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BASIC AREAS
Article

Imbibition and drying periods in desiccation tolerance of peanut seeds

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ABSTRACT: The objective of this research was to evaluate the biochemical and physiological quality of peanut cultivar seeds under periods of imbibition and drying. A completely randomized statistical design was adopted, in factorial scheme, with four replications. The three peanut cultivars were: BR1, BRS 151-L7, and IAC 505. The imbibition and drying periods were: 0, 12, 24, 36 and 48 hours. The seeds were imbibition with the aid of germitest paper and distilled water, then dried on a metal screen in a plastic box with silica, according to the periods studied. Physiological variables were evaluated (percentage of germination, normal seedlings, abnormal seedlings in the first count and abnormal seedlings in the final count, accelerated aging, seedling length, electrical conductivity, speed index, and average germination time) and biochemical variables (sugar concentration total, reducing sugars, hydrogen peroxide, total superoxide dismutase proteins, and total proteins). The desiccation tolerance of peanut seeds is reduced as the period of water absorption followed by drying increases. Seeds of cultivar IAC 505 have greater tolerance to imbibition and subsequent desiccation compared to seeds of BR1 and BRS 151-L7.

Key words: *Arachis hypogaea* L., germination, water content, biochemical and physiological quality.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an agricultural crop that is relatively simple to manage compared to other species, with great socioeconomic importance as it generates income in the field and is used for human and animal consumption. In the 2022 harvest, Brazilian production was 848 thousand tons of peanuts, with average productivity of 3.8 Mg·ha^{-1}. The Southeast region is the largest national producer, holding 94.7% of production, with average productivity of 4 Mg·ha^{-1} (IBGE 2023).

Seed quality directly influences the success of peanut cultivation, mainly under adverse soil and climate conditions. In this context, conducting research to determine the germination potential and vigor of seeds, to minimize the risk of losses during plant establishment in the field using high-quality seeds, is important. The quality of peanut seeds is easily lost due to fluctuations in humidity in the growing environment, which makes it necessary to establish seed conservation strategies or use cultivars tolerant to greater or lesser water availability (Bertolin et al. 2011, Santos et al. 2013).

Water is the main factor linked to seed germination. Inadequate humidity conditions in the growing environment accelerate deterioration due to increased seed metabolism. When water is removed from seeds below the limit supported at the cellular level, there are an increase in the concentration of solutes, changes in intercellular pH, acceleration of degenerative reactions, denaturation of proteins and loss of membrane integrity, which generate irreversible damage to the seeds (Smolikova et al. 2021).

The fact that peanuts produce pods under the surface of the soil, combined with a process of uneven fruit maturation, the occurrence of rain during harvest, in addition to open-air drying, a type of drying still common in Brazil, makes considerable variation common in water content of the seeds, which makes them more susceptible to phytopathogenic organisms and insects (Araújo et al. 2017, Martín et al. 2022). Therefore, minimizing the action of pathogenic microorganisms and increasing the chance of success of crops about the seasonality of rainfall and, consequently, variation in soil moisture, by identifying cultivars tolerant to the imbibition and desiccation of peanut seeds, prove to be a promising technique.

Despite its importance, the identification of peanut cultivars with high productivity and production stability that tolerate desiccation is still little studied. Therefore, studies on peanut seed desiccation are necessary (Gantait et al. 2019). Given the above, this work aimed to evaluate the biochemical and physiological quality of peanut cultivar seeds under different periods of imbibition and drying.

MATERIAL AND METHODS

Study location, statistical design, and treatments

The research was carried out in the municipality of Arapiraca, Alagoas, Brazil (9°45’58”S; 35°38’58”W; 324 m altitude). The seeds of the cultivars used in the research were donated by Empresa Brasileira de Pesquisa Agropecuária (BR1 and BRS 151-L7) and Instituto Agronômico (IAC 505). The BR1 cultivar is an erect plant that has medium-sized pods, with three or four seeds, an average oil content of 45%, a cycle of around 90 days, with a productive potential of up to 3.80 $Mg{\cdot}ha^{-1}$, under irrigated conditions. The BR 151-L7 cultivar has an erect plant, medium-sized pods, with two seeds, an average oil content of 46%, a cycle of around 90 days, with a productive potential of up to 4.50 $Mg{\cdot}ha^{-1}$, under irrigated conditions. These two cultivars can be planted in all regions of Brazil. Their cultivation is carried out mainly by small and medium-sized farmers, which makes them socioeconomically important (Santos et al. 1997). The IAC 505 cultivar is characterized as a low-growing plant, cycle 130 days, has a high oil content, with potential productivity of up to 6 $Mg{\cdot}ha^{-1}$, under irrigated conditions (Kasai and Deuber 2011). In a germination test initially carried out to determine the quality of the seeds, the germination percentage was greater than 80% for all cultivars studied, confirming the high quality of the seeds.

A completely randomized statistical design was used, in a factorial scheme (cultivars × imbibition periods), with four replications. The factor peanut cultivars were made of three treatments: BR1, BRS 151-L7, and IAC 505. The factor periods of imbibition and subsequent drying of peanut seeds was made up of five periods: 0, 12, 24, 36 and 48 hours.

Imbibition and drying seeds

Initially, the seeds were soaked, which generated the imbibition curve for each cultivar. For this, 500 seeds of each cultivar were weighed, totaling 100 seeds per soaking period and 25 seeds per repetition. It should be noted that this procedure was carried out four times. Therefore, 2,000 seeds were used per cultivar throughout the research. Although the statistical design was assembled four times, this characterizes only one experiment conducted, since these repetitions were assembled to obtain sufficient material to determine all variables according to the periods studied. The germitest paper was made in the form of a roll, consisting of three sheets, to which 50 mL of distilled water was added. The rolls were placed in covered containers to maintain humidity inside germination chambers with biochemical oxygen demand (BOD), at a regulated temperature of 25°C, in the presence of light. Subsequently, the seeds were weighed at intervals of 2 hours, until root protrusion (radicle greater than 2 mm).

To obtain the drying curve, soaked seeds were used and weighed every two hours during water loss. The seeds were placed in plastic boxes, on a metal screen and 70 g of silica–the silica was replaced every 12 hours. The box was covered and placed in BOD at 25°C, in the presence of light.

After these procedures, the seeds were rehydrated, placing the dried seeds for 24 hours in a plastic box, on a metal screen, and 50 mL of distilled water, keeping it closed and covered by aluminum foil in BOD at 25°C. Subsequently, the seeds were placed on germitest paper moistened with distilled water (the amount of water corresponding to 2.5 times the weight of the dry paper). After 24 hours, seed growth resumed (Brasil 2009).

Physiological and biochemical analytics

Physiological and biochemical evaluations of the seeds were carried out immediately after the imbibition and drying process. Regarding physiological analyses, germination tests were set up, and the following items were evaluated: percentage of germination, normal seedlings, abnormal seedlings in the first count, abnormal seedlings in the final count and seedling length (Brasil 2009), accelerated aging (Jianhua and McDonald 1996), electrical conductivity (Vanzolini and Nakagawa 2005), germination speed index (Maguire 1962), and average germination time (Labouriau 1983).

Regarding the biochemical analysis of the seeds, concentrations of total sugars (Yemm and Willis 1954), reducing sugars (Miller 1959), total proteins (Bradford 1976), hydrogen peroxide (Alexieva et al. 2001), and total proteins of superoxide dismutase (Dubois et al. 1956) were analyzed.

Statistical analysis

The collected data were subjected to analysis of variance with the Sisvar software (Ferreira 2011). When significant using the F test ($p < 0.05$), qualitative treatments (cultivars) were compared using the Tukey's test ($p < 0.05$), and quantitative treatments (imbibition periods and drying) were subjected to regression analysis. The adopted regressions were significant by the F test at 5% significance (Ferreira 2018).

RESULTS AND DISCUSSION

Significance ($p < 0.05$) was observed about the cultivar factor for the variables: percentage of abnormal seedlings, germination speed index, average germination time, hydrogen peroxide, and total superoxide dismutase proteins. Regarding the factor imbibition periods, significance was found for the variables: percentage of abnormal seedlings, and germination speed index. For the interaction of the factors studied (cultivar vs. imbibition periods), significance was observed in relation to the variables: percentage of normal seedlings, percentage of abnormal seedlings, percentage of germination, electrical conductivity, seedling length, and accelerated aging (Table 1).

Table 1. Analysis of variance of physiological and biochemical variables of peanut cultivar seeds under periods of imbibition and drying.

Source of variation	DF	Medium squares			
		GER	PN	PA	GERA
Cultivars (C)		1,800.26*	2,242.40*	787.26*	548.60*
Periods (P)	4	6,223.56*	7,381.56*	5,064.76*	4,030.93*
C × P	8	103.26*	187.56*	243.01*	110.93^{NS}
Residue	45	37.02	64.51	96.26	60.84
CV (%)		19.71	18.81	22.16	13.83
		AA	SL	EC	ISG
Cultivars (C)	2	259.20**	12,155.24*	1,316,190.52*	86.76*
Periods (P)	4	8,598.76*	3,516.17*	1,223,028.96*	4.42*
C × P	8	146.86*	105.30*	214,435.85*	0.99^{NS}
Residue	45	59.80	18.16	23,086.96	0.61
CV (%)		32.36	4.34	24.52	6.86
		TAG	AT	AIR	PT
Cultivars (C)	2	3.38*	45.06^{NS}	447,254.3^{NS}	2,668.02^{NS}
Periods (P)	4	0.05^{NS}	18.47^{NS}	192,304.5^{NS}	904.37^{NS}
C × P	8	0.03^{NS}	11.64^{NS}	203,970.4^{NS}	615.00^{NS}
Residue	45	0.02	1.47	17,049.30	47.48
CV (%)		4.07	Cultivars (C)	2	25.83

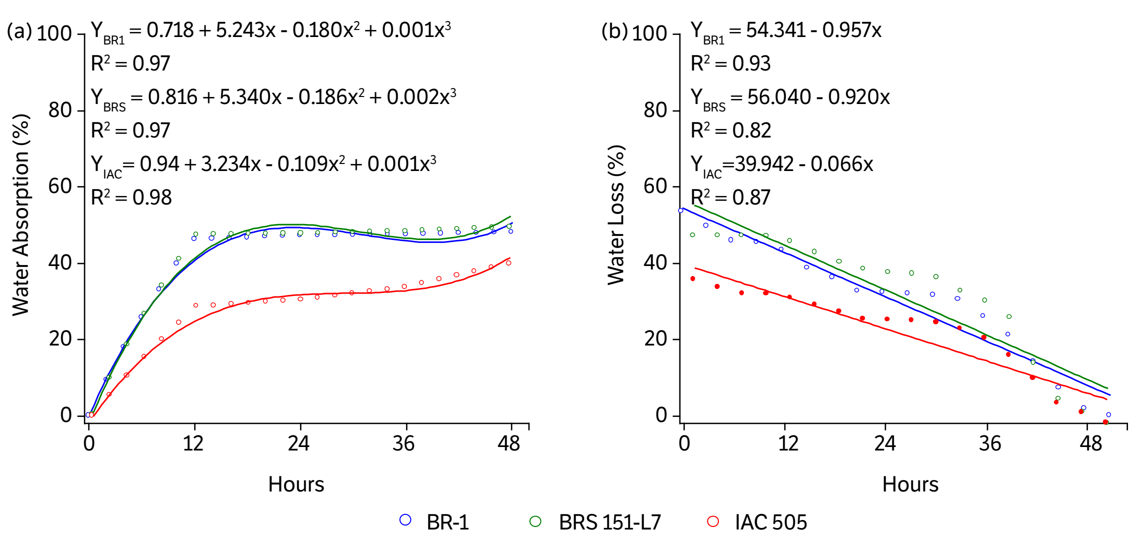
Continue...

Table 1. Continuation...

Source of variation	DF	Medium squares	
		H_2O_2	SOD
Cultivars (C)	2	2,245.62*	3,174.89*
Periods (P)	4	77.93^{NS}	325.03^{NS}
C × P	8	12.97^{NS}	45.89^{NS}
Residue	45	13.34	101.52
CV (%)		23.28	44.82

CV: Coefficient of variation; DF: degrees of freedom; NS: Not significant; *significant by F test ($p < 0.05$); GER: germination percentage; PN: percentage of normal seedlings; PA: percentage of abnormal seedlings after the first count; GERA: final percentage of abnormal seedlings; AA: accelerated aging; SL: seedling length; EC: electrical conductivity; ISG: germination speed index, TAG: average germination time; AT: total sugars; AIR: reducing sugars, PT: total proteins; SOD: total superoxide dismutase proteins. Source: elaborated by the authors.

In general, the seed imbibition curve of peanut cultivars followed a standard three-phase model, as described by Marcos Filho (2005), with rapid water absorption in the first 12 hours and root protrusion 48 hours after the start of the test. The cultivars BR1 and BRS 151-L7, in the first 12 hours, increased in relation to their initial mass, 39.4 and 41.6%, respectively. The cultivar IAC 505 showed an increase of only 24.9% (Fig. 1a). According to Singh et al. (2021), the difference in water absorption by peanut seeds is related to the oil content of the seeds; the higher the oil content, the lower the water absorption. This is related to the fact that these compounds are immiscible. Therefore, it is observed that IAC 505 tends to have a higher oil content and absorbs less water.



Source: Elaborated by the authors.

Figure 1. Variation in water content of seeds of different peanut cultivars as a function of time. (a) Imbibition curves and (b) seed drying to obtain the studied treatments and experimental analyses.

Drying the seeds until they reached their initial mass, regardless of the cultivar, lasted 50 hours. Water loss adjusted linearly, the cultivars IAC 505, BR1, and BRS 151-L7 obtained a final weight of 50 seeds of 189.3, 129.7 and 127.5 g, respectively (Fig. 1b).

The BRS 151-L7 and BR1 cultivars had a higher percentage of abnormal seedlings compared to the IAC 505 cultivar (Table 2). The lower occurrence of abnormal seedlings indicates greater seed germination potential, in addition to characterizing a good cultivar, which generates more homogeneous crops resulting in greater agricultural productivity (Santos et al. 1999). Therefore, it is observed that the IAC 505 cultivar has a greater capacity to present viable seedlings after imbibition and drying.

Table 2. Test of means of physiological and biochemical variables of peanut cultivar seeds under periods of imbibition and drying*.

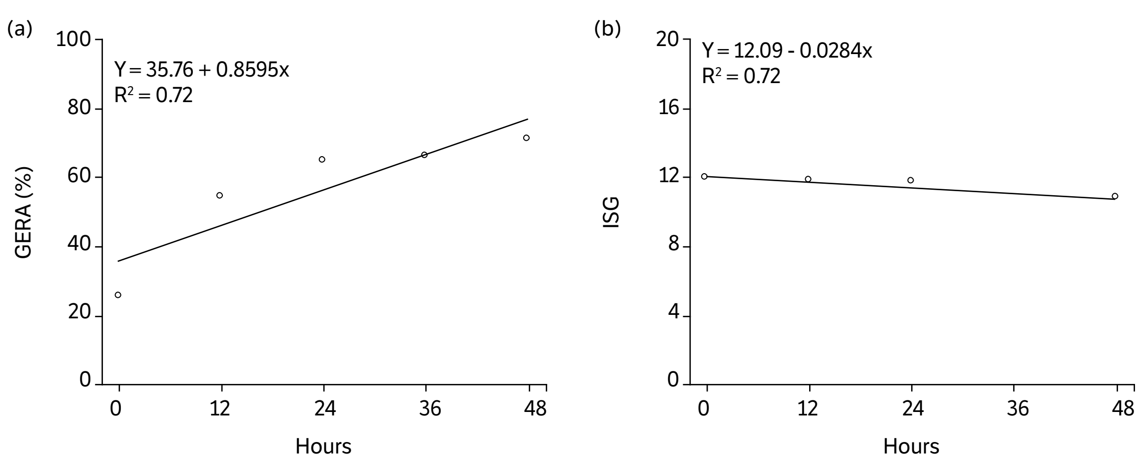
Cultivars	GERA	ISG	TAG	H_2O_2	SOD
	%	-	Days	$mmol \cdot kg^{-1}$	$G \cdot kg^{-1}$ DW
BRS 151-L7	60.50 b	10.15 b	4.22 b	27.63 c	14.68 b
BR1	58.20 b	10.28 b	4.26 b	12.05 b	15.74 b
IAC 505	50.50 a	13.82 a	3.53 a	7.39 a	37.01 a

*Means followed by the same letter in the same column do not differ statistically among themselves by Tukey's test ($p < 0.05$); GERA: percentage of abnormal seedlings; ISG: germination speed index; TAG: average germination time; SOD: total superoxide dismutase proteins. Source: elaborated by the authors.

The cultivar IAC 505 obtained the highest germination speed index, and surpassed BR1 and BRS 151-L7, which obtained an average value of 26% lower in relation to the highest value observed. In relation to the average germination time, IAC 505 obtained the shortest time, a value 16.7% lower in relation to cultivars BR1 and BRS 151-L7 (Table 2). Seeds with a higher speed index and shorter average germination time are preferred in cultivations, as they maximize the use of momentary soil moisture conditions, which guarantees a more homogeneous stand in the field, especially in crops under rainfed conditions (Ramos et al. 2008). Therefore, it is possible to state that the IAC 505 cultivar overcomes the germination process more quickly, a desirable characteristic in agricultural cultivation.

The highest concentration of hydrogen peroxide was observed in seeds of the cultivar BRS 151-L7, a value 278% higher than the one obtained by the cultivar IAC 505 (Table 2). High levels of hydrogen peroxide, such as that found in BRS 151-L7 seeds, generate the inactivation of enzymes and damage at the cellular level, which can lead to seed death or reduced germination potential (Wang et al. 2023). The cultivar IAC 505 had a higher content of superoxide dismutase proteins, while the other cultivars had, on average, a content 58% lower in relation to the highest value observed (Table 2). Superoxide dismutase proteins have an antagonistic effect on hydrogen peroxide, catalyzing excess peroxide in cells, and acting as an antioxidant, which increases the period of seed viability (Taveira et al. 2012). That said, it is observed that the cultivar IAC 505, as it has a lower concentration of hydrogen peroxide and a higher concentration of superoxide dismutase, tends to have a greater capacity to catalyze harmful compounds produced at the cellular level under conditions of high deterioration, which makes the seeds of this cultivar to have a greater viability for a longer period.

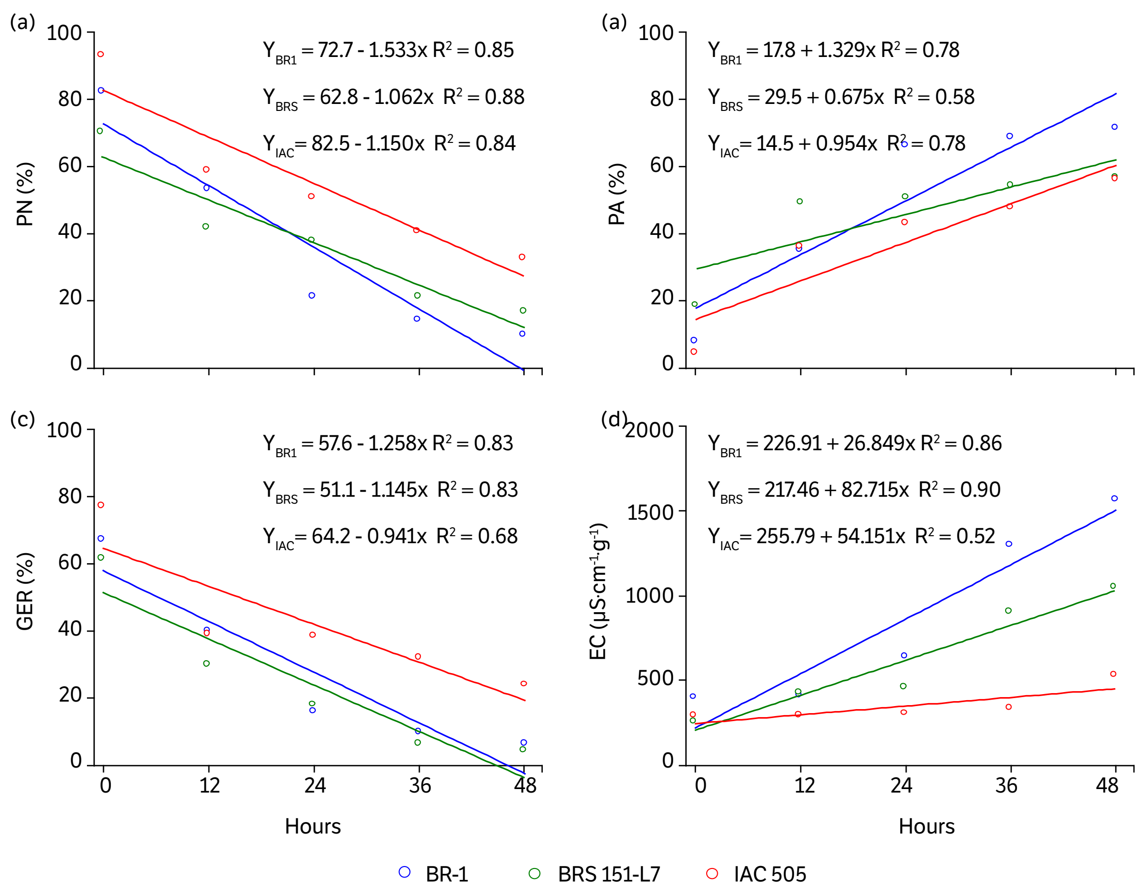
Regarding the imbibition and drying periods factor, the highest percentage of abnormal seedlings was observed in the 48 hours, 71.1%. During this period, the lowest germination speed index was also observed, 10.8. (Figs. 2a and 2b). Researchers (Oliva et al. 2012, Ahmed and Ahmed 2020) state that, after soaking for long periods and then suffering sudden drying, damage occurs to seed tissues, which tends to produce higher percentages of abnormal seedlings, lower germination speed, and even death of the seed. This confirms the results of this research, since seeds under a longer period of imbibition and subsequent drying produced a higher percentage of abnormal seedlings and a lower germination speed index.



GERA: percentage of abnormal seedlings; ISG: germination speed index. Source: Elaborated by the authors.

Figure 2. Final percentage of (a) abnormal seedlings and (b) germination speed index of peanut cultivar seeds under periods of imbibition and drying.

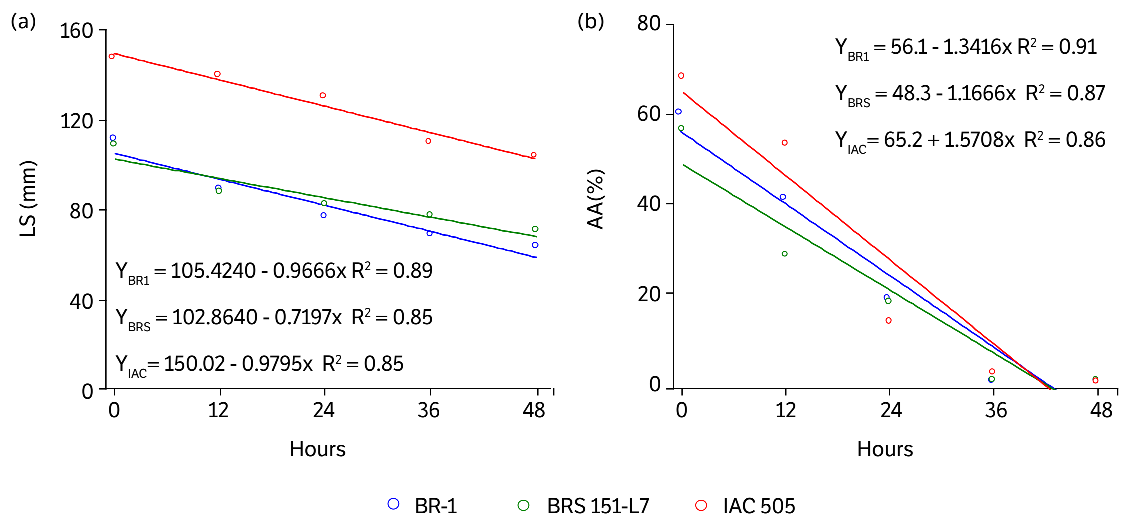
About the interaction of the factors studied, the highest percentage of normal seedlings were observed in 0 hour, 70, 82 and 92.5%, respectively, for BRS 151-L7, BR1, and IAC 505. The lowest values for normal seedlings were observed in the 48-hour treatment, in which BR1, BRS 151-L7, and IAC 505 obtained 9.5, 16.5 and 32.5%, respectively (Fig. 3a). Inversely proportional behavior was observed in relation to the percentage of abnormal seedlings after the first count, the highest number of abnormal seedlings was observed in the 48-hour treatment for all cultivars, with values of 56, 56.5 and 71%, respectively, for IAC 505, BRS 151-L7 and BR1. In turn, for the period of 0 hour, the lowest abnormal seedling values were 4.5, 8, and 18.5%, for IAC 505, BR1, and BRS 151-L7, respectively (Fig. 3b). Seeds subjected to a longer period of soaking and drying generally suffer irreversible damage to structures essential to the germination process due to the variation in moisture content, which generates poor morphological formation of seedlings and, consequently, a low expectation of their survival (Marcos Filho 2005). Based on the above, the cultivar IAC 505 showed it can produce seedlings with better morphological conditions compared to the other cultivars after the soaking and drying process.



PN: percentage of normal seedlings; PA: percentage of abnormal seedlings after the first count; GER: germination percentage; EC: electrical conductivity.
Source: Elaborated by the authors.

Figure 3. Percentage of (a) normal seedlings, (b) percentage of abnormal seedlings, (c) percentage of germination, and (d) electrical conductivity of peanut cultivar seeds under periods of imbibition and drying.

The IAC 505 cultivar obtained the highest germination percentage, 76.5 and 23.5%, under periods of 0 and 48 hours, respectively, while the BRS 151-L7 cultivar obtained the lowest values, 61 and 4%, respectively (Fig. 3c). The greatest seedling length was observed with the cultivar IAC 505, in the 0-hour period, 147.8 mm, and in the 48-hour period, when all cultivars showed reduction, 104 mm (Fig. 4a). The highest electrical conductivity values of seeds were observed in the 48-hour period, 1,574, 1,058 and 537 µS•cm-1.g-1, for BR1, BRS 151-L7, and IAC 505, respectively (Fig. 3d). Researchers (Araújo et al. 2011, Oliveira Sá et al. 2020) state that the higher electrical conductivity in seed analysis indicates the release of metabolites during imbibition, which indicates compromised membrane permeability and consequent reduction in seed viability. Thus, the longer period of imbibition and drying favors the disarrangement of peanut seed tissues, mainly for BR1, and BRS 151-L7, which affects the germination power and seedling length more markedly when compared to seeds of cultivar IAC 505.



LS: seedling length; AA: accelerated aging. Source: Elaborated by the authors.

Figure 4. Physiological and biochemical responses of peanut cultivar seeds as a function of imbibition and drying periods. a) Seedling length and (b) accelerated aging.

In the period of 0 hour, the greatest seed vigor was observed in relation to accelerated aging, with values of 56, 60 and 68.5%, for BRS 151-L7, BR1, and IAC 505, respectively. Within 48 hours, the seeds of the studied cultivars died (Fig. 4b). The accelerated aging test evaluates the vigor of seeds under stress conditions, which generates a high respiratory rate and reserve consumption, which makes lower-quality seeds susceptible to dying (Carvalho and Carvalho 2009). Thus, it is possible to state that the seeds of the IAC 505 cultivar tend to maintain greater vigor for longer periods compared to the other cultivars studied.

CONCLUSION

The desiccation tolerance of peanut seeds is reduced as the period of water absorption followed by drying increases. Seeds from cultivar IAC 505 have higher biochemical and physiological quality after imbibition and subsequent desiccation compared to seeds from cultivars BR1 and BRS 151-L7. Although the results obtained are important indicators of which cultivar tolerates the greatest water deficit, it is highlighted that there is a need for additional research field in multiple environments, as there is a scarcity of studies analyzing these cultivars under conditions of hydric stress.

CONFLICT OF INTEREST

Nothing to declare.

AUTHORS' CONTRIBUTION

Conceptualization: Albuquerque Neto, J. C., Pavão, J. M. S. J., Souza, A. A. and Santos Neto, A. L.; **Methodology:** Albuquerque Neto, J. C., Pavão, J. M. S. J., Alves, M. C. J. L., Souza, A. A. and Santos Neto, A. L.; **Investigation:** Albuquerque

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DATA AVAILABILITY STATEMENT

Data will be available upon request.

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