2 (1.0 x 1.2 m).

Polyethylene plastic bags (15.0 x 25.0 cm), with a capacity of 1.8 dm^{-3}, filled with substrate were used to produce *Dipteryx alata* seedlings. The substrate was composed of 20% cattle manure, 30% soil, 30% sand and 20% vermiculite. The substrate had the following chemical characteristics: $pH_{(CaCl)}$: 4.6, Ca: 2.00 $cmol_c\ dm^{-3}$, Mg: 3.40 $cmol_c\ dm^{-3}$, Al: 0.15

$cmol_c$ dm^{-3}, Cu: 0, 5 mg dm^{-3}, Fe: 159.0 mg dm^{-3}, Mn: 47.0 mg dm^{-3}, Zn: 7.6 mg dm^{-3}, O.M. 36.1 g.dm^{-3}), CTC: 9.3 $cmol_c$ dm^{-3}, base saturation: 62.2%.

Two seeds were sown per plastic bag on November 1st, 2016, and the emergence was observed 14 days after sowing (DAS), on November 15th, 2016. After the formation of three definitive leaves, thinning was performed (with the aid of scissors), leaving the seedling more developed.

At 80 DAS, plant height (PH), stem diameter (SD), number of leaves (NL), shoot dry matter (SDM), and root dry matter (RDM) were evaluated. The relative chlorophyll index (RCI) was obtained using a digital chlorophyll meter. After evaluations, the followings ratios, plant height/stem diameter (PH:SD), plant height/shoot dry matter (PH:SDM), shoot dry matter/root dry matter (SDM:RDM), root dry matter/total dry matter (RDM:TDM) were estimated. The following equation obtained the Dickson quality index (DQI) DQI = [TDM/(PH/SD)+(SDM/RDM)].

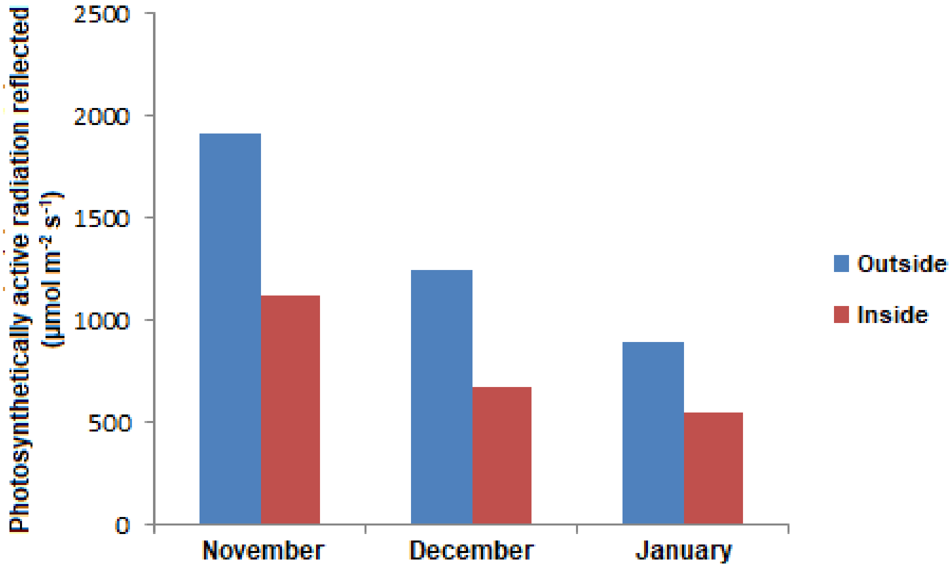
At 10 am, the reflected photosynthetically active radiation (micromol $m^{-2}s^{-1}$) from each material (treatment) was collected with the device facing downwards at an average distance of 20 cm from the reflective material, and the incident photosynthetic active radiation (micromol m^{-2} s^{-1}) inside and outside the protected environment with the equipment facing upwards. For such evaluations, the Apogee model MP-200 was used.

The data were submitted to analysis of variance (F test), and the Tukey test compared the means at 5% probability. The reflected photosynthetically active radiation data were transformed into $\sqrt{(x + 0.5)}$. Subsequently, through multivariate analysis, the correlation of variables was analyzed. Statistical analyses were performed using software R version 3.6.1 (R, 2019).

3. Results and Discussion

Figure 1 shows the photosynthetically active radiation in the cultivation environment and the external environment.

Figure 1. Photosynthetically active radiation outside and inside the protected environment from November 1st, 2016 to January 25th, in Cassilândia-MS, 2017.



Source: Authors.

The photosynthetically active radiation (PAR) inside the protected environment is around 58,3% of PAR outside of the protected environment. The polyethylene film associated with the thermo-reflective screen allowed the passage of almost 60% of the external radiation (Figure 1). Table 1 shows the photosynthetically active radiation reflected by the reflective materials in the cultivation benches.

Table 1. Photosynthetically active radiation reflected (µmol m^{-2} s^{-1}) in reflective materials on the cultivation bench, from November 1st, 2016 to January 25th, in Cassilândia-MS, 2017.

Reflective material	November	December	January
Control	28.90[1] c	18.10[1] b	17.10[1] b
Reflective fabric	92.00 b	64.20 a	42.70 ab
Laminated paper tray	98.40 b	49.00 ab	42.00 ab
Aluminum foil	151.20 a	68.30 a	49.20 a
Mirror	123.90 ab	95.80 a	65.40 a
Mean square	65.17**	38.50**	17.68**
C.V (%)	15.45	29.51	30.44

** significant at 1% probability by the F test. Means followed by distinct letters in the columns differ by the Tukey test at 5% probability. [1]Original means and statistical analysis with the data transformed into $\sqrt{(x + 0.5)}$. Source: Authors.

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There was a difference in the reflected RFA between the reflective materials ($p < 0.01$), and these were superior to treatments without reflective material (Table 1).

Table 2 shows the summary of the analysis of variance for reflective material on cultivation bench, and with or without rice husk over the substrate.

Table 2. Summary of analysis of variance for the variables evaluated on *Dipteryx alata* seedlings produced using reflective material on the cultivation bench, and with or without rice husk over the substrate, in Cassilândia-MS, 2017.

S.V	PH	SD	NL	RCI	SDM	RDM
RM	7.200^{ns}	0.232^{ns}	0.193^{ns}	17.201^{*}	1.880^{**}	0.752^{*}
RH	28.110^{ns}	0.124^{ns}	0.269^{ns}	60.412^{**}	3.929^{**}	0.138^{ns}
RM*RH	11.353^{ns}	0.318^{ns}	0.025^{ns}	4.526^{ns}	0.412^{ns}	0.448^{ns}
C.V (%)	13.8	7.16	5.84	11.01	16.57	28.89
S.V	TDM	H:D	S:R	R:T	H:S	DQI
RM	4.676^{**}	0.131^{ns}	0.707^{ns}	0.004^{ns}	1.076^{ns}	0.215^{*}
RH	2.594^{ns}	0.526^{*}	1.455^{*}	0.026^{*}	0.858^{ns}	0.018^{ns}
RM*RH	1.679^{ns}	0.160^{ns}	0.139^{ns}	0.002^{ns}	0.547^{ns}	0.092^{ns}
C.V (%)	17.89	12.03	26.02	18.46	17.09	24.65

S.V. Source of variation; ^{ns}not significant; ** and * significant at 1% and 5% probability by the F test.
Source: Authors.

The reflective materials on the bench, the rice husks on the substrate, and the interaction between these two factors did not influence the stem diameter (SD), number of leaves (NL), and the plant height/shoot dry matter ratio (H:S) (Table 2). The reflective materials influenced the root and total dry matter, and the Dickson quality index. The variables, plant height, and the ratios, plant height:stem diameter, shoot dry matter:root dry matter, and root dry matter:total dry matter were influenced only using rice husks on the substrate. The relative chlorophyll index and shoot dry matter were affected by the interaction between the two factors (Table 2).

Table 3 shows the plant height, stem diameter, number of leaves, and relative chlorophyll index of seedlings in the reflective material on the cultivation bench and with or without rice husk over the substrate.

Table 3. Plant height (PH), stem diameter (SD), number of leaves (NL), and relative chlorophyll index (CL) of *Dipteryx alata* seedlings produced using reflective material on the cultivation bench, and with or without rice husk over the substrate, in Cassilândia-MS, 2017.

Reflective material	PH (cm)	SD (mm)	NL (nº plant^{-1})	RCI
Control	15.56	5.78	6.3	*20.16 ab
Laminated paper tray	16.80	5.73	6.54	18.60 b
Mirror	17.83	5.96	6.65	21.45 ab
Reflective fabric	16.31	5.55	6.55	21.92 a
Aluminum foil	17.05	5.86	6.33	19.96 ab
With rice husk	15.96 b	5.73	6.46	19.32 b
Without rice husk	17.46 a	5.83	6.61	21.52 a

*Means followed by distinct letters in the columns differ by the Tukey test at 5% probability.
Source: Authors.

The highest value found in the relative chlorophyll index was obtained with the use of the reflective fabric on the bench. The absence of rice husks over the substrate promoted the highest relative chlorophyll index (Table 3).

The physiological changes caused using the reflective material were evaluated by the relative chlorophyll index (Table 3). The relative chlorophyll index is an indirect assessment related to the chlorophyll content of the vegetable, which can be applied in the field in a simplified way, with a good relationship with traditional methods of chlorophyll content. According to Porto et al. (2014), it is a method that also allows the diagnosis of nitrogen levels in the plant. The relative chlorophyll index has the advantage of being a non-destructive method for assessing chlorophyll content. It is also used to ascertain abiotic stresses, besides to be a parameter for determining plant stress due to water deficiency (Silva et al., 2014).

Table 4 shows the root dry matter, shoot dry matter, and total dry matter of seedlings in the reflective material on the cultivation bench, and with or without rice husk over the substrate.

Table 4. Root dry matter (RDM), shoot dry matter (SDM), and total dry matter (MST) of *Dipteryx alata* seedlings produced using reflective material on the cultivation bench, and with or without rice husk over the substrate, in Cassilândia-MS, 2017.

Reflective material	RDM	SDM	TDM
	------------------------ g plant^{-1}	------------------------	
Control	*1.52 b	*3.18 b	*4.69 b
Laminated paper tray	1.67 ab	3.38 b	5.05 b
Mirror	2.23 a	4.28 a	6.51 a
Reflective fabric	1.93 ab	3.39 b	5.31 ab
Aluminum foil	1.74 ab	3.72 ab	5.45 ab
With rice husk	1.87	3.31 b	5.17
Without rice husk	1.76	3.87 a	5.63

*Means followed by distinct letters in the columns differ by the Tukey test at 5% probability.
Source: Authors.

The use of the mirror on the bench provided a higher accumulation of total dry matter in the *Dipteryx alata* seedlings, differing from the treatment without reflective material (Table 4).

The growth variables are essential to determine the moment and quality of seedlings that will be taken to the field. Considering only the plant height can be a mistake, as the etiolated seedlings are larger than healthy seedlings (Taiz et al., 2017).

Table 5 shows the plant height/stem diameter ratio, plant height/shoot dry matter ratio, shoot dry matter/root dry matter ratio, root dry matter/total dry matter ratio, and Dickson quality index of seedlings in reflective material on the cultivation bench, and with or without rice husk over the substrate.

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Table 5. Plant height/stem diameter ratio (H:D), plant height/shoot dry matter ratio (H:S), shoot dry matter/root dry matter ratio (S:R), root dry matter/total dry matter ratio (R:T), and Dickson quality index (DQI) of *Dipteryx alata* seedlings produced using reflective material on the cultivation bench, and with or without rice husk over the substrate in Cassilândia-MS, 2017.

Reflective material	H:D	H:S	R:T	S:R	DQI
Control	2.69	5.05	0.31	2.52	*0.95 b
Laminated paper tray	2.93	5.02	0.32	2.06	1.02 ab
Mirror	2.98	4.27	0.34	1.94	1.34 a
Reflective fabric	2.94	4.91	0.36	1.85	1.13 ab
Aluminum foil	2.92	4.63	0.32	2.30	1.07ab
With rice husk	2.79 b	4.91	0.35 a	1.95 b	1.12
Without rice husk	2.99 a	4.64	0.31 b	2.29 a	1.08

*Means followed by distinct letters in the columns differ by the Tukey test at 5% probability.
Source: Authors.

When evaluating the seedling quality indexes, it is possible to observe that, despite the ratios H:D, H:S, S:R, and R:T did not present differences regarding the reflective materials; the Dickson quality index demonstrates that the use of the mirror on the cultivation bench resulted in higher quality seedlings than those produced without reflective material (Table 5).

The use of the mirror as a reflective material on the cultivation bench was beneficial for the quality of *Dipteryx alata* seedlings. This material could reflect satisfactory PAR for the plant. The mirror had one of the highest reflected PAR averages (Table 1), resulting in a favorable change in the growth of the plant, enabling seedlings with a better distribution of dry matter, which favored the Dickson quality index (Table 5).

Other studies using reflective material have obtained similar results regarding the benefit of using reflective materials. In the study of jambolan (*Syzygium cumini*) grown in a protected environment with 30% shading, the seedlings produced on aluminum foil as a reflective material had a higher Dickson quality index than those produced without reflective material (Salles et al., 2017). Santos et al. (2017) evaluating different reflective materials to produce passion fruit (*Passiflora edulis*) seedlings found that the use of the mirror was the most appropriate because it promoted the highest growth rate (relative and absolute) in the seedlings.

The use of rice husks over the substrate provided low values of plant height and relative chlorophyll index (Table 3) shoot dry matter (Table 4), the plant height:stem diameter and the shoot dry matter:root dry matter ratio (Table 5). However, it was observed that the presence of rice husks over the substrate provided the highest values of the root dry matter:total dry matter ratio (Table5).

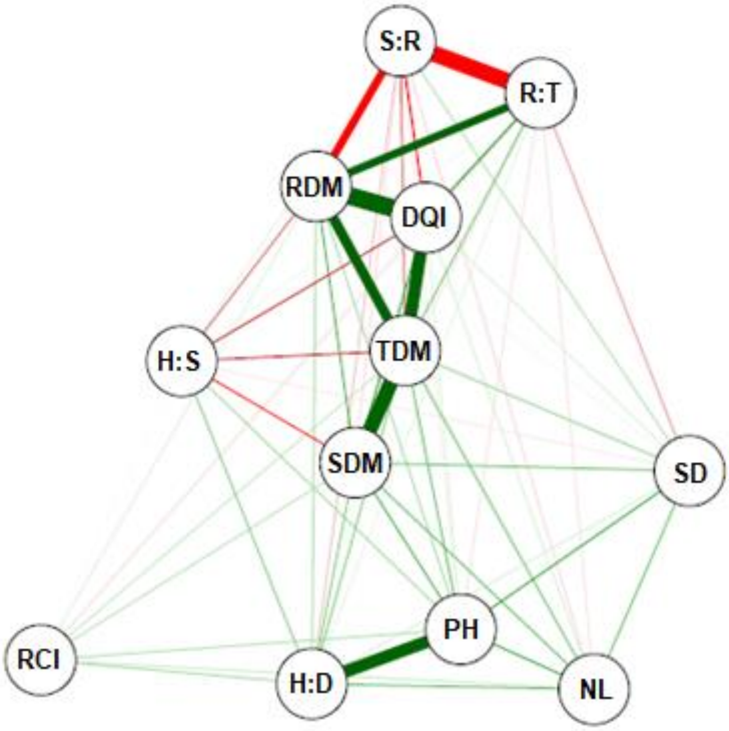
Rice husk is widely used because it is easily accessible, has a high amount of silicon with a high C:N ratio. Plant material with a high C:N ratio allows soil protection for a more extended period than those with a low C:N ratio (Lynch et al. 2016). In contrast, rapidly decomposing plant material can supply the initial demand for N in a crop (Abbasi et al., 2015). Dickson quality index, in the present study, there was no difference in seedling quality with the use of rice husk over the substrate (Table 5).

The relationship between plant height and stem diameter (H:D) determines that a plant with balanced growth has an H:D value lower than a plant with unbalanced architecture. Thus, the highest values coincide with seedlings with a fragile stem to support the shoot. The relationship between plant height and shoot dry matter (H:S) presents a similar behavior to the H:D ratio; the lower values indicate higher survivability in the field and characterize lignified stems, with greater potential for survival in the field. The relationship between shoot dry matter and root dry matter (S:R) should have a value close to 2.0, as this value represents a balance between the aerial part and the root of the seedling (Dutra et al., 2016). The relationship between the root dry matter and the total dry matter (R:T) indicates the proportion of biomass that has accumulated in the root system and indicates a higher survival capacity of seedlings in situations of water deficiency. The Dickson quality index (DQI) is one of the most used indexes to determine the quality of seedlings and the highest values are indicative of quality, as it demonstrates the balance of the distribution of dry biomass and allows determining the most rustic seedlings (Silva et al., 2018).

In the present work, it can be confirmed that the Dickson quality index is highly correlated with the accumulation of dry matter. According to Freitas et al. (2013), dry matter is relevant because it is associated with the ability to survive in times of water deficit. After all, when plants are adequately developed, they are better protected against dehydration and thus guarantee the survival and growth after planting.

Figure 2 shows the correlation network between characteristics of seedlings produced in the reflective material on the cultivation bench, and with or without rice husk over the substrate

Figure 2. Correlation network between characteristics of *Dipteryx alata* seedlings produced using reflective material on the cultivation bench, and with or without rice husk over the substrate, in Cassilândia-MS, 2017.



Plant height (PH), stem diameter (SD), number of leaves (NL), relative chlorophyll index (RCI), shoot dry matter (SDM), root dry matter (RDM), plant height:stem diameter ratio (H:D), plant height:shoot dry matter ratio (H:S), shoot dry matter:root dry matter ratio (S:R), root dry matter:total dry matter ratio (R:T) and the Dickson quality index (DQI). Source: Authors.

The correlation network is a multivariate analysis, and for its interpretation, it is necessary to consider that the variables are represented by nodes, which are connected by lines. Each line contains an implicit numerical value that determines the strength of the correlation between the connected nodes that is converted to the thickness of the line. The length of the lines is also an indication of the intensity of the correlations so that shorter lines indicate stronger correlations, thus demonstrating how the variables are grouped (Epskamp et al., 2012) (Figure 2).

The probability used to assess the correlation between variables was 70%. According to this network, it is possible to determine that, among the seedling quality indexes, the Dickson quality index is highly correlated with the accumulation of dry matter, root, shoot, and total dry matter and the root dry matter:total dry matter ratio is highly associated with the root dry matter and total dry matter. However, the plant height:shoot dry matter ratio and the shoot dry matter:root dry matter ratio are negatively correlated with the Dickson quality index (Figure 2).

The Dickson quality index can be considered the most reliable index among those used, considering the results of the mean test (Table 2) and the positive correlations with most of the growth variables (Figure 2), mainly with those related accumulations of dry matter. The analysis of correlation networks can be used as a single analysis of the data or to complement the test of means, being widely used in many areas, such as in the biological sciences (Saba et al., 2014; Pearce et al., 2015) and agronomic studies (Silva et al., 2016).

It can be inferred that the use of the mirror on the bench to reflect photosynthetically active radiation positively altered the levels of chlorophylls (Table 3) in *Dipteryx alata* seedlings, culminating in the accumulation of dry matter (Table 4) and Dickson quality index most appropriate (Table 5).

4. Final Considerations

The use of rice husk over the substrate did not increase of the *Dipteryx alata* seedlings quality.

The mirror as a reflective material produced *Dipteryx alata* seedlings of higher quality than the system without material reflector, called control.

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