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SEED AND SEEDLINGS QUALITY OF *Anadenanthera colubrina* (Vell.) Brenan HARVESTED IN PARANÁ STATE, BRAZIL

Maria Soraia Fortado Vera Cruz[1*], Marlene de Matos Malavasi[1], Ana Carolina Pinguelli Ristau[1], Ubirajara Contro Malavasi[1], João Alexandre Lopes Dranski[2], Hannah Braz[1]

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ABSTRACT - The place of harvest influences the quality of the seeds and, consequently, the quality of the seedlings formed. Thus, the work aimed to quantify the influence of harvesting place on the physiological potential of seeds and on the quality of *A. colubrina* seedlings. The lots refer to the seed harvesting locations, Marechal Cândido Rondon (MCR), Diamante D'Oeste (DO) and Santa Helena (SH). The design was completely randomized. For seed quality, the thousand weight, percentage, average germination time (AGT) and germination speed index (GSI), dry seedling mass (DSM) and respiration rate (RESP) were evaluated. For seedling quality, height, stem diameter, shoot, root and total dry biomass, Dickson quality index, and root electrolyte loss were evaluated. For the DO+SH, the unfolding of the correlations indicated the AGT as the most influential characteristic, both with a direct and indirect effect on the basic variables, that is, seedling quality. Additionally, it is noteworthy that the characteristics evaluated stem diameter, total dry mass of the plant and root electrolyte loss, proved to be good indicators of the quality of seedlings of *A. colubrina*, presenting themselves quite responsive in the correlation analysis. The place of harvest influenced the quality of seeds and seedlings of *Anadenanthera colubrina*, with the distinction of origins into two groups: seed lot from MCR and DO+SH. Germination attributes contributed to explain the effects of seed lot quality on seedling quality and can be used to select better quality seeds and seedlings.
Keywords: angico, provenance, quality attributes, physiological potential of seeds, seedlings performance.

QUALIDADE DE SEMENTES E MUDAS DE Anadenanthera colubrina (Vell.) Brenan COLHIDAS NO PARANÁ, BRASIL

RESUMO - O local de colheita exerce influência na qualidade das sementes e consequentemente na qualidade das mudas formadas. Deste modo, o trabalho objetivou quantificar a influência dos locais de colheita no potencial fisiológico de sementes e na qualidade de mudas de *A. colubrina*. Os lotes referem-se aos locais de colheita das sementes, Marechal Cândido Rondon (MCR), Diamante D'Oeste (DO) e Santa Helena (SH). O delineamento utilizado foi inteiramente casualizado. Para a determinação da qualidade das sementes foram avaliados, a massa de mil, porcentagem, tempo médio de germinação (TMG), índice de velocidade de germinação, massa seca de plântulas e taxa de respiração. Para a qualidade de mudas foram avaliados altura de planta, diâmetro do coleto, massa seca de parte aérea, raiz e total, índice de qualidade de Dickson e perda de eletrólitos radiculares. Para DO+SH, os desdobramentos das correlações indicaram o TMG como a característica de maior influência, tanto com efeito direto como indireto sobre as variáveis básicas, ou seja, de qualidade de mudas. Adicionalmente, ressalta-se que as características avaliadas diâmetro de coleto, massa seca total de planta e perda de eletrólitos de raízes, mostraram-se como bons indicadores da qualidade de mudas de *A. colubrina*, apresentando-se bastante responsivas na análise de correlação. O local de colheita influenciou na qualidade de sementes e mudas de *Anadenanthera colubrina*, com a distinção das procedências em dois grupos: lote de sementes de MCR e de DO+SH. Atributos de germinação contribuíram para explicar os efeitos da qualidade do lote de sementes sob a qualidade de mudas, podendo ser utilizados para selecionar sementes e mudas de melhor qualidade.
Palavras-chave: angico, procedência, atributos de qualidade, potencial fisiológico de sementes, desempenho de mudas.

INTRODUCTION

*Anadenanthera colubrina (*Vell.) Brenan belongs to the Fabaceae family, subfamily Mimosoideae is an arboreal species known popularly as angico. The species presents high annual seed production with autocoric dispersion occurring at the end of the dry period (BISPO et al., 2017). Propagation of the species is mainly by seeds. Thus, seed quality to be used becomes a crucial factor to be considered by the seedling producers. The use of seed lots with low physiological potential in nurseries entails significant input costs (substrate, fertilizer, container, irrigation) which may make it unfeasible to produce seedlings as an economic activity. The place of origin of the adult trees supplying seeds is a factor of high influence on the final quality of the lot, as soil and climatic characteristics can directly interfere with seed formation process, from flowering to the final stages of maturation and dispersion.

[1]Universidade Estadual do Oeste do Paraná (Unioeste), *Campus* Marechal Cândido Rondon, Marechal Cândido Rondon, PR, Brasil. E-mail: soraiafl@hotmail.com. *Corresponding author.
[2]Faculdade Educacional de Medianeira (UDC), Medianeira, PR, Brasil.

Botezelli et al. (2000), in a study on the characteristics of the fruits and seeds of four origins of *Dipteryx alata* Vogel, explained that although belonging to the same species the provenance exerted great interference in the characteristics of the seeds. According to the same authors, in each locality seeds are subject to variations in temperature, length of the day, rainfall and other variants that end up highlighting certain aspects of their genetic composition. Therefore, the environment may be suitable for expressing certain characteristics that in other places do not manifest themselves.

The effect of provenance, i.e., place of harvest, on seed and seedling characteristics was also observed by other authors. Souza et al. (2013) reported phenotypic differences between individuals for fruit production and morphophysiological characteristics of seeds from *Schinus terebinthifolius* Raddi from various fragments in the lower São Francisco (state of Sergipe). Carvalho et al. (2015) noted the effects of provenance o quality and tolerance to different water and nutritional regimes of Canafistula seedlings. Additionally, Pereira et al. (2017) found differences for germination and vigor when testing the performance of *Cedrella fissilis* Vell. seeds, as well as seedling quality depending on different seed provenances.

For the determination of seedling quality of native wood species some attributes can be evaluated such as stem thickness and dry biomass. Those characteristics indicate the presence of reserve substances in the seedling internal tissues, which will facilitate root contact with substrate enhancing seedling field establishment and formation of new roots. A new root system can increase root-substrate interaction providing adequate nutritional status, and controlling pests and diseases (ARAÚJO et al., 2018).

In the light of the above, this research suggests the hypothesis that seed provenance (i.e. where the seeds are harvested) has an influence on seed physiological potential and consequently, on the development and/or quality of the resulting seedlings. Thus, the work aimed to quantify the influence of the seed harvest sites on seed germination and vigor and on the quality of the propagated seedling quality of *A. colubrina*.

MATERIAL AND METHODS

Ripe fruits of *Anadenanthera colubrina* were randomly harvested from three adult trees with a minimum distance of 100 m from each other in September of 2017 in the municipalities of Marechal Cândido Rondon (24°32'42"S and 054°02'35" O), Diamante D'Oeste (24°56'34" S and 54°06'12" O) and Santa Helena (24°51'51" S and 59 49" O), all in the state of Paraná. It was considered as ripe a fruit that presented a dark brown reddish or A light brown color according to Vera Cruz et al. (2021).

Immediately after harvesting, fruits were taken to the laboratory where the seeds were extracted manually. Fruits from each municipality were mixed and homogenized making up the seed lots according to the places of collection. Prior to the installation of the germination test, *A. colubrina* seeds from each lot were sampled and weighed for the determination of the mass of one thousand seeds (MTS), according to the Forest Species Seed Analysis Instructions (BRAZIL, 2013).

Characterization of seed lot quality was carried out in an entirely random design by means of: germination test (GER), average germination time (AGT), germination speed index (GSI), dry seedling biomass (DSB) and seed respiration test (RESP).

For the germination test (expressed in percentage) eight sub-samples of 25 seeds each were used on substrate roll of germitest® paper, moistened with distilled water 2.5 times the value of its weight, in germination chamber type BOD with photoperiod of 12 h of light and constant temperature of 25°C.

The mean germination time measured in days was calculated according to Labouriau (1983), by Equation 1:

$$AGT = (\sum n_i t_i) / \sum n_i \qquad \text{(Equation 1)}$$

Where:
ni = number of seeds sprouted per day and
ti = time between sowing and the ith observation.

The germination speed index was performed in conjunction with the germination test where daily counts of the number of sprouted seedlings were tallied and subsequently calculated the GSI, according to Maguire (1962) (Equation 2):

$$GSI = G_1/N_1 + G_2/N_2 + ... G_n/N_n \qquad \text{(Equation 2)}$$

Where:
G1, G2, ... Gn = number of germinated seedlings and
N1, N2 ... Nn = number of days after sowing.

The dry seedling biomass, measured in grams per plant, was evaluated at the end of the germination test, in which seedlings were packed in kraft paper bags and placed into an air circulation oven at 65°C for 72 h, then weighed in an analytical balance.

The seed respiration test measured in µmol of CO_2 g^{-1} according to Dranski et al. (2013), where eight sub-samples of 25 seeds from each lot were placed in 60 mL glass jars with lid for injectables and conditioned with water volume to reach a moisture level of 30%. Subsequently, the vessels were incubated in BOD chambers at 25°C for 60 min. Then, the peak concentration of CO_2 released during seed respiration was read using a gas analyser (Lycor 6400 XT). To mitigate the effects of delay in reading the amples the evaluation was carried out in casualized block design.

For the initial growth assessment, *A. colubrina* seeds were sown in polyethylene plugs with a capacity of 180 cm^3 filled with commercial substrate using one seed per plug. Seeding and subsequent seedling was carried out at the Protected Cultivation and Biological Control “Professor Dr. Mário César Lopes” of the Center of Agrarian Sciences at “Universidade Etadual do Oeste do Paraná”, Marechal Cândido Rondon, (PR).

The seedlings grew in the plugs for a period of approximately 180 days after seed emergence, under daily irrigation by spraying with an average water table of 4.0 mm (the irrigation apparatus was already installed in the shade house with a frequency of irrigation of three times a day at 7:00, 15:00 and 17:00 h and weekly fertilization with 2 mL of nutritive solution (Table 1) per seedling. After the 180-day period, seedlings were transplanted into vases (8 L) filled with washed sand of medium texture. At the time of the seedling transplant, the sand was irrigated to saturation.

TABLE 1 - Composition of the nutrient solution applied to seedlings of *Anadenanthera colubrina* (Vell.) Brenan, conducted in a shade house.

Nutrient solution					
KH_2PO_4	$MgSO_4$	KNO_3	$Ca(NO_3)_2\,4H_2O$	Complete micro	Fe-EDTA
mL L^{-1}					
1.0	2.0	5.0	5.0	1.0	1.0

KH_2PO_4 = monobasic potassium phosphate, $MgSO_4$ = magnesium sulfate, KNO3 = potassium nitrate, Ca (NO3)2 4H2O = calcium nitrate, Fe-EDTA= iron chelate.

To assess seedling quality, a sample of 12 seedlings from each provenance was kept under irrigation with an average water depth of 4 mm and a frequency of watering three times daily during 42 days. In addition, another sample of equal proportion was conducted during the same period without irrigation. The trials were conducted in a shade house with low density polyethylene film and anti- UV 50 µ thick film equivalent to 20% shading in a randomized block design and four seedlings per plot.

During the experiment, air temperature and humidity data of the seedling beds were obtained with a datalogger. The mean, minimum and maximum temperature values during the experimental period were 18°C, 33.7°C and 6.0°C, respectively with an average relative humidity of 76.7%.

At the end of the experiment, seedling quality attributes included: seedling height (H), stem diameter (SD) shoot dry biomass (SDB), root dry biomass (RDB), total dry biomass (TDB), Dickson quality index (DQI), and root electrolyte loss (REL). Seedling height (in centimeter) was evaluated from the base of the stem to the apical bud and the stem diameter (in millimeter) was determined with the aid of a digital caliper.

Afterwards, seedlings were separated into shoot and root parts which were placed in kraft paper bags and dried in a air circulation oven at 65°C for 72 h followed by weighing with an analytical scale to determine air dry biomass. Dickson quality index (DICKSON et al., 1960) was calculated according to Equation 3:

$$DQI = TDB / [(H/SD) + (SDB/RDB)] \quad \text{(Equation 3)}$$

The root electrolyte loss test was determined according to Wilner (1955). We washed seedling roots with running tap water followed by deionized water to avoid contaminants on root tissue surfaces such as ions that could overestimate the obtained values (%). The midle and central portions of the root system were removed and the radicels with a diameter smaller than 2 mm located in the upper third of the root system were maintained. The root sample was then placed in a glass tube with 20 mL of distilled water and accommodated in a BOD chamber at 20°C for 24 h. Reading of electrical conductivity of the living roots (Clive) was carried out with a conductivity meter (CD12/Bel Engineering® model). Then the solution was autoclaved at 100°C for 10 min. and keept at room temperature for cooling the solution and its conductivity of the dead root (Cdead) measured. The final value of the root tissue electrolyte test was obtained by Equation 4:

$$REL\ (\%) = (Clive / Cdead) * 100 \quad \text{(Equation 4)}$$

Seed physiological potential as well as seedling initial development under irrigated and non-irrigated conditions as a function of seed provenance was evaluated by principal components analysis using software XLSTAT (XLSTAT, 2015).

The correlation between seed quality attributes and seedling quality characteristics with and without irrigation was analyzed separately for the two groups of provenances resulting from the principal component analysis. The correlation was determined by Pearson coefficient, which is a measure of the linear association between quantitative variables, ranging between -1 and 1. If the value of the coefficient is equal to -1 the negative correlation is perfect; if the coefficient equal to 1 the correlation is positive and perfect. A coefficient equal do zero results in a non-correlation (FIGUEIREDO FILHO et al., 2014). For the qualitative evaluation of the Pearson correlation coefficient (r), the criterion established by Callegari-Jacques (2003) was adopted where: if $0.00 < r < 0.30$, there is a weak correlation; if $0.30 \leq r < 0.60$ there is moderate linear correlation; if $0.60 \leq r < 0.90$ there is a strong linear correlation; if $0.90 \leq r < 1.00$ there is a very strong linear correlation.

For path analysis to determine the direct and indirect effects of seed quality upon seedling quality traits we used stem diameter, total dry biomass and value of the root electrolyte loss test as dependent variables and as explanatory variables we used mass of one thousand seed, germination speed index, average germination time, seed respiration, dry seedling biomass and germination test. Path analysis was carried out with the aid of software SAEG 9.1 (FAB, 2007).

RESULTS AND DISCUSSION

Analysis of principal components with seed physiological attributes (Figure 1) revealed that principal component 1 (PC1) accounted for 76.62% while principal component 2 (PC2) accounted for 23.38% of the total data variance. Regarding the places where the seeds were harvested (i.e. provenance) PC1 separated the seed lots into two groups where those harvested in Marechal Cândido Rondon (MCR) were on the opposite side from those of Diamante D'Oeste (D'O) and Santa Helena (SH).

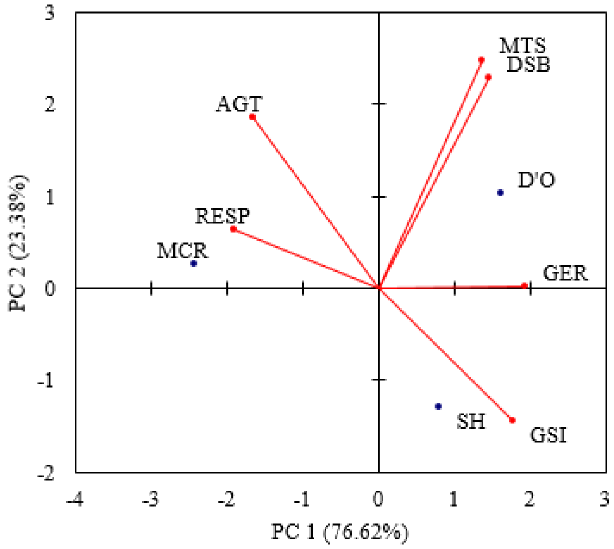

FIGURE 1 - Analysis of the principal components for the attributes of physiological quality of *Anadenanthera colubrina* seeds of Marechal Cândido Rondon (MCR), Diamante D'Oeste (D'O) and Santa Helena (SH). Average germination time (AGT), respiration test (RESP), mass of one thousand seeds (MTS), dry seedling biomass (DSB), germination test (GER), germination speed index (GSI), principal component 1 (PC1), principal component 2 (PC2).

In addition, all the variables analyzed were efficient and important in the group breakdown, because for the MCR seed lot the variables average germination time (AGT) and seed respiration (RESP) were mainly responsible for identifying the dissimilarity of this seed lot. However, the variables mass of one thousand seeds (MST) and dry seedling biomass (DSB) were highlighted for the DO seed lot. With SH seed lot, the germination speed index (GSI) was the most representative.

Thus, it can be inferred that the seeds collected from MCR had lower physiological quality, because higher AGT and RESP are indicators of low physiological potential. At the same time, high vigor is associated with seeds collected in DO and SH confirmed the greater vigor compared to provenance of MCR.

Besides genetic variability, the environmental factor also exerts great influence on the differences observed between the seeds or seed lots from the same species. Therefore, the results from the present study were an inherent response of the genotype x environment interaction of each seed source or provenance. This a statement is based on Botezell at al. (2000) which reported that in each location, seeds are subject to a specific condition of precipitation, temperature, humidity, winds and photoperiod among others, and that those environmental factors interact directly with the genetic factor of the species, resulting in adaptation to local conditions, culminating in the expression of intraspecific genetic variability.

Cherobini et al. (2008) also verified the germination potential and vigor of *Cedrela fissilis* Vell. seeds of different origins, where seeds harvested in Rio Grande do Sul and Santa Catarina showed higher germination potential than those collected from Paraná. Similarly, Pereira et al. (2017) observed strong influence of the seed origin under the germination and vigor of *C. fissilis* seeds. Rodrigues et al. (2007) found lower average germination time value and higher average IVG in seeds coming from Cruz das Almas, Bahia, denoting these as more vigorous. At the same time, the authors observed a more regular rainfall regime for that origin, considering that such environmental factor may have contributed to the better performance of the seed lot from Cruz das Almas.

Rodrigues et al. (2007) observed distinct germinative behavior of *A. colubrina* seeds collected in different locations from Tanquinho and Cruz das Almas, Bahia. The authors justified the results by the fact that the populations studied, although from the same species, demonstrated adaptation to the collection site, which presented distinct pedo-climatic conditions. According to Malavasi et al. (2018), the place of origin of seed producing adult trees has great interference in the development of the seeds, demonstrating that the trees are genetically adapted to the climatic conditions of the habitat. Dorneles et al. (2013) observed heterogeneous germinative behavior of *A. colubrina* seeds harvested from distinct parent trees attributing this result to the probable climatic and ecological oscillations that occurred during the pollination, formation and maturation phases of fruits and seeds.

The dissimilarity between seedling quality attributes propagated with the seed lots under irrigation (Figure 2A) resulted in 63.82% of the variability was explained by PC1 and 36.18% by PC2. For seedlings under water deficit (Figure 2B) 72.77% of the variability was explained by PC1. For irrigated seedlings (Figure 2A) PC1 grouped the characteristics of the seedlings of the SH and DO provenances, distanced and opposite to those of the MCR provenance lot, in a similar way to that observed for the physiological quality characteristics of the seed lots. It can thus be inferred that the quality of the seed lots influenced the initial performance of the seedlings produced, and that this influence is directly linked to the place of seed harvest.

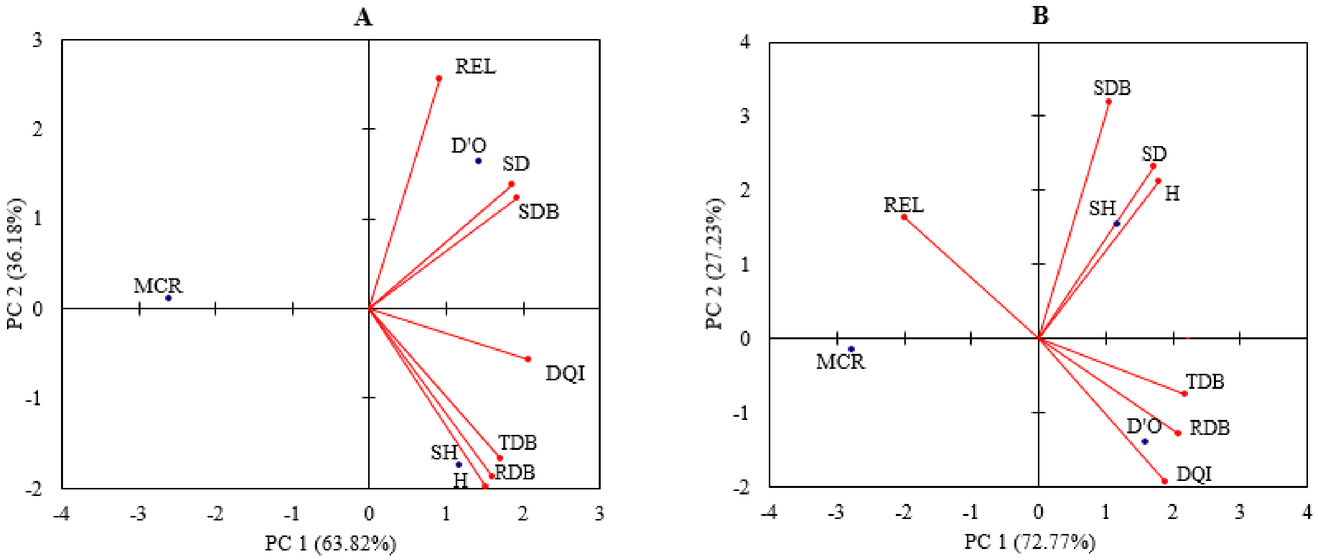

FIGURE 2 - Principal component analysis of *Anadenanthera colubrina* seedling quality attributes propagated from Marechal Cândido Rondon (MCR), Diamante D'Oeste (D'O) and Santa Helena (SH) seeds under irrigation (A) and without irrigation (B). Seedling height (H), stem diameter (SD), dry biomasses shoot (SDB), root (RDB) and total (TDB), Dickson quality index (DQI), root electrolyte loss (REL). Principal component 1 (PC1), principal component 2 (PC2).

For the quality of seedlings, it was observed that the parameters assessed were sensitive to the differences between the groups, because attributes that indicated seedling quality such as seedling height (H), stem diameter (SD), shoot dry biomass (SDB), root dry biomass (RDB), total dry biomass (TDB) and Dickson Quality Index (DQI) were assigned to lots provenance of the SH and D'O.

According to Pereira et al. (2017) seedling height combined with the stem diameter as well as dry biomass are good quality indicators seedlings. The same authors verified, for *Cedrela fissilis* Vell. seedlings that those parameters were efficient for differing the quality from different origins. Cherobini et al. (2008) also found similar results for *C. fissilis* seeds harvested from different provenances, where seeds from Rio Grande do Sul and Santa Catarina presented higher averages for the quality parameters of seedlings, because of the influence of the higher vigor of the seeds observed for these same origins, to the detriment of the quality of seeds and seedlings of the material originating from Paraná.

As observed for seed quality and irrigated seedlings, the interpretation of the principal component with results of seedling quality grown without irrigation yielded a difference between seedling propagated with MCR seeds in relation to the other two seed lots (Figure 2B). The value highest root electrolyte loss (REL) was associated with seedlings from the MCR seed lot. For the SH lot, were as highlighted the SDB, SD and H variables. Whereas seedlings propagated with seed from D'O resulted in the largest TDB, RDB and DQI. Therefore, the observed results ratified the lower quality of seeds from MCR origin, in relation to D'O and SH.

In the present study it was observed that the quality of seed lots had an influence on the initial performance of the seedlings produced and that this influence was directly linked to the place of harvest. Felippi et al. (2012) studied phenology, morphology, seed and seedling analysis of *Cordia trichotoma* (Vell.) Arrab. ex Steud. and stated that the quality of seedlings is closely related to the quality of the seeds. Corroborating the above-mentioned idea, we found that seedlings traits such as height, stem diameter, dry biomass and Dickson quality index were also outstanding results similarly to those recorded with seed lots from SH and D'O.

In addition, it was also observed that when *A. colubrina* seedlings were subjected to water restriction the increased root electrolytes loss was associated with MCR provenance. The root electrolytes loss is a parameter that refers to the integrity of the cell membrane of root tissues. When plants are subjected to stress situations physiological changes occur that result in extravasation of molecular ions due to a loss of cell membrane selectivity (LANDIS et al., 2010). Loss of the selective permeability property of the plasma membrane can be considered as the last stage in terms of stress to a plant. That is, a series of other defense mechanisms including the action of specific enzymes has already been activated to reestablish the metabolism, though without success. Thus, the greater loss of electrolytes from seedlings is an indicator of low quality.

On the other hand, variables such as height and diameter, dry biomass and Dickson quality index are indicators of high seedling quality as mentioned by Cherobini et al. (2010), Navroski et al. (2016) and Pereira et al. (2017). In general, we observed the influence of the place of origin of *A. colubrina* seeds to is physiological potential as well as to the seedling initial development. The results suggested that these observed variations are adaptation responses to a given environment. Therefore, because of the interaction between genotype and environment even individuals of the same species showed distinct performances.

The Pearson's simple correlations (Table 2) between the physiological potential of seeds and the quality traits of seedlings under irrigated and non-irrigated conditions resulted separation between MCR and D'O+SH provenances. With the MCR group under constant irrigation a very strong significant correlation was observed between AGT and TDB and between DSB and REL. With the non-irrigated treatments, we calculated very strong significant correlations of MTS, TDB and REL, AGT with TDB and REL, RESP with SD and DSB with TDB.

TABLE 2 - Pearson's simple correlations between quality attributes of seeds and seedlings of *Anadenanthera colubrina* with or without irrigation.

Prov.	with irrigation				without irrigation			
	e.v.	b.v.			e.v.	b.v.		
		SD	TDB	REL		SD	TDB	REL
MCR	MTS	-	-	-	MTS	-	-0.99*	-0.94*
	GSI	-	-	-	GSI	-	-	-
	AGT	-	0.93*	-	AGT	-	-0.99*	-0.98*
	RESP	-	-	-	RESP	0.92*	-	-
	DSB	-	-	-0.93*	DSB	-	-0.95*	-
	GER	-	-	-	GER	-	-	-
D’O + SH	MTS	0.75*	-	0.79*	MTS	-0.81*	-0.89*	-0.89*
	GSI	-	0.74*	-	GSI	-	-	-
	AGT	-	-0.86*	0.78*	AGT	-	-0.90*	-0.90*
	RESP	-	-	-	RESP	-	-	-
	DSB	-	-	0.71*	DSB	-0.92*	-	-
	GER	-	-	-	GER	-	-	-

*Significant at 5% probability of error by t test. Provenance (prov.), Marechal Cândido Rondon (MCR), Santa Helena and Diamante D'Oeste (SH+D’O), explanatory variables (e.v.), basic variables (b.v.), mass of a thousand seeds (MTS), germination speed index (GSI), average germination time (AGT), respiration rate (RESP), dry seedling biomass (DSB), germination (GER), stem diameter (SD), total dry biomass (TDB), root electrolytes loss (REL).

Relative to the D’O+SH group, significant strong correlations were calculated for seedlings under irrigation between SD and MTS, TDB with GSI and AGT and REL with MTS, AGT and DSB. Under the non-irrigation condition there was a significant correlation between SD with MTS and DSB, TDB with MTS and AGT and REL with MTS and AGT. Under non-irrigation, for both groups, the characteristics were more responsive, resulting in greater significant correlations. It can be inferred, therefore, that the stress condition made possible a greater expression of the vigor of the seeds in the performance of the seedlings. The comparison between the groups, it was observed that the D’O+SH group stood out from MCR in the irrigated condition, in which there were greater interactions between the characteristics evaluated for seed quality versus seedling quality.

The direct and indirect effects breakdown of the above correlations for seedlings conducted under constant irrigation (Table 3) indicated that the estimates of the coefficients of determination (R^2) satisfactorily explained the variations in the characteristics evaluated, evidenced by their high values combined with the low residual effects. This result indicates that the variables present an excellent contribution to the selection of seedlings of good quality. Esposito et al. (2012) explained that path analysis performs the decomposition of correlation coefficients into direct and indirect effects and provides a more practical relationship of characters, helping in the identification of high-effect components.

For the interpretation of the path analysis coefficients, it should be considered that if the correlation coefficient and the direct effect of path analysis show similarities in magnitude and direction, the association between the variables is explained by the direct effect. Where the correlation coefficient is positive and the direct effect is negative or negligible, the correlation is explained by the indirect effects. When the correlation coefficient is negligible, and the direct effect is high and positive, indirect effects are responsible for the lack of correlation. Finally, if the correlation coefficient is negative, and the direct effect is positive and high, indirect effects should be eliminated and only direct effects should be used (ESPÓSITO et al., 2012; OLIVOTO et al., 2015).

The results from Table 3 demonstrated that for the MCR group the correlation between TDB and AGT was influenced by the indirect effects of GSI and DSB. In parallel, direct effect of DSB on REL was observed. Therefore, it can be inferred that the characteristic dry biomass of seedlings was more responsive for this group under irrigation condition to select seedlings of greater vigor. Marcos-Filho (2015) classified evaluations based upon seedling performance as physiological vigor tests, where one tries to determine a specific physiological activity, whose manifestation depends on vigor. The author argued that the higher performance of seedlings, in this case identified by the greater accumulation of dry matter, is a reflection of the greater vigor of the seed lot, where there is greater efficiency in transferring dry matter to the development of the embryo, increasing the germination speed.

For the D’O+SH group it was observed that the explanatory variable AGT had a direct effect on the total dry biomass of the plant, i.e. cause and effect relationship. In addition, indirect effects of AGT were observed in the TDB and GSI correlations, REL and MTS and REL and DSB. It was also possible to observe that the GSI indirectly influenced the correlations between REL and MTS, REL and AGT and REL and DSB. Thus, it was found that for the D’O+SH group the AGT and GSI traits could be selected as seedling quality attributes to estimate seedling performance under irrigated environment. The tests that evaluate the germination speed of the seeds, such as average germination time, average germination index and germination speed index start from the principle that seeds of high physiological potential develop (germinate) faster than others of lesser vigor. Consequently, the seedlings resulting from those seed will show a greater possibility of development, as observed by Gonçalves et al. (2013).

TABLE 3 - Estimation of direct and indirect effects from path analysis among quality traits of seeds and seedlings of *Anadenanthera colubrina*, with or without irrigation.

Prov.	Association pathways	b.v.: TDB	b.v.: REL
		Estimate	Estimate
		v.e. AGT	v.e. DSB
MCR	Direct effect	-3.19	-6.77
	IE through MTS	-0.10	0.10
	IE through GSI	2.57	-5.96
	IE through AGT	-	8.37
	IE through RESP	0.35	0.36
	IE through DSB	2.62	-
	IE through GER	-1.31	2.97
	total	0.93	-0.93
	R^2	0.99	0.99
	Residual effect	0.10	0.10

Prov.	Association pathways	b.v.: SD	b.v.: TDB		b.v.: REL		
		Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
		v.e. MTS	v.e. GSI	v.e. AGT	v.e. MTS	v.e. AGT	v.e. DSB
D’O+SH	Direct effect	1.18	-1.21	-2.86	0.21	-1.95	-0.65
	IE through MTS	-	-0.48	0.68	-	0.18	0.17
	IE through GSI	1.73	-	0.98	1.97	2.65	1.88
	IE through AGT	-2.46	2.3	-	-1.66	-	-1.43
	IE through RESP	0.03	0.04	-0.02	0.03	-0.25	0.15
	IE through DSB	-0.36	-0.06	0.08	-0.51	-0.48	-
	IE through GER	0.63	0.16	0.28	0.75	0.63	0.59
	total	0.75	0.74	-0.86	0.79	0.78	0.71
	R^2	0.98	0.99		0.87		
	Residual effect	0.14	0.1		0.36		

Provenance (prov.), Marechal Cândido Rondon (MCR), Diamante D'Oeste + Santa Helena (D’O+SH), explanatory variable (e.v.), basic variable (b.v.), indirect effect (IE), mass of one thousand seeds (MTS), germination speed index (GSI), average germination time (AGT), respiration rate (RESP), dry seedling biomass (DSB), germination (GER), stem diameter (SD), total dry biomass (TDB), root electrolyte loss (REL), determination coefficient (R^2).

Besides the average germination time, DSB and GSI were the characteristics that showed the greatest influences on the correlations with seedling quality traits. For the D’O+SH group, the unfolding of the correlations indicated the AGT as the characteristic with the greatest influence, both with a direct and indirect effect on the basic variables, that is, on seedling quality. In addition, it should be noted that the characteristics evaluated stem diameter, total dry biomass of plant and root electrolytes loss as good indicators of the quality of seedlings of *A. colubrina* being very responsive in the correlation analysis.

The variables average germination time, germination speed index and dry seedling biomass stood out as the quality characteristics of seeds that could predict the performance of seedlings. These results would apply to practical activities, since by means of results obtained with the analysis of seeds, which theoretically can be obtained more quickly than those for seedlings, have a better chance to select quality seedling with greater survival and better field performance.

CONCLUSIONS

The place of seed harvest (provenance) influenced seed and seedling quality of *Anadenanthera Colubrina* with the distinction of the provenances in two groups: seed lot of Marechal and seed lots of Diamante D'Oeste + Santa Helena.

Germination attributes explained the lot seeds quality effects upon seedling quality and can be used to select better seeds and seedlings.

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