PERMEABILITY TO WATER AND VIABILITY IN HETEROMORPHIC COLOR SEEDS OF *Bowdichia Virgilioides* KUNTH

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ABSTRACT – Species that produce seeds with a rigid integument represent a serious problem because their impermeable coat restricts the entry of water, which makes germination difficult. The heteromorphism of the integument in *Bowdichia virgilioides* causes water imbibition to vary substantially and, therefore, the objective of this work was to study the relation of seed coat color with permeability and viability in *Bowdichia virgilioides*. Seeds were separated into five different colors (yellowish-orange, orange, orange/reddish, reddish, and rusty red) and the following parameters were analyzed: water absorption, germination, mortality, viability, synchrony, and maximum potential of germination. The color was a determining factor for most of the evaluated parameters. The seeds with yellowish or orange/reddish coats tend to be little permeable to water while seeds with reddish or rusty red coats are highly permeable. The results indicated that seeds with reddish color had greater physiological potential indicating a probable relationship with the maturation point of the species. However, in the seeds of the species studied, irrespective of coloring, germination was late with low synchrony and low daily seed germination count, typical characteristics of dormancy.

Keywords: Seed coat; Water uptake; Germination.

PERMEABILIDADE A ÁGUA E VIABILIDADE DE SEMENTES HETEROMÓRFICAS DE Bowdichia virgilioides *KUNTH*

RESUMO – Espécies que produzem sementes com tegumento rígido representam um sério problema, pois esta estrutura restringe a entrada de água, o que dificulta a germinação. O heteromorfismo do tegumento em ***Bowdichia virgilioides*** *faz com que a embebição de água varie substancialmente e, portanto, o objetivo deste trabalho foi estudar a relação da cor do tegumento com a permeabilidade e viabilidade em* ***Bowdichia virgilioides****. As sementes foram separadas em cinco cores diferentes (amarelado/alaranjado, alaranjado, alaranjado/ avermelhado, avermelhado e vermelho ferrugíneo) e os seguintes parâmetros foram analisados: absorção de água, germinação, mortalidade, viabilidade, sincronia e potencial máximo de germinação. A cor foi um fator determinante para a maioria dos parâmetros avaliados. As sementes com camadas amareladas, alaranjadas e alaranjados/avermelhado tendem a ser pouco permeáveis à água, enquanto as sementes com camadas avermelhadas ou vermelho ferrugíneo são altamente permeáveis. Os resultados indicaram que sementes com coloração avermelhada apresentaram maior potencial fisiológico indicando provável relação com o ponto de maturação da espécie. Porém, nas sementes da espécie estudada, independentemente da coloração, a germinação foi tardia, com baixa sincronia e baixa contagem diária de germinação, características típicas de dormência.*

Palavras-Chave: Tegumento; Absorção de água; Germinação.

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1. INTRODUCTION

The species *Bowdichia virgilioides* can be found in most Brazilian states, within the biomes of the Atlantic Rainforest, Cerrado, Caatinga and Pantanal (Rizzini and Mors, 1995; Silva Júnior and Santos, 2005; Cruz et al., 2012). It is a pioneer species and is adapted to dry and poor soils, growing well in full sun, and can be used for the recovery of degraded areas and floristic restoration (Silva and Vinha, 1991; Lorenzi, 1992; Smiderle and Sousa, 2003; Silva Júnior and Santos, 2005).

Its seedling formation process is slow due to the occurrence of dormancy. Its hard tegument makes it difficult for water to enter and, consequently, for the seed to germinate, which occurs slowly and in a low percentage. Furthermore, *B. virgilioides* seeds show heteromorphism marked by variations in seed coat color, ranging from greenish to rusty red with yellow and orange in between (Ribeiro-Oliveira et al., 2013; Dalanhol et al., 2014), and also variations in shape and size (Rosa-Magri and Meneghin, 2014). These different colors of tegument can be found within the same fruit, and this is believed to be associated with seed maturation, which may influence its physiological potential (Dalanhol et al., 2014) and imbibition pattern.

Color is a morphological seed coat characteristic, while variations in shade between and within individuals of the same species result from heteromorphism, which contribute to variation in germination timing and irregular seedling emergence (Imbert, 2002; Baskin and Baskin, 2014). Factors that contribute either alone or in combination to seed heteromorphism, particularly those related to coat color, include phenotypic plasticity, environmental conditions and genetic factors.

When seeds differ in plasticity, a genotype can produce different phenotypes and influence their morphology (Pichancourt and Van Klinken, 2012; Penfield and MacGregor, 2017). DNA-based phylogenetic analyses reveal that in the genus *Bowdichia* floral plasticity results from the evolution of the subfamily Papilionoideae (Cardoso et al., 2012). Within this context, seed coat color also may represent a component of plasticity in *Bowdichia virgilioides* Kunth (Fabaceae-Papilionoideae).

Seed coat color can be influenced by the expression of the genes associated with the distribution of pigments and chemical compounds found in the epidermal layer (Dellagostin et al., 2011; Yu, 2013; Hong et al., 2017), day length and dry or wet seasons (Chan et al., 2017), as well as specific acids and proteins. Regardless of the factors involved, it is known that the seed coat color heteromorphism is correlated with water absorption, germination, mortality and maturation in other species (Nakagawa et al., 2007, Boyle and Hladun, 2005; Atis et al., 2011; Gu et al., 2011; Alves et al., 2013).

The influence seed coat color is not the same for all species though. For example, the darker seed coat of *Vicia faba* L., *Gleditsia triacanthoso* L. and *Brassica napus* L. is more permeable to water, whereas the darker seed coats of *Halopyrum mucronatum* L. and *Panicum miliaceum* L. are harder and offer greater resistance to water entry (Kantar et al., 1996; Khan et al., 2008; Zhang et al., 2008; Siddiqui and Khan, 2010). Furthermore, due to the heterogeneity, usual estimates of water absorption, based on the sample mean weigh (Moura et al., 2016; Shapira et al., 2016), may not be representative because differences in water absorption can be seen even in the structure of each seed (Geisler et al., 2017; Lev and Blahovec, 2016).

Considering the scarcity of research that relates the color of the tegument to the imbibition and seedling production of this species, the objective of this study was to assess the correlation of color with permeability (without breaking dormancy), germination, mortality, viability, germination timing, synchrony and maximum potential of germination in *Bowdichia virgilioides* heteromorphic seeds.

2. MATERIAL AND METHODS

2.1 Study site, seed collection year and sampling

B. virgilioides fruits were collected in Cerrado and Atlantic Rainforest areas located in the states of Espírito Santo, Minas Gerais and São Paulo. Sample seeds were grouped according to seed coat color as follows: A_1 (yellowish/orange coat), A_2 (predominantly orange coat), A_3 (orange/reddish coat), A_4 (predominantly reddish coat), and A5 (rusty red coat).

A1 consisted of seeds from three individuals, collected in 2011. These seeds were homogenized.

Those not showing the desired coloring were discarded. A_2 and A_5 included seeds collected from a single individual in 2009. For A_3 and A_4, commercially available seeds (collected in 2010) were used after cleaning.

2.2 Correlation of seed coat color with permeability

Water absorption capacity was measured after the seeds, orthodox species (Carvalho, 2006), had been stored for 3-5 years, in plastic bags and kept in a cold chamber with temperature and humidity control. Twenty seeds from each of the five samples in the yellow-to-rusty red spectrum (A_1, A_2, A_3, A_4, A_5), were individually tagged, and laid over two foils of blotter paper saturated with distilled water in plastic boxes of the gerbox type. The boxes were kept in a B.O.D. incubator at 25 °C, under white fluorescent light for 7 days.

The seeds were then individually weighed on a 0.0001g accuracy digital scale every 1-2 hours according to hydration speed. Weighing was performed over 10 straight hours alternated with 14 overnight hours of rest. When seed mass loss occurred due to partial detachment of the seed coat, assessment was discontinued.

Seed water absorption rate was calculated from the expression$((p_i - p_o)/p_o)100$, where P_i is the mass of the seed (g) imbibed at time and P_o is seed initial mass (g) before imbibing. Graphs of water absorption rate as a function of imbibition time were plotted for each seed and for each of the 20-seed groups (represented by their mean value). Given that water absorption in rusty red seeds was much higher than in the remaining seeds, the graph scale was doubled.

The hydration speed index was calculated from the equation, $HSI = \sum_{i=1}^{k} (P_i / t_i)$ where: P_i is seed mass at time i;t_i: time (hour) at the i-th weighing, and k is the final imbibition time (Nakagawa et al., 2007) expressed in grams per hour. This formula is an adaptation of the formula of Maguire (1962) as proposed by Nakagawa et al. (2007), who replaced the number of germinated seeds by the mass of imbibed seeds.

2.3 Influence of seed coat color on physiological potential

This experiment was conducted in a completely randomized design with three 25-seed replications. Seeds from A_1, A_2, A_3, A_4, and A_5 were placed on blotter paper moistened with distilled water in gerbox plastic containers. No pre-germination treatment was applied. The boxes were kept in a B.O.D. chamber at a mean temperature of 25 °C, under continuous white fluorescent light, and a mean irradiance of 23.3 ± 6.2 μmol m^{-2} s^{-1} (Ribeiro-Oliveira et al., 2013).

Radicle protrusion was evaluated every 24 hours for 65 days. Subsequently, non-germinated seeds (remaining seeds) were scarified with sandpaper (França Neto et al., 1998) and hydrated, then they were immersed in a 0.5% solution of 2, 3, 5 - triphenyl – tetrazolium chloride for 2 h and 30 min. Seeds showing reddish pink stained tissues in more than 50% of the embryo, including the embryonic axis, were considered viable. Seeds were classified as non-viable when over 50% of the embryo was not stained reddish pink and/or damage to the embryo structure was observed. The percentage of remaining seeds detected by the tetrazolium test plus the percentage of germination were considered, in this work, as the maximum germinative potential for seeds of the species.

Germination percentage, mortality and viability were calculated for the non-germinated seeds alone; initial (t_o) and final (t_f) germination time (Labouriau, 1983); mean germination time, $\bar{t} = \sum_{i=1}^{k} n_i t_i \Big/ \sum_{i=1}^{k} n_i$, where t_i: time interval between the beginning of the experiment and the i-th day of observation; n_i number of seeds germinated at t_i , and k: last seed germination time (Labouriau, 1983); germination speed index, $GSI = \sum_{i=1}^{k} (n_i / t_i)$ (Maguire, 1962), and synchrony, $Z = \sum C_{n_i,2} N^{-1}$, with $C_{n_i,2} = n_i (n_i - 1)/2$ and $N = \sum n_i (\sum n_i - 1)/2$,where$c_{ni,2}$ combination of seeds germinated in time i, two joints, and number of seeds germinated at time i (Primack, 1980). Graphs showing seed germination frequency by color as a function of time were built according to Labouriau and Pacheco (1978) using the formula $f_i = n_i / \sum_{i=1}^{k} n_i \, 100$.

2.4 Statistical Analysis

The statistical analysis of the quantitative characters determined experimentally was performed by using the Kolmogorov-Smirnov test to check the normality of ANOVA residues, and the test of Lavene was used to test the homogeneity of variances at a significance level of 0.01. Since all data that required transformation were expressed as percentage, when one or more of the assumptions was not satisfied

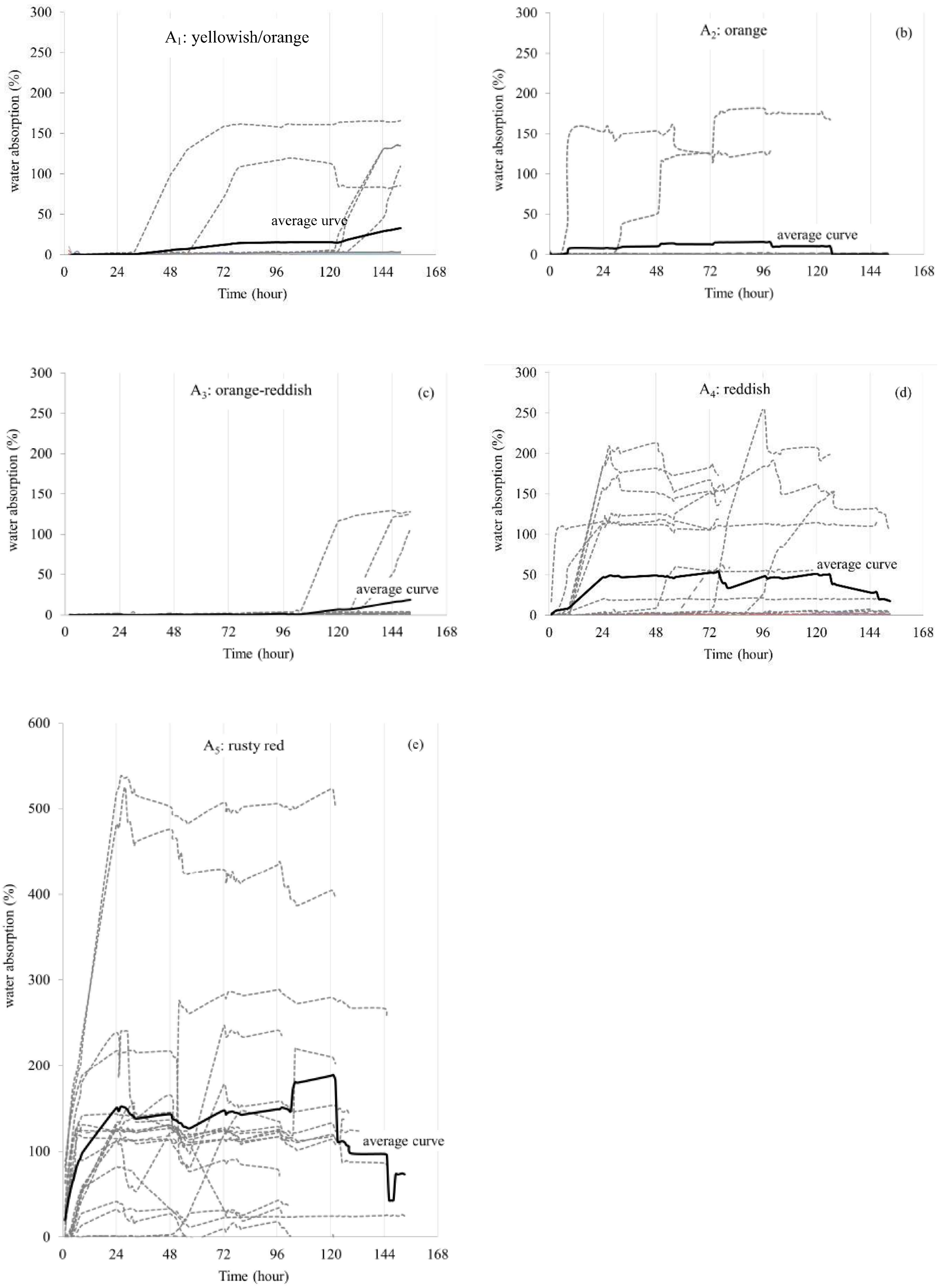

Figure 1 – Curves of water absorption as a function of imbibition time in *Bowdichia virgilioides Kunth*. (Fabaceae – Papilionoideae). Dashed curves represent water absorption in each seed while continuous curves represent the average.

Figura 1 *– Curvas de absorção de água em função do tempo de embebição em* ***Bowdichia virgilioides Kunth****. (Fabaceae - Papilionoideae). As curvas tracejadas representam a absorção de água em cada semente, enquanto as curvas contínuas representam a média.*

the arcsen $\sqrt{x/100}$ transformation was applied. For all germination measurements and technological characteristics, analysis of variance (ANOVA) was followed by the Tukey test for comparison of the mean at a significance level of 0.05.

Given that the hydration speed index (*HSI*) was determined through a sampling process rather than experimentally, box plot graphs were used for comparing the seeds with different coat colors (A_1, A_2, A_3, A_4, A_5).

3. RESULTS

The gradient between the lowest and highest water absorption of *B. virgilioides* seeds followed the tegument browning gradient, starting with the less permeable yellowish/orange coats. At seven days, no imbibition was observed in about 80% of the seeds in A_1, A_2 and A_3 (Figure 1 a, b and c). On the other hand, the imbibition rate of over 50% seen in the seeds with predominantly reddish and rusty red seed coats (A4 and A5, respectively) indicated high permeability (Figure 1 d and e).

Within the first 24 hours of imbibition, immediate water absorption occurred in most *B. virgilioides* seeds in A_5. Notably, in two seeds absorption was more than 500% of seed mass (Figure 1e). Nonetheless, in about 30% of the seeds of this color, water imbibition did not occur up to the end of the experiment, indicating that even among seeds of similar coloring, permeability differs due to a characteristic of the

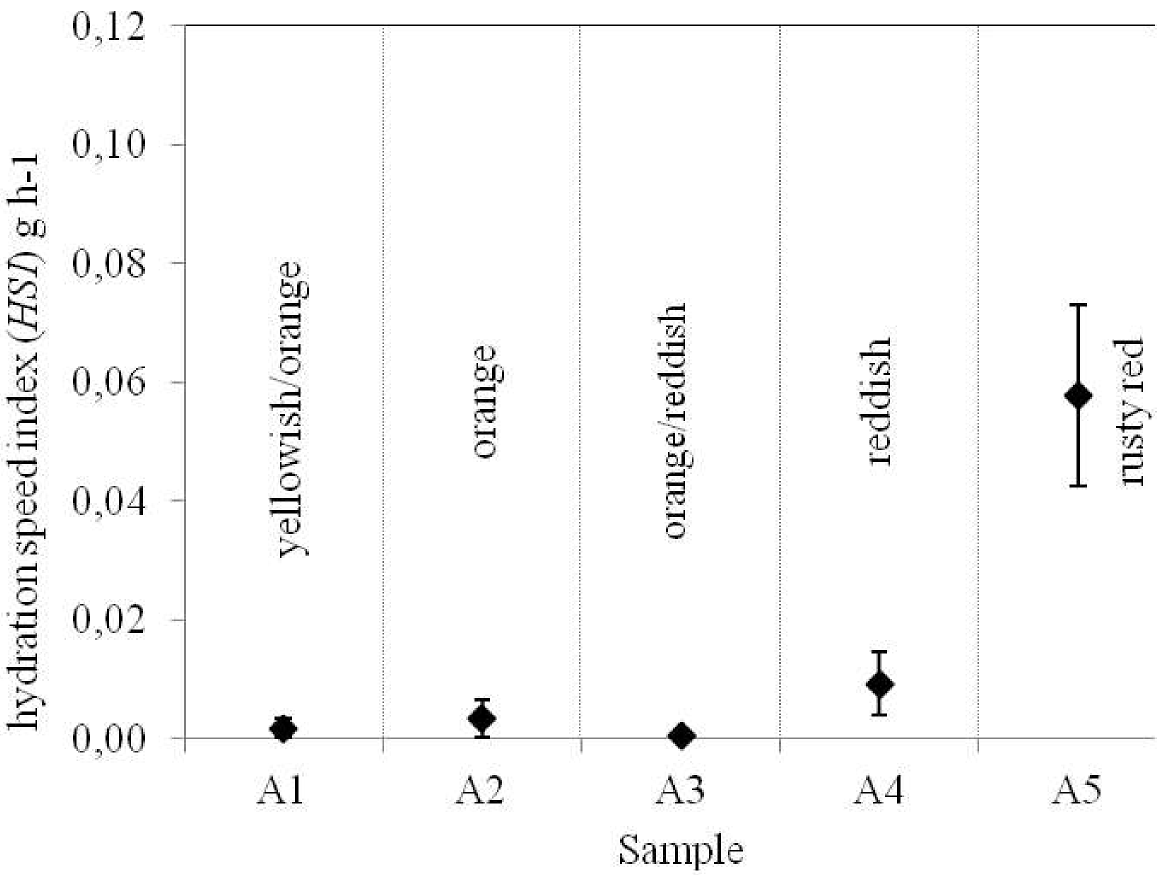

Figure 2 – *Box-plot* and confidence interval values for hydration speed index (*HSI*) in *Bowdichia virgilioides Kunth*. (Fabaceae – Papilionoideae) seeds with coats of different colors.
Figura 2 *–* ***Box-plot*** *e valores do intervalo de confiança para o índice de velocidade de hidratação* ***(IVH)*** *das sementes de* ***Bowdichia virgilioides Kunth****. (Fabaceae - Papionoideae) com tegumento com diferentes colorações.*

Table 1 – Germination rate, viability, mortality, speed, synchrony and timing in *Bowdichia virgilioides* Kunth. (Fabaceae- Papilionoideae) seeds with coats of different colors.
Tabela 1 *– Germinação, viabilidade, mortalidade, velocidade, sincronia e tempo de germinação de sementes de* ***Bowdichia virgilioides*** *Kunth. (Fabaceae- Papilionoideae) com diferentes colorações.*

[1]Seed coat color	*G*(%)	Mortality (%)	Viability(%)	GSI(seeds day^{-1})
yellowish/orange (A_1)	38.0 ab	34.0 a	28.0 a	0.300 ab
orange (A_2)	25.0 b	44.0 a	31.0 a	0.176 bc
orange/reddish (A_3)	47.0 ab	46.0 a	7.0 b	0.373 ab
reddish (A_4)	55.0 a	37.0 a	8.0 b	0.482 a
rusty red (A_5)	1.0 c	99.0 b	0.0 c	0.009 c
[2]Pressuppositions	[2,3]K-S = 0.129; F= 2.577	[3]K-S =0.129; F= 4.586	[3]K-S =**0.177**; F= **2.403**	K-S = **0.165**; F= **3.487**
[1] Seed coat color	t_0 (day)	$\bar{t}$	t_f (day)	Z
yellowish/orange (A_1)	20.75 ab	35.45 a	56.75 a	0.061 a
orange (A_2)	25.00 b	42.58 a	58.50 a	0.024 a
orange/reddish (A_3)	20.50 ab	36.59 a	58.25 a	0.074 a
reddish (A_4)	18.25 a	31.53 a	49.50 a	0.065 a
rusty red (A_5)	28.00[4]	28.00[4]	28.00[4]	
Pressupositions	**K-S = 0.209; F= 5.80**	**K-S= 0.250; F=1.34**	**K-S= 0.192; F=2.45**	**K-S = 0.179; F= 1.31**

[1]Mean values followed by different letters in the same column differ (Tukey test at 0.05 significance); [2]*K-S, F*: Kolmororov-Smirnov and Levene tests, respectively; values in bold indicate normally distributed residues and homogeneous variances, respectively (significance at 0.01). [3]Data transformed by arcsine $\sqrt{x/100}$; [4]Given that only one seed germinated at 28 days, time was recorded but the sample was excluded from the statistical analysis.
[1]Médias seguidas por letras distintas na coluna são diferentes (teste de Tukey a 0,05 de significância); [2]K-S, F: estatísticas dos testes de Kolmororov-Smirnov e Levene, respectivamente; valores em negrito indicam resíduos com distribuição normal e variâncias homogêneas, respectivamente, ambos a 0,01 de significância. [3]Dados transformados por arcoseno x /100. [4]Como apenas uma semente germinou aos 28 dias, o tempo foi registrado, porém essa amostra foi excluída da análise estatística. *significância. [3]Dados transformados por arcoseno x /100. 4Como apenas uma semente germinou aos*

seed itself. Overall, the curves representing 20-seed mean values, which reached a maximum of 50%, underestimated the water absorption rate. In some seeds with rusty red seed coats (A5), the individual value was up to 400% above maximum absorption mean value (Figure 1e).

The number of imbibed seeds and water absorption rate was similar in A_1, A_2 and A_3 samples, respectively (Figure 1 a, b and c). However, the seeds collected in 2009 from a single individual that to comprised two distinct samples, A_2 and A_5, showed low and high permeability, respectively.

Of the five samples, the seeds could be separated into two groups. The first group was formed by seeds with predominantly yellow, orange and transitioning between orange and red coats with low water absorption capacity and low hydration speed (A1, A2 and A3; Figure 2). The other group was formed by seeds with predominantly red to darker red coats (rusty) with high water absorption capacity and high hydration speed.

An unevenness in the quantity of soaked seeds and water absoption speed was more accentuated in groups A4, with an oscillation between 0 and 0.4 g hour^{-1}, and A5, oscillating between 0 and 0.12 g hour^{-1}. This behavior is likely to be explained by the higher permeability resultant from the advanced stage of maturation of these seeds, particularly those with a rusty red seed coat. These oscilations are observable through the confidence intervals (Figure 2).

The germination test showed that seeds with reddish tegument had 55% germination. Rusty red seeds had the lowest rate of germination (1%) and highest rate of mortality (99%). The late germination timing (~20 days) and the long duration of the experiment (~ 60 days) were characterized by a low and irregular germination frequency, typical of dormancy (table 1). In the interval between the initial and the final germination time, the low values of the germination speed index (between 0.009 and 0.482) for seeds in different colors occurred due to the daily frequency of germinated seeds (one every 2 and 3 days). This irregularity and the almost zero chance of seeds germinating in the same time interval reflected in the loss of synchrony (Z values between 0.024 and 0.074), regardless of skin color.

In figure 3, it is possible to observe that the proximity between maximum germinative potential

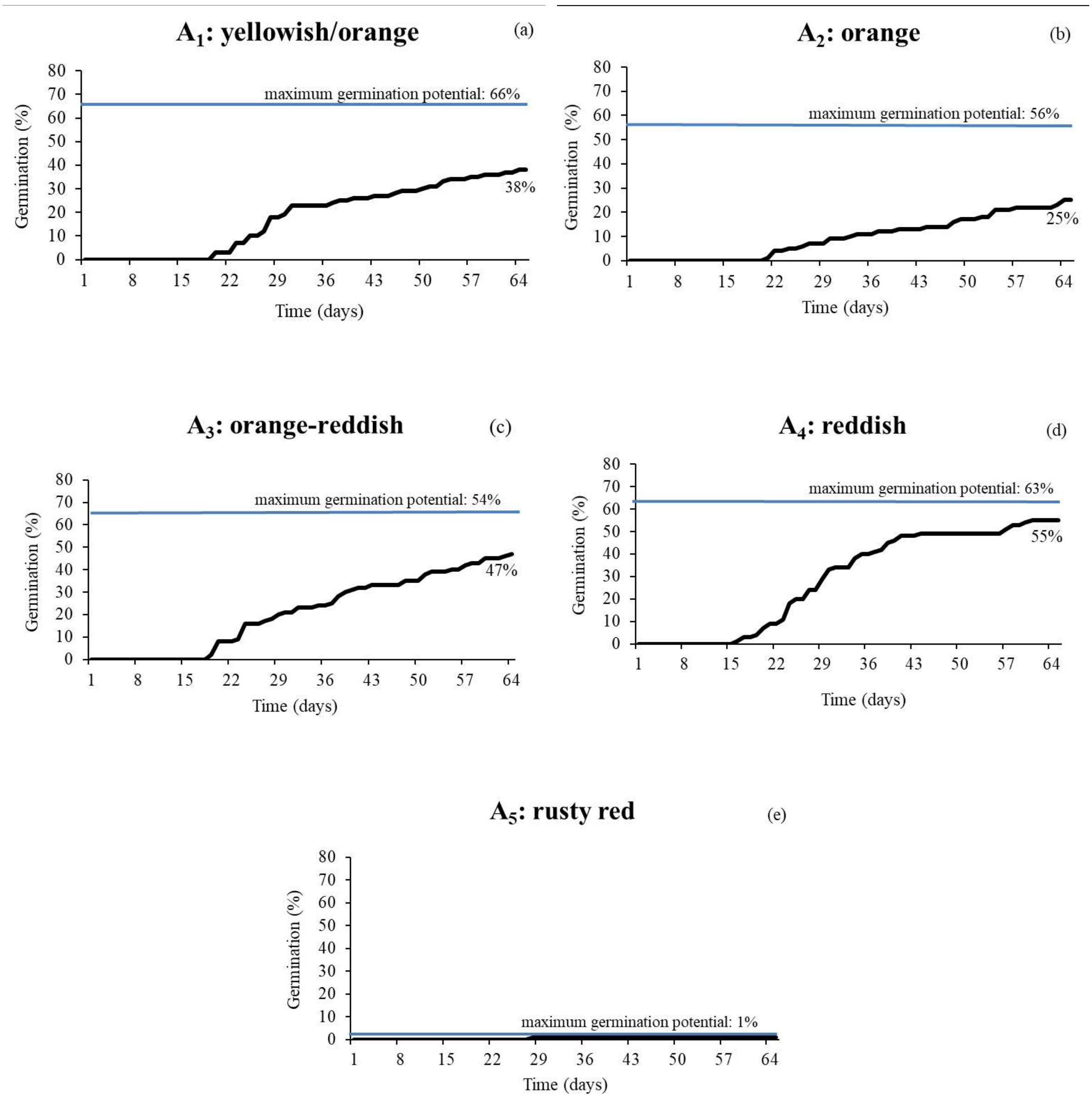

Figure 3 – Germination accumulated for 65 days and maximum germination potential for *Bowdichia virgilioides* Kunth seeds. (Fabaceae - Papilionoideae) with seed coats of different colors.

Figura 3 *– Germinação acumulada por 65 dias e potencial máximo de germinação das sementes de* ***Bowdichia virgilioides*** *Kunth. (Fabaceae - Papilionoideae) com tegumento com diferentes colorações.*

and germination was also greater for reddish seeds (55% of germination and 63% of maximun germination potential), as well as the speed of germination. The rusty-red seeds also had similar maximum germination potential results, but in this case it happened because the mortality (99%), which nulled the expectation of germination after the experiment period. For the other colors, the increase in germination did not match the maximum germination potential, even though it was low. The reason was a large amount of seeds from groups A1 and A2 were still dormant (28% and 31%, respectively) at 65 days after sowing.

4. DISCUSSION

A mass increase below 200% was observed within the first 48 hours in the few seeds from groups A_1 and A_2 that did soak, and after 96 hours in seeds from A_3. The association of seed coat color with water absorption is not unexpected (Ertekin and Kirdar, 2010; Atis et al., 2011; Koen at al., 2017). However, this did not ensure the same permeability within the same group.

The differences in water absorption capacity observed among seeds with coats of the same coloring or within the same color spectrum may be related to seed coat thickness (Souza and Marcos Filho, 2001), which corroborates with the metioned heteromorphism in seeds of the studied species. Variations in thickness among seeds of a same species or, more specifically, on the surface of a same seed may be the result of a non-uniform seed coat anatomy (Cavariani et al., 2009; Jaganathan, 2016; Soares et al., 2017). Another possibility is the deposition of chemical substances, such as suberin, lignin, cutin, tannins, pectins, as well as quinine derivatives on the seed coat (Marcos Filho, 2005; Rosa-Magri and Meneghin, 2014; Pierce et al., 2018). In Cassia grandis L.f., *Anadenanthera macrocarpa* (Benth.) Brenan and *Enterolobium contortisiliquum* (Vell.) Morong, lignin despite its hydrophobic nature has been reported to facilitate water diffusion as its presence in the seed integument allows a higher flux of liquids (Costa et al., 2011).

Seed coat impermeability has been attributed to several causes such as the presence of a waxy layer and high content of suberin and cutin on the integument surface, lignin deposition on cell walls, presence of fatty acids in the palisade intercellular spaces, oxidation of the phenolic compounds present in seed coat pigmented cells, among others (Marcos Filho, 2005; Pierce et al., 2018). Of such compounds, *B. virgilioides* seeds are known to show a high content of lipids, hence the classification of this plant as oleaginous (Almeida, 2013), and the presence of phenolics (Rosa-Magri and Meneghin, 2014).

Besides higher rates of water absorption, seeds with reddish (A_4) and rusty red (A_5) seed coats also had greater mass loss. This is explained by the fact that deteriorated seeds absorb a larger amount of water at a higher speed. Hence, electrolyte loss varies with deterioration level (Krzyzanowski et al., 1991; Desai et al., 2004; Ataíde et al., 2016). In addition, some of the seeds might have lost their seed coats causing electrolyte leakage. This leakage can be verified during weighing.

Although the combination of genetic and environmental factors are not excluded as the cause of coloring variations in *B. virgilioides*, the most likely hypothesis is that the seed coat darkens as it deteriorates. In studies of *B. virgilioides* seed vigor, red, black-spotted bright red and red/black seeds not only were at a more advanced stage of deterioration, but also showed lower germination rates (Ribeiro-Oliveira et al., 2013; Dalanhol et al., 2014; Rosa-Magri and Meneghin, 2014). In *Cyamopsis tetragonoloba* L. (Liu et al., 2007) and *Trifolium pratense* L. (Atis et al., 2011), darker seed coat colors (black and brown) were associated with deterioration. In contrast, in *Pisum sativum* L. (Atak et al., 2008), *Citrullus lanatus* (Thunb.) Mansf. (Mavi, 2010) and *Viola* x *wittrockiana gamsa* (Agnieszka and Hołubowicz, 2008), dark green and dark brown were linked to greater seed vigor.

Water uptake is one of the main requirements for germination. However, the lack of a relationship between water absorption curves and germination can be explained by the different factors necessary for each of these events to take place. Initial imbibition occurs regardless of the seed physiological quality, depending solely on seed permeability as it is a process governed by the water potential gradient (Ψw) between seed and environment. This explains why viable and dead seeds are not distinghished; water penetrates as long as it finds a permeable seed coat (Guimaraes et al., 2008; Pimenta et al., 2014).

In contrast, germination requires live and permeable seeds to reach an imbibition stage marked by changes that will only happen as the embryonic axis development is resumed through cell expansion and/or division (Guimarães et al., 2008; Lev and Blahovec, 2016). The initial permeability for seeds of different colors did not allow determining when or which seeds would enter the third stage of imbibition because, besides being intact, none germinated within the seven days of assessment.

The best data related to physiological capacity (germination, mortality, germination speed and maximun potential of germitation) were those found for seeds of group A4 (reddish) indicating a probable relationship with the maturation point of the species. Usually, seeds presented the maximum germination and vigor at this stage and some maturity indexes could be verified with different caracteristics, such as changes in water content, size, germination, vigor, seedling dry matter, and fruit and seed color (Bewley et al., 2013). Other authors also observed a correlation between color and the physiological quality of the seeds of *B. virgilioides* (Ribeiro-Oliveira et al., 2013; Rosa-Magri and Meneghin, 2014; Dalanhol et al., 2014). However, the association of color and physiological maturity will vary in different species. In *Myrciaria dubia* (H.B.K.) McVaugh, dark brown seeds germinated less compared to mixed and green seeds (Yuyama and Silva Filho, 2003). In contrast, dark brown seeds of *Sebastiania commersoniana* (Baill.) Smith & Dons germinated comparatively more in relation to light brown seeds (Santos and Aguiar, 2005).

For seeds belonging to group A5, a significant reduction in vigor was observed (1% germination and 99% mortality). According to Marcos Filho (2015), the process of deterioration of seeds starts progressively from the point of physiological maturity, characterized by physical, physiological and biochemical changes, which determine a decrease in its quality. Thus, the results obtained in this study show that the dark red color indicates deterioration.

Testing the non-germinated seeds with tetrazolium revealed important details of their physiological status and differences among the samples that were not quantified by the absorption curves and germination rates. About 30% of seeds with lighter seed coats (yellowish, orange, between orange and reddish) that did not germinate were still viable, even after 65 days, at the end of the experiment. This capacity to remain viable even after a long period pointed to dormancy mechanisms.

5. CONCLUSIONS

Color was a determining factor for the parameters analized. The heteromorphic seeds of *Bowdichia virgilioides* with yellowish or orange/reddish coats tended to be little permeable to water while seeds with reddish or rusty red coats were highly permeable. The results indicated that seeds with a reddish color had the best physiological capacity showing a probable relationship with the maturation point of the species.

6. AUTHOR CONTRIBUTIONS

Raquel Gonçalves Silva: Data collection/Data analysis and interpretation/Drafting the article.

Denise Garcia de Santana: Data analysis and interpretation/Statistical analysis/Drafting the article.

Cristiane Carvalho Guimarães: Data analysis and interpretation/Drafting the article/Critical revision of the article.

Edvaldo Aparecido Amaral da Silva: Conceived and designed the analysis/Data analysis and interpretation/Drafting the article/Critical revision of the article.

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