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Viability and vigor of *Moringa oleifera* Lam. seeds by means of rapid tests[1]

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ABSTRACT - *Moringa oleifera* Lam. is an arboreal forest species of great economic potential, adapted to the climatic conditions of the Brazilian semi-arid region, whose multiplication is mainly by seeds. Rapid viability and vigor tests help in the choice of lots. Thus, the objective of this study was to assess the efficiency of the pH of exudate and primary root protrusion tests in the evaluation of viability and vigor, respectively. Two seed lots were initially evaluated for moisture content, germination, first count, germination speed index, seedling length, seedling dry mass and electrical conductivity. For the pH of exudate test, phenolphthalein (1%) and sodium carbonate (2 and 4 g L^{-1}) solutions were prepared, with three soaking periods (1, 3 and 5 h) and three temperatures (25, 30 and 35 °C). Exudate solution in strong to light pink color indicated viable seeds, whereas very light pink color to colorless indicated non-viable seeds. The primary root protrusion test was performed under 25, 30 and 35 °C, evaluating the primary root protrusion of at least 2 mm, every 12 h until 196 h. The experimental design was completely randomized, with four replicates. pH of exudate test with 1 h of soaking at 25 or 30 °C with 2 g L^{-1} sodium carbonate solution was promising, but further studies are needed before it is indicated as routine use for the species. Primary root protrusion test is efficient and can be conducted at 35 °C with evaluation after 48 h.

Key words: *Moringaceae*. Forest seeds. Viability. Vigor.

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INTRODUCTION

Moringa (*Moringa oleifera* Lam.) is a tree of Indian origin, adapted to the climatic conditions of tropical countries (Asensi; Villadiego; Berruezo, 2017). Due to its chemical and medicinal properties, it can be used in the production of cosmetics, food supplementation and bioremediation in the treatment of water resources (Tavares *et al*., 2020). Considering the potential of commercial planting, easy management and edaphoclimatic adaptation, the cultivation of this species can serve as an instrument to leverage the development of the Brazilian semi-arid region (Carvalho *et al*., 2017).

Economic exploitation of *M. oleifera* requires a survey of the physiological potential of its seeds. In this aspect, the use of viability and vigor tests with precise methodologies is important to assess the quality of seed lots, as well as serving to support their use (Ponce *et al*., 2019). This assessment is routinely performed by means of the germination test; however, depending on the species, it requires relatively long periods for its completion. For *M. oleifera*, 10 to 16 days were needed to complete this test (Alves *et al*., 2005; Pereira *et al*., 2015). Thus, it is essential to use tests that help in classifying the quality of seed lots quickly and safely aiming at decision making.

Of the rapid tests employed to assess viability, the pH of exudate test stands out (Wendt *et al*., 2017). Adjusting its methodology for each species is essential to obtain successful results. The pH of exudate is a biochemical method that is based on the chemical reactions that occur in the process of membrane deterioration, causing a reduction in seed viability, in addition to being a fast and low-cost test (Carvalho *et al.*, 2018). Thus, it makes it possible to classify the lots, identify seeds with inadequate performance in the field, and determine the level of viability (Wendt *et al*., 2017).

The pH of exudate test is based on the amount of solutes released between viable and non-viable seeds subjected to soaking, whose viability is related to deterioration events, such as membrane permeability and leaching of solutes (Carvalho *et al.*, 2018). This test proved to be efficient in evaluating the viability of seeds of 'araucaria' (*Araucaria angustifolia* Bertol.) (Araldi; Coelho, 2015), 'crambe' (*Crambe abyssinica* Hochst) (Alves *et al*., 2016), 'pau-ferro' (*Libidibia ferrea* Martius ex Tul.) (Souto *et al*., 2019), 'aroeira-do-sertão' (*Astronium urundeuva* Fr. M. Allemão Engl.) (Alves *et al*., 2020) and 'pau-roxo' (*Peltogyne confertiflora* (Mart. Ex Hayne) Benth.) (Ferreira *et al*., 2020).

The primary root protrusion test is considered a fast and very promising method for evaluating seed vigor. This test is based on the principle that seeds with greater vigor will produce the primary root before less vigorous ones (Oliveira *et al*., 2019). This test has been used in several agricultural species with promising results, such as chia (*Salvia hispanica* L.) (Oliveira *et al*., 2019), lettuce (*Lactuca sativa* L.) (Silva *et al*., 2020) and soybean (*Glycine max* L.) (Rêgo *et al*., 2023).

Due to the results obtained for several agricultural species, the pH of exudate and primary root protrusion tests can be used in the analysis of seed viability and vigor, contributing to the decision making for the selection of suitable lots for seedling production, storage or commercialization. Thus, the objective of this study was to assess the efficiency of the pH of exudate and primary root protrusion tests in the evaluation of viability and vigor, respectively, in moringa seeds.

MATERIAL AND METHODS

Acquisition and initial evaluation of seeds

Moringa seeds comprised two lots collected in 2017 and 2021, from five parent trees located on the central campus of the Federal Rural University of the Semi-Arid Region (UFERSA), Mossoró, RN, Brazil (5°12'16.95"S and 37°19'20.76"W). After collection, the seeds were processed, and those that were malformed, attacked by insects or empty were discarded. The selected ones were packed in plastic bags and stored in a controlled environment (17 °C; 45% RH) at the Seed Analysis Laboratory of UFERSA, until the beginning of the experiments, in September 2022. Initially, the lots were evaluated in relation to moisture content, germination speed index (GSI), seedling length, seedling dry mass and electrical conductivity, as described below:

a) Moisture content – determined by the oven method at 105 °C/24h (Brasil, 2009), with two replicates of 5 g and results expressed as percentage of moisture content (MC) (wet basis).

b) Germination - four replicates of 25 seeds were sown interspersed on two sheets of paper towels and covered by a third sheet, previously moistened with a volume of distilled water equivalent to 2.5 times the dry weight of the papers. With this, paper rolls were formed, packed in plastic bags and kept in a germination chamber at 25 °C for 10 days (Pereira *et al*., 2015). In the final evaluation, the criterion of normal seedling formation was adopted (Brasil, 2009).

c) Germination speed index (GSI) - performed together with the germination test, with a daily count of germinated seeds (root protrusion). Germination began on the third day after setting up the test. The results were calculated according to the formula proposed by Maguire (1962).

d) Seedling length - performed at the end of the germination test, with random collection of 10 normal seedlings to measure their total length using a ruler graduated in centimeters. The data were expressed in cm seedling^{-1}.

e) Total seedling dry mass - normal seedlings were placed in kraft paper bags, identified and dried in a forced air circulation oven at 65 °C for 72 hours. When they reached constant mass, they were weighed on a precision analytical balance and the results were expressed in g seedling^{-1}.

f) Electrical conductivity test - performed with four replicates of 50 seeds from each lot, previously weighed on a semi-analytical balance. The seeds were immersed in 75 mL of distilled water for 4 h at 25 °C (Medeiros; Pádua; Pereira, 2017). Then, the solution was read in a benchtop conductivity meter and the results were expressed in µS cm^{-1} g^{-1}.

pH of exudate test

Pre-tests were conducted with different concentrations of sodium carbonate and numbers of drops of each solution. Using a Pasteur pipette, one, two, and three drops of each indicator solution were tested, with sodium carbonate at concentrations of 1.0, 2.0, 3.0, and 4.0 g L^{-1} and phenolphthalein (1 gram dissolved in 100 mL of alcohol plus 100 mL of boiled distilled water (Souto *et al*., 2019) placed in 10 mL of distilled water. The amounts of one and two drops at all concentrations resulted in a very light pink color, as well as the concentration of 1.0 g L^{-1}. Concentrations of 2.0, 3.0 and 4.0 g L^{-1} resulted in similar color (strong pink - reference color).

The pH test was set up in a completely randomized experimental design with four replicates of 25 seeds for each lot, individually distributed in 50 mL plastic cups containing 10 mL of distilled water. To facilitate reading, 25 cups were arranged in each plastic tray.

Cups containing seeds immersed in distilled water were kept in a germination chamber for 1, 3 and 5 h at 25, 30 and 35 °C, at concentrations of 2.0 and 4.0 g L^{-1} of sodium carbonate. After these soaking periods, three drops of sodium carbonate solution and three drops of phenolphthalein solution were added to each cup with a Pasteur pipette. Then, the solutions were homogenized with glass rod and immediately evaluated, and the color obtained from the exudate in the soaking solution was checked. Interpretation was performed according to the color of the solution: dark pink or light pink color of the solution identified viable seeds, while very light pink color or colorless solution pointed to non-viable seeds (Souto *et al*., 2019).

The results were expressed as percentage of viable seeds. Analysis of variance was performed and means were compared by Tukey test at 5% probability level, using the computer statistical analysis system SISVAR (Ferreira, 2014).

Primary root protrusion test

The test was carried out in a completely randomized design with four replicates of 25 seeds, sown on two paper towel sheets and covered by a third sheet, previously moistened with distilled water in the proportion of 2.5 times the weight of the dry substrate. The substrate containing the seeds was arranged into rolls, which were packed in plastic bags and placed in an germination chamber separately at temperatures of 25, 30 and 35 °C.

For the evaluation of the primary root protrusion test, every 12 h from its setup until completing 196 h, the seeds were observed for the protrusion of at least 2 mm of primary root. The result of the number of seeds with radicles protruded early was expressed as a percentage. In addition, the primary root protrusion index, calculated by the formula proposed by Maguire (1962), was also evaluated.

The data were subjected to analysis of variance and the means were compared by Tukey test at 5% probability level, using the statistical program SISVAR (Ferreira, 2014).

RESULTS AND DISCUSSION

The moisture content values were similar among the lots (Table 1). Moringa seeds are orthodox and the low amount of water keeps them conserved for longer (Medeiros *et al*., 2019). In addition, the little variation in moisture content between the two lots makes it possible to infer that the seeds are at the same level of metabolic activity, increasing the reliability of the results (Marcos-Filho, 2015).

Table 1 - Means of moisture content (MC), first count (FC), germination (G), germination speed index (GSI), seedling length (SL), seedling dry mass (SDM) and electrical conductivity (EC) of two lots of moringa (*Moringa oleifera* Lam.) seeds

Lots	MC (%)	FC (%)	G (%)	GSI	SL (cm seedling^{-1})	SDM (g seedling^{-1})	EC (µS cm^{-1} g^{-1})
2017	7.05	0 b	56 b	1.24 a	4.66 b	2.54 b	1079.32 b
2021	6.69	51a	96 a	4.95 a	13.3 a	2.80 a	402.35 a
F	-	181.46*	71.05*	145.10*	282.17*	15.00*	196.19*
CV(%)	-	21	15.25	14.05	8.09	3.45	9.23

* significant by F test. Means followed by the same letter do not differ from each other by Tukey test at 5% probability level. CV - coefficient of variation

In the initial quality tests, there was a significant effect of the lots on all the variables analyzed, with the 2021 lot standing out compared to the 2017 lot (Table 1). Thus, the 2021 lot is considered to have a higher physiological potential compared to the one harvested in 2017. To assess the efficiency of the pH of exudate test, it is essential to work with lots that show differences in their quality (Grzybowski *et al*., 2022).

The first germination count of the 2021 lot was 51% and germination was 96%. On the other hand, seeds from the 2017 lot did not germinate in the first count and resulted in 56% germination (Table 1).

In the present study, it was observed that moringa seeds from the lot harvested in 2017, stored for 60 months (five years), had compromised germination and vigor. Storage is one of the factors that can contribute to the loss of seed viability due to physiological, biochemical, physical, and cytological changes caused by deterioration (Silva *et al*., 2019).

Aging is a natural process that results in the peroxidation of lipids, disruption of cell membranes, and disintegration of the cell nucleus. Thus, depending on the species, seeds may lose their physiological potential during the storage period, compromising or preventing germination (Silva *et al*., 2019). The viability and vigor of moringa seeds in cold chambers are maintained for 15 to 27 months (Melo, 2017; Silva; Andrade; Souza, 2012).

Regarding seedling length and dry mass, the 2021 lot led to a higher mean total length than the 2017 lot. This result was already expected, since the 2021 lot showed better physiological performance in all other initial quality tests. Proportionally, the dry mass of seedlings was also statistically higher for those from the 2021 lot (Table 1). In four seed lots of the same species, Medeiros *et al.* (2019) found variation in seedling length from 12 to 16 cm. Likewise, Noronha, Medeiros and Pereira (2018) also recorded seedlings with length between 13 and 15 cm for moringa seed lots with more than 50% germination and 6.5 cm for lots with less than 50% germination.

Emergence, seedling emergence speed, height, stem diameter, number of leaves and dry mass are affected by the reduction in seed vigor (Ferreira; Gentil, 2003). Thus, considering the low development of moringa seedlings from the 2017 lot and, consequently, their low dry mass, it must be reinforced that this lot has reduced physiological potential compared to the 2021 lot (Table 1).

The electrical conductivity test confirmed the superiority of seeds from the 2021 lot over those from the 2017 lot (Table 1). This test measures the amount of electrolytes leached by the seeds soaked in water for a given time. Seeds with damaged or deteriorating membranes tend to leach more electrolytes, which indicates that they are less vigorous (Silva *et al*., 2019).

The results obtained by the pH of exudate test indicated that viable seeds were those with a dark or light pink soaking solution after contact with phenolphthalein and sodium carbonate solutions (Figures 1A and 1B). On the other hand, seeds classified as non-viable were those that had a very light pink or colorless soaking solution (Figures 1C and 1D). These classifications were based on the study conducted by Souto *et al*. (2020) with seeds of *L. ferrea* Martius ex Tul.

At the concentration of 2 g L^{-1} of sodium carbonate at 25 °C in the soaking periods of 1 and 3 h, it was not possible to differentiate the lots. However, in the soaking period of 5 h, there was statistical difference between the lots, indicating the 2021 lot as superior to the 2017 lot (Table 2). However, the means of viable seeds obtained by the pH of exudate test were well below those obtained in the germination test, for both lots.

Under the temperature of 30 °C, it was observed that there was statistical difference between the lots with 1 h of soaking. On the other hand, at 35 °C, the soaking periods of 1 and 3 h were able to differentiate the lots (Table 2). In both combinations, the results obtained were similar and close to the initial germination percentage (Table 1).

Figure 1 - Color of the exudate after contact with indicator solutions in moringa (*Moringa oleifera* Lam.) seeds classified as viable (A and B) and non-viable (C and D) by the pH of exudate test

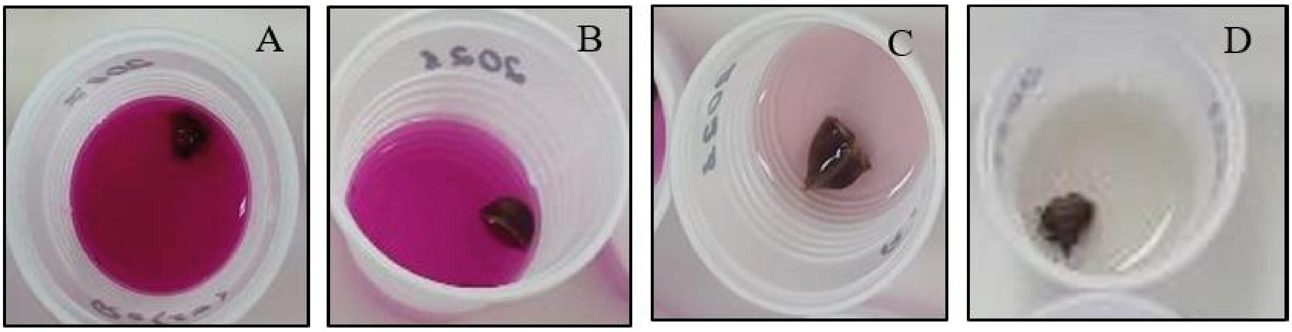

Table 2 - Means of viable seeds of moringa (*Moringa oleifera* Lam.) by the pH of exudate test at 25, 30 and 35 °C at concentrations of 2 and 4 g L^{-1} of sodium carbonate

Lots	25 °C			30 °C			35 °C		
	2 g L^{-1}								
	1 h	3 h	5 h	1 h	3 h	5 h	1 h	3 h	5 h
2017	58 a	56 a	33 b	57 b	59 a	47 a	58 b	46 b	50 a
2021	68 a	58 a	51 a	77 a	56 a	47 a	76 a	62 a	44 a
F	3.95^{ns}	0.06^{ns}	6.48*	13.95*	0.16^{ns}	0.0^{ns}	22.10*	8.72*	0.40^{ns}
CV (%)	11.30	20.46	23.81	11.30	18.57	22.38	8.08	14.18	28.44
	4 g L^{-1}								
2017	100 a	100 a	97 b	99 a	95 b	98 a	99 a	99 a	98 a
2021	100 a	100 a	100 a	99 a	100 a	96 a	87 b	76 b	89 a
F	1.00^{ns}	1.00^{ns}	9.00*	0.0^{ns}	25.0*	0.43^{ns}	6.20*	58.80*	3.10^{ns}
CV (%)	0.0	0.0	1.44	2.02	1.45	4.45	7.35	4.85	7.76

^{ns} not significant at 5% probability level. * significant by the F test. Means followed by the same letter do not differ from each other by Tukey test at 5% probability level. CV - coefficient of variation

At the concentration of 4 g L^{-1} of sodium carbonate, the 2017 lot resulted in a high mean of viable seeds (Table 2), for all combinations between temperatures and soaking periods. This result was not consistent with the classification obtained for the initial tests (Table 1). At the temperature of 25 °C, only the treatment with 5 h of soaking caused statistical difference between the lots. However, the mean number of viable seeds in the 2017 lot differed from the results obtained in the initial evaluation, proving to be relatively high. On the other hand, at the temperature of 30 °C, there were differences between the lots only for the period of 3 h (Table 2). However, once again, the 2017 lot resulted in a high percentage of viable seeds, contradicting the results obtained in the initial classification (Table 1).

The temperature of 35 °C resulted in a divergent behavior compared to the other temperatures, as it indicated the 2017 lot with higher mean of viable seeds compared to the 2021 lot, for all soaking periods. Thus, it is understood that the concentration of 4 g L^{-1} of sodium carbonate is not indicated for evaluating the viability of moringa seeds in any of the periods and temperatures used. Probably, this concentration was quite high, overestimating the quality of the 2017 lot, because under these conditions a longer seed soaking period would be necessary to obtain consistent results. On the other hand, it would not be economically viable, since there were more promising results using the lower concentration.

In addition to the concentration of sodium carbonate, variables such as the number of droplets, soaking time, and the amount of distilled water for seed soaking can influence the results of the pH oh exudate test (Theodoro *et al*., 2018). The volume chosen for soaking depends on the size of the seed analyzed. Therefore, it is necessary to make the adjustment between the concentration of sodium carbonate used and the volume of water used in the soaking, all of this to obtain the reference color (dark pink) with phenolphthalein and carbonate solutions, as observed in studies with seeds of ‘mutamba’ (*Guazuma ulmifolia* L.), ‘angico do cerrado’ (*Anadenanthera falcata* Benth.), ‘macambira’ (*Encholirium spectabile* L.) and ‘jucá’ (*L. ferrea* Martius ex Tul.) (Araújo; Silva, 2018; Barboza *et al*., 2014; Souto *et al*., 2019; Stallbaun *et al*., 2015).

Thus, it can be seen that the pH of exudate test is promising in the evaluation of moringa seeds if the protocol of sodium carbonate concentration of 2 g, soaking period around 1 h and temperature between 30 and 35 °C is established.

Regarding the primary root protrusion test, there was a significant difference between the lots from 96 h at 25 °C, resulting in more than 50% root protrusion in seeds from the 2021 lot and none for those from the 2017 lot (Table 3). This result was similar to that obtained in the first germination count (Table 1). Primary root protrusion values close to those obtained for germination were found at 144 and 156 h.

The temperature of 25 °C slowed down the process of primary root protrusion compared to the others. This has also been observed in seeds of ‘gabiroba’ (*Campomanesia adamantium* O. Berg.) by Leão-Araújo *et al*. (2019) and chia (*S. hispanica* L.) by Oliveira *et al*. (2019). Lower temperatures can reduce seed metabolic activities and water absorption, causing delayed germination and low germination index, as observed in most seeds of tropical and subtropical species (Ojeda *et al*., 2021).

The temperature of 30 °C accelerated the germination process, and it was possible to observe seeds with root protrusion in just 60 h, but only 10%. From 168 h, the 2021 lot stabilized root protrusion, while in the 2017 lot the stabilization occurred from 180 h (Table 4). However, these root protrusion percentages are not consistent with the results of the initial quality test (Table 1).

For the results obtained at temperature of 35 °C, it was found that root protrusion occurred earlier compared to the other temperatures, and it was possible to distinguish the two lots in only 48 h, but with a lower final percentage for the 2017 lot (Table 5).

At higher temperatures, enzymatic activities in seeds tend to occur more quickly, accelerating the germination process (Silva *et al*., 2018). However, seeds with low vigor are more demanding in terms of optimal temperature for germination, while more vigorous seeds can germinate within a wide temperature range

Table 3 - Percentage of primary root protrusion in two lots of moringa (*Moringa oleifera* Lam.) seeds, at 25 °C

Lots	Hours							
	12	24	36	48	60	72	96	108
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0 b	21.0 b
2021	0.0	0.0	0.0	0.0	0.0	2	56.0 a	88.0 a
F	-	-	-	-	-	3.0^{ns}	168.0*	91.6*
CV (%)	-	-	-	-	-	163.30	21.82	18.1
Lots	Hours							
	120	132	144	156	168	180	192	196
2017	36.0 b	52.0 b	55.0 b	58.0 b	60.0 b	63.0 b	63.0 b	64.0 b
2021	93.0 a	93.0 a	93.0 a	94.0 a	94.0 a	95.0 a	95.0 a	95.0 a
F	191.1*	30.93*	22.8*	16.2*	15.7*	14.91*	14.91	13.16*
CV (%)	9.04	14.38	15.21	16.64	15.73	14.83	14.83	15.20

^{ns} not significant at 5% probability level. * significant by the F test. Means followed by the same letter in the column do not differ by Tukey test at 5% probability level. CV - coefficient of variation

Table 4 - Percentage of primary root protrusion in two lots of moringa (*Moringa oleifera* Lam.) seeds, at 30 °C

Lots	Hours							
	12	24	36	48	60	72	96	108
2017	0.0	0.0	0.0	0.0	1.0 b	8.0 b	23.0 b	38.0 b
2021	0.0	0.0	0.0	0.0	10.0a	66.0 a	85.0 a	87.0 a
F	-	-	-	-	16.2*	120.1*	66.2*	53.3*
CV (%)	-	-	-	-	57.5	20.23	19.9	15.1
Lots	Hours							
	120	132	144	156	168	180	192	196
2017	43.0 b	44.0 b	44.0 b	45.0 b	46.0 b	47.0 b	47.0 b	47.0 b
2021	87.0 a	87.0 a	87.0 a	87.0 a	88.0 a	88.0 a	88.0 a	88.0 a
F	34.9*	32.4*	32.4*	29.0*	37.8*	41.0*	41.0*	41.0*
CV (%)	16.1	16.3	16.3	16.6	14.4	13.2	13.4	13.4

* significant by the F test. Means followed by the same letter in the column do not differ by Tukey test at 5% probability level. CV - coefficient of variation

(Carvalho; Nakagawa, 2012). The optimal temperature for germination can be conceptualized as the one at which the seed expresses its maximum germination potential in the shortest time (Figueiredo *et al*., 2019). Thus, it is understood that higher temperatures accelerate the process of primary root protrusion, promoting a faster analysis of the quality of the lots. From 156 h onwards, the percentage of seeds with root protrusion stabilized in both lots. At higher temperatures, there is a reduction in viscosity and an increase in the kinetic energy of water, accelerating imbibition and consequently increasing the speed of seed metabolism reactions (Marcos-Filho, 2015). On the other hand, lower temperatures result in increased viscosity and reduced water mobility (Leão-Araújo *et al*., 2019).

There was a significant effect on the primary root protrusion index for all temperatures tested (Table 6). The 2021 lot was more vigorous compared to the 2017 lot at all temperatures evaluated. Thus, the results were consistent with the classification of the initial quality and with the percentage of primary root protrusion. Under the temperature of 35 °C, it was possible to observe higher values of this index for the two lots.

Primary root protrusion earliness is associated with the period required and the energy consumed for reactivation of metabolism towards germination, activities of repair mechanisms in the membrane system, and resumption of DNA and protein synthesis. The period is longer and the consumption is greater in more deteriorated or less vigorous seeds, delaying the protrusion of the primary root (Krzyzanowski *et al*., 2020). In the present study, it was possible to verify this information, since the lot classified as having lower vigor resulted in lower primary root protrusion capacity.

In view of the results, the root protrusion test in moringa seeds can be conducted at 35 °C with evaluation after 48 h. Information involving this line of research is scarce, especially for forest seeds, as the studies found are more directed to vegetable and major crop species.

Table 5 - Percentage of primary root protrusion in two lots of moringa (*Moringa oleifera* Lam.) seeds, at 35 °C

Lots	Hours							
	12	24	36	48	60	72	96	108
2017	0.0	0.0	0.0	0.0 b	8.0 b	25.0 b	34.0 b	34.0 b
2021	0.0	0.0	0.0	27.0 a	27.0 a	85.0 a	92.0 a	97.0 a
F	-	-	-	115.1*	18.3*	154.2*	148.4*	150.7*
CV (%)	-	-	-	26.3	35.8	12.4	10.69	11.08
Lots	Hours							
	120	132	144	156	168	180	192	196
2017	36.0 b	40.0 b	44.0 b	46.0 b	46.0 b	46.0 b	46.0 b	46.0 b
2021	97.0 a	98.0 a	98.0 a	98.0 a	98.0 a	98.0 a	98.0 a	98.0 a
F	166.6*	194.0*	128.6*	126.7*	126.7*	126.7*	126.7*	126.7*
CV (%)	10.05	8.53	9.48	9.07	9.07	9.07	9.07	9.07

* significant by the F test. Means followed by the same letter in the column do not differ by Tukey test at 5% probability level. CV - coefficient of variation

Table 6 - Primary root protrusion index in two lots of moringa (*Moringa oleifera* Lam.) seeds, at 25, 30 and 35 °C

Lots	Temperatures (°C)		
	25	30	35
2017	3.24 b	3.77 b	4.27 b
2021	6.37 a	8.70 a	10.35 a
F	29.1*	42.07*	93.7*
CV (%)	17.03	17.21	12.13

* significant by the F test. Means followed by the same letter in the column do not differ by Tukey test at 5% probability level. CV - coefficient of variation

CONCLUSIONS

1. pH of exudate test with 1 h of soaking at 30 or 35 °C with 2 g L^{-1} sodium carbonate solution is promising in the analysis of viability of moringa seeds, but needs further studies before being indicated as routine for the species;
2. Primary root protrusion test is efficient in classifying the vigor of moringa seed lots and can be conducted at 35 °C with evaluation after 48 h.

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