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Comparison of electrical conductivity and radicle emergence tests as predictors of seed vigor and field emergence in different sunflower hybrids (*Helianthus annuus* L)

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Abstract

To advance in Electrical conductivity (EC), test standardization is necessary to evaluate its repeatability and reproducibility in different sunflower hybrids and laboratories. The radicle emergence (RE) test also appears as potentially effective for this species. Growing degree days (GDD) are used to predict field emergence, although its association with sunflower seed vigor has not been analyzed. The aims were to i) analyze the ability of the EC test to differentiate sunflower seed vigor among hybrids in different laboratories during the storage ii) compare EC with RE tests and establish their association with sunflower field emergence. Three sunflower hybrids were evaluated during storage months. EC was measured on 50 dehulled seeds after 24 h in six laboratories. RE was examined by counting radicles > 2mm, between 24-52 h after sowing. Field emergence was evaluated by Time for 50% of maximum seedling emergence (SE50), Mean Time of emergence, and Daily mean emergence, expressed in chronological days and GDD. After 11 months, EC increased, while RE decreased. EC test detected genotypic differences among sunflower hybrids, being reproducible and repeatable within and among laboratories. Sunflower seeds with less vigor have high GDD, indicating a lower field emergence rate. RE did not predict sunflower seed deterioration or field seedling emergence.

Keywords - *Electrical conductivity, field emergence, radicle emergence, sunflower seeds, vigor*.

I. INTRODUCTION

Seed vigor expresses seed lots activity and performance with acceptable germination in a wide range of environments [1]. If a seed lot can perform satisfactorily under not optimal conditions for the species, it is considered vigorous [2]. Seed vigor is not a single measurable property and is determined by the complex interaction between genetic and environmental components, which influence not only field performance but also storage potential [3]. Only a small number of species have standardized vigor tests incorporated in the ISTA rules. Before a test is standardized, it should be well tested by intra-laboratory and inter-laboratory validation [4]. In the validation process, test performance is evaluated by its repeatability and reproducibility [5]. In sunflower, no test has yet been validated or included in the ISTA rules.

The electrical conductivity test (EC) evaluates the degree of damage suffered by cell membranes due to seed deterioration [6]. It is a simple and rapid test and is not affected by seed dormancy ([7], [9]).

The EC test was repeatable, and differences between sunflower genetic materials were identified, even though this depended on the variety and the thickness of pericarp rather than on seed vigor [8]. In one genetic material and seeds without a pericarp, the EC test consistently identified the differences of sunflower seed vigor, being reproducible and repeatable among and within the different laboratories [9]. Given that the genetic background could explain differences in sunflower seed vigor ([10], [11]), the EC test requires validation with different genotypes to advance with its standardization.

Recently, the radicle emergence count (RE) came up as a simple and quick method, with potential for seed vigor evaluation [12]. High radicle emergence percentages at the beginning of germination indicate high vigor, while low counts indicate low vigor [2]. Additionally, a longer time for radicle emergence is an indicator of deteriorated seeds with low vigor ([13], [14]). This test was introduced and validated in the ISTA rules for corn, rapeseed, and radish [2]. Furthermore, it has been shown to discriminate vigor in some species, such as leek [15], corn ([16], [17]), and wheat [18]. For sunflower, radicle emergence has been evaluated in many genetic materials ([19], [8]), although it has not yet been standardized or validated. Moreover, RE test conditions can influence their results; for example, germination rate is temperature-dependent, occurring faster at the optimum temperature [20]. This test's potential use and advantages make it an interesting alternative to the EC test in sunflower seeds.

The vigor tests should also allow the estimation of seed field behavior ([21], [7]). In sunflower, the association between the EC and field emergence was analyzed, being highly significant for some authors and not significant for others ([9], [22], [23], [24], [25]). The methodologies were diverse, including different field estimators such as seedling percentage, emergence rate in seedlings/day, Time for 50% of maximum seedling emergence, expressed in days, and growing degree days (GDD). Because of its simplicity, the GDD has been used in various species to predict the emergence rate [26]. However, its association with seed vigor has not been analyzed in depth. The highest number of degree days would indicate a lower field emergence rate [27] and associated with a lower vigor of sunflower seeds. In this crop, 20 GDD were determined for radicle appearance on a base temperature of 8.5 °C [28]. At the same time, seedling emergence occurs in the range of 64 - 69.8 GDD, on a base temperature of 7,9 ± 0.36 °C [29].

This study's aims were to i) analyze the ability of the EC test to differentiate sunflower seed vigor among hybrids in different laboratories during the storage time ii) compare EC with RE and establish their association with different estimators of sunflower field emergence.

II. MATERIALS AND METHODS

A. Seed material

Seeds from three sunflower hybrids, obtained during 2018/2019 in Venado Tuerto, Santa Fe, (33° 44’ S; 61° 58’ O) and General Alvarado, Buenos Aires (38° 11’ S; 57° 95’ O) Argentina, were evaluated. All of them had different genetic backgrounds and production conditions (experimental site, date of sowing, crop practices, type, and date of harvest).

B. Treatments

After three months from harvest, to create the vigor levels within each hybrid, the seeds were stored under two conditions:

(a) Proper storage: 10 ± 2 ºC of temperature

(b) Improper storage: between 18 and 25 °C of temperature, with 24 h to 38°C in each storage month

These storage conditions for each hybrid resulted in the following combinations of treatments:

TABLE 1
Classification of seed treatment according to hybrid and storage conditions.

	Storage conditions	
Hybrid	Proper	Improper
1	1 Pr	1 Im
2	2 Pr	2 Im
3	3 Pr	3 Im

Until their analysis, seeds were stored in trilaminated paper bags, sealed with film paper, in moisture-proof containers. After 6 months of storage, germination was between 90 and 95% for all treatment [2]. Consequently, dormancy levels at that time may be considered non-existent. Samples were coded independently and distributed for each laboratory. The participating laboratories were:

1) Seeds Laboratory of Faculty of Agricultural Sciences, University of Lomas de Zamora, Bs. As., Argentina (UNLZ).

2) National Institute of Agricultural Research, Oliveros Experimental Station, Oliveros, Argentina (INTA-Oliveros).

3) Laboratory of Agronomic Specialties, Colón, Bs. As., Argentina (LEA).

4) Urma Pampa Laboratory, Rio Primero, Córdoba, Argentina (Urma Pampa).

5) Faculty of Agricultural Sciences, University of Mar del Plata. National Institute of Agricultural Research, Balcarce Experimental Station, Integrated Unit Balcarce, Bs. As., Argentina (UNdMP – INTA Balcarce).

6) Seeds Laboratory of Arbitral Chamber of Cereals of Santa Fe Commercial Stock Schange, Santa Fe, Argentina (BC-Santa Fe).

C. Laboratory test

a) Electrical conductivity test (EC)

After 3 months, electrical conductivity was measured in only one laboratory (UNLZ) to determine the highest vigor level achieved by each hybrid. After 6 months of storage, each laboratory received seed samples and completed the same method's conductivity test. Three 50-seed replicates were dehulled in each laboratory. They were then weighed and placed in 5 cm- diameter, 8 cm-high plastic cups with 38 ml distilled water at 25 °C for 23 h. The cups were covered with film paper. One control cup was used with 38 ml distilled water with 0 ± 5 µs cm-1 g-1 at 25°C temperature. After 23 h, the samples were taken out of the chamber and mixed up. EC was measured after 24 h using a conductivity meter and expressed as µS.cm-1. g-1 [30]. Electrical conductivity assesses the degree of damage in cell membranes as a result of seed deterioration. A higher deterioration leads to a lower membrane repair capacity and a greater amount of solute released during imbibition [7]. Thus, high electrolytes released into the solution (and higher electrical conductivity values) involve lower seed vigor [1].

b) Radicle emergence test (RE)

Radicle emergence was evaluated by placing three 50-seed replications of each treatment in 9-cm-diameter Petri dishes on two pieces of Whatman N°1 filter paper, moistened with 2.5 ml distilled water. Afterward, the Petri dishes were wrapped up in plastic film and placed in a chamber at continuous 25°C [1] with 12 hours of alternating light/dark. The numbers of seeds with emerged radicles > 2mm [31] were counted at 24, 26, 28, 30, 32, 34, 36, 38, 40, 44, 48, and 52 hours from sowing. These moments were determined by observing the time from which the emergence of the radicle in the sunflower was evident, according to previous work [32]. The time required for the emergence of 50% of radicles (RE50) was calculated according to the following formula [33], expressed in hours for 50% of maximum radicle emergence:

$$\mathrm{RE50} = \frac{\left[\left({RE_{MAX}}\big/{2}\right) - R_1\right] \times \left(H_2 - H_1\right)}{R_2 - R_1} + H_1$$

Where RE_{MAX} is the final percentage of seeds with radicle emerged, H1 refers to the hours from the beginning of the radicle emergence period, H2 corresponds to the hours to the end of the radicle emergence period, R1 is the number of radicles that emerged counted at H1 and, R2 is the number of radicles emerged counted at H2. Also, RE50 was calculated in GDD as the sum of the average chamber temperature - the base temperature to obtain RE50 expressed in degree centigrade days (°Cd), with a base temperature of 6 °C [34]. Like EC, the RE test was determined, only in the UNLZ laboratory, at 3 (prior storage), 6, and 11 months of storage.

D. Field emergence test

The field emergence tests were performed on a Typic Argiudoll soil in the experimental field of Agronomy, University of Lomas de Zamora (34º 45º S; 58º 29' W), Argentina. Two sowings were conducted on 08/22/2019 (experiment 1) and 02/21/2020 (experiment 2), coinciding with 6 and 11 months of storage, respectively. Fifty seeds were sown in each 1 × 1 m plot with 4 rows separated by 0.25 m and 5 cm soil depth. These plots were free from weeds, diseases, and pests and without fertilization and supplementary irrigation. Field emergence was evaluated counting the emerged seedlings [35] at intervals of 2 or 3 days after sowing, considering the following variables:

i) Time for 50% of maximum seedling emergence (SE50) was calculated using the same formula for RE50, replacing hours for days, and the number of radicles for the number of seedlings.

ii) Mean Time of emergence (TME) was calculated according to the Nakagawa formula [36] and expressed in days (d).

iii) Daily Mean emergence (DME) was calculated according to Maguire's formula [37] and expressed by seedling per chronological day (i.e., seedlings.d-1).

These variables were also calculated and expressing in °Cd [34], considering the air and soil temperature to obtain °Cd-Air.-1 and °Cd-Soil.-1, respectively.

E. Statistical analysis

Laboratory tests were studied by means of a complete randomized design (CRD) with 4 replicates and two factors: the participating laboratories and the hybrids. The analysis contemplated a random effect model for a factorial arrangement for each run (6 and 11 storage months). Field tests were studied by means of a complete randomized design (CRD) with 4 replicates and two factors: hybrids and storage conditions, for each experiment. Analysis of variance and LSD Fisher tests were performed with a 5 % significance level. After 6 months, for validation analysis, repeatability and reproducibility were analyzed with the statistical tool based on ISO 5725-2 [53]. This allowed the calculation of h- and k-values. The h-values showed the tendency for a laboratory to overestimate or underestimate the mean values compared to the mean of all the results available, whereas the k-values give a measure of the variability of the replications. Significant h-values indicate an over or underestimation of the mean value compared with the overall mean. Alternatively, significant k-values indicate greater variability among lots within a laboratory. Both were compared with the critical statistical value at 1 or 5 % significance. Determination coefficients (R2) were calculated between laboratory vigor tests and field data. Info starts statistical software was used [52].

III. RESULTS

A. Electrical conductivity (EC)

a) Validation analysis

EC test was reproducible and repeatable within and among laboratories. Regarding reproducibility (h values), at 1% and 5%, no significant h-values were found in most laboratories, indicating that EC measurements were not significant over or underestimated (Fig. 1a). Only hybrids 3 Im in laboratory 2 and 2 Pr in laboratory 4 had h-result above 5% critical value (Fig. 1a). Regarding repeatability within laboratories (k values), at 1% and 5%, significant variability among replicates was observed for hybrid 3 Pr in laboratory 2 and hybrids 1 Pr and 2 Im, in laboratory 5 (Fig. 1b). Hybrid 1 Im in laboratory 4 only had significant variability at 5% critical value (Fig. 1b).

b) Differentiation of seed vigor between hybrids in different laboratories during storage time

In most of the laboratories, EC increased over Time, expressing a decrease in seed vigor (Fig. 2). Although,

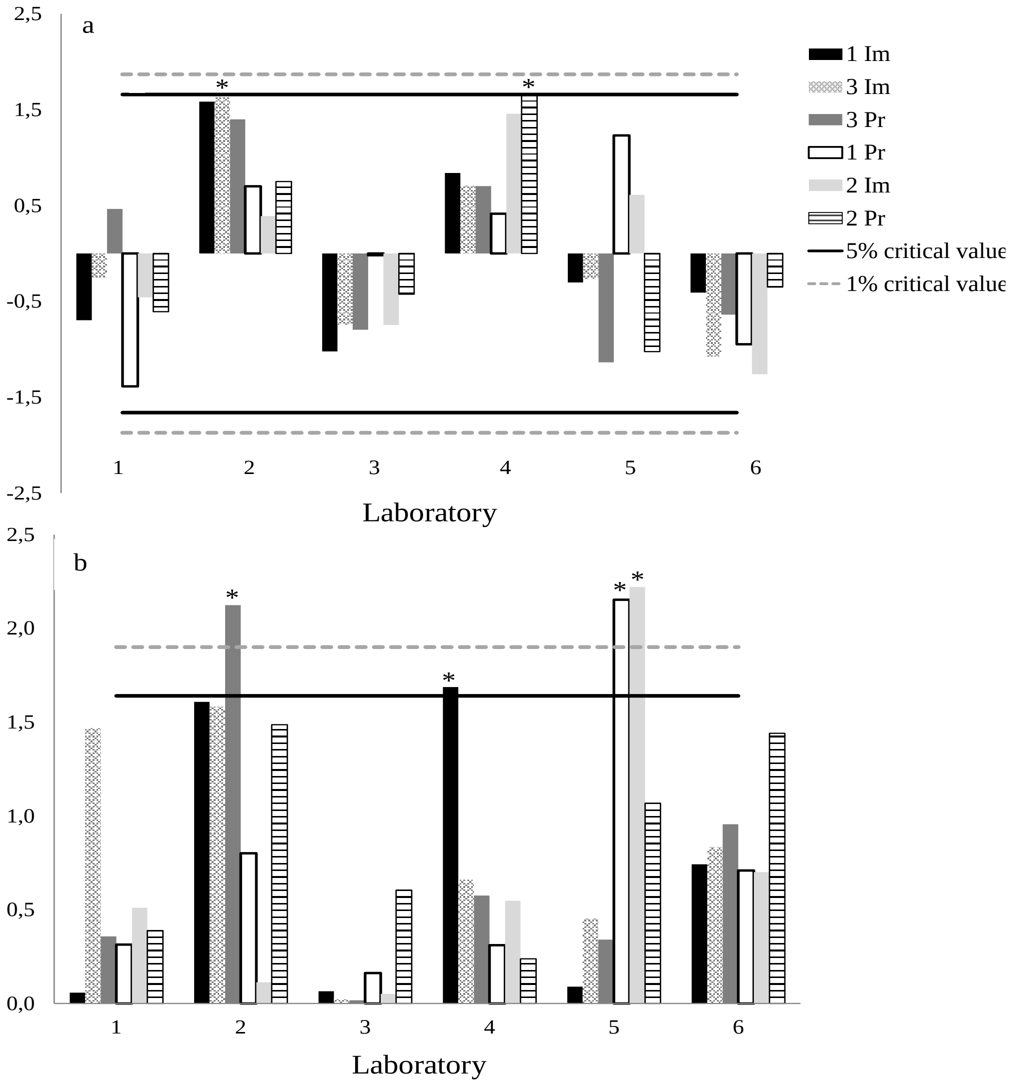

Fig 1. h (a) and k values (b) using EC test in six laboratories: Faculty of Agricultural Sciences, University of Lomas de Zamora – UNLZ (1), National Institute of Agricultural Research, Oliveros Experimental Station -INTA Oliveros (2) , Laboratory of Agronomic Specialties – LEA (3), Urma Pampa Laboratory – Urma Pampa (4), Faculty of Agricultural Sciences, University of Mar del Plata, National Institute of Agricultural Research, Balcarce Experimental Station – UndMP – INTA Balcarce (5), and Seeds Laboratory of Arbitral Chamber of Cereals of Santa Fe Commercial Stock Schange – BC Santa Fe (6), at 6 months for three sunflower hybrids in Proper (Pr) and Improper (Im) storage conditions. References: hybrid 1 Im (black bars), hybrid 1 Pr (white bars), hybrid 2 Im (light grey bars), hybrid 2 Pr (striped bars), hybrid 3 Im (dotted bars) and hybrid 3 Pr (dark grey bars). * indícate a significant difference at 1% or 5% critical value.

in laboratory 2, EC showed a reduction of EC after 11 storage months (Fig. 2b). This may be due to the high variability among replicates in this laboratory (Fig. 1b). All laboratories showed that hybrid 3 had the highest EC levels, indicating a lower vigor (Fig. 2). Differences between hybrid 1 and 2 were smaller in most laboratories and months, with lower EC levels (Fig. 2). Although there were higher EC levels (less vigor) under inappropriate storage conditions, only for hybrid 1 after 11 months and hybrid 2 after 6 months, were these differences significant (Fig. 3).

B) Radicle emergence (RE)

After 3 storage months (coinciding with the highest vigor level), hybrid 2 had the longest radicle emergence time (RE50) with 40.6 h, while hybrids 1 and 3 showed a shorter time with 35.3 and 33.6 h, respectively. When they were expressed in GDD, radicle emergence coincided with 32.1, 27.9, and 26.6 °Cd for the same hybrids. If the evolution during storage is analyzed, a significant reduction in radicle emergence time was observed at 11 months, in all hybrids and conditions (Table 2).

C. Field emergence

a) Comparison between the EC and RE tests in relation to different estimators of field emergence

Field emergence was measured with different estimators (Table 1, 2, and 3 in supplementary data). Of all of them, only SE50 (°Cd-Soil) showed a significant and positive association with EC (Fig. 4a). This occurred both at 6 and 11 months, with determination coefficients of 0.76 and 0.70, respectively. An increase in field emergence time (SE50) was observed as EC increased (Figure 4a). That is, seeds with less vigor (i.e., high EC) take longer to emerge under field conditions.

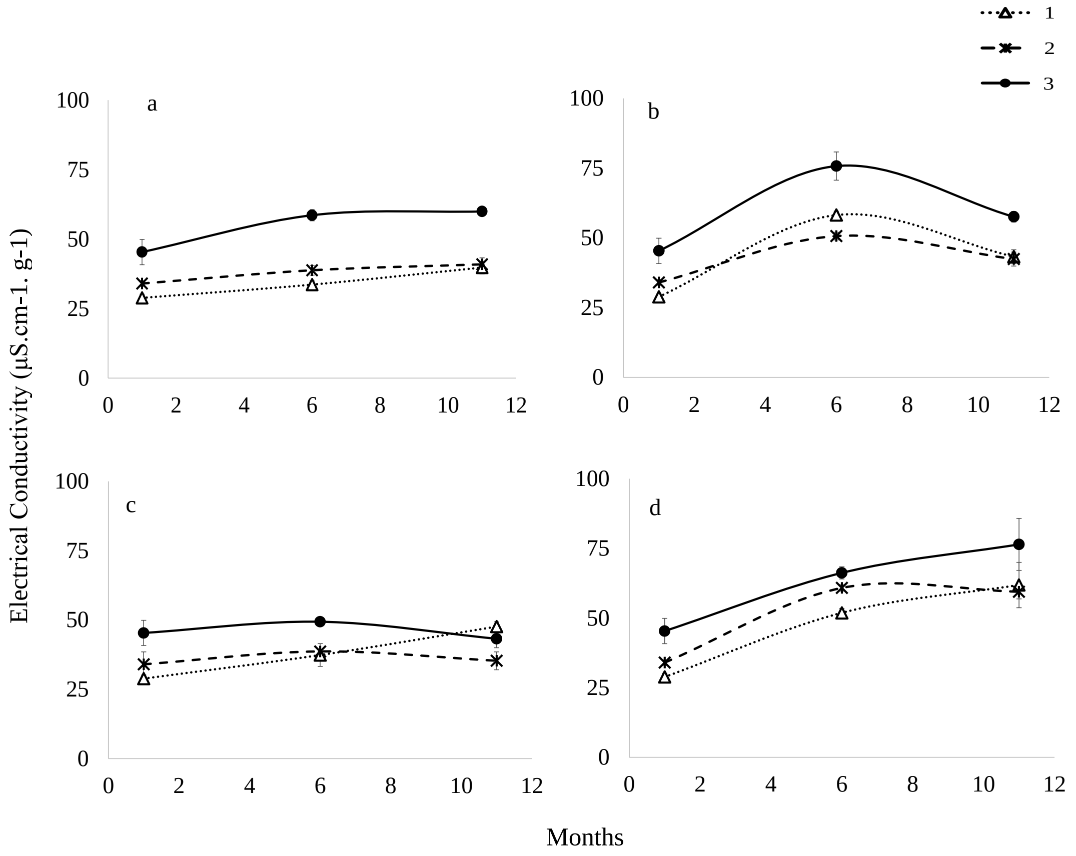

Fig 2. Evolution of EC during storage for three sunflower hybrids in four Laboratories: Faculty of Agricultural Sciences, University of Lomas de Zamora – UNLZ (a), National Institute of Agricultural Research, Oliveros Experimental Station - INTA Oliveros (b), Laboratory of Agronomic Specialties – LEA (c) , Urma Pampa Laboratory - Urma Pampa (d). References: hybrid 1 (triangle symbol dotted line), hybrid 2 (cross symbol cut line) and hybrid 3 (circle symbol full line). Vertical bars indicate ± 1 standard deviation (SD). Each ponit was average form data of improper and proper conditions. Two points differ significantly when the SD bars do not touch each other.

TABLE II
Comparison of radicle emergence time (RE50) between sunflower hybrids expressed in hours and GDD (°Cd) during 6 and 11 months storage in two conditions. Abbreviations: Pr = proper, Im = improper storage conditions.

		Hours		°Cd	
	Storage	Months		Months	
Hybrid	Condition	6	11	6	11
1	Pr	42,4 Aa	32,8 Ba	33,6 Aa	26,0 Ba
	Im	42,0 Aa	29,3 Ba	33,3 Aa	23,2 Ba
2	Pr	45,7 Aa	32,6 Ba	36,2 Aa	25,8 Ba
	Im	45,8 Aa	33,5 Ba	36,3 Aa	26,5 Ba
3	Pr	35,9 Aa	26,2 Ba	28,4 Aa	20,7 Ba
	Im	37,6 Aa	24,4 Ba	29,8 Aa	19,3 Ba

* Different capital letters in each line indicate significant differences between months and lowercase in each column between storage conditions (P< 0.05).

In addition, the field emergence time of the seeds stored for 11 months was greater than seeds stored for 6 months (Fig. 4a). Association between SE50 (°Cd-Soil) with RE was not significant (Fig. 4b). Furthermore, a decrease in field emergence time (SE50) was observed as RE increased.

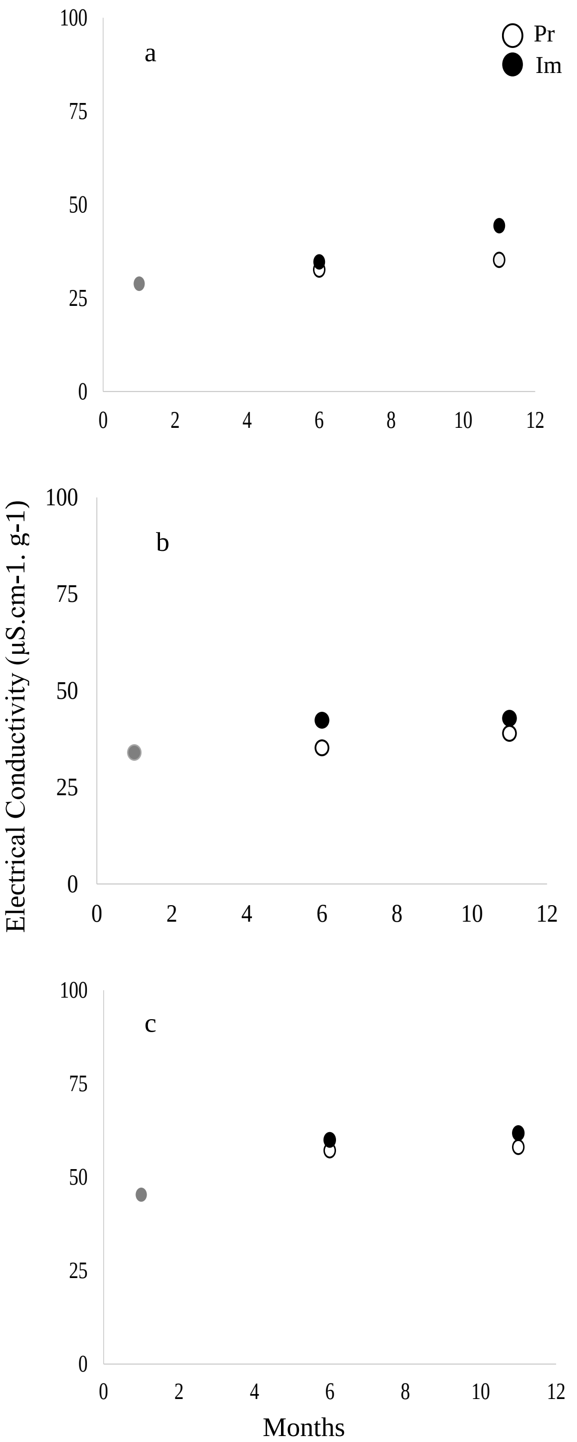

Fig 3. Evolution of EC for three sunflower hybrids in different storage conditions in UNLZ laboratory: hybrid 1 (a), hybrid 2 (b) and hybrid 3 (c). References: Proper (empty circle symbol), Improper (black full circle symbol) storage conditions, minimum electrical conductivity (ie, high vigor) before storage (gray full circle symbol). Vertical bars indicate ± 1 standard deviation (SD). Two points differ significantly when the SD bars do not touch each other.

That is, seeds with less vigor (higher RE50) would take less °Cd to emerge under field conditions (Fig. 4b). Comparing results across months of storage, seeds with 11 storage months had shorter radicle emergence time with high °Cd to emerge under field conditions (Fig. 4b), namely seeds with high vigor in the laboratory took longer for field emergence.

b) EC test as field emergence estimator for different hybrids and during storage time

For field emergence, hybrid 3 showed the highest SE50 values, both at 6 and 11 months (Fig. 5). This expresses a lower emergence time in the field, coinciding with their lower seed vigor in the laboratory. When comparing between storage conditions, the effect was less evident, since only in hybrid 1 the seeds stored under improper conditions had a slower field emergence, with a greater °Cd (Fig. 6).

IV. DISCUSSION

A. Electrical conductivity (EC)

The EC test has shown a high capacity to detect genotypic differences among sunflower hybrids, being reproducible and repeatable within and among six laboratories. Out of the 36 h values analyzed, only 2 were outside the 5 % critical value. A small variability among replicates was found in some laboratories (k-values), especially at 1 %. Validation results indicate the potential of EC as a method for sunflower seed vigor evaluation, coinciding with those found in other species ([38], [39], [40], [54]).

B. Radicle emergence (RE)

Concurrently with [19] and [8], the RE test identified differences between sunflower genetic materials. Our RE results indicate a different ranking than that found with the EC test. When RE was expressed in GDD, it showed a range around 25-35 °Cd, similar to that obtained by [28] and [41]. However, the reduction in radicle emergence time at 11 months would indicate an increase in the vigor over time, which contradicts the natural seed deterioration as a result of aging ([13], [16], [43], [51]). Because deteriorated seeds take more time for radicle appearance ([13], [18]), this variable was not adequate for estimating sunflower seed vigor.

C. Field emergence

a) Comparison between the EC and RE tests in relation with different estimators of field emergence

In other crops, [42] and [44] found both EC and RE were highly and significantly correlated with seedling field emergence, while in this work, the association between RE and EC with field emergence estimators were different. EC was significantly and positively related with seedling field emergence identifying increases in field emergence time as EC increases according to [45] and [46]. Also, seeds stored for longer periods (11 months) have high EC and take longer to emerge under field conditions, evidencing seed quality deterioration as they age. In our results, an unusual association between radicle and seedling emergence was observed. It was inversely but not significantly related. However, the behavior in other crops show a positive association between these variables ([42], [47], [48], [49]), indicating that seeds with less vigor, it takes more time to emerge under field conditions. In addition, seeds with 11 storage months, which have less radicle emergence time, take longer for seedling emergence (high °Cd).

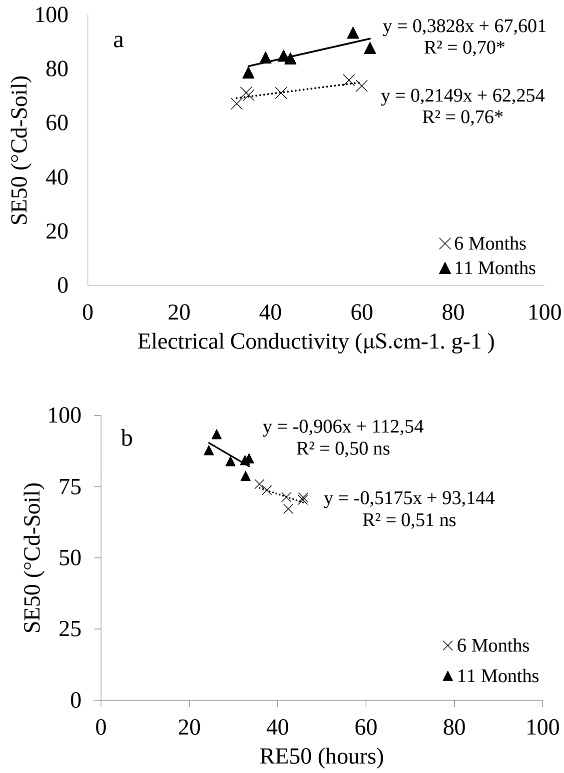

Fig 4. Association between laboratory seed vigor EC (a) and RE (b) tests with field emergence time mesured in days for 50% of maximum seedling emergence (SE50), expressed in GDD (°Cd-Soil) for three sunflower hybrids. Determination coefficients (R2), *p values < 0.05; ns= not significant. References: 6 (cross symbol) and 11 (triangle simbol) months of storage.

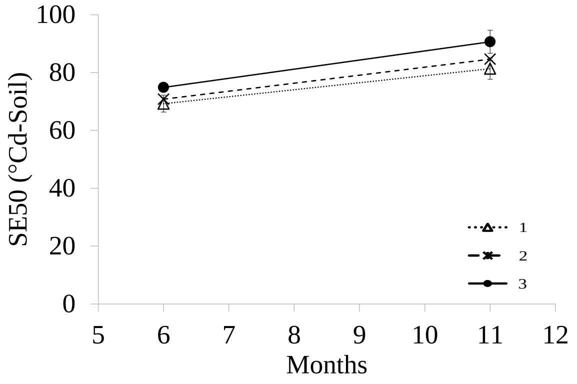

Fig 5. Evolution of field emergence time mesured in days for 50% of máximum seedling emergence (SE50), expressed in GDD (°Cd-Soil) for three sunflower hybrids. References: hybrid 1 (triangle symbol dotted line), hybrid 2 (cross symbol cut line) and hybrid 3 (circle symbol full line). Vertical bars indicate ± 1 SD. Two points differ significantly when the standard deviation bars do not touch each other.

Therefore, in field conditions, the RE test was unable to describe the vigor losses as sunflower seeds aged.

Thus, a question remains as to why RE results did not predict field sunflower seedling emergence. A possible explanation for this behavior is that the RE test conditions in this work were performed under optimal moisture and temperature, while radicle emergence in field conditions is generally under stress conditions [3]. For some authors [8], a thick pericarp could limit water absorption during imbibition and explain the delay in radicle emergence. This genetic trait could, therefore, reduce the application of the RE test for sunflower. It is also important to consider genetic and molecular factors mediating in the root meristem's re-activation during germination [50]. DNA repair is linked to cell expansion, resulting in radicle emergence in the many species remains to be established [55].

b) EC test as field emergence estimator for different hybrids and during storage time

Differences in seed vigor between sunflower hybrids observed in the laboratory were transferred to field seedling emergence, especially when SE50 was expressed in °Cd, including the soil temperature (°Cd-Soil). Seedling emergence occurs in the range of 70 - 90 °Cd, similar to [29] and [31] results. Therefore, the GDD could be used as an adequate field emergence estimator for sunflower seeds. For example, seeds with lower vigor (high EC) have 95 °Cd or above, which expresses a lower field sunflower emergence rate. It would be useful to investigate the ranges (values) in which these variables are associated more deeply, especially when seeds are stored for a much longer time (i.e., twenty months) or have higher deterioration levels. Also, base temperature showed important variability among sunflower genetic materials [11]. Thus, such variability should be incorporated into SE50 and GDD calculation to optimize its use and application.

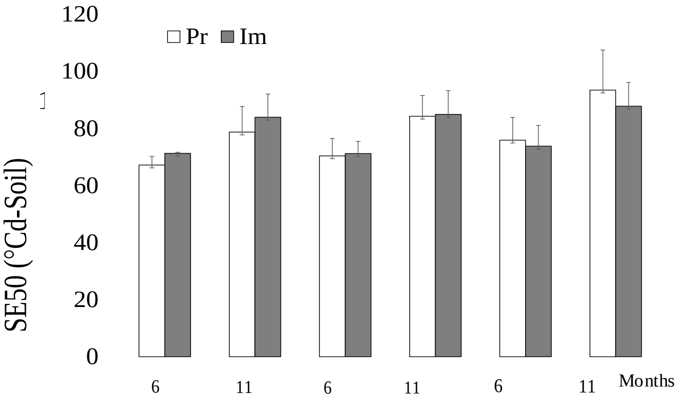

Fig 6. Field emergence time mesured in days for 50% of maximum emergence (SE50), expressed in GDD (°Cd-Soil) for three sunflower hybrids at 6 and 11 months for seeds stored in different conditions. References: Proper (withe bars), Improper (black bars) storage conditions.

V. CONCLUSION

EC test, performed in sunflower seeds without a pericarp, identified differences among hybrids during storage time, being successfully validated within and among laboratories. Time for 50% of maximum seedling emergence (SE50) was an adequate field emergence estimator for sunflower seeds. Sunflower seeds with less vigor have high centigrade degree days, expressing a lower field emergence rate. Under the conditions applied in this work, the RE test did not predict sunflower seed deterioration or field seedling emergence.

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SUPLEMENTARY DATA

TABLE I

Time for 50% of maximum seedling emergence (SE50) for three sunflower hybrids expressed in days and GDD (°Cd) considering air (°Cd-Air) and soil temperature (°Cd-Soil) at 6 and 11 months for seeds stored in different conditions. References: Proper (Pr), Improper (Im) storage conditions.

		Days		°Cd-Air		°Cd-Soil	
	Storage condition	Months		Months		Months	
Hybrid		6	11	6	11	6	11
1	Pr	8,7	4,1	89,4	69,1	67,2	78,7
	Im	9,5	4,2	92,8	69,8	71,3	83,9
2	Pr	9,3	4,3	91,9	71,2	70,4	84,3
	Im	9,5	4,5	92,7	72,3	71,2	85,0
3	Pr	9,8	4,7	93,4	77,7	75,9	93,5
	Im	9,6	4,4	93,6	73,0	73,8	87,8

TABLE II

Mean time of emergence (TME) for three sunflower hybrids expressed in days and GDD (°Cd) considering air (°Cd-Air) and soil temperature (°Cd-Soil) at 6 and 11 months for seeds stored in different conditions. References: Proper (Pr), Improper (Im) storage conditions.

		Days		°Cd-Air		°Cd-Soil	
	Storage condition	Months		Months		Months	
Hybrid		6	11	6	11	6	11
1	Pr	10,9	7,2	99,5	129,5	78,7	149,3
	Im	11,5	7,4	101,4	128,6	81,5	151,2
2	Pr	11,9	7,4	107,4	129,5	87,9	148,4
	Im	11,4	7,8	102,0	139,9	82,0	152,9
3	Pr	12,1	7,6	103,6	133,6	84,3	155,7
	Im	12,0	7,6	104,5	131,4	84,5	153,9

TABLE III

Daily Mean emergence (DME) for three sunflower hybrids expressed in seedlings /days and seedlings/GDD (°Cd) considering air (°Cd-Air) and soil temperature (°Cd-Soil) at 6 and 11 months for seeds stored in different conditions. References: Proper (Pr), Improper (Im) storage conditions.

		Seedlings/ days		Seedlings/ °Cd-Air		Seedlings/ °Cd-Soil	
	Storage condition	Months		Months		Months	
Hybrid		6	11	6	11	6	11
1	Pr	4,1	5,8	0,424	0,318	0,544	0,290
	Im	4,2	5,7	0,457	0,334	0,579	0,280
2	Pr	3,5	5,6	0,385	0,327	0,480	0,284
	Im	4,2	5,8	0,392	0,224	0,573	0,283
3	Pr	4,4	4,5	0,430	0,260	0,526	0,220
	Im	4,3	5,6	0,404	0,333	0,517	0,280