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MATRICONDITIONING ON PHYSIOLOGICAL PERFORMANCE OF AMARANTH SEEDS

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ABSTRACT - Matriconditioning is a technique that aims to standardize and accelerate the germination of seeds and the emergence of plantlets. The objective of the study is to evaluate the effect of that methodology under the physiological performance of amaranth seeds. The experiment used two lots of seeds at the Universidade Tecnológica Federal do Paraná (UTFPR), *Campus* Dois Vizinhos (Parana State). Plastic boxes of the Gerbox type were the matriconditioning environment, containing 55.5 g of sterile vermiculite moisturized with distilled water at 100% of the retention capacity. Plastic boxes were placed in a germination chamber at ten degrees Celcius. Four repetitions of 100 seeds had their weight measured at 0, 2, 4, 8, 16, and 32 h after the procedure started to obtain the curve of imbibition. The following tests were performed after each period: Germination test, first germination count; length and dry mass of plantlets; emergence speed index, and accumulated emergence tests. Amaranth seeds achieve phase II of germination around 8 h of imbibition by matriconditioning. The effect of matriconditioning in the physiological performance of amaranth seeds varies as a function of the used lot.
Keywords: *Amaranthus* sp., quality aspects, pseudo-cereals.

MATRICONDICIONAMENTO SOBRE O DESEMPENHO FISIOLÓGICO DE SEMENTES DE AMARANTO

RESUMO - O matricondicionamento é uma técnica que visa uniformizar e acelerar a germinação de sementes e emergência de plântulas. Assim, o estudo teve por objetivo avaliar o efeito dessa metodologia sobre o desempenho fisiológico de sementes de amaranto. O experimento foi realizado com dois lotes de sementes, na Universidade Tecnológica Federal do Paraná (UTFPR), *Campus* Dois Vizinhos (PR). O matricondicionamento foi realizado em caixas plásticas do tipo gerbox, contendo 55,5 g de vermiculita esterilizada e umedecida com água destilada, em 100% de capacidade de retenção. Os gerbox foram acondicionados em câmara germinadora a 10ºC, sendo realizadas pesagens de quatro repetições de 100 sementes as 0, 2, 4, 8, 16 e 32 h depois do início do processo para obtenção da curva de embebição. Após cada período foram realizados os testes de germinação, primeira contagem de germinação, comprimento e massa seca das plântulas, índice de velocidade de emergência e emergência acumulada. As sementes de amaranto atingem a fase II da germinação em torno de 8 h de embebição por meio do matricondicionamento. O efeito do matricondicionamento no desempenho fisiológico de sementes de amaranto varia em função do lote utilizado.
Palavras-chave: *Amaranthus* sp., atributos de qualidade, pseudo-cereal.

INTRODUCTION

Amaranth (*Amaranthus* sp.) is a pseudo-cereal, originated from South and Central Americas. All Brazilian states cultivate it, predominantly in the northeast (COSTA and LIMA, 2010). The crop is essential due to the high level of essential amino acids, particularly lysine, thus, having the potential to supplement rice, corn, and wheat proteins (RODAS and BRESSANI, 2009).

The utilization of the crop needs to be higher in Brazil, including as a cover crop in a no-till system (POSSENTI et al., 2016). However, the knowledge of its seed quality is fundamental, besides technologies that can improve the performance of amaranth seeds in the field, helping in the velocity and uniformity of germination and the emergence of plantlets.

The rapid water absorption occurs during germination to resume the embryo development and then the protrusion of radicle roots. However, this process can cause damage because of imbibition if it does not occur in a slow and gradual form. The physiological conditioning is one technology that can help in this revival. It bases itself on the imbibition of seeds in water, moisturized substrated, and osmotic or saline solution to the activation of

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metabolic processes that occur during germination (ARAÚJO et al., 2011) through controlled hydration.

This process comprehends the imbibition of seeds in phases I and II of the three phases pattern, not reaching phase III, which is characterized by the beginning of the radicle protrusion and germination (CARDOSO et al., 2012). Seeds in different germination phases can exist in the same lot (BEWLEY and BLACK, 1978). Imbibition can help seeds have more uniform germination, that all seeds would reach phase III by the end.

There are several methodologies available for physiological conditioning, as osmoconditioning, hydroconditioning, and matriconditioning, which aim for slow hydration until it reaches the desired level of water in the seed by the use of materials such as vermiculite, sand, and others (MARCOS FILHO, 2015). Although there are some studies with osmoconditioning in amaranth seeds (TIRYAKI et al., 2005; MOOSAVI et al., 2009), there is a lack of information about the use of matriconditioning. Thus the objective was to evaluate the effect of this methodology on the physiological performance of amaranth seeds.

MATERIAL AND METHODS

The experiment was conducted at the Seed Analysis Laboratory at Universidade Tecnológica Federal do Paraná (UTFPR), *Campus* Dois Vizinhos (Parana State), with two lots (L1 and L2), of amaranth seeds, produced by family farms of the Prado region (Rio Grande do Sul State).

First, the water level was determined by the hothouse method at 105 ±3.0°C, according to the Rules for Seed Analysis - RAS (BRASIL, 2009), for the calculations of moisture gain during imbibition. A Gerbox type plastic box with 55.5 g of sterile vermiculite and moisturized with distilled water until 100% of the retention capacity was the environment for the seed imbibition. Seeds were on an inox screen covered with a germitest paper sheet inside those boxes. Masking tape was used to seal the lids. Then, they were placed in a germination chamber regulated at 10°C to reduce the physiological activity of the embryo. Four repetitions of 100 seeds had their weight measured at 0, 2, 4, 8, 16, and 32 h after the process started. The initial and final weight of each sample permitted the calculation of the percentage of imbibition, with the formula:

$$\%I = \frac{Pf - Pi}{Pi} x100$$

Where:
%I = imbibition,
Pf = final sample weight and
Pi = initial sample weight.

After each period of imbibition, germination tests were performed according to RAS (BRASIL, 2009), having four repetitions of 100 seeds, distributed in plastic boxes (gerbox), and on two filter paper sheets moisturized with distilled water in the 2.5 proportion of the paper mass. After seedling, the temperature was constant at 20°C for 14 days, where the boxes were (POSSENTI et al., 2016). The first count of germination was performed on the fifth day after the installation of the test results obtained as a percentage of normal plantlets.

Plantlet length (PL): performed with four repetitions of 25 seeds aligned in the superior third of the paper rolls that stayed in a germination chamber for 14 days, at the temperature of 20ºC, when occurred the evaluation of plantlet total length in each repetition with a graph paper (NAKAGAWA, 1999). The results were in millimeters per plantlet.

Plantlet dry mass: using the same plantlets used for the PL test that after the length measurements had their cotyledons removed and stored in kraft paper bags and put in the hothouse with forced air maintained at the temperature of 80ºC, for 24 h (NAKAGAWA, 1999). Upon the end of the period, each repetition had its mass measured in a 0.001 g precision scale. The results were in milligrams per plantlet.

Emergence speed index (ESI): conducted in the germination chamber, adapting the methodology proposed by Nakagawa (1999). The seedling of four repetitions of 100 seeds for each treatment occurred at a uniform depth of two centimeters in 23 x 23 x 35 cm plastic trays with sieved soil and after covered in a thin layer of soil. The count of emerged plantlets happened daily at the same time, considering emerged the seedlings showing their cotyledons emerged above the ground. The calculation of ESI used the formula proposed by Maguire (1962). During the same period of the ESI test, the evaluation of accumulated emerged plants was done by the daily counting of emerged plantlets and calculating the cumulative percentage. Results were adjusted to a curve of a mathematical model that had higher representativity.

The completely randomized design was used, in a 2 x 6 factorial scheme (two lots x six imbibition periods), containing four repetitions. The data passed through the Lilliefors normality test to verify the homoscedasticity assumption. After model assumptions were confirmed, the analysis of variance was performed to ascertain the effect of the tested factors and their interactions by the F test. In the case of a significant difference, a Tukey test at a 5% error probability was applied using the statistical software Genes (CRUZ, 2006).

RESULTS AND DISCUSSION

Figure 1 illustrates the imbibition curve of L1 and L2 of amaranth seeds submitted to matriconditioning. Generally, the observation was of a two-phase pattern (phase I and phase II) because when phase III (radicle protrusion) starts after 32 h, the evaluation ended. Seeds achieved phase II of germination around 8 h of imbibition by matriconditioning. It was also verified that even the lots had started at a similar moisture concentration, varying by 1%, after 8 h of imbibition lot 2 reached 43.7% moisture, being superior to lot 1 (32.5%) at the same period. According to Marcos Filho (2015), water uptake in considerable quantities is crucial to the restart of the metabolic activities of seeds after maturity, i.e., the faster this step is, the earlier germination starts. However, the index of water absorption by the seed can indicate variation in the physiological potential (COSTA et al., 2002).

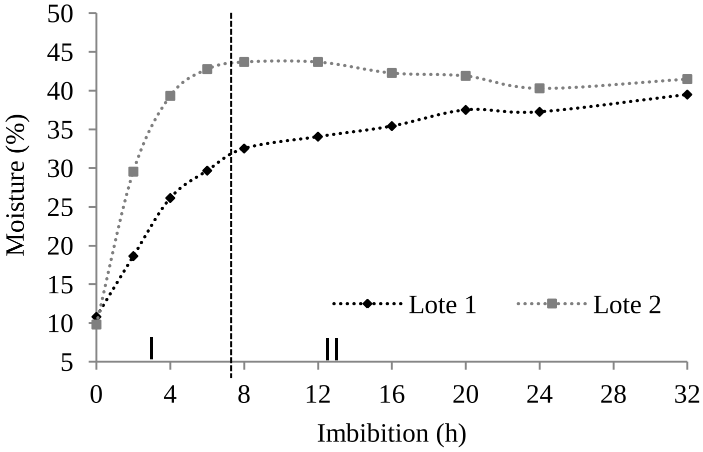

FIGURE 1 - Curve of imbibition for two amaranth seed lots matriconditioned in vermiculite at 100% of water retention capacity.

The analysis of variance showed significance by the F test to the first count for the hours of imbibition, and for the interaction between factors (lots x hours) for germination and emergence speed index (Table 1), and from those results the separate regressions were derived. Another observation was the interaction between factors for plantlet dry mass; however, non-significant effects in the responses related to plantlet length (PTL, SL, and RL) (Table 2).

TABLE 1 - Analysis of variance and mean square of the first germination count (FGC), germination (G), and emergence speed index (ESI) from two lots of amaranth seeds submitted to imbibition by matriconditioning.

Variation sources	DF	FGC (%)	G (%)	ESI
Lots	1	105.0208333^{ns}	18.7500000^{ns}	119.82702^{**}
Imbibition	5	675.0875000^{**}	133.333333^{**}	191.9079^{**}
Lots x Imbibition	5	206.5208333^{ns}	132.7500000^{*}	55.683151^{**}
Residual	36	83.6180556	38.9027778	6.9133323
CV (%)		22.75	10.83	10.52

^{ns} = non-significant, **significant ($p<0.01$), *significant ($p<0.05$).

TABLE 2 - Analysis of variance and mean square of the dry mass of plantlets (DMP), plantlet total length (PTL), shoot length (SL), and root length (RL) from two lots of amaranth seeds submitted to imbibition by matriconditioning.

Variation sources	DF	DMP (g)	PTL (cm)	SL (cm)	RL (cm)
Lots	1	0.0000029^{ns}	0.137636^{ns}	0.002145^{ns}	0.016272^{ns}
Imbibition	5	0.0000021^{ns}	0.365880^{ns}	0.018497^{ns}	0.001384^{ns}
Lots x Imbibition	5	0.0000068^{**}	0.119810^{ns}	0.005764^{ns}	0.006863^{ns}
Residual	36	0.0000011	0.1997275	0.0109034	0.0142147
CV (%)		10.27	5.07	4.51	5.13

^{ns} = non-significant, **significant ($p<0,01$).

The percentage of germinated seeds in the first count of germination was adjusted to a positive quadratic model, with the decrescent trend until 16 h of imbibition, followed by an increase of seven percentage points in the last evaluated period (Figure 2). Rocha et al. (2017), when comparing the matriconditioning technique with non-monitored hydration, matriosmoconditioning, and moist atmosphere in Abyssinian (*Crambe abyssinica* Hochst) seeds, verified that matriconditioned seeds presented superior values of normal plantlets in the first count of the germination test.

Analyzing the germination data (Figure 3), it was possible to observe inverse effects between lots. L1 presented a positive quadratic behavior, similar to the occurrence in the mean of the lots for the first germination count test, passing from 47 to 60% of germinated seeds between 16 and 32 h of imbibition. This increase after 32 h of imbibition is probably due to the seeds already be on the verge of phase III of the three-phase pattern of germination, helping in this process. In contrast, L2 presented a linear reduction in germination with the increase in imbibition hours.

The findings of this study are in agreement with the observations by Gurgel Júnior (2009) in cucumber seeds that there were no differences for germination percentage using hydroconditioning in paper towel sheets. Similarly, “barbatimão” (*Stryphnodendron adstringens*) seeds osmoconditioned for 24 h in the potential of -1.0 MPa with PEG 6000, PEG 6000 + KNO_3 and KNO_3, showed a reduction in the percentage of germination with the increase of conditioning time, being the highest values obtained for non-conditioned seeds (0 h), with germination close to 50% (KISSMANN et al., 2010).

Controversially, several studies show an increase in the performance of seeds from diverse species by the physiological conditioning, like cucumber (LIMA and MARCOS FILHO, 2009), green pepper (ALBUQUERQUE et al., 2009) and melon (PAIVA et al., 2012). Seeds of Abyssinian matriosmoconditioned and matriconditioned presented higher germination rate (ROCHA et al., 2017), supporting the results observed in rapeseed (*Brassica napus* L.), hydroconditioned for 24 h at 25ºC after drying in laboratory conditions presented higher germination and reduction in the time for germination (BIZANJADEH et al., 2010). Besides, studies state the benefit of conditioning in the increase of germination when in adverse conditions. Moosavi et al. (2009) observed that osmoconditioning increased germination and the growth of amaranth plantlets under saline stress.

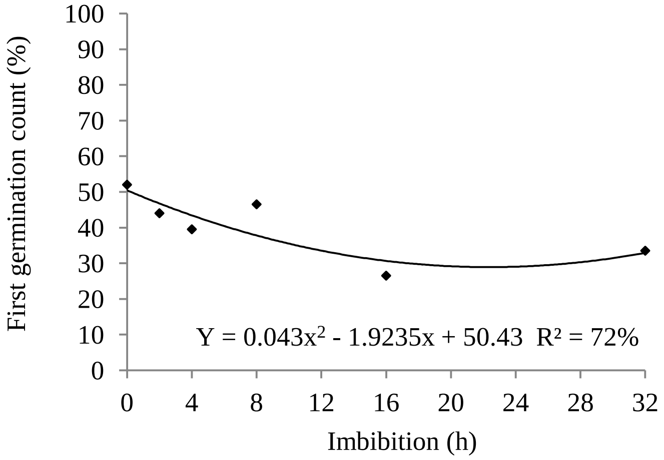

FIGURE 2 - First germination count of two lots of amaranth seeds submitted to imbibition by matriconditioning.

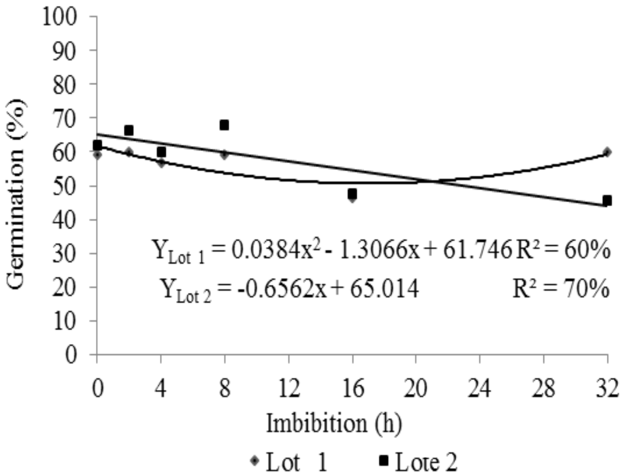

FIGURE 3 - Germination of two lots of amaranth seeds submitted to imbibition by matriconditioning.

Oliveira et al. (2019) evaluating the conditioning of melon seeds under saline stress concluded that under severe saline stress, hydrocontitioning should be used to increase the percentage of germination and higher initial growth rate when compared to osmoconditioning. The same authors state that the use of melon seeds without previous conditioning should not be adopted in cultivation areas affected by salinity, because they result in a lower germination rate and reduced initial growth of plants.

Matriconditioning showed a positive effect on the emergence speed index for L1 (Figure 4), with the increase of the imbibition period. Silva et al. (2016) observed that soybean seeds of low vigor presented higher ESI when conditioned for 48 h at -1.0 Mpa; however, without differing from the other treatments. Hydroconditioned seeds of “tucumã-açu” (*Astrocaryum aculeatum*) imbibed for two, four, and six days, in different temperatures, presented a higher emergence speed index, independent of temperature and period of imbibition (NAZÁRO and FERREIRA, 2010).

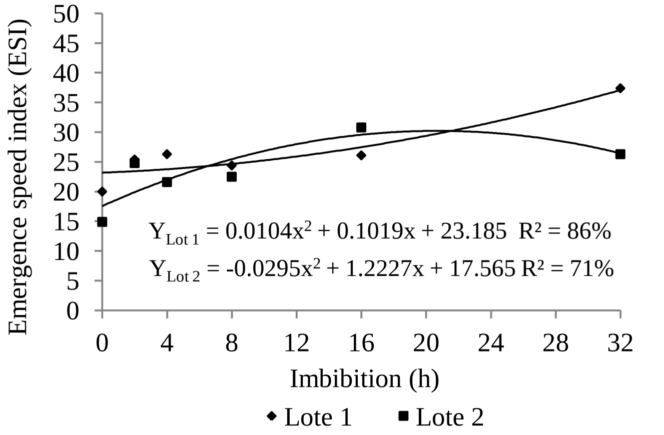

FIGURE 4 - Emergence speed index (ESI) of two lots of amaranth seeds submitted to imbibition by matriconditioning.

In the evaluation of accumulated emergence, it was possible to note that the lots of *Amaranthus* sp. Presented stability at 4 and 5 days for L1 and L2, respectively (Figures 5A and 5B). For both lots, the imbibition for 32 h had the best emergence results, while the control (0 h of imbibition) presented, for L2, the lowest performance.

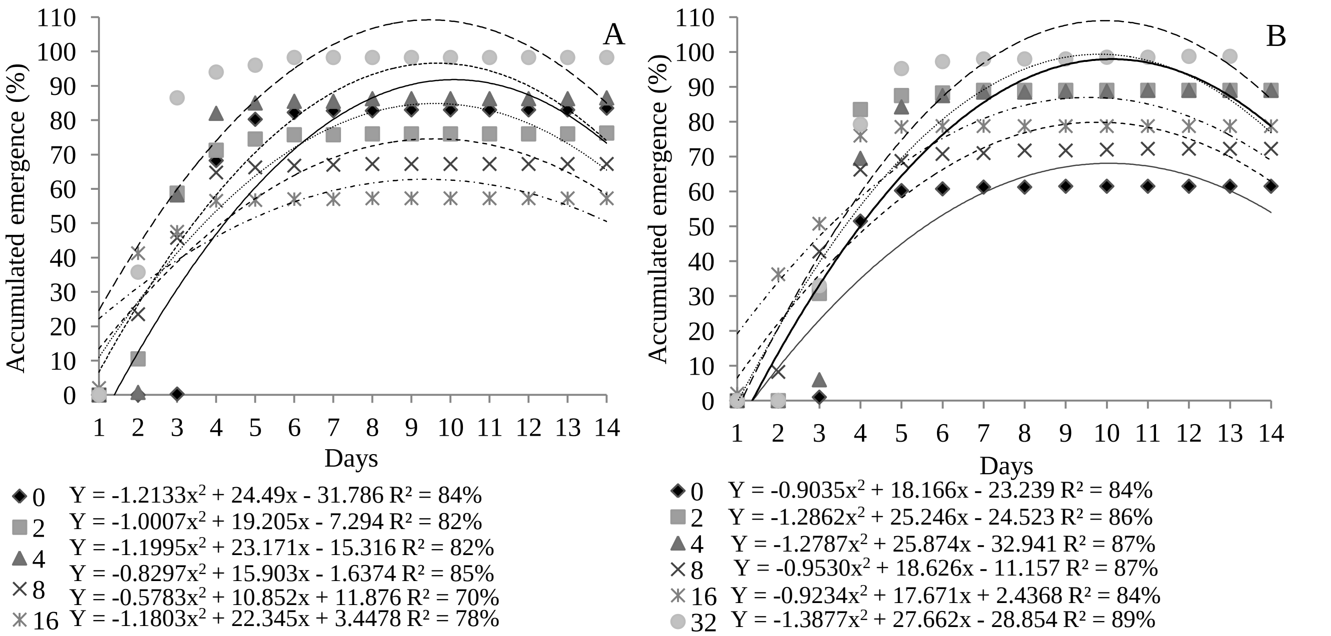

FIGURE 5 - Accumulated emergence prevenient from amaranth seeds from L1 (A) and L2 (B) submitted to imbibition by matriconditioning.

This result is in concordance with the ones reported by Nazáro and Ferreira (2010) in “tucumã-açu”, confirming the superior plantlet emergence from imbibed seeds compared to the control. Rabbani et al. (2013) observed that the imbibition of moringa seeds (*Moringa oleifera* Lam.), for 24 h, benefitted the plantlet emergence. Shah et al. (2012) found benefits of the osmotic conditioning by 4 h, in diluted solutions of phosphorus, not only in the emergence of plantlets but also in the performance and earliness in seeds of mung bean (*Vigna radiata)*. L1 presented a crescent tendency to dry mass (Figure 6) as a function of the imbibition periods, while lot 2 had a decrescent tendency. For L2, not matriconditioned seeds presented a higher accumulation of dry mass.

In a watermelon seed study, Guimarães et al. (2013) verified that the periods of 63.21 and 134.70 h of pre-imbibition showed to be superior to the others, for this same variable. In contrast, seeds of *S. polyphyllum* that were not osmoconditioned and pre-imbibed presented superior results for dry mass, agreeing with what was verified in this study, in at least one of the lots (L2) (SCALON et al., 2014). Similarly, Rabbani et al. (2013) had the highest dry mass in the plantlets of moringa (*Moringa oleifera* Lam.) from seeds that were not submitted to conditioning, imbibed for 24 h.

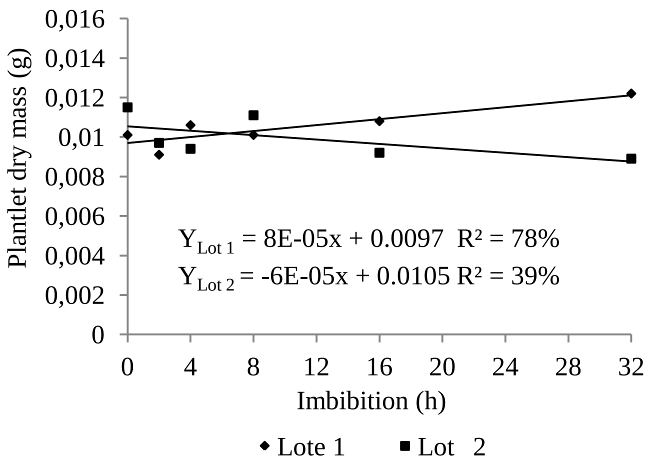

FIGURE 6 - Dry mass of plantlets from two lots of amaranth seeds submitted to imbibition by matriconditioning.

The highest dry mass of amaranth plantlets from matriconditioned seeds of L1 is probably due to some intrinsic characteristic of the lot not studied by this study. It also can be attributed to the metabolic processes that occur during matriconditioning, which induce prolonged protein synthesis, favoring the metabolic balance generating quality attributes that will influence not only germination but also in the establishment of the plantlet and biomass accumulation (TRIGO et al., 1999).

The periods of imbibition did not provide changes in the root, shoot, or total plantlet length for Amaranth (Table 2). The results are in agreement with the findings by Scalon et al. (2014), in which the root length did not suffer variation in function of the period of imbibition in "barbatimão" (*Stryphnodendron adstringens* and *S. polyphyllum*) seeds. Silva et al. (2016), evaluating soybean seeds osmoconditioned at -1.0 and 1.2 MPa, did not verify differences for plantlet total length compared to the ones without treatment before seedling. In the same way, Marcos Filho and Kikuti (2008) stated the absence of effect of conditioning in plant height in cauliflower seeds hydrocontitioned between paper sheets in a period from 30 to 36 h.

In general, variation between lots was observed, even with similar germination at 0 h. L1 presented favorable results to matriconditioning, mainly with the increase in imbibition hours, verified by the increase in dry mass and the emergence speed index, as well as faster stability in accumulated emergence. However, L2 did not show improvement in the physiological performance of matriconditioned seeds. Matriconditioning can vary as a function of the lot of seeds used. Thus, there is a need for more studies on this methodology to rectify the results and help solidify the scientific basis around the subject.

CONCLUSIONS

Amaranth seeds reach phase II of germination around 8 h of imbibition by matriconditioning.

The effect of matriconditioning in the physiological performance of amaranth seeds varies as a function of the lot used.

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