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NOTE

Adjustment of the electrical conductivity test to evaluate the seed vigor of chickpea (*Cicer arietinum* L.)

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ABSTRACT: The definition of methodologies that allow evaluating the physiological potential of chickpea seeds is important to ensure the commercialization of lots with high performance. Thus, this research aimed to determine the most suitable conditions for conducting the electrical conductivity test in chickpea seeds to classify lots according to vigor level. Therefore, seeds from five lots of cultivar BRS Aleppo and four lots of cultivar Cícero were subjected to tests to characterize their initial quality and the results were compared with those obtained in the electrical conductivity test. To assess electrical conductivity, five soaking periods (2, 4, 8, 12, and 24 hours) were combined with four volumes of water (75, 100, 150, and 250 mL) at 25 °C temperature. The results show that the electrical conductivity test is efficient in evaluating the physiological potential of chickpea seeds, providing information equivalent to other vigor tests. For the electrical conductivity test, it is recommended to use 50 seeds soaked in 150 mL of water, for 24 h, at 25 °C.

Index terms: *Cicer arietinum* L., physiological potential**,** soaking period, water volume.

RESUMO: A definição de metodologias que permitam avaliar o potencial fisiológico das sementes de grão-de-bico é importante para assegurar a comercialização de lotes com alto desempenho em campo. Assim, objetivou-se determinar as condições mais adequadas para a condução do teste de condutividade elétrica em sementes de grão-de-bico visando a classificação de lotes quanto ao vigor. Para tanto, sementes de cinco lotes da cultivar BRS Aleppo e de quatro lotes da cultivar Cícero foram submetidas a diferentes testes para a caracterização da sua qualidade inicial e os resultados comparados com os obtidos no teste de condutividade. Para avaliar a condutividade elétrica, 5 períodos de embebição (2, 4, 8, 12 e 24 horas) foram combinados a 4 volumes de água (75, 100, 150 e 250 mL) sob a temperatura de 25 °C. O teste de condutividade elétrica é eficiente para a avaliação do potencial fisiológico de sementes de grão-de-bico fornecendo informações equivalentes a outros testes de vigor. Para a condução do teste de condutividade elétrica recomenda-se a utilização de 50 sementes imersas em 150 mL de água, por 24 horas, a 25 °C.

Termos para indexação: *Cicer arietinum* L., potencial fisiológico, período de embebição, volume de água.

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INTRODUCTION

Chickpea (Cicer arietinum L.) is a legume worldwide cultivated and is beginning to show up as very important to food security and human nutrition, with encouragement consumption acts it is a great source of vegetable protein, fibers, minerals, and vitamins (Merga and Haji, 2019).

In Brazil, the growth of chickpeas is expanding and becoming a good option to farmers during the second harvest period, as well as in the winter, under an irrigation system (Nascimento and Silva, 2019). This way, the demand for seeds is also increasing. The Embrapa, the holder of most cultivars available, is promoting the production of seeds in the country. In this context, defining appropriate methods to evaluate the physiological potential of chickpea seeds is important to ensure a high-quality standard in the market.

The electrical conductivity test is a quick and practical method to evaluate the vigor of the seeds, which is related to the loss of the cell membranes system integrity, which is one of the first changes that occur due to deterioration (Delouche and Baskin, 1973). The higher the speed of recovery the integrity of the cell membranes system during the seed imbibition, the lower will be the leaching of electrolytes to the external environment and, therefore, the electrical conductivity, indicating a higher vigor (Powell, 1986; Baalbaki et al., 2009).

This test has been showing itself very promising to be used in quality control programs because, depending on the species, the results can be obtained in less than 24 hours (h) (Lima et al., 2015; Torres et al., 2015; Marques and Dutra, 2018; Melo et al., 2019), allowing faster decisions about the management of the seed lots.

Several factors can change the test results, such as the presence of mechanical damages or insects, level of moisture content in the seed, chemical treatments (Loeffler et al., 1988), besides the methodology particular characteristics as the number of seeds by replication, temperature, water volume and soaking time (Baalbaki et al., 2009; Vieira and Marcos-Filho, 2020).

The electrical conductivity test has been indicated to large seeds species (Vieira and Marcos-Filho, 2020), especially Fabaceae family as soybean (Dias and Marcos-Filho, 1996; Baalbaki et al., 2009), pea (Ferreira et al., 2017), and bean (Silva et al., 2013). For these species, has been recommended the use of 50 seeds samples soaked in 75 mL of water for 24 h (Vieira and Marcos-Filho, 2020). In soybean seeds, Dias and Marcos-Filho (1996) found out that shorter periods of soaking (8 to 12 h) allowed the identification of more significant differences between the vigor level of seed lots, while evaluations performed after 16 h were more sensitive to variations in seed quality, classifying the lots into vigor levels.

The results related to the test efficacy to evaluate the vigor of the chickpea seeds are still inconclusive, probably because of too much methodology variation. According to Khajeh-Hosseini and Rezazadeh (2011), low vigor lots can be identified within 2 h of imbibition; they also observed that using 50 seeds soaked in 250 mL of water, after 2 h and 24 h there was a correlation with the emergence of seedlings. Similar results were obtained with 5 g of seeds soaked in 50 mL of water in different periods, from 30 minutes to 24 h (Qasim et al., 2010).

Castilho et al. (2019) suggest that the test should be done with 25 chickpea seeds replications, using 50 mL of water for 4 h at 30 °C. However, the reduction from 50 to 25 seeds is not recommended, since it can increase the coefficient of variation and interfere with the accuracy of the results (Loeffler et al., 1988; Vieira e Marcos-Filho, 2020).

According to Hampton and Tekrony (2020) recommendations, the electrical conductivity test must be done with 50 pure seeds samples, as also reported by Vieira and Marcos-Filho (2020). Another important factor is the water volume used, which must be compatible with the size of the seeds and the sample, so all the seeds are kept submerged, and the imbibition solution must not be extremely concentrated or diluted (Vieira and Marcos-Filho, 2020).

Therefore, the aim of this research was to adapt the methodology to the electrical conductivity test to evaluate the vigor in chickpea seeds.

MATERIAL AND METHODS

This research was made at the Seed Research Laboratory of the Agronomy Department from *Universidade Federal de Viçosa*, Minas Gerais, Brazil. Seeds from nine chickpea lots were used, five from BRS Aleppo and four from Cícero, grown at the 2018 harvest and supplied by *Embrapa Hortaliças*. The seeds from each lot were stored in paper bags and kept in a cold chamber (10 ± 2 °C e 50% UR) during all the experimental periods.

Only the seeds used for for evaluating initial quality were treated with fungicide (Carbendazim, 150 $g.L^{-1}$ + Thiram, 350 $g.L^{-1}$), at a dose of 200 mL.100 Kg^{-1} of seeds, determining the following characteristics:

Moisture content: was conducted with four replications of 25 seeds by the oven drying method at 105 ± 3 °C for 24 h (Brasil, 2009). The results were expressed in percentage (wet basis).

Thousand-seed weight: it was conducted by using eight replications of 100 seeds for each lot, following the prescriptions from the Rules for Seed Testing (Brasil, 2009). The results were expressed in grams.

Germination: four replications of 50 seeds were distributed on a paper towel, moistened with distilled water in the amount of two times the weight of the dry substrate. We prepared paper rolls that were kept in a germinator at 20 °C. Evaluations of normal seedlings were made at the fifth (first count) and eighth day (final count) (Brasil, 2009). The results were expressed in the percentage of normal seedlings.

Cold test: it was conducted using a paper towel substrate moistened as described for the germination test, which was kept at 10 °C for 24 h before sowing. Four replications of 50 seeds were distributed on two sheets of paper towel and covered with 40 mL of soil. After that, the rolls were were placed in plastic bags and kept in a chamber (BOD) at 10 °C for seven days. After that period, the rolls, without the plastic bags, were transferred to a seed germinator at 20 °C for five days to then proceed to the evaluation of the percentage of normal seedlings.

Seedling emergence: it was conducted in a growth chamber in plastic trays containing a mixture of soil and sand at 1:2 proportion, moistened until reaching 60% of retention capacity. Four replications of 50 seeds were used, sown at a depth of 2 cm. The seedling emergence percentage was calculated by the total of emerged seedlings (with the epicotyl above the substrate surface) after the complete stabilization, which occurred at the 10^{th} day after sowing. The results were expressed as percentage of normal seedlings.

Emergence speed index: calculated by the daily values collected from the number of emerged seedlings, from the first to the last day of the test (Maguire, 1962).

Seedling dry matter: it was evaluated using the seedlings obtained at the end of the germination test. The cotyledons were removed with the aid of a scalpel. The seedlings were placed in paper bags and kept in a forced air circulation laboratory oven at 65 °C for 72 h. After drying, the material was weighed on a precision scale with a resolution of 0.0001 g. The results were expressed in $mg.seedling^{-1}$ (Krzyzanowski et al., 2020).

Electrical conductivity: four replications of 50 seeds were weighed (0.001 g precision) and placed in plastic cups containing the following distilled water volumes: 75, 100, 150, and 250 mL. The cups were kept in a chamber (BOD type) at 25 °C for 2, 4, 8, 12, and 24 h. After each period, the electrical conductivity was determined by a conductivity meter (Digimed CD 21 model) and the results were expressed in $\mu S.cm^{-1}.g^{-1}$ seeds (Vieira and Marcos-Filho, 2020).

Experimental design and statistical analysis: a completely randomized experimental design was used. For each cultivar, the data of the physiological characterization were submitted to variance analysis and the means were compared by the Tukey test at 5% of probability. The data from the electrical conductivity test were analyzed in a triple factorial design (lots x water volumes x imbibition periods). The means of the qualitative factors, for each treatment, were compared by the Tukey test at 5% of probability. A polynomial regression analysis was made for the quantitative factor. For all analyses, the statistic software R 3.5.2 (R Core Team, 2018) was used.

RESULTS AND DISCUSSION

The results related to the characterization of the physiological quality of lots are shown in Table 1. The seed moisture content was similar in every lot, with a small variation from 12.2 to 12.8% for BRS Aleppo and from 12.3 to 12.5% for Cícero. According to Marcos-Filho (2016), the uniformization of seed moisture content is important to create an evaluation standardization and a secure comparison of the physiological potential of the analyzed lots.

For the BRS Aleppo, it was observed greater germination in lots A1 and A2, and a lower value for lot A4 (Table 1). From the first counting of the germination test, which indirectly evaluates the germination speed, it is observed that the lot A4 did not have any difference from the lot A5, but it was lower to lots A1, A2, and A3. The lot A4 was also lower than the other lots, which did not have any difference between them by the seedling emergence test. The emergence speed index, cold test, and dry matter results were very similar for the seed lots A1, A2, and A3, not differing with each other and being greater to lot A4, with a lower vigor, leaving lot A5 in an intermediary position.

For BRS Aleppo (Table 1) the one thousand-seed weight from lots A1, A2, and A5 were superior to lots A3 and A4 values, and lot A4 was the one with the lower value, which is the same one with the lower vigor as pointed out before. Denser seeds are usually those with well-formed embryos with greater amounts of reserves, possibly more likely to be vigorous (Carvalho and Nakagawa, 2000). The information from the one thousand-seed weight is related to the size of the seeds, as well as their maturity and healthy state (Brasil, 2009). For the Cícero cultivar, the one thousand-seed weight was significantly different for all lots, with higher value to lot C3, followed by lots C4, C1, and C2, with variations from 503.8 to 606.6 g. Therefore, it was observed that the seeds from this cultivar presented a bigger size than BRS Aleppo's seeds (Nascimento et al., 2016; Dias et al., 2019), which values variation from 350.4 to 398.1 g.

Table 1. Characterization initial of the seed lots quality from two chickpea cultivars: moisture content (MC), germination (G), first germination count (FGC), emergence of seedlings (E), emergence speed index (ESI), cold test (CT), seedlings dry matter (DM) and one thousand-seed weight (TSW).

Lot	MC (%)	G (%)	FGC (%)	E (%)	ESI (index)	CT (%)	DM (mg. seedling^{-1})	TSW (g)
BRS Aleppo								
A1	12.7	95 ab	75 a	99 a	5.7 a	97 a	39.2 ab	391.3 a
A2	12.8	97 a	79 a	98 a	5.5 a	96 a	39.6 a	389.5 a
A3	12.8	90 b	79 a	94 a	5.2 ab	89 ab	35.3 ab	373.5 b
A4	12.7	80 c	56 b	84 b	4.1 c	73 c	25.5 c	350.4 c
A5	12.2	91 b	68 ab	92 a	4.8 b	88 b	32.8 b	398.1 a
F	-	23.51*	5.68*	12.49*	19.00*	24.82*	15.03*	66.07*
CV (%)	-	3.01	11.41	3.63	5.51	4.31	8.63	1.24
Cícero								
C1	12.5	68 b	22 b	64 b	3.1 a	57 b	32.3 b	520.5 c
C2	12.3	78 a	41 a	79 ab	3.7 a	82 a	31.2 b	503.8 d
C3	12.5	80 a	30 ab	81 a	3.7 a	80 a	39.0 a	606.6 a
C4	12.4	81 a	38 a	78 ab	3.6 a	76 a	38.3 a	542.7 b
F	-	9.49*	7.88*	4.47*	1.26 ^{ns}	47.16*	14.87*	372.83*
CV (%)	-	5.05	18.57	9.73	14.91	4.62	5.98	0.86

The means followed by the same letter in the column for each cultivar do not differ statistically by Tukey's test at 5% probability. * = Significant; ns = not significant; F = calculated F value; CV = coefficient of variation.

Regarding the physiological potential of the seeds from Cícero (Table 1), there was lower germination in lot C1 in comparison to the others, which did not differ from each other. Similar results were also obtained in the cold test. From the first germination counting, seed lot C1, with lower values than the lots C2 and C4, did not differ from lot C3. There was no significant difference among the lots related to the emergence speed index, but by the percentage of seedling emergence, lots C3 and C1 were classified as the best and the worst performance, respectively. For the seedling dry matter, higher values were observed for seed lots C3 and C4, superiors to lots C1 and C2. So, in a general way, it is possible to observe that the lower physiological potential for seed lot C1 was revealed in most of the tests, with minor variations among seed lots with higher vigor (Table 1). Marcos-Filho (2016) emphasizes the importance of using more than one test to evaluate the seed vigor, because it could have a variation in the lot's behavior related to the method, especially in medium quality seed lots.

For the electrical conductivity test, higher values indicate lower vigor, due to a lower speed of membranes organization during hydration and, by consequence, greater leaching solutes (Vieira and Marcos-Filho, 2020). For BRS Aleppo, in the 75 mL water volume, there was a separation according to the physiological potential of seed lots within 2 h of imbibition, with lower vigor for lot A4, intermediary values for lots A3 and A5, and higher vigor for lots A1 and A2 (Table 2). However, in a long-term period, like 12 and 24 h, the separation was even clearer, with a higher vigor for lot A2, followed by lots A1, A3, and A5, and lower vigor for seed lot A4. This way, the lots A1 and A2 that presented similar physiological quality in the other periods, were statistically different after 12 and 24 h of imbibition. At periods of 8, 12, and 24 h, the classification in vigor levels was very similar when water volumes of 100-, 150- and 250-mL were used. Greater vigor was observed for seed lots A1 and A2 followed by lots A3 and A5. These results are similar to the seed lots rating, obtained from the initial seed quality characterization tests (Table 1), in which seed lot A4 also had a worse performance than the others, with the best performance to lots A1 and A2.

Table 2. Electrical conductivity (μS.cm^{-1}.g^{-1}) from different chickpea seed lots, BRS Aleppo and Cícero cultivars, in different distilled water volumes and soaking periods.

Soaking period	Lots	Volume of water (mL)			
		75	100	150	250
		BRS Aleppo			
2 h	A1	21.29 cA	16.93 cB	11.11 cC	9.15 cC
	A2	21.49 cA	17.64 cB	10.86 cC	9.06 cC
	A3	28.23 bA	21.54 bB	13.92 bcC	10.43 bcD
	A4	35.80 aA	27.74 aB	18.06 aC	14.50 aD
	A5	30.80 bA	25.99 aB	16.97 abC	12.46 abD
4 h	A1	29.12 dA	23.60 dB	16.25 cC	10.99 cD
	A2	28.39 dA	23.83 dB	16.05 cC	11.81 cD
	A3	36.76 cA	29.85 cB	20.10 bC	14.03 cD
	A4	51.32 aA	39.96 aB	25.49 aC	22.21 aD
	A5	41.81 bA	35.50 bB	23.30 abC	18.68 bD
8 h	A1	37.58 dA	30.62 dB	21.60 dC	16.50 dD
	A2	36.33 dA	30.36 dB	21.17 dC	16.61 dD
	A3	47.13 cA	37.78 cB	26.16 cC	20.05 cD
	A4	67.27 aA	52.17 aB	35.20 aC	29.49 aD
	A5	56.37 bA	46.73 bB	31.14 bC	24.63 bD

Continue...

Table 2. (Continuation) Electrical conductivity (µS.cm^{-1}.g^{-1}) from different chickpea seed lots, BRS Aleppo and Cícero cultivars, in different distilled water volumes and soaking periods.

Soaking period	Lots	Volume of water (mL)			
		75	100	150	250
		BRS Aleppo			
12 h	A1	45.02 dA	35.50 dB	25.41 dC	19.73 dD
	A2	41.26 eA	35.12 dB	24.20 dC	18.98 dD
	A3	54.44 cA	44.42 cB	30.45 cC	23.61 cD
	A4	78.65 aA	62.73 aB	42.10 aC	34.70 aD
	A5	67.14 bA	56.01 bB	37.01 bC	28.91 bD
24 h	A1	56.77 dA	43.74 dB	31.07 dC	23.98 dD
	A2	50.54 eA	43.35 dB	30.04 dC	22.82 dD
	A3	66.08 cA	53.70 cB	36.17 cC	28.17 cD
	A4	91.91 aA	73.71 aB	52.24 aC	40.97 aD
	A5	81.48 bA	65.89 bB	46.03 bC	34.54 bD
CV(%)		6.66			
		Cícero			
2 h	C1	27.06 aA	23.68 aB	18.35 aC	9.64 aD
	C2	26.76 aA	22.36 aB	15.82 bC	9.47 aD
	C3	21.94 bA	16.54 bB	12.04 cC	8.50 aD
	C4	21.89 bA	16.80 bB	11.64 cC	8.34 aD
4 h	C1	36.28 aA	31.30 aB	23.70 aC	13.97 aD
	C2	36.00 aA	29.79 aB	20.63 bC	13.95 aD
	C3	29.58 bA	23.61 bB	16.48 cC	12.56 aD
	C4	29.27 bA	23.91 bB	15.65 cC	12.22 aD
8 h	C1	46.99 aA	42.69 aB	31.23 aC	19.75 aD
	C2	48.29 aA	42.48 aB	28.88 bC	20.39 aD
	C3	40.17 bA	31.44 bB	22.67 cC	17.31 bD
	C4	39.55 bA	31.87 bB	21.55 cC	16.94 bD
12 h	C1	53.65 bA	48.52 aB	36.51 aC	24.14 aD
	C2	57.49 aA	49.77 aB	35.09 aC	25.07 aD
	C3	49.02 cA	39.12 bB	28.13 bC	21.39 bD
	C4	48.13 cA	39.54 bB	26.73 bC	20.95 bD
24 h	C1	59.13 cA	54.68 bB	44.20 aC	31.21 aD
	C2	60.47 bcA	61.20 aA	43.83 aC	31.07 aC
	C3	63.62 aA	50.05 cB	38.24 bC	27.18 bD
	C4	62.06 abA	51.04 cB	35.42 cC	27.02 bD
CV (%)		4.57			

The means followed by the same letters, within each soaking period, uppercase in the rows and lowercase in the column, do not differ from 5% probability by Tukey's test. CV = coefficient of variation.

For Cícero cultivar (Table 2), with 75 mL of water for 2, 4 and 8 h, the results were similar; lots C3 and C4 superior to lots C1 and C2, which had a greater conductivity value, indicating greater disorganization of cell membranes (Powell, 1986).

Similar results, separating the lots in two levels of physiological potential, were also observed with 100 mL for 2, 4, 8 and 12 h, and with 250 mL at 8, 12 and, 24 h periods. Dias et al. (2019) used the volume of 100 mL to conduct the conductivity test with chickpea seeds, but using samples of 75 seeds and an imbibition period of 30 h. According to the observations done at the present research, within 30 h the seeds release the primary root in most vigorous seed lots. Furthermore, 75 seeds immersed in 100 mL of water analyzes the conductivity harder to be done, because the volume of the seeds increases after imbibition. A similar situation was observed at the present research when 50 seeds were immersed in 75 mL of water, especially for cultivars that have bigger size seeds, like Cícero.

At shorter periods (2 and 4 h) with a higher water volume (250 mL), it was not possible to separate the seed lots in physiological quality levels, probably due to the larger dilution of the imbibition combined with a shorter time of leaching. This volume was used in the electrical conductivity test in chickpea (Khajeh-Hosseini and Rezazadeh, 2011) and pea seeds (Machado et al., 2011).

Then, the electrical conductivity results obtained for cultivar Cícero were consistent with the other physiological quality tests (Table 1), especially the ones related to identifying the best and worst performance seed lots. It is important to stand out the results with 150 mL of water in 2, 4, 8, and 24 h, which allow separating the lots into three physiological potential levels.

Comparing the different water volumes (Table 2), we can observe that, in general, higher and lower conductivity values were obtained with 75 mL and 250 mL of water, respectively. That way, with the increase of water volume there was a greater imbibition dilution from cultivars, as was expected. Although it allowed separation of lots based on vigor, with 75 mL of water there were some difficulties in inserting the conductivity meter electrode in the solution for the data readings once the seeds expanded their size (Figure 1). Therefore, this volume was considered inadequate, especially for bigger seeds than the ones from Cícero. In chickpea, there are differences in the weight and size of the seeds from each cultivar (Nascimento et al., 2016; Dias et al., 2019). The one thousand-seed weight from BRS Aleppo is about 390 g (Table 1) but Cícero's seeds can reach values more than 600 g (Nascimento et al., 2016). One recommendation from the Association of Official Seeds Analysts to conduct the conductivity test is that there must be no directly contact between the conductivity meter cell and the seeds, only with the solution (Baalbaki et al., 2009), which is very difficult with the combination of 50 seeds and 100 mL of water.

Therefore, for bigger seeds such as chickpea, some authors have been using volumes of up to 250 mL (Khajeh-Hosseini and Rezazadeh, 2011), but in the present study, in this volume, there was a lower classification of the lots when compared to the other volumes studied, for Cícero cultivar.

In polynomial regression analysis (Figure 2), for both cultivars, it is possible to verify that the imbibition period has a great influence on the electrical conductivity, and in each water volume, the data were adjusted to squaring function.

Figure 1. Illustration of every solution volume from BRS Aleppo and Cícero cultivars after 24 h of soaking. For every volume were used plastic cups with 300 mL capacity.

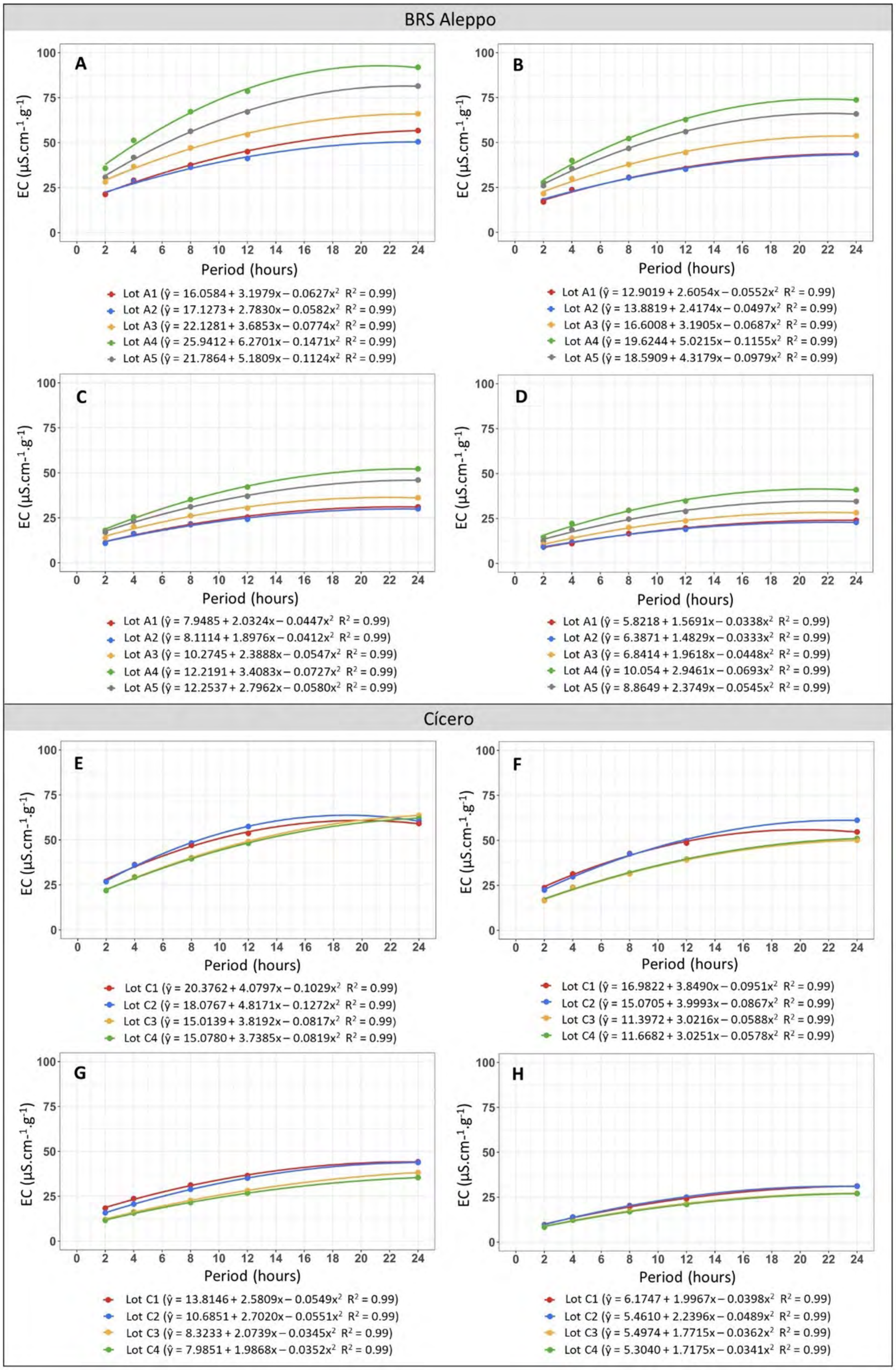

Figure 2. Electrical conductivity in different chickpea seeds lots, BRS Aleppo and Cícero cultivars, after soaking periods of 2, 4, 8, 12 and 24 h in 75 (A and E), 100 (B and F), 150 (C and G), and 250 mL (D and H) of distilled water.

Therefore, the release of exudates increased exponentially according to imbibition periods. For BRS Aleppo, in each volume, a higher electrical conductivity was found in seeds from lot A4, indicating a lower vigor, and lower values from seed lots A1 and A2, indicating a higher vigor, with the lots A3 and A5 classified as medium vigor. With 75, 100, and 150 mL of water, the difference between conductivity values can be observed on initial imbibition periods, keeping up to 24 h and allowing the lots separation in physiological potential levels (Table 2 and Figures 2A, B, and C). However, it is important to consider that 8- and 12-h periods are not too practical as 24 h, considering better schedules for the reading data. This period has been recommended for most of the Fabaceae seeds as peas (Machado et al., 2011), beans (Silva et al., 2013), *Vigna unguiculata* (Moura et al., 2017), and soybean (Vieira and Marcos-Filho, 2020). In soybean seeds, shorter imbibition periods (4 to 8 h) allowed to identify of more marked differences between the lots, while evaluations made from 16 h were more sensitive to small variations in seed vigor (Dias and Marcos-Filho, 1996). In mung beans seeds (*Vigna radiata*), the conductivity test allowed the separation between lots according to their vigor after 3 h of imbibition (Araújo et al., 2011), being appropriate to the physiological potential evaluation of these seeds using 50 seeds soaked in 75 mL of water.

The conductivity values obtained from the five lots soaked in 250 mL water volume (Figure 2D) were very low and closer in each soaking period, due to a bigger solution dilution in comparison to the other volumes, which was also verified in lots from cultivar Cícero (Figure 2H). Closer values can be difficult to interpret and to classify the lots in vigor levels, especially when there is a large number of lots. According to Khajeh-Hosseini and Rezazadeh (2011), the electrical conductivity test made with 250 mL of water for 2 and 24 h gave an emergence indicative in some of the chickpea lots. Trancoso et al. (2021), testing the electrical conductivity in 50 seeds immersed in 250 mL of water for 24 h, identified some differences in the physiological potential of chickpea seeds harvested at different maturation states. It must be considered that, sometimes, in seed quality control programs, absolute values are used to compare the seed lots, so higher differences between the conductivity values can facilitate the interpretation of the results to select the lots with the best and worst performance.

For Cícero cultivar, in general, we can observe a lot of separation in two groups, with higher values for lots C1 and C2 and lower values for lots C3 and C4 in the most periods and each water volume (Table 2 and Figures 2E, F, G, and H). It is important to emphasize that the 75 mL water volume, although it has been efficient to separate the seed lots in terms of vigor, it made difficult to perform the readings, as already commented before.

Based on this research results, it is established that the electrical conductivity test can be used to detect vigor differences in chickpea seeds lots in a safe, practical, and fast way, and can help the companies to make faster and safer decisions, especially related to the harvest, store, and marketing of the seed lot.

CONCLUSIONS

The electrical conductivity test is efficient in classifying chickpea lots in different vigor levels. To conduct the test, it is recommended the use of 50 seeds immersed in 150 mL of water, for 24 h at 25 °C.

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