ABRATES

Journal of Seed Science
ISSN 2317-1545
www.abrates.org.br/revista

ARTICLE

Implications of seed coat cracking on soybean seed quality

Journal of Seed Science, v.46, e202446030, 2024

http://dx.doi.org/10.1590/2317-1545v46288842

Sheila Bigolin Teixeira[1]*, Maria de Fátima Zorato[2], Geri Eduardo Meneghello[1]

ABSTRACT: Seed coat cracking is a “physiological defect” that occurs in soybean seeds, affecting their integrity. The objective of this study was to evaluate the effect of seed coat cracking on the physiological quality and storability of soybean seeds. Seeds from three lots were used: one from the NS 7209 IPRO cultivar and two from the 8473 RSF cultivar, produced in the states of Goiás and Mato Grosso, Brazil. Each lot was manually segregated into three portions: the original lot (OL), seeds with an intact seed coat (IS), and seeds with a cracked seed coat (CS), which were stored at temperatures of 15 °C and 28 °C for 270 days. The experiment was carried out in a completely randomized design. Vigor and viability were evaluated using the tetrazolium test, first germination count, germination test, accelerated aging, and electrical conductivity at 0, 45, 90, 135, 180, 225, and 270 days of storage, as well as seedling emergence in a seedbed after 0, 90, 180, and 270 days of storage. Seed coat cracking in soybean reduced the physiological quality of the lots in all the tests compared to seeds with intact seed coats, and this effect was more pronounced when seeds were stored at 28 °C. Seed coat cracking contributes to increased seed deterioration in soybean when seeds are stored under high-temperature conditions.

Index terms: deterioration, permeability, storage, viability, vigor.

RESUMO: O rasgo é um “defeito fisiológico” que ocorre no tegumento das sementes de soja e afeta a sua integridade. O objetivo deste estudo foi avaliar o efeito da presença de rasgo no tegumento sobre a qualidade fisiológica e armazenabilidade de sementes de soja. Utilizou-se sementes de três lotes, sendo um da cultivar NS 7209 IPRO e dois da cultivar 8473 RSF, produzidas nos estados de Goiás e Mato Grosso. Cada lote foi segregado manualmente em três porções, sendo elas: Lote original (LO), sementes com tegumento íntegro (TI) e com presença de rasgo no tegumento (TR), as quais foram armazenadas sob as temperaturas de 15 °C e 28 °C durante 270 dias. O experimento foi realizado em delineamento inteiramente casualizado. Foram avaliados o vigor e viabilidade pelo teste de tetrazólio, primeira contagem de germinação, porcentagem de germinação, envelhecimento acelerado e condutividade elétrica aos 0, 45, 90, 135, 180, 225 e 270 dias de armazenamento, além de emergência em canteiro aos 0, 90, 180 e 270 dias. A presença de rasgo no tegumento da semente de soja reduziu a qualidade fisiológica dos lotes em todos os testes realizados quando comparada a semente com o tegumento íntegro, de forma mais acentuada no armazenamento a 28 °C. O rasgo no tegumento contribui para o aumento da deterioração das sementes, quando o armazenamento se dá sob condição de alta temperatura.

Termos para indexação: deterioração, permeabilidade, armazenamento, viabilidade, vigor.

***Corresponding author**
sheilabigolin@gmail.com

Received: 07/25/2024.
Accepted: 09/02/2024.

[1]Programa de Pós-graduação em Ciência e Tecnologia de Sementes, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas (UFPel), 96160-000, Pelotas, RS, Brasil.

[2]MFZorato - Treinamento e desenvolvimento profissional e de gestão em qualidade de sementes. Rua Rebouças, 414, apto 34 Vila Vitória, 86060-680, Londrina, PR, Brasil

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important leguminous plant for grain production and one of the most valuable oilseed crops in the world. Due to its chemical composition, it is widely used and grown throughout the world, and Brazil (169.0 $M.t^{-1}$), the United States (120.7 $M.t^{-1}$), and Argentina (51.0 $M.t^{-1}$) are the largest producers (USDA, 2024).

Over the years, there have been constant efforts to increase soybean production in Brazil by expanding the growing area and, above all, by increasing yield. These efforts include the use of healthy seeds of high genetic, physical, and physiological quality, which is essential for success in soybean growing. According to França-Neto et al. (2016), high-vigor plants with superior field performance ensure higher yield.

However, in the seed production system, the challenge is not only to produce high quality seeds, but also to preserve them up to the time of sowing, since the storage period can be long and under conditions that are not always ideal.

Among the intrinsic factors that affect seed storage potential, the seed coat plays a prominent role, for although it is quite thin, it performs an important function in protecting the embryo from pathogen attacks and mechanical damage. The seed coat is responsible for modulating gas exchanges between the seed and its environment and for regulating the rate of water absorption and desorption during imbibition and drying of the seed, protecting the embryo from injuries that could be caused by rapid imbibition (Chachalis and Smith, 2000; Marcos-Filho, 2015). The permeability of the seed coat changes when there are cracks, fissures, and scratches resulting from handling procedures (such as harvesting, drying, processing, and sowing operations), insect attack, or certain environmental conditions during seed maturation (Qutob et al., 2008). Thus, to efficiently preserve seed quality, it is of utmost importance for the seed coat to be intact, that is, without fissures or cracks on the surface.

Seeds of some soybean cultivars have cracks in the seed coat, also known as physiological rupture. This is defined as a physiological defect of the seed and is one of the forms of damage that compromises the seed coat. Seen in the grain filling phase, at the R5.4 stage, it appears as a rupture/crack in the dorsal lining brought about by the rapid turgidity of the seed cells due to excess water (Senda et al., 2018). It is therefore correlated with moisture, though it does not necessarily arise from it. The cracking shows variation among the different genotypes, with different shapes and sizes, and is randomly distributed over the seed. Depending on the shape of the seed, it can extend from the cotyledon to the embryonic axis in the region of the radicle. Furthermore, according to the environmental conditions the plants will experience in the field, above all when they reach the point of physiological maturity (R7 stage), the genotypes in which the seeds show cracking of the seed coat may be affected by moisture deterioration. As storage progresses, the seeds with the cracked seed coat are more susceptible to deterioration, which, depending on the location of its occurrence, may make plant tissues important for radicle emergence unviable (Huth et al., 2016; Zorato, 2018).

The appearance of this physiological defect in seeds in different soybean lots and genotypes has raised questions in relation to possible reduction in seed vigor and viability. Thus, the aim of this study was to evaluate the effect of seed coat cracking on the physiological quality and longevity of soybean seeds.

MATERIAL AND METHODS

The study was developed in the Seed Analysis Teaching Laboratory (*Laboratório Didático de Análise de Sementes*) of the graduate studies program in seed science and technology of the *Universidade Federal de Pelotas* in the municipality/county of Capão do Leão, RS, Brazil. Three soybean seed lots were used: one from the cultivar NS 7209 IPRO (Nidera Seeds), maturity group 7.2, produced in the state of Mato Grosso (MT); and two from the cultivar 8473 RSF (Brasmax-GDM), maturity group 7.4, one produced in Goiás (GO) and the other in the state of Mato Grosso (MT). The seeds of each lot were evaluated considering the original lot (OL) and manually segregated into seeds with an intact seed coat (IS) and cracked seed coat (CS) (Figure 1 and Table 1).

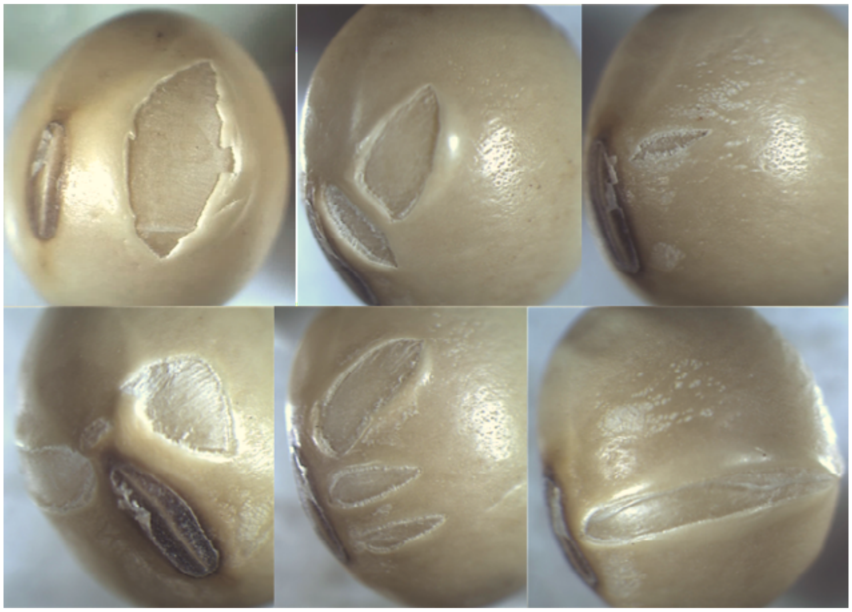

Figure 1. Appearance of seeds with seed coat cracking.

Table 1. Initial characterization of seed lots regarding origin, percentage of seed coats that are cracked, moisture content (MC), and 1000 seed weight (1000SW).

Cultivar	Origin	Identification	Cracking (%)	MC (%)	1000SW (g)
NS 7209 IPRO	MT[1/]	Original lot (OL)	18	11.6	220.0
NS 7209 IPRO	MT	Intact seed coat (IS)	0	11.6	220.6
NS 7209 IPRO	MT	Cracked seed coat (CS)	100	11.7	220.4
8473 RSF	GO	Original lot (OL)	38	11.6	206.3
8473 RSF	GO	Intact seed coat (IS)	0	11.8	203.0
8473 RSF	GO	Cracked seed coat (CS)	100	11.8	212.9
8473 RSF	MT	Original lot (OL)	24	11.5	189.4
8473 RSF	MT	Intact seed coat (IS)	0	11.6	186.4
8473 RSF	MT	Cracked seed coat (CS)	100	11.6	197.0

[1/] MT: Mato Grosso. GO: Goiás (Brazil).

The seed lots were stored at temperatures of 15 °C and 28 °C in semi-hermetic packaging to maintain seed moisture throughout the storage period. Analyses to monitor quality were carried out at 45-day intervals for a total of seven evaluation times: 0, 45, 90, 135, 180, 225, and 270 days of storage. After each period, the following evaluations were made:

Tetrazolium test (TZ): two 50-seed subsamples were used per replication, placed between sheets of germination testing (germitest) paper moistened with distilled water and pre-conditioned for 16 hours in an incubation chamber at 25 °C $\pm$ 2 °C. At the end of that period, the seeds were transferred to 50 mL volume plastic cups and were totally immersed in tetrazolium solution (0.075%) and kept at 35 °C in a BOD type chamber until they were stained, a period of around 120 minutes. After staining and washing in running water, the seeds were classified from 1 to 8 according to the type and intensity of seed damage. Viability was represented by the sum of the percentages of seeds within classes from 1 to 5; whereas vigor level was assessed using classes from 1 to 3. The seeds that exhibited moisture damage were quantified, with vigor reduction classified as MD 4-5 and viability reduction as MD 6-8. Results were expressed as percentages (França-Neto and Krzyzanowski, 2022).

Germination test (G): this was conducted with four 50-seed subsamples per replication, and the substrate was three sheets of germination testing paper moistened with distilled water in the amount of 2.5 times the weight of the dry paper. The seeds were kept in a germination chamber at a temperature of 25 °C ± 2 °C. The seedlings considered normal were counted at eight days after sowing, as recommended by the Rules for Seed Analysis (Regras para Análise de Sementes) (BRASIL, 2009).

First germination count (FGC): this was performed along with the germination test, counting the number of normal seedlings on the fifth day after setting up the test.

Accelerated aging (AA): in this test, the methodology recommended by the ISTA (2017) and supplemented by Marcos-Filho (2020) was adopted. Approximately 200 seeds from each treatment, per replication, were distributed in a single layer on an aluminum screen fastened inside the germination box (gerbox) plastic boxes, functioning as an individual compartment. To each gerbox, 40 mL of water was added, and the boxes were placed in a BOD type chamber. The temperature was regulated to 41 °C ± 0.3 °C for a period of 48 hours, and then the germination test was performed on the seeds, following the recommendations of the Rules for Seed Analysis (BRASIL, 2009).

Bulk Electrical Conductivity (EC): a total of 25 seeds per subunit were used for each replication; the seeds were weighed and then immersed in 75 mL of deionized water for a period of 24 hours, keeping the temperature at 25 °C ± 2 °C in a BOD incubator (Krzyzanowski et al., 2023). After this period, electrical conductivity readings were taken of the imbibition solution with the aid of a digital benchtop conductivity meter, Digimed brand, and the values were expressed in $\mu S\ cm^{-1}\ g^{-1}$.

Emergence in a seedbed: for this analysis, 200 seeds per experimental unit were used, which were sown in the soil at a depth of 3 cm. Emerged seedlings were counted at 14 days after sowing. This analysis was carried out every 90 days (0, 90, 180, and 270 days of storage).

Statistical analyses: a split-plot experimental design was used, with the three groups segregated from each lot allocated to the main plot and the seven storage times allocated to the split-plot, with three replications for each test. The three seed lots were evaluated individually [NS 7209 IPRO, 8473 RSF (GO), and 8473 RSF (MT)] at each of the temperatures (15 °C and 28 °C). Analysis of variance was performed on the data, which met the suppositions of normality and homoscedasticity, followed by comparisons of means by Tukey's test for each of the variables evaluated. For the quantitative factor (storage periods), polynomial and exponential regressions were carried out. The statistical programs R 4.2.3 (R Core Team, 2023) and SigmaPlot 12.5 were used.

RESULTS AND DISCUSSION

There was no interaction between the seed coat cracking and storage period (SP) factors for first germination count (FGC) in the seeds stored at the temperature of 15 °C. However, on average, the FGC of the seeds with a cracked seed coat (CS) had significantly lower values than the seeds with an intact seed coat (IS) (Table 2).

At the storage temperature of 28 °C, there was interaction between the segregated seeds and the storage periods, and significant differences between the segregated seed groups were observed at 45, 90, and 180 days for seed lots 8473 RSF (MT), NS 7209 IPRO, and 8473 RSF (GO), respectively (Table 2).

Although no interaction was observed between the factors at the storage temperature of 15 °C for FGC, the seeds with a cracked seed coat showed germination (G) lower than that of the seeds with an intact seed coat as of 135 days of storage for the NS 7209 IPRO seed lot, and at 270 days for the 8473 RSF (MT) seed lot (Table 2). However, no significant differences were observed between the seeds with cracked seed coats and intact seed coats from the 8473 RSF (GO) seed lot over the periods evaluated.

Table 2. Tests of first germination count (FGC) and germination percentage (G) of three soybean seed lots from the cultivars NS 7209 IPRO and 8473 RSF from the states of GO and MT, Brazil, segregated into the groups of the original lot (OL), of seeds with intact seed coat (IS), and of seeds with a cracked seed coat (CS) stored at temperatures of 15 °C and 28 °C.

	SP (Days)	NS 7209 IPRO						8473 RSF (GO)						8473 RSF (MT)						
		15 °C			28 °C			15 °C			28 °C			15 °C			28 °C			
		IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	
FGC	0	93	94	98	93	94	98	100	98	99	100	98	99	99	98	96	99	98	96	NS
	45	91	90	89	87	85	85	99	98	98	96	95	94	98	98	96	95	96	89	A
	90	93	92	91	86	85	76	99	98	99	96	94	91	98	97	98	96	92	85	AB
	135	93	91	85	71	62	59	97	97	95	92	93	89	94	94	92	91	89	85	B
	180	93	92	89	18	15	7	98	96	96	70	49	40	97	95	93	80	67	49	BC
	225	89	91	88	0	0	0	99	96	96	54	30	15	96	96	94	45	35	27	C
	270	83	79	76	0	0	0	97	94	95	11	3	0	95	95	90	5	0	0	
	Mean	91	90	88	51	49	46	98	97	97	74	66	61	97	96	94	73	68	62	
G	0	97	98	98	97	98	98	100	100	99	100	100	99	99	98	99	99	98	99	
	45	94	91	90	92	89	89	99	98	98	98	97	97	98	98	96	97	97	91	
	90	94	93	93	88	85	77	100	99	99	96	95	93	98	98	98	97	92	87	
	135	95	94	88	74	66	59	97	97	97	96	96	94	95	95	93	93	92	86	
	180	97	94	91	21	16	7	99	98	96	76	53	46	98	97	97	83	69	62	
	225	92	93	91	0	0	0	99	98	97	64	34	16	98	97	96	49	39	32	
	270	92	81	79	0	0	0	97	98	97	11	3	0	96	99	92	5	0	0	
	Mean	94	92	90	53	51	47	99^{ns}	98	98	77	68	64	97	97	96	75	70	65	

[1/] Means that have the same color in the row do not differ from each other by Tukey's test ($p \leq 0.05$). SP: storage period. ns: not significant. OL: original lot. IS: seeds with intact seed coat. CS: seed with cracked seed coat.

Under storage conditions at 28 °C, similar results were observed; however, significant differences between germination of seeds with and without a cracked seed coat already occurred at 90 days of storage for the NS 7209 IPRO and 8473 RSF (MT) seed lots. In contrast, for the 8473 RSF (GO) lot, a difference was observed as of 180 days, and all the segregated groupings of seeds already had germination percentages below the legal requirements for seed commercialization (80%) (MAPA, 2013) (Table 2).

Evaluation of the performance of the seed lots over the period of storage at 15 °C shows that the seeds of the NS 7209 IPRO lot maintained their FGC percentage up to 225 days without significant variations. After that period, a reduction of approximately 10 percentage points was observed (Figure 2A). However, the cultivar 8473 RSF showed reduction of 3.4 percentage points in the seed lot from GO and 3.9 percentage points in the seed lot from MT at the end of storage (Figure 2C and 2E).

The seed lots stored at 28 °C exhibited similar FGC values for nearly 90 days. However, after that period, there was exponential reduction in the FGC up to 180 days for NS 7208 IPRO and up to 270 days for 8473 RSF (GO and MT) (Figure 2B, 2D, and 2F). Seeds with a cracked seed coat from both 8473 RSF lots showed lower storage potential than the other segregated groups (Figure 2D and 2F).

Seeds from the NS 7209 IPRO lot at the temperature of 15 °C had lower germination as of 225 days of storage (Figure 3A). However, in seeds from the lot stored at 28 °C, the germination percentage declined at 90 days, with drastic reduction up to 180 days, followed by a stabilization period, fitting a sigmoidal model (Figure 3B). There was no interaction between the segregated groups and the storage periods for the 8473 RSF (GO) lot, which showed an overall reduction of approximately 2% in germination throughout the period of storage at 15 °C (Figure 3C). However, in storage at 28 °C, seeds from this lot that had intact seed coats had greater storability; they maintained their germination level for approximately 180 days, whereas the other segregated groups showed reduction in germination at 135 days (Figure 3D). A similar response was observed for the 8473 RSF (MT) lot (Figure 3E and 3F).

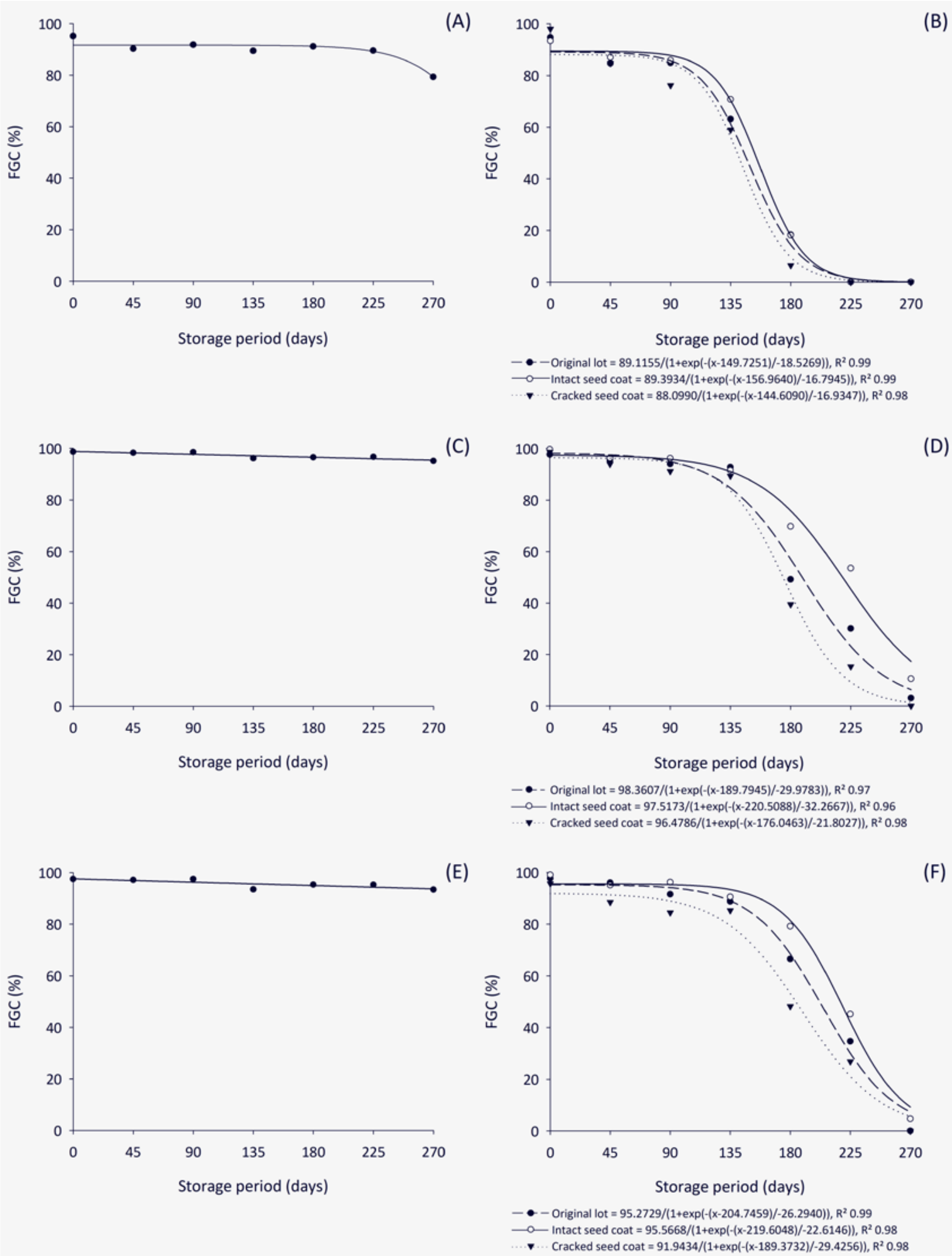

Figure 2. First germination count (FGC) of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from GO (C and D) and from MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with a cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

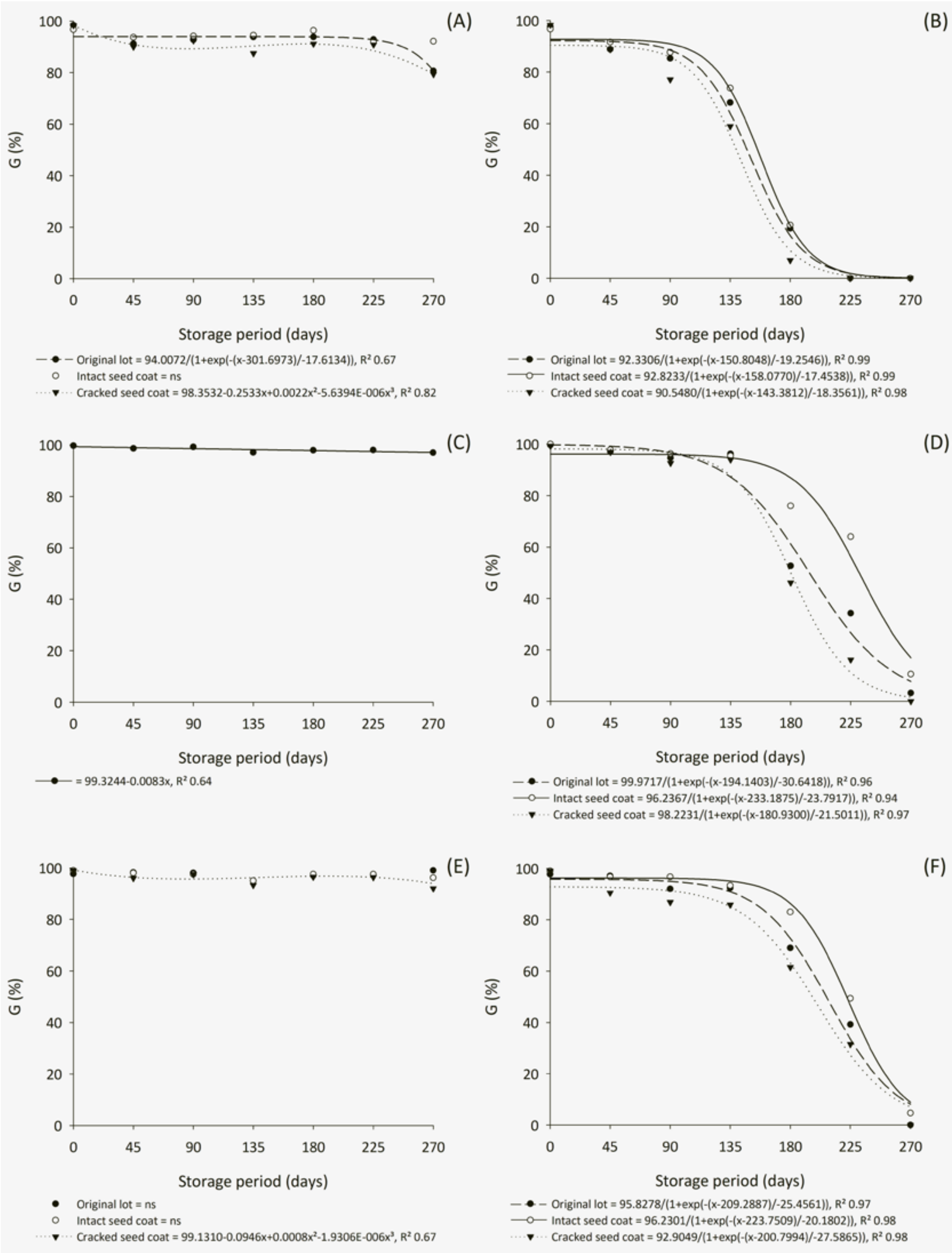

Figure 3. Germination percentage (G) of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from GO (C and D) and from MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with a cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

Seed germination capacity declines as storage time increases. This reduction in viability is highly affected by the temperature (T) and relative humidity (RH) of the environment (Radha et al., 2014); the lower the T and RH, the lower the rate of reduction in quality from an advancing seed deterioration process (Delouche, 2002; Krzyzanowski et al., 2022) (Figures 2 and 3).

Storage potential not only varies among cultivars, but also varies among seed lots and even among the seeds of a single lot. That was observed in this study, where segregated groups of seeds (OL, IS, and CS) coming from the same seed lot showed different storage potential (Figures 2 and 3), with more intense reduction in the values of FGC and G in the seeds with a cracked seed coat (CS), particularly observed in storage at the temperature of 28 °C.

The results regarding seed vigor and viability evaluated by the tetrazolium test are shown in Table 3. Comparing the three seed lots used, greater vigor was seen in the seeds with an intact seed coat (IS) in relation to those that had a cracked seed coat (CS and OL), corroborating the results of Pieper et al. (2024). This was confirmed at both temperatures (15 °C and 28 °C) beginning at 0 storage time, and it was more evident as of 90 days of storage, above all for the seed lot from the cultivar NS 7209 IPRO when stored at 28 °C. The seeds of the original lot (OL) showed intermediate results, tending toward the results of the seeds with intact seed coat. The percentage of cracked seeds found in the original seed lots was below 40% in the three lots evaluated (Table 1).

The results of seed viability and vigor obtained using the tetrazolium test were similar to each other, and the seeds with cracked seed coats showed data significantly lower than the other segregated groups as of 90 days of storage for the cv. 8373 RSF seed lots, and as of 135 days for the NS 7209 IPRO seed lot at both temperatures (Table 3). This reduction in physiological quality over the storage period is mainly due to moisture damage, the only damage that intensifies over the storage period.

At the temperature of 15 °C, vigor through the tetrazolium test decreased an average of 10 percentage points comparing time 0 and 270 days (Figures 4A, 4C, and 4E). These results fit second- and third-degree polynomial regression

Table 3. Vigor (VG) and viability (VB), evaluated using the tetrazolium test (TZ), of three soybean seed lots from the cultivars NS 7209 IPRO and 8473 RSF from the states of GO and MT, segregated into groups of the original lot (OL), of seeds with intact seed coat (IS), and of seeds with cracked seed coat (CS), stored at temperatures of 15 °C and 28 °C.

	SP (Days)	NS 7209 IPRO						8473 RSF (GO)						8473 RSF (MT)						
		15 °C			28 °C			15 °C			28 °C			15 °C			28 °C			
		IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	
VG	0	91	89	92	91	89	92	94	97	90	94	97	90	98	97	92	98	97	92	NS
	45	94	93	83	88	89	85	98	95	93	91	89	87	95	95	94	87	91	83	A
	90	95	90	89	78	77	70	97	94	87	88	86	86	92	92	86	88	85	81	AB
	135	93	91	83	78	76	66	93	92	87	87	82	78	96	93	91	82	75	71	B
	180	97	90	88	54	46	37	94	92	87	70	64	47	96	94	88	79	74	68	BC
	225	88	84	79	5	3	0	95	91	85	60	45	19	94	84	80	38	37	27	C
	270	78	73	68	0	0	0	87	82	79	22	21	8	89	86	79	6	3	3	
	Mean	91	87	83	56	54	50	94	92	87	73	69	59	94	92	87	68	66	61	
VB	0	95	96	95	95	96	95	99	97	96	99	97	96	98	99	95	98	99	95	
	45	97	97	92	97	95	94	100	98	97	97	96	95	97	98	96	95	95	90	
	90	98	97	95	88	88	87	100	97	92	96	92	90	96	92	89	95	90	89	
	135	97	99	93	93	89	83	99	98	96	93	87	88	97	98	93	93	86	81	
	180	99	95	92	86	79	68	98	94	95	85	77	65	97	95	94	88	85	80	
	225	95	92	89	29	18	11	98	94	91	74	59	50	94	96	87	67	60	52	
	270	85	80	77	7	0	0	96	94	89	43	34	16	95	93	84	30	25	17	
	Mean	95	94	90	71	66	63	99	96	94	84	77	71	96	96	91	81	77	72	

[1/] Means that have the same color in the row do not differ from each other by Tukey's test ($p < 0.05$). SP: storage period. ns: not significant. OL: original lot. IS: seeds with intact seed coat. CS: seed with cracked seed coat.

models. Furthermore, the seeds with cracked seed coats had shorter viability than the seeds of the original lot and the intact seeds without cracking.

However, the lots stored at the temperature of 28 °C had a different response, obtaining non-linear regression curves, with a sigmoidal trend. The seeds went through a period with little variation in vigor level from time 0 to 135 days (Figures 4B, 4D, and 4F). After that period, there was a sharp reduction in the vigor of these seeds, followed by a new phase of stability. This reduction in vigor was more pronounced in the cv. NS 7209 IPRO lot and in the seeds with cracked seed coat from the cv. 8473 RSF (GO) lot. For the lot from this cultivar, stabilization occurred at 225 days of storage (Figure 4B).

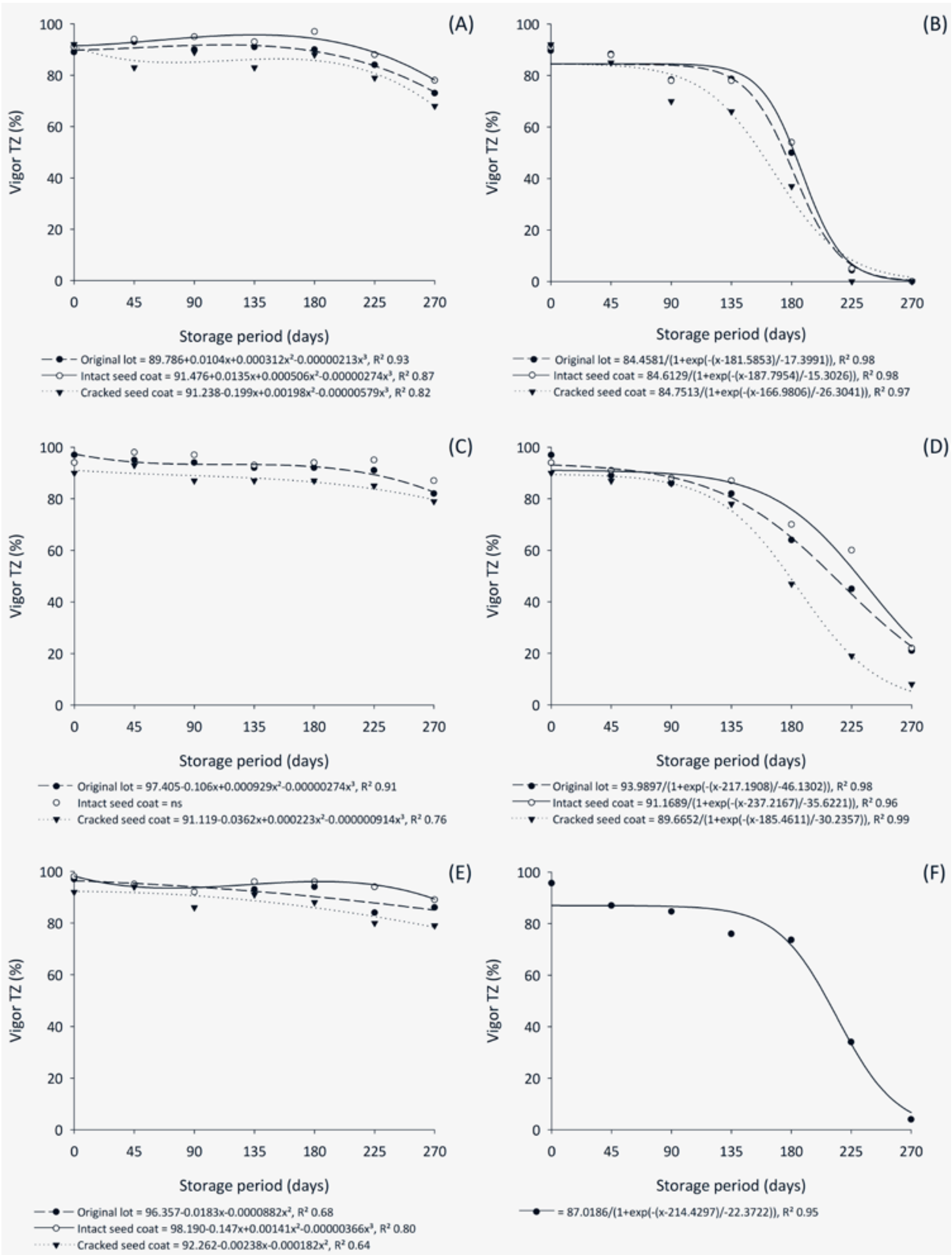

Figure 4. Vigor, evaluated using the tetrazolium test (TZ), of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from the states of GO (C and D) and MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

As the storage period progressed, there was greater distance between vigor levels comparing the seeds segregated from the original lot, the intact seed coat group, and the cracked seed coat group for the 8473 RSF (GO) seed lot (Figure 4D). There was no interaction between the factors in the 8473 RSF (MT) lot for the vigor variable (Figure 4F).

In storage at 15 °C, there was a slight reduction in seed viability only as of 225 days of storage (Figures 5A, 5C, and 5E). However, in the seed lots stored at 28 °C, viability reduced significantly at 180 days, especially in the NS 7209 IPRO lot (Figure 5B). Seeds with a cracked seed coat from the 8473 (GO) lot had lower longevity than the other segregated groups, especially compared to seeds with an intact seed coat (Figure 5D).

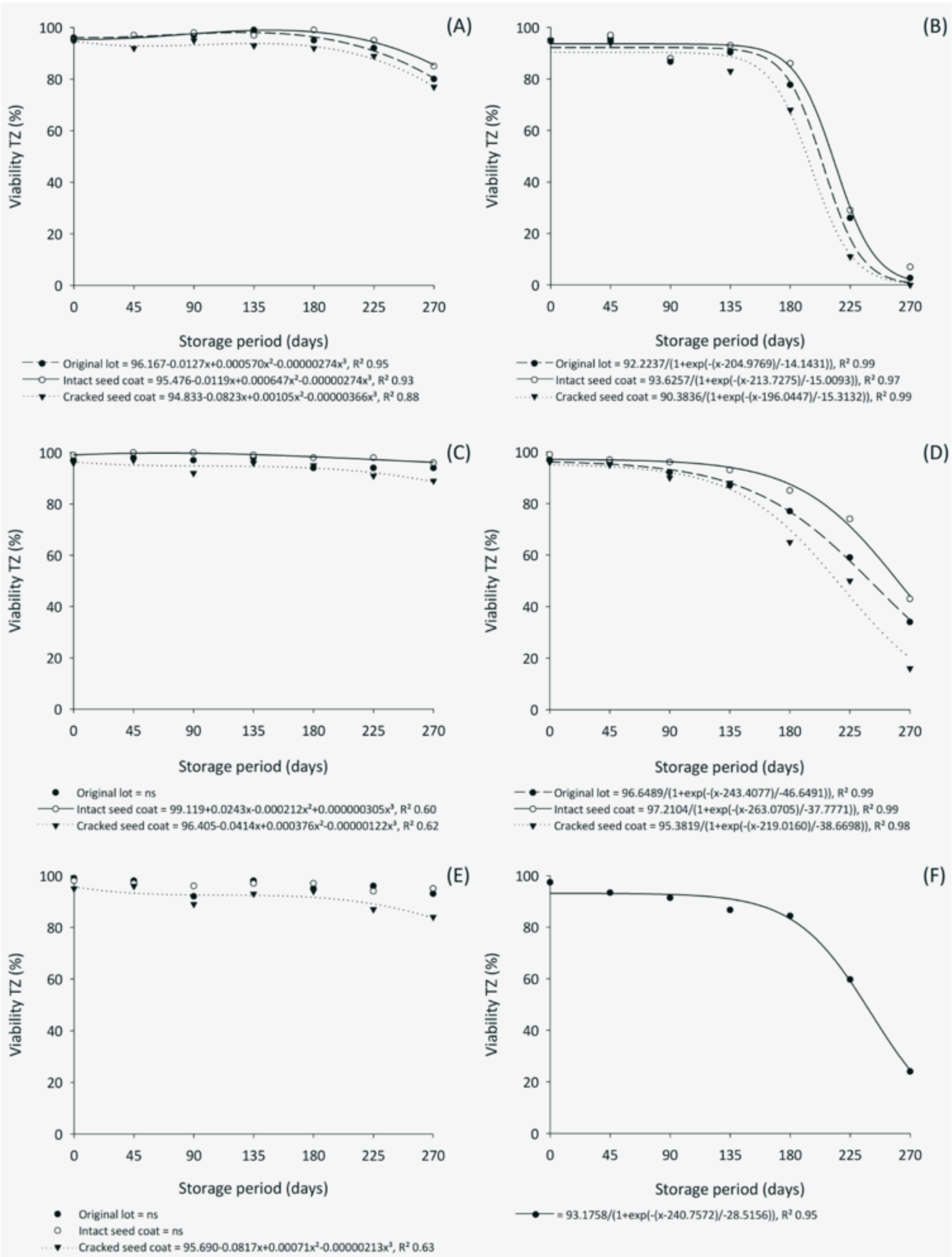

Figure 5. Viability, evaluated using the tetrazolium test (TZ), of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from the states of GO (C and D) and MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

On average, seeds with a cracked seed coat had a higher percentage of moisture-damaged seeds in the 4 and 5 classification of the tetrazolium test (MD 4-5), that is, viable seeds but without vigor, as well as in the 6 to 8 classification (MD 6-8), representing seeds that died from this damage (Table 4). That is because the cracked seed coat is an easy entry point for water in the seed, favoring moisture deterioration at the end of maturation of seeds in the field (França-Neto and Krzyzanowski, 2022). Moisture deterioration tends to progress during the storage period in a more or less rapid way depending on temperature and relative humidity conditions of the environment the seeds are in (Moreano et al., 2011). Thus, seeds that were placed in classes 4 and 5 (MD 4-5) may pass to classes 6 to 8 (MD 6-8) over the period; and a higher percentage of seeds in classes 4 and 5 may represent a lower percentage in classes 6 to 8, as observed in seeds with an intact seed coat in storage at 28 °C at 270 days of storage (Table 4).

Regardless of the segregated grouping of the seeds, over the period of storage at 15 °C, an increase of approximately 7 percentage points in MD 4-5 was observed for the NS 7209 IPRO lot (Figure 6A). In storage at 28 °C, an increase in MD 4-5 was observed for all the lots and their segregated groups, and in a faster way in seeds with a cracked seed coat from lots NS 7209 IPRO and 8473 RSF (MT) (Figures 6B and 6F). However, seeds from the NS 7209 IPRO lot and seeds with a cracked seed coat from the 8473 RSF (GO) lot showed a reduction in MD 4-5 as of 180 days (Figures 6B and 6D), a period in which there was a significant increase in MD 6-8 (Figures 7B and 7D).

Over the storage period at 15 °C, differences were not observed among the segregated groups of seeds within the same lot for MD 4-5 (Figures 6A, 6C, and 6E), but MD 6-8 increased for the seeds with a cracked seed coat already at the beginning of the storage period (Figures 7A, 7C, and 7E). MD 6-8 represents the percentage of seeds that died through

Table 4. Moisture damage in classes 4 and 5 (MD 4-5) and in classes 6 to 8 (MD 6-8) using the tetrazolium test, of three soybean seed lots from the cultivars NS 7209 IPRO and 8473 RSF from the states of GO and MT, segregated into groups of the original lot (OL), of seeds with intact seed coat (IS), and of seeds with cracked seed coat (CS), stored at temperatures of 15 °C and 28 °C.

		NS 7209 IPRO						8473 RSF (GO)						8473 RSF (MT)						
		15 °C			28 °C			15 °C			28 °C			15 °C			28 °C			
		IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	
MD 4-5	0	2	2	2	2	2	2	2	0	3	2	0	3	0	0	1	0	0	1	NS
	45	2	2	6	8	4	8	1	2	3	4	5	5	0	1	0	5	2	3	A
	90	2	3	6	10	11	17	3	0	2	8	4	4	3	2	3	7	4	7	AB
	135	4	5	8	13	12	17	3	3	6	5	1	9	0	1	0	10	8	7	B
	180	2	4	4	32	33	31	2	0	4	14	11	18	0	0	1	5	10	11	BC
	225	8	9	10	28	14	11	2	2	3	14	13	24	0	4	3	27	22	24	C
	270	11	7	8	7	0	0	7	5	7	21	13	8	3	4	3	22	21	14	
	Mean	4	5	6	14	11	12	3	2	4	10	7	10	1	2	2	11	10	10	
MD 6-8	0	2	3	1	2	3	1	0	1	0	0	1	0	1	0	2	1	1	2	
	45	1	1	4	3	3	3	0	0	1	3	3	2	2	1	2	2	3	8	
	90	2	3	4	12	12	13	0	3	5	3	8	7	2	3	11	5	8	9	
	135	2	1	6	7	10	15	0	0	3	4	6	9	1	2	6	6	13	18	
	180	0	3	5	14	21	32	0	4	2	13	22	31	0	1	5	9	11	17	
	225	4	7	10	63	81	87	1	4	6	23	41	54	3	2	8	29	37	48	
	270	11	18	16	92	100	100	3	4	10	56	65	82	4	6	15	69	74	83	
	Mean	3	5	7	28	33	36	1	2	4	15	21	26	2	2	7	17	21	26	

[1/] Means that have the same color in the row do not differ from each other by Tukey's test ($p < 0.05$). SP: storage period. ns: not significant. OL: original lot. IS: seeds with intact seed coat. CS: seed with cracked seed coat.

moisture deterioration, and thus shows that the cracked seed coat, especially when located near the embryonic axis, can be quite consequential in reducing seed viability through moisture damage at that site (Zorato, 2018).

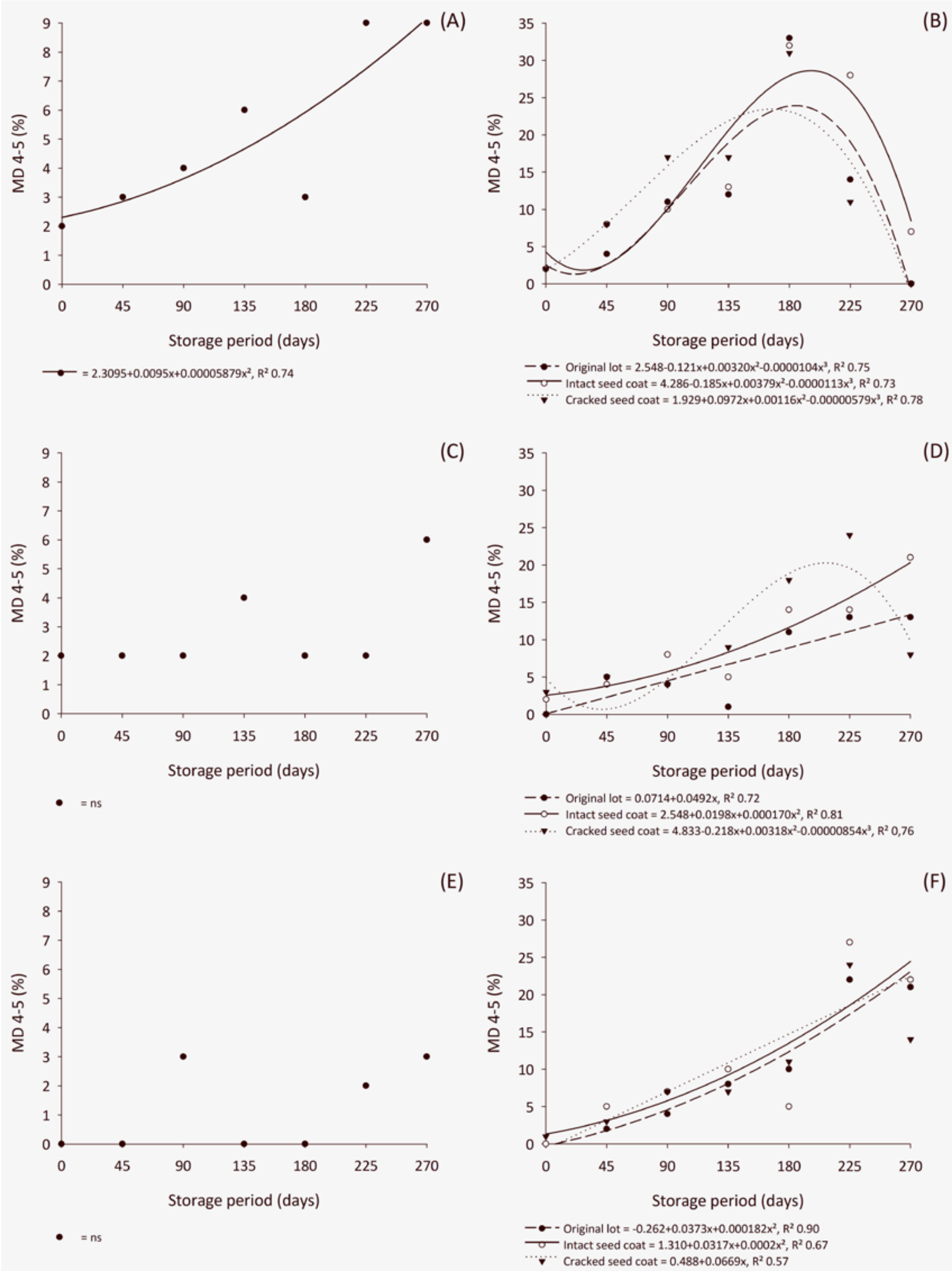

Figure 6. Moisture damage in classes 4 and 5 (MD 4-5) using the tetrazolium test, of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from the states of GO (C and D) and MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

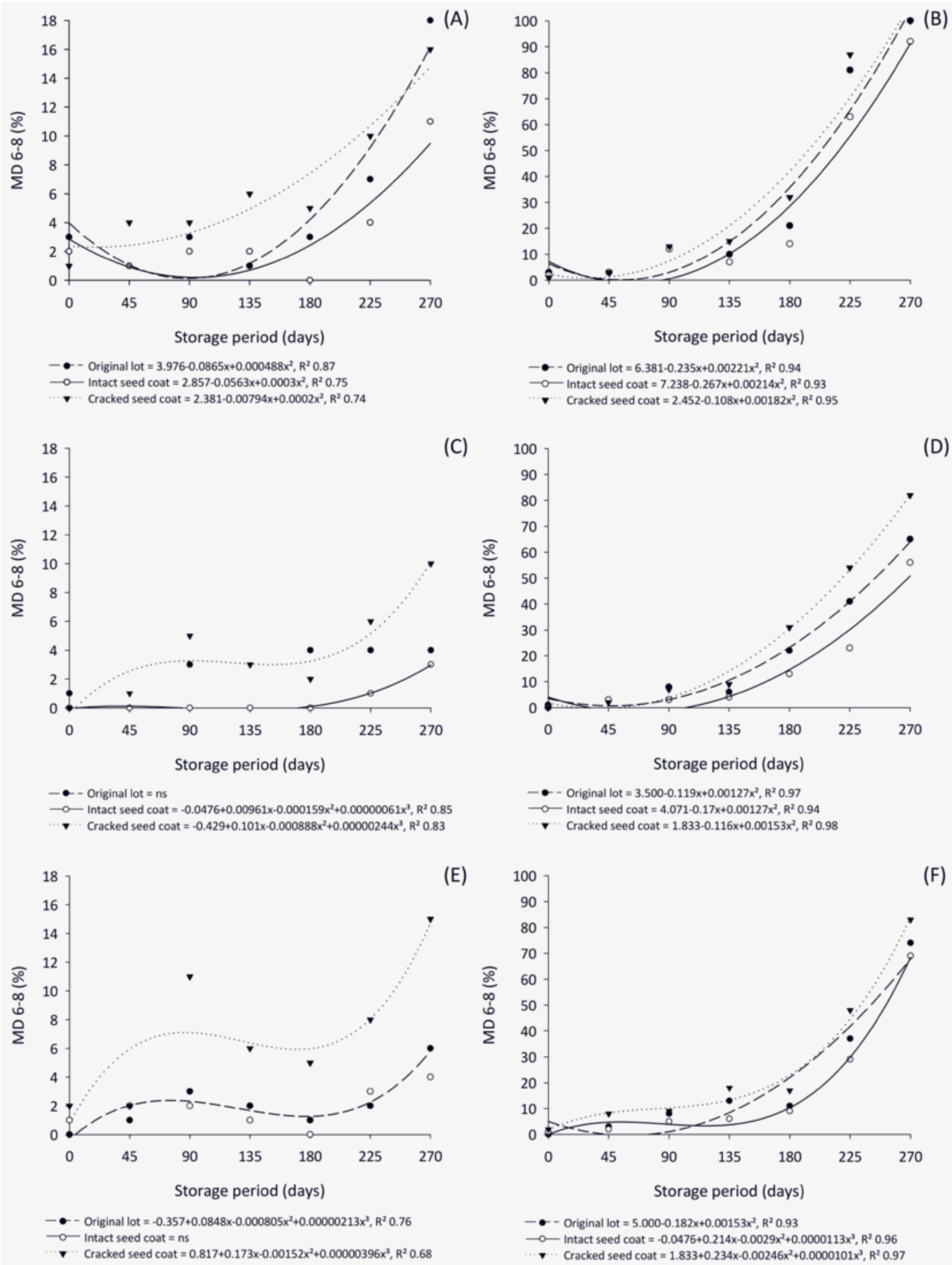

Figure 7. Moisture damage in classes 6 to 8 (MD 6-8) using the tetrazolium test, of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from the states of GO (C and D) and MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

In the accelerated aging test, there was no interaction among the factors for NS 7209 IPRO and 8473 RSF (MT) seed lots stored at 15 °C. However, the 8473 RSF (GO) lot clearly showed that seeds with the cracked seed coat had greater reduction in quality after exposure to the stress test, which was observed at 180 days of storage for the 8473 RSF (GO) lot (Table 5). Nevertheless, in storage under the temperature of 28 °C, beginning at 45 days, significant differences were seen among the segregated groups of seeds, with lower values of germination after aging in seeds that had a cracked seed coat (Table 5).

When stored at the temperature of 15 °C, the seeds from the NS 7209 IPRO and 8473 RSF (MT) lots exhibited a sigmoidal curve regarding accelerated aging over the storage period, decreasing in vigor up to 90 days, followed by a period of stabilization that lasted up to 180 days, with subsequent decline (Figure 8A and 8E). However, in the 8473 RSF (GO) lot, the seeds with intact seed coat maintained their quality up to 225 days after the beginning of storage, whereas seeds from the original lot and those with a cracked seed coat showed reduced vigor as of 180 days (Figure 8C).

The seeds from the NS 7209 IPRO lot at the temperature of 28 °C after 48 h of AA had pronounced reduction in vigor from the beginning of storage, reaching near zero germinated seeds at 135 days of storage (Figure 8B). This reduction was observed in the other lots [8473 RSF (GO) and (MT)] only at 45 days of storage and reached zero at 225 days for the cv. 8473 RSF (GO) and at 180 days for the cv. 8473 RSF (MT) for seeds with a cracked seed coat (Figures 8D and 8F).

Seed storability is a genetically regulated trait, and it is affected by the initial quality, pre-storage history, seed moisture content, relative humidity and temperature of the environment, and length of storage, as well as biotic agents and other factors of lesser importance (Gris et al., 2010). Therefore, especially the accelerated aging test shows a difference in vigor between the seed lots of the cultivars (NS 7209 IPRO and 8473 RSF) and also between the lots of the same cultivar (8473 RSF from GO and from MT) (Table 5 and Figure 8). Furthermore, evaluation of the segregated groups of seeds from the same lot shows that those that have a cracked seed coat had a sharper reduction in quality than the others, probably through having absorbed water more rapidly during the test due to the defect in the seed coat, which is an important barrier that regulates the rate of water absorption (Marcos-Filho, 2015).

In the electrical conductivity test, the seeds that had cracking in the seed coat (OL and CS) had higher leachate levels than the seeds with an intact seed coat (IS), especially in storage at 28 °C. Seeds from the 8473 RSF (MT) lot stored at 15 °C did not show interaction among the factors; nevertheless, electrical conductivity in CS was 21% higher than in IS (Table 6).

Table 5. Accelerated aging (AA) of three soybean seed lots from the cultivars NS 7209 IPRO and 8473 RSF from the states of GO and MT, segregated into groups of the original lot (OL), of seeds with intact seed coat (IS), and of seeds with cracked seed coat (CS), stored at temperatures of 15 °C and 28 °C.

	SP (Days)	NS 7209 IPRO						8473 RSF (GO)						8473 RSF (MT)						
		15 °C			28 °C			15 °C			28 °C			15 °C			28 °C			
		IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	
AA	0	88	86	85	88	86	85	98	96	92	98	96	92	93	96	93	93	96	93	NS
	45	83	78	75	41	27	21	95	96	95	88	87	65	94	90	87	85	85	66	A
	90	78	67	61	5	4	0	95	94	93	59	56	51	89	90	87	58	54	26	AB
	135	71	64	56	0	0	0	90	91	92	51	41	20	92	88	84	40	29	4	B
	180	70	67	60	0	0	0	95	90	88	0	0	0	90	88	84	0	0	0	BC
	225	71	52	50	0	0	0	92	85	84	0	1	1	88	84	81	0	0	0	C
	270	21	17	10	0	0	0	75	70	58	0	0	0	77	74	67	0	0	0	
	Mean	69	62	57	19	17	15	91	89	86	42	40	33	89	87	83	39	38	27	

[1/] Means that have the same color in the row do not differ from each other by Tukey's test ($p < 0.05$). SP: storage period. ns: not significant. OL: original lot. IS: seeds with intact seed coat. CS: seed with cracked seed coat.

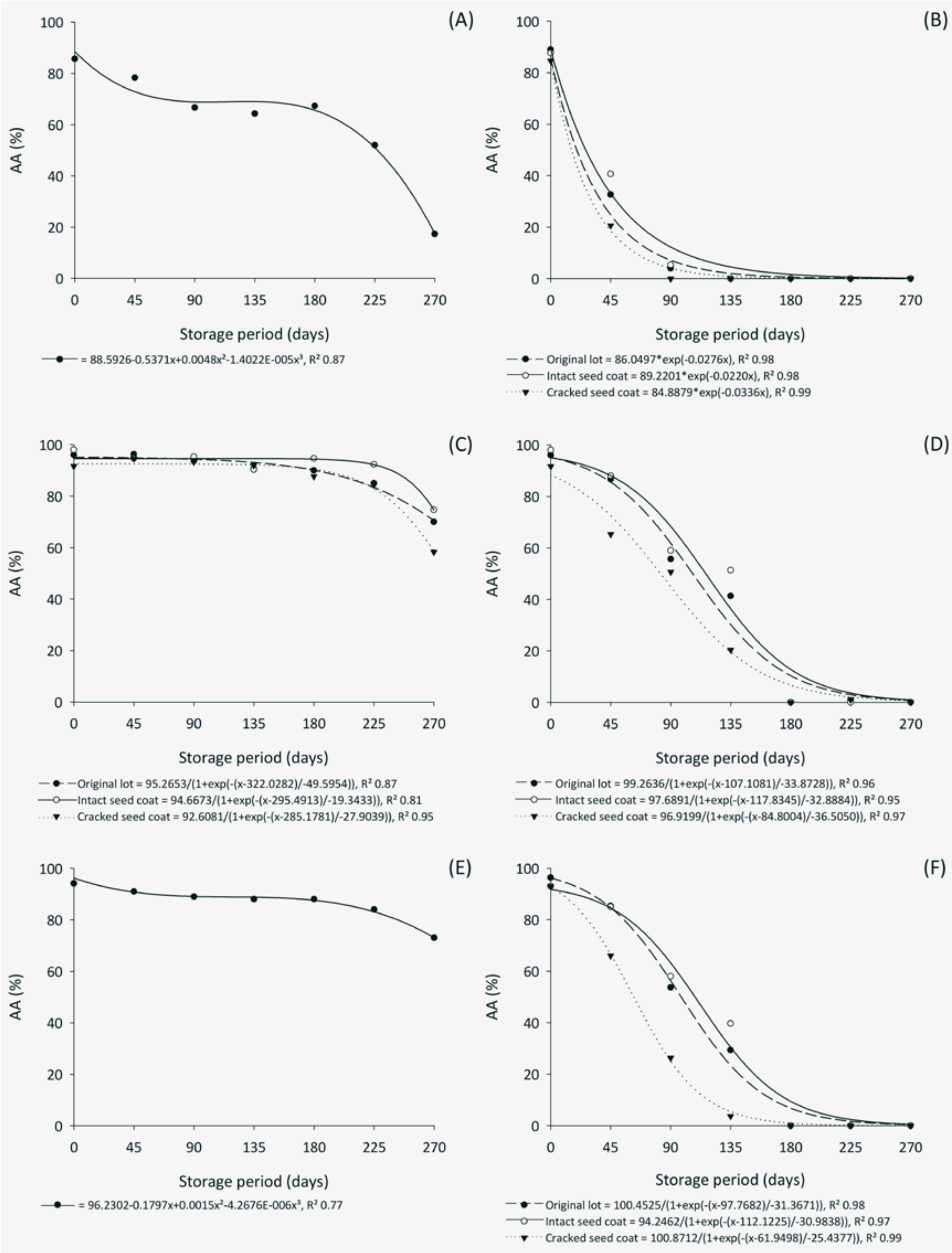

Figure 8. Accelerated aging (AA) of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from the states of GO (C and D) and MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

Table 6. Electrical conductivity (EC) of three soybean seed lots from the cultivars NS 7209 IPRO and 8473 RSF from the states of GO and MT, segregated into groups of the original lot (OL), of seeds with intact seed coat (IS), and of seeds with cracked seed coat (CS), stored at temperatures of 15 °C and 28 °C.

	SP (Days)	NS 7209 IPRO						8473 RSF (GO)						8473 RSF (MT)						
		15 °C			28 °C			15 °C			28 °C			15 °C			28 °C			
		IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	IS	OL	CS	
EC	0	50	61	66	50	61	66	44	46	49	44	46	49	39	41	45	39	41	45	NS
	45	64	65	65	74	74	91	51	62	63	62	63	64	53	59	61	63	64	72	A
	90	77	86	87	96	110	125	61	70	67	75	77	89	61	58	70	63	64	84	AB
	135	71	73	73	137	124	142	63	59	67	96	92	100	55	57	66	67	78	81	B
	180	74	98	93	145	151	157	74	86	82	95	90	106	65	78	77	76	90	116	BC
	225	85	88	88	178	190	192	58	72	77	106	119	137	59	64	72	97	106	112	C
	270	90	111	116	199	217	231	83	81	90	133	143	163	62	74	81	133	141	144	
	Mean	73	83	84	125	132	143	62	68	71	87	90	101	56	61	67	77	83	93	

[1/] Means that have the same color in the row do not differ from each other by Tukey's test ($p < 0.05$). SP: storage period. ns: not significant. OL: original lot. IS: seeds with intact seed coat. CS: seed with cracked seed coat.

There was an increase in the electrical conductivity of the seeds as the storage period increased, above all in the seeds stored at 28 °C (Figure 9). This increase was more expressive in the leaching of cellular exudates in the first 45 days of storage and after 225 days, fitting sigmoidal regression models (Figures 9A, 9C, 9D, 9E, and 9F). Seeds from the original lot (OL) and those with an intact seed coat (IS) from the NS 7209 IPRO lot stored at 28 °C exhibited a linear increase in electrical conductivity of 5.9 and 5.6 µS cm^{-1} g^{-1}, respectively, every 10 days of storage (Figure 9B). No interaction among the factors was found for the cv. 8473 RSF (MT) stored at 15 °C (Figure 9E).

During the seed aging process under high temperature, membranes loosen, increasing the rate of metabolic reactions. That facilitates the formation of free radicals, also favoring increased leaching of intracellular content, typically sugars, creating an environment favorable to multiplication of microorganisms around the seed (Table 6 and Figure 9) (Souza and Marcos-Filho, 2001; Kumar et al., 2015; Taiz et al., 2017; Krzyzanowski et al., 2022). This cascade effect of harmful reactions can be even more pronounced in seeds with a cracked seed coat, since such seeds have one less protective barrier than the others (Figure 1). They provide an easier route for entry and exit of water and intracellular content, making them more susceptible to deterioration (Yaklich and Barla-Szabo, 1993).

Regarding the seedbed emergence test for the NS 7209 IPRO cultivar lot stored at 15 °C, the seeds with a cracked seed coat had significantly lower results than the others at 90 and 180 days of storage. It was the only segregated group of the lot that lost quality over the storage period (Table 7). In this same lot stored at 28 °C at 90 days of storage, seedlings from seeds without seed coat cracking had greater emergence capability. In the 8473 RSF (GO) lot, there was no interaction among the factors when the seeds were stored at 15 °C. However, on average, seeds with seed coat cracking showed lower seedling emergence than the others, and reduction was observed at 180 days. For the 8473 RSF (MT) lot at both temperatures (15 °C and 28 °C), and for the 8473 RSF (GO) lot stored at 28 °C, the seeds with a cracked seed coat produced seedlings with lower emergence than the others at all the times tested, while the OL seeds exhibited intermediate results.

Under the conditions in which this experiment was conducted, during the storage period, all the lots stored at 28 °C showed reduction in seedling emergence at each 90-day interval. Seeds with a visually intact seed coat (IS) stored at 15 °C did not show significant reduction in seedling emergence over the period evaluated (Table 7).

The deterioration process is inevitable and intensifies as storage time increases. Nevertheless, this can be slowed through the use of refrigerated storage and maintenance of suitable seed moisture content. Soybean seed coat cracking is a real defect present in a large number of cultivars currently used on the market, and this needs to be understood and managed responsibly, always prioritizing final seed quality.

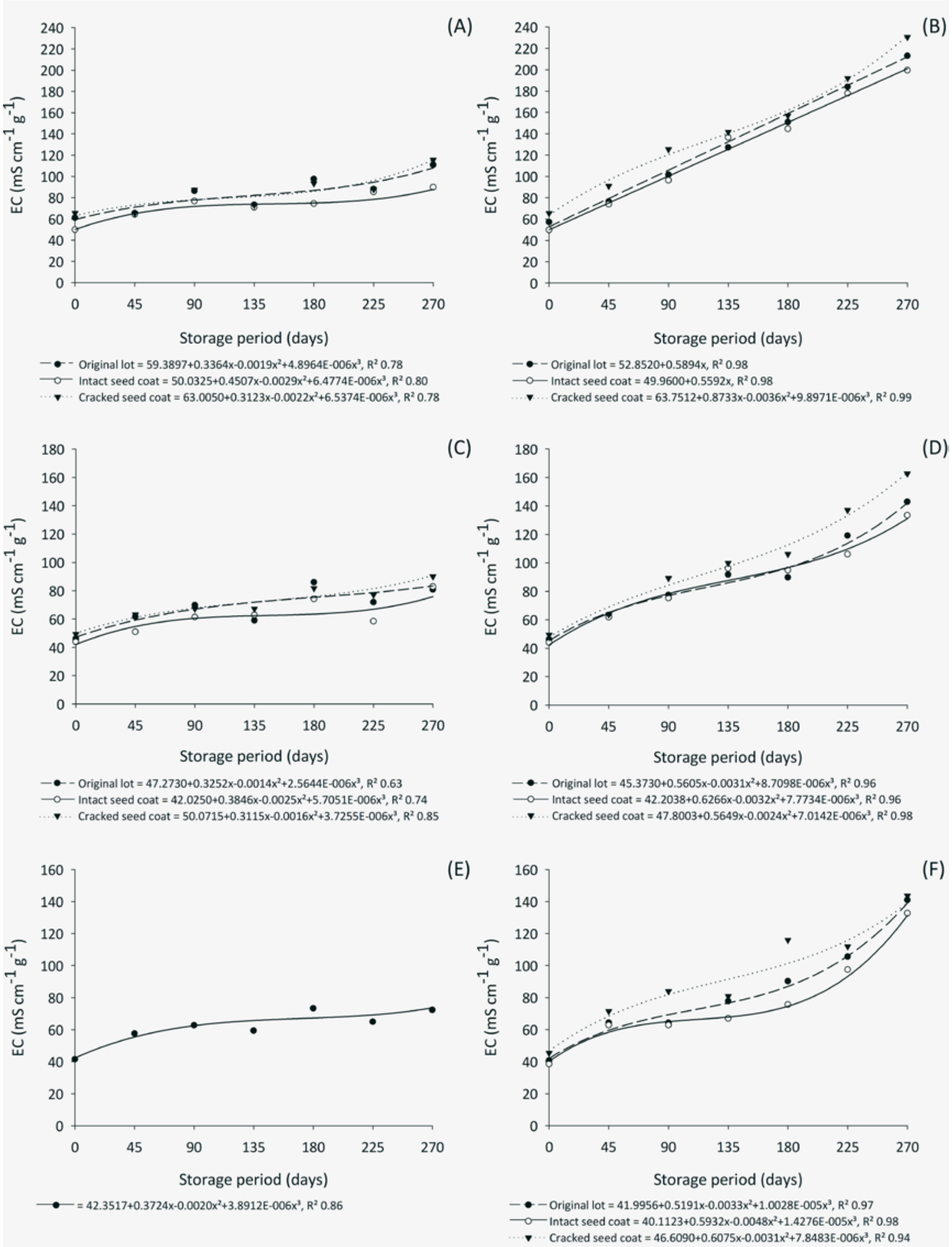

Figure 9. Electrical conductivity (EC) of three soybean seed lots from the cultivars NS 7209 IPRO (A and B) and 8473 RSF from the states of GO (C and D) and MT (E and F), segregated into groups of the original lot, of seeds with intact seed coat, and of seeds with cracked seed coat, stored at temperatures of 15 °C (A, C, and E) and 28 °C (B, D, and F).

Table 7. Seedbed emergence of three soybean seed lots from the cultivars NS 7209 IPRO and 8473 RSF from the states of GO and MT, segregated into groups of the original lot (OL), of seeds with intact seed coat (IS), and of seeds with cracked seed coat (CS), stored at temperatures of 15 °C and 28 °C.

SP (days)	Seedbed emergence (%)												
	NS 7209 IPRO				8473 RSF (GO)				8473 RSF (MT)				
	15 °C												NS
	IS	OL	CS	Mean	IS	OL	CS	Mean	IS	OL	CS	Mean	A
0	88 a	88 a	92 a	89	94	90	86	90 a	96 a	92 a	88 a	92	AB
90	87 a	85 a	83 b	85	95	93	89	92 a	90 a	88 b	83 b	87	B
180	91 a	88 a	79 b	86	85	84	78	82 b	95 a	89 b	82 b	89	BC
Mean	89	87	85	-	91 A	89 A	84 B	-	94	90	84	-	C
	28 °C												
	IS	OL	CS	Mean	IS	OL	CS	Mean	IS	OL	CS	Mean	
0	88 a	88 a	92 a	89	94 a	90 a	86 a	90	96 a	92 a	88 a	92	
90	73 b	61 b	58 b	61	85 b	83 b	70 b	79	82 b	79 b	76 b	79	
180	22 c	20 c	20 c	21	57 c	52 c	42 c	50	64 c	57 c	57 c	59	
Mean	61	56	57	-	79	75	66	-	81	76	74	-	

1/ Means that have the same color in the row and the same letter in the column do not differ from each other by Tukey's test ($p \leq 0.05$). SP: storage period. ns: not significant. OL: original lot. IS: seeds with intact seed coat. CS: seed with cracked seed coat.

CONCLUSIONS

Seed coat cracking in soybean has a negative effect on the longevity of seed lots, especially when the seeds already have a certain level of deterioration. Therefore, seeds with cracking of the seed coat should preferably be stored at low temperature.

ACKNOWLEDGMENTS

The authors thank the *Universidade Federal de Pelotas, Programa de Pós-Graduação em Ciência e Tecnologia de Sementes*; and the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil* (CAPES) for granting a scholarship to the first author.

REFERENCES

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. *Regras para Análise de Sementes*. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília: MAPA/ACS, 2009. 399p. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/arquivos-publicacoes-insumos/2946_regras_analise__sementes.pdf

CHACHALIS, D.; SMITH, M.L. Imbibition behavior of soybean (*Glycine max* (L.) Merril) accessions with different testa characteristics. *Seed Science and Technology*, v.28, p.321-331, 2000. https://www.cabidigitallibrary.org/doi/full/10.5555/20003034656

DELOUCHE, J. Germinação, deterioração e vigor da semente. *SEED News*, v.6, p.24-31, 2002. https://seednews.com.br/artigos/2018-germinacao-deterioracao-e-vigor-da-semente-edicao-novembro-2002

FRANÇA-NETO, J.B.; KRZYZANOWSKI, F.C. *Metodologia do teste de tetrazólio em sementes de soja.* Londrina: Embrapa Soja, 2022, 111p. (Documentos 449). https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1148061/1/DOCUMENTO-449-on-line.pdf

FRANÇA-NETO, J.B.; KRZYZANOWSKI, F.C.; HENNING, A.A.; DE PÁDUA, G.P.; LORINI, I.; HENNING, F.A. *Tecnologia da produção de semente de soja de alta qualidade*. Londrina: Embrapa Soja, 2016. 82p. (Embrapa Soja, Documentos, 380). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/151223/1/Documentos-380-OL1.pdf

GRIS, C.F.; VON PINHO, E.V.R.; ANDRADE, T.; BALDONI, A.; CARVALHO, M.L.M. Qualidade fisiológica e teor de lignina no tegumento de sementes de soja convencional e transgênica RR submetidas a diferentes épocas de colheita. *Ciência e agrotecnologia*, v.34, n.2, p.374-381, 2010. https://doi.org/10.1590/S1413-70542010000200015

HUTH, C.; MERTZ-HENNING, L.M.; LOPES, S.J.; TABALDI, L.A.; ROSSATO, L.V.; KRZYZANOWSKI, F.C.; HENNING, F.A. Susceptibility to weathering damage and oxidative stress on soybean seeds with different lignin contents in the seed coat. *Journal of Seed Science*, v.38, n.4, p.296-304, 2016. https://doi.org/10.1590/2317-1545v38n4162115

ISTA. Iinternational Seed Testing Association. Seed vigour testing. In: *International Rules for Seed testing.* Bassersdorf, cap.5, p.15.6-8. 2017.

KRZYZANOWSKI, F.C.; DIAS, D.C.F.S; FRANÇA-NETO, J.B. *Deterioração e vigor da semente*. Londrina: Embrapa Soja, 2022. (Circular técnica 191). https://ainfo.cnptia.embrapa.br/digital/bitstream/doc/1151118/1/Circ-Tec-191.pdf

KRZYZANOWSKI, F.C.; FRANÇA-NETO, J.B.; PRADO, J.P.; HENNING, F.A. *Teste de condutividade elétrica para avaliar o vigor da semente de soja*. Londrina: Embrapa Soja, 2023. (Circular técnica 199). https://ainfo.cnptia.embrapa.br/digital/bitstream/doc/1158188/1/Circ-Tec-199.pdf

KUMAR, J.S.P.; PRASAD, S.R.; BANERJEE, R.; THAMMINENI, C. Seed birth to death: dual functions of reactive oxygen species in seed physiology. *Annals of Botany*, v.116, n.4, p.663-668, 2015. https://doi.org/10.1093/aob/mcv098

MAPA. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa Nº 45, de 17 de setembro de 2013. Anexo XXIII - Padrões para produção e comercialização de sementes de soja.

MARCOS-FILHO, J. *Teste de envelhecimento acelerado*. In: Vigor de sementes: conceitos e testes. Tradução. Londrina: Abrates, 2020. p. 601 : il. . Acesso em: 07 ago. 2024.

MARCOS-FILHO, J. *Fisiologia de sementes de plantas cultivadas*. 2. ed. Londrina, ABRATES, 2015, 659p.

MOREANO, T.B.; BRACCINI, A.L.; SCAPIM, C.A.; KRZYZANOWSKI, F.C.; FRANÇA-NETO, J.B.; MARQUES, O.J. Changes in the effects of weathering and mechanical damage on soybean seed during storage. *Seed Science and Technology*, v.39, p.604-611, 2011. https://doi.org/10.15258/sst.2011.39.3.07

QUTOB, D.; MA, F.; PETERSON, C.A.; BERNARDS, M.A.; GIJZEN, M. Structural and permeability properties of the soybean seed coat. *Botany*, v.86, n.3, p.219-227, 2008. https://doi.org/10.1139/B08-002

PIEPER, M.S.; MENEGHELLO, G.E.; POSSER, G.F.; BRUINSMA, M.S.; FRANCO, M.S.; MACHADO, N.L. Avaliação e respostas do tratamento químico em Sementes de soja com e sem tegumento rompido. *Contibuiciones a Las Ciencias Sociales*, v.17, n.3, p.01-11, 2024. https://doi.org/10.55905/revconv.17n.3-200

R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, 2023.

RADHA, B.N.; CHANNAKESHAVA, B.C.; BHANUPRAKASH, K.; PANDURANGE GOWDA, K.T.; RAMACHANDRAPPA, B.K.; MUNIRAJAPPA, R. DNA damage during seed ageing. *IOSR Journal of Agriculture and Veterinary Sciences*, v.7, p.34-39, 2014. https://doi.org/10.9790/2380-07113439

SENDA, M.; KAWASAKI, M.; HIRAOKA, M.; YAMASHITA, K.; MAEDA, H.; YAMAGUCHI, N. Occurrence and tolerance mechanisms of seed cracking under low temperatures in soybean (*Glycine max*). *Planta*, v.248, n.2, p.369-379, 2018. https://doi.org/10.1007/s00425-018-2912-z

SOUZA, F.H.; MARCOS-FILHO, J. The seed coat as a modulator of seed-environment relationships in Fabaceae. *Brazilian Journal of Botany*, v.24, p.365-375, 2001. https://doi.org/10.1590/S0100-84042001000400002

TAIZ, L.; ZEIGER, E.; MOLLER, I.M.; MURPHY, A. *Fisiologia e desenvolvimento vegetal.* 6ª Ed. Artmed Editora, 2017, 888p.

USDA. United States Department of Agriculture. Graphical Query: *Statistics By Commodity*. Reported On: Jul'24. Source: FAS USDA. https://apps.fas.usda.gov/psdonline/app/index.html#/app/statsByCommodity

YAKLICH, R.W.; BARLA-SZABO, G. Seed coat cracking in soybean. *Crop Science*, v.33, n.5, p.1016-1019, 1993. https://doi.org/10.2135/cropsci1993.0011183X003300050028x

ZORATO, M.F. O tegumento de sementes de soja e o seu impacto na qualidade. *SEED News*, v.3, 2018. https://seednews.com.br/artigos/350-o-tegumento-de-sementes-de-soja-e-o-seu-impacto-na-qualidade-edicao-maio-2018