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Electrical conductivity for seed vigor test in sorghum (*Sorghum bicolor*)

KHODRATIEN FATONAH♥, IRFAN SULIANSYAH, NALWIDA ROZEN
Department of Agronomy, Faculty of Agriculture, Universitas Andalas. Kampus Unand Limau Manih, Pauh, Padang 25165, West Sumatra, Indonesia.
Tel.: +6275172701, Fax.: +62-751-72702. ♥email: irfan.suliansyah@yahoo.com

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Abstract. *Fatonah K, Suliansyah I, Rozen N. 2017. Electrical conductivity for seed vigor test in sorghum (*Sorghum bicolor*). Cell Biol Dev 1: 6-12.* The objectives of this study were to obtain an electrical conductivity test method for seed vigor test in sorghum, to recognize the relationship between the electrical conductivity test and potassium leakage, and to recognize the relationship between the electrical conductivity test and another variable on seed vigor. This study has two-step experiments. The objective of experiment I was to determine accurate combinations of water volume and amount of seed of the electrical conductivity test for seed vigor test in sorghum. A completely Randomized Design of 15 seed lots with 3 replications was used to determine the electrical conductivity method with different vigor. Experiment II was to test the electrical conductivity method of 21 seed lots of sorghum without an accelerated aging test, and 21 seed lots of sorghum were given an accelerated aging test. A completely Randomized Design of 21 seed lots with 3 replications was used in Experiment II. The variable observed was; standard germination, field emergence, speed of germination, first count, conductivity, potassium leakage, and eight combination conductivity method of water volume (50, 100, 150, and 200 ml) and amount of seed sorghum (50 and 75 seed count). The result of these experiments showed that the electrical conductivity test method with 150 ml water volume and 75 seed count was accurate and suitable for the sorghum seed vigor test; the electrical conductivity test showed a positive correlation with potassium leakage; and the electrical conductivity test can be used for seed vigor test in sorghum and provided the potential of physiological seed were shown through; standard germination test, field emergence test, first count test and speed of germination with negative correlation.

Keywords: Sorghum seeds, electrical conductivity test, seed vigor test

INTRODUCTION

The seed vigor test is a more sensitive index of seed quality than the germination test; any events that precede germination loss could serve as vigor tests. Therefore, seed vigor testing has increased the importance of ranking seed lots according to their physiological potential. One of the main concerns regarding seed vigor evaluation is obtaining reliable results within a short time for quality control programs. Literature shows that available rapid seed vigor tests which produce consistent information on seed physiological potential are those associated with the determination of enzymatic and respiratory activities and cell membrane integrity, such as the tetrazolium and electrical conductivity tests, respectively (Abdul-Baki and Baker 1973; Ramos et al. 2012; Lamarca and Barbedo 2014; Szemruch et al. 2015).

A vigor test can measure one or more of these events. The conductivity test is a measurement of electrolytes leaking from seeds. Changes in the organization of cell membranes occur during seeds' development before physiological maturity, seed desiccation before harvest, and imbibition before germination (ISTA 1995). As a seed rehydrates during early imbibition, the ability of its cellular membranes to reorganize and repair any damage that may have occurred will influence the extent of electrolyte leakage from seeds. The greater the speed with which the seeds are able to re-establish their membrane integrity, the lower the electrolyte leakage. Higher vigor seeds are able to reorganize their membranes more rapidly and repair any damage to a greater extend than lower vigor seeds.

Consequently, electrolyte leakages measured from high vigor seeds are less than those from low vigor seeds. In addition, low vigor seeds have been shown to have decreased membrane integrity due to storage deterioration and mechanical injury. However, no suggested or recommended procedures for electrical conductivity sorghum seed vigor tests are available in the handbooks of vigor tests from the International Seed Testing Association (AOSA 1983; ISTA 1995).

The research reported here is aimed at; (i).obtaining an electrical conductivity test method for seed vigor test in sorghum. (ii) recognizing the relationship between the electrical conductivity test and potassium leakage, and (iii) recognizing the relationship between the electrical conductivity test and another variable on seed vigor.

MATERIALS AND METHODS

The experiments were carried out from February to July 2015. All the laboratory and field emergence tests were conducted at the Indonesian Center for Seed Testing and Quality of Food Crops and Horticulture Research and Development, Cimanggis, Depok, West Java, Indonesia. In addition, potassium leakage was conducted at the Laboratory of Soil Department, Bogor Agriculture University, West Java, Indonesia.

Seed water content

Seed water content was determined at 130°C for 2 hours in duplicate samples of ground seeds of fine-scale as recommended by the AOSA Rules for Testing Seeds (AOSA 2014). The results were expressed as percentage water content (fresh weight basis).

Germination test:

Performed on three 100-seed replicates planted between rolled paper towels moistened and germinated at 25°C. Seedling counts were conducted four and teen days after seeding, evaluated for normal development, and results were expressed as percent normal seedlings for each lot.

Germination first count

The seeds were performed simultaneously with the germination test, and the percent of normal seedlings was recorded four days after seeding.

Speed of Germination

The normal seedlings are evaluated daily, starting from the first count till the final count

Accelerated aging

A single layer of seeds of each lot was placed on a wire mesh screen and suspended over 40 mL of distilled water inside a plastic accelerated aging box. Boxes were held at 43°C and 95% relative humidity for 72 hours in an incubator. Seed water content (oven method at 130°C/2 h) was also determined before and after the aging period to evaluate the accuracy of the accelerated aging results.

Electrical conductivity

The electrical conductivity of the leachate from whole imbibed seeds was determined by eight combination electrical conductivity methods (Table 1) and held in a germinator at 20°C. After 24 hours, the electrical conductivity of leachates was determined. In addition, each replication's electrical conductivity of leachates was measured using a conductivity meter (Type Cond 330i), and conductivity per gram of seed weight was calculated ($\mu S\ cm^{-1}g^{-1}$) and recorded.

Potassium leakage

Three replicates of 50 seeds per lot were weighed and placed in disposable plastic cups with 50 mL of deionized water and held at 20°C. After 24 hours of imbibition, the amount of leached potassium was determined by a flame photometer Type Corning 405. Results were expressed in ppm.

Table 1. Eight combinations of electrical conductivity method

Treatment	Amount of seed	Water (mL)
1	50	50
2	50	100
3	50	150
4	50	200
5	75	50
6	75	100
7	75	150
8	75	200

Field emergence

Three replicates of 50 seeds each per seed lot were distributed in a plastic box 38 cm long, 30 cm wide, and 12 cm deep, holding sand sufficiently wet for germination. Emerged seedlings were counted 7, 14, and 21 days after planting and the mean percentage determined for each lot.

Statistical analysis

A completely Randomized Design of 15 seed lots with 3 replications were used to determine the electrical conductivity method with different vigor levels ranging from 39-94% as determined by standard germination. In addition, a completely Randomized Design of 21 seed lots with 3 replications was used to explore the relationship between the electrical conductivity test and other variable tests on the physiological quality of seed. The quality of selected seed lots was determined by standard germination, field emergence, first count, germination speed, conductivity, and potassium leachate. Analysis of variances was performed on the data with the Statistical Analysis System (SAS version 9.0 for Windows). Correlation coefficients between all test results were calculated to observe the relationships of all tests.

RESULT AND DISCUSSION

Determine electrical conductivity method as sorghum seed vigor test

The electrical conductivity as seed vigor test in sorghum is not recommended electrical conductivity test method for sorghum seeds has been prescribed in international seed vigor testing handbooks. Seed vigor comprises those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. Recently, Hampton and TeKrony (1995) emphasized that seed vigor testing must rank lots of commercially accepted germination.

Although germination and vigor are closely associated, seed vigor is highly complex compared to standard germination. It provides additional information to assist in the differentiation of the physiological potential of seed lots, seed storability, and potential field performance. Practical vigor tests should consider rapidity, simplicity, objectivity, reproducibility of test results, and relationship with seedling emergence. The conductivity test offers a quick (24 hrs), objective vigor test that can be conducted easily in most seed testing laboratories with minimum equipment and personnel training expenditure. Physically injured and mechanically damaged seeds can influence the results.

Furthermore, to identify the electrical conductivity method for seed vigor test in sorghum, 15 seed lots of different vigor levels were tested for standard germination test, field emergence, 8 electrical conductivity methods, and several vigor tests. Correlation coefficients among all the tests were observed.

A highly significant correlation (r = 0.90) between standard germination and field emergence 21 days test is shown in Table 2. A recent study (Baskin et al. 1993) showed a relationship between standard germination tests and field emergence of sorghum under favorable and unfavorable field conditions. Standard germination percent of seed lots ranged from 63% to 99%, with a mean of 89.5%. Under favorable conditions, the field emergence percent ranged from 69% to 97%, with a mean of 86.5%, and a highly significant correlation (r = 0.825**) was observed with the standard germination test. Under unfavorable field conditions (cold wet 69 soil condition), the mean-field emergence percent decreased to 65.9%. A low correlation coefficient (r = 0.501**) was observed between the standard germination test and field emergence.

All seed vigor tests, first count (r = 0.83), potassium leakage (r = -0.83) and conductivity test with 150 ml deionized water and 75 seed count (r = -0.89) provided highly significant correlations with standard germination. Among eight combinations of the electrical conductivity method, the highest correlations with field emergence at 21 days (r = -0.78), first count (r = -0.79), and standard germination (r = -0.89) determine by the electrical conductivity method with 150 ml deionized water and 75 seed count. According to the conductivity test with 150 ml deionized water and 75 seed count, potassium leakage also showed the highest correlation (r = 0.93).

From the results of maximum correlation coefficients (r) of electrical conductivity method with 150 ml deionized water and 75 seed count with standard germination, first count, field emergence 21 days obtained, and potassium leakage; electrical conductivity method with 150 ml deionized water and 75 seed count is recommended as a preliminary recommendation for sorghum seed vigor test.

Negative correlations were always observed between conductivity, standard germination, and other seed vigor tests. That is because low germination and vigor seeds give a high amount of leakage of electrolytes (measured in µS cm-1g-1); in contrast, high vigor seeds give a low amount of leakage of electrolytes.

The electrical conductivity test is acknowledged as one of the best tests for the evaluation of the loss of cell membrane integrity by the concentration of electrolytes released by seeds during imbibition, such as inorganic ions; cell membrane integrity is considered one of the primary physiological events of seed deterioration process (Delouche and Baskin 1973). Furthermore, the conductivity test is rapid and simple and does not need personal skills for result analysis.

The lower the membrane integrity, the greater the electrolyte leakage in the steep water; thus, the greater the conductivity measurement (ISTA 2011; Woodstock et al. 1985) found relationships between weathering deterioration, respiratory germination metabolism, and leaching in cotton seeds. Electron microscopy confirmed the deterioration of membranes due to weathering by cotyledon's lipids and proteins bodies and correlated well with conductivity measurements.

The electrical conductivity test is based on the measurement of resistance to the flow of an electric current imposed upon the seed steep water. Resistance is a function of the number of electrolytes in the solution. Pure water has a great electrical resistance, but solutions of electrolytes, which are ionic substances, allow electric currents to flow. Many cellular constituents are acids, bases, or their salts, i. e., electrolytes. Electrolyte efflux from seeds during imbibition presumably indicates seed cell membrane condition. Weak seeds generally possess poorer membrane structure, which results in greater electrolyte loss and higher conductivity measurements (Pandey 1992).

Table 2. Correlation coefficients (r) of standard germination (DB), field emergence 7, 14, 21 days after planting (DT-7, 14, 21), first count (IV), potassium leakage (Ion K), and 8 combinations electrical conductivity method of 15 seed lots of sorghum

	IV	*DB*	*DT-7*	*DT-14*	*DT-21*	*50 50ml*	*75 50ml*	*50 100ml*	*75 100ml*	*50 150ml*	*75 150ml*	*50 200ml*	*75 200ml*	*Ion K*
IV	1													
DB	**0.83**	1												
DT-7	0.76	0.87	1											
DT-14	0.77	0.89	1.00	1										
DT-21	**0.77**	**0.90**	0.99	1.00	1									
50-50ml	-0.69	-0.81	-0.64	-0.67	-0.67	1								
75-50ml	-0.76	-0.84	-0.68	-0.71	-0.71	0.98	1							
50-100ml	-0.70	-0.81	-0.65	-0.68	-0.68	0.99	0.99	1						
75-100ml	-0.77	-0.86	-0.72	-0.75	-0.75	0.98	0.99	0.98	1					
50-150ml	-0.76	-0.85	-0.70	-0.72	-0.73	0.98	0.99	0.99	0.99	1				
75-150ml	**-0.79**	**-0.89**	-0.74	-0.77	**-0.78**	0.96	0.98	0.97	0.99	0.99	1			
50-200ml	-0.75	-0.88	-0.74	-0.77	-0.77	0.96	0.98	0.97	0.99	0.99	0.99	1		
75-200ml	-0.75	-0.87	-0.71	-0.74	-0.74	0.96	0.98	0.97	0.99	0.98	0.99	0.99	1	
Ion K	**-0.71**	**-0.83**	-0.74	-0.76	**-0.77**	0.84	0.90	0.87	0.91	0.89	**0.93**	0.92	0.93	1

Potassium is the main ion leached by seeds during imbibition, followed by sodium and calcium, and may be used as an indicator of cell membrane integrity. The potassium leachate test is based on the same principle as the electrical conductivity test, producing results in a considerably shorter time. In addition, it focuses on a specific ion, while the electrical conductivity test evaluates a set of electrolytes released (Miguel and Filho 2002. Potassium leachate and electrical conductivity tests yielded similar results in ranking seed lots' physiological potential. However, based on the same principle, the electrical conductivity test provides results only after a 24 h imbibitions period when performed under the current procedure.

Relationship between electrical conductivity test and other variable tests on the physiological quality of seed

Our results showed that the electrical conductivity method with 150 ml deionized water and 75 seed count could predict standard germination and field emergence and could be used as a seed vigor test is generally recommended for sorghum seeds. But before seed agencies or sorghum seed centers standardize the conductivity test, the electrical conductivity method must be verified, especially for different sorghum types.

The highest correlation coefficients (r) showed among standard germination, first count, field emergence of 21 days obtained, potassium leakage, and electrical conductivity method 150 ml deionized water and 75 seed count, therefore electrical conductivity method 150 ml deionized water and 75 seed count were recommended for seed vigor tests in sorghum. Moreover, 21seed lots of 15 sorghum varieties were used in the experiment to verify the recommendations made from the results.

Seed sources and quality of 21lots determined by standard germination, first count, field emergence of 21 days, speed of germination, conductivity test, and potassium leakage are shown in Table 3. Standard germination percentages ranged from 39.83 to 94.00%, with a mean of 75.39 %. The standard germination showed very highly significant differences among seed lots. Highly significant differences among 21 seed lots were also observed in the first count, field emergence, germination speed, conductivity test, and potassium leakage results.

Table 3. Standard germination and vigor tests of 21 seed lots of sorghum without accelerated aging treatment, data sorted according by storage period and minimum to maximum percentages of standard germination test

Lot Benih		Lama simpan	DB	IV	DT 21	KCT	DHL	ION K
Varietas	No	(bulan)	(%)	(%)	(%)	(%/etmal)	(µS/cm.g)	(ppm)
BMR P-3-5	21	0 - 6	56.83	44.83	38.67	16.05	12.27	889.47
BMR P-3-4	20	0 - 6	60.33	54.83	49.33	17.02	13.56	1,226.21
BMR P-3-3	19	0 - 6	64.00	50.83	37.33	17.83	10.72	684.61
KD4	15	0 - 6	73.00	66.50	82.00	18.39	17.04	886.50
BMR P-3-2	18	0 - 6	77.83	75.50	49.33	24.36	10.92	691.96
Samurai 1	4	7 - 12	39.83	36.67	61.33	11.49	24.69	1,640.65
Kawali 2014	14	7 - 12	72.50	68.00	92.00	24.42	14.30	620.73
Numbu 2014	10	7 - 12	73.83	72.17	88.67	17.83	9.48	471.28
Samurai 2	5	7 - 12	81.83	67.17	90.67	19.89	11.39	687.58
Numbu Freezer 2014	6	7 - 12	83.50	61.00	88.00	24.05	10.14	441.95
Super 2-2014	12	7 - 12	88.17	87.67	97.33	29.12	10.12	652.60
Pahat 2014	3	7 - 12	88.83	70.00	92.67	18.42	10.36	796.52
Super 1-2014	2	7 - 12	89.67	85.00	92.00	28.29	7.24	482.70
Tongkol Jantung	8	7 - 12	93.50	77.33	98.67	26.29	11.47	648.78
Telaga Bodas	7	7 - 12	94.00	74.83	100.00	23.98	3.87	227.46
Kawali 2013	13	13 - 18	84.50	66.83	87.33	23.29	9.88	438.73
Numbu 2013	9	13 - 18	86.00	81.67	82.67	25.11	6.78	423.50
Super 1-2013	1	13 - 18	89.00	86.50	94.00	27.80	7.33	443.13
Super 2-2013	11	13 - 18	90.50	88.17	94.00	28.73	8.89	555.96
Pahat 2010	16	> 24	44.17	29.67	44.67	17.78	24.76	2,191.98
Durra 2010	17	> 24	51.33	40.67	45.33	12.29	16.66	1,430.58
Mean			75.39	65.99	76.48	21.54	11.99	787.28
Max			94.00	88.17	100.00	29.11	24.76	2191.98
Min			39.83	29.67	37.33	11.49	3.87	227.46
F test			**	**	**	**	**	**
CV (%)			3.92	5.29	8.08	3.64	7.31	11.04

Note: ** = Significant difference at $p < 0.01$.

Similar correlations among all tests found in the above experiment to determine the electrical conductivity method were also observed to verify the recommendations from the above results. Correlation coefficients among the first count, standard germination, field emergence of 21 days, germination speed, potassium leakage, and conductivity test with 150 ml water volume and 75 seed count of 21 seed lots of 15 sorghum varieties are shown in Table 4.

The results showed highly significant correlations between the electrical conductivity method with 150 ml deionized water and 75 seed count and the standard germination (r = -0.85), first count (r = -0.79), and potassium leakage (r = 0.92). But a lower correlation was observed between the electrical conductivity test with field emergence (r = -0.53) and speed of germination (r = -0.66).

All test results were compared in an accelerated aging treatment test to survey the possibility of alternative sorghum seed vigor tests. In addition, this test provided information comparable to the other vigor tests performed between sorghum seed given accelerated aging treatment and seed sorghum as control.

Moreover, 21 seed lots of the 15 sorghum varieties were also used in this experiment to compare seed control and seed after accelerated aging treatment. Each seed lots after accelerated aging treatment were conducted by standard germination, first count, field emergence 21 days, germination speed, conductivity test, and potassium leakage. Correlation coefficients among the first count, standard germination, field emergence 21 days, germination speed, potassium leakage, and conductivity test with 150 ml water volume and 75 seed count, of 21 seed lots of 15 sorghum varieties observed in this experiment and shown in Table 5.

After the accelerated aging test, the germination percentages ranged from 4.50 to 92.33%, and the germination percentage mean was 61.71%. After the accelerated aging test, the germination percentages showed highly significant differences among seed lots (Table 6). Highly significant differences among 21 seed lots were also observed in the first count, field emergence, germination speed, conductivity test and potassium leakage results.

An accelerated aging test was developed by (Delouche and Baskin 1973) to measure seed storability and evaluate vigor. The technique involved the exposure of seeds to adverse temperatures (40-45ºC) and 100% RH for varying lengths of time, followed by a regular germination test. As a result, the seeds absorbed moisture from the humid atmosphere and aged rapidly due to high temperature. The basis for this test is that higher vigor seeds tolerate the high temperature-high humidity treatment and thus retain their capability to produce normal seedlings in the germination test (AOSA 1983).

During aging, the decline in seed vigor, respiration rate, phosphatase activity, and sugar content accompanied by a complete decline of alpha-amylase activity are noticeable. The concentration, number of amino acids, and RNA and DNA contents also show a similar reduction with higher RNAse activity. Moreover, a rise in respiration rate, phosphatase activity, and sugar content accompanied by a complete decline in alpha-amylase activity and RNA, DNA, and protein content were noticeable in rice during seed deterioration (Zhoe et al. 2002).

Conductivity tests can predict field emergence and standard germination. The electrical conductivity test has been proven to indicate seed vigor in various crop species. In addition, it has been successfully related to field emergence and stands establishment. Analysis of linear regression was used to estimate field emergence and standard germination (Table 6).

In conclusion, based on the experiments and data collected from all tests, the following conclusions can be drawn: Electrical conductivity test method with 150 ml water volume and 75 seeds count was accurate and suitable for the sorghum seed vigor test; the electrical conductivity test showed a positive correlation with potassium leakage; and electrical conductivity test can be used for seed vigor test in sorghum and provided the potential of physiological seed were shown through standard germination test, field emergence test, first count test and speed of germination with negative correlation.

Table 4. Correlation coefficients (r) of standard germination (DB), field emergence 21 days after planting (DT), first count (IV), potassium leakage (Ion K), and electrical conductivity method 150 mL water volume and 75 seed count of 21 seed lots of sorghum without accelerated aging treatment

	IV	*DB*	*DT*	*KCT*	*DHL*	*Ion K*
IV	1					
DB	0.92	1				
DT	0.87	0.82	1			
KCT	0.86	0.83	0.67	1		
DHL	-0.79	-0.85	-0.53	-0.66	1	
Ion K	-0.81	-0.86	-0.65	-0.67	0.92	1

Table 5. Correlation coefficients (r) of standard germination (DBaa), field emergence 21 days after planting (DTaa), first count (IVaa), potassium leakage (Ion Kaa), and electrical conductivity method 150 mL water volume and 75 seed count of 21 seed lots of sorghum After accelerated aging treatment

	IVAA	*DBAA*	*DTAA*	*KCTAA*	*DHLAA*	*Ion KAA*
IVAA	1					
DBAA	0.98	1				
DTAA	0.84	0.86	1			
KCTAA	0.94	0.95	0.87	1		
DHLAA	-0.76	-0.82	-0.73	-0.71	1	
Ion KAA	-0.76	-0.81	-0.73	-0.72	0.91	1

Table 6. Standard germination and vigor tests of 21 seed lots of sorghum after accelerated aging treatment, data sorted according by storage period and minimum to maximum percentages of standard germination test

Lot Benih		Lama simpan	DBAA	IVAA	DT 21AA	KCTAA	DHLAA	ION KAA
Varietas	No	(bulan)	(%)	(%)	(%)	(%/etmal)	(µS/cm.g)	(ppm)
BMR P-3-4	20	0 - 6	38.33	23.17	34.67	9.11	13.55	783.81
BMR P-3-5	21	0 - 6	38.67	30.17	44.00	9.49	11.95	674.78
BMR P-3-2	18	0 - 6	46.83	32.83	49.67	11.21	12.50	669.87
BMR P-3-3	19	0 - 6	48.33	33.83	48.00	11.80	9.13	553.44
KD4	15	0 - 6	56.33	53.67	48.67	17.89	16.07	979.29
Samurai 1	4	7 - 12	30.33	28.50	15.33	10.64	23.36	1,246.27
Numbu 2014	10	7 - 12	55.33	53.67	42.67	12.97	9.23	534.36
Pahat 2014	3	7 - 12	59.67	58.50	68.67	17.35	9.96	566.04
Kawali 2014	14	7 - 12	68.83	56.83	67.33	17.02	8.80	805.05
Numbu Freezer 2014	6	7 - 12	69.00	66.00	49.33	13.39	10.15	580.58
Samurai 2	5	7 - 12	71.17	56.83	48.00	21.32	8.96	723.14
Super 2-2014	12	7 - 12	79.17	63.00	86.00	26.22	9.38	560.81
Super 1-2014	2	7 - 12	83.83	80.00	87.33	26.73	6.28	456.11
Telaga Bodas	7	7 - 12	85.17	79.50	74.67	22.83	3.75	276.69
Tongkol Jantung	8	7 - 12	92.33	88.17	89.33	28.05	10.14	693.05
Kawali 2013	13	13 - 18	74.67	66.33	28.00	20.32	7.12	551.95
Super 2-2013	11	13 - 18	81.33	79.00	77.33	22.70	9.64	587.39
Super 1-2013	1	13 - 18	86.83	84.67	85.33	28.08	6.02	337.23
Numbu 2013	9	13 - 18	91.33	83.67	84.67	29.48	5.20	249.90
Pahat 2010	16	> 24	4.50	3.00	7.33	0.70	23.35	1,702.95
Durra 2010	17	> 24	34.00	27.83	33.33	8.48	12.13	1,163.55
Mean			61.71	54.72	55.70	17.42	10.79	699.82
Max			92.33	88.17	89.33	29.48	23.36	1702.95
Min			4.50	3.00	7.33	0.70	3.75	249.90
F test			**	**	**	**	**	**
CV (%)			6.07	6.63	15.10	5.92	7.68	11.76

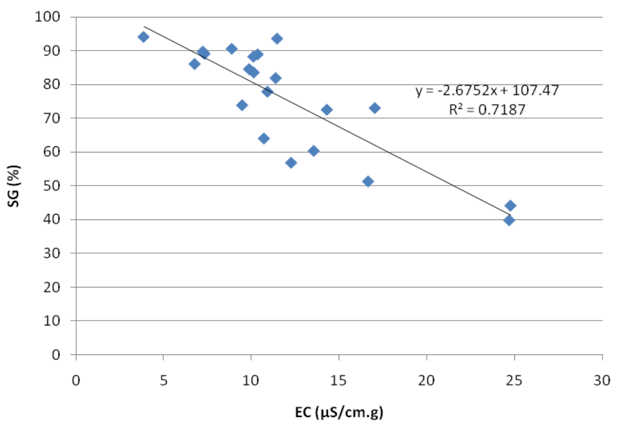

Figure 1. Linear regression between electrical conductivity (EC) and standard germination (SG)

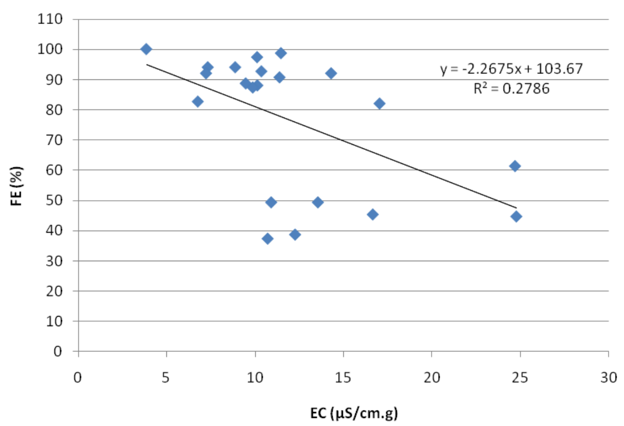

Figure 2. Linear regression between electrical conductivity (EC) and field emergence (FE)

Table 6. Prediction of standard germination value and Field emergence value by electrical conductivity test

EC (µS/cm.g)	Prediction of SG (%)	Prediction of FE (%)
≤ 5.0	≥ 94.09	≥ 92.33
5.1 - 7.5	87.41 - 93.83	86.66 - 92.11
7.6 - 10.0	80.72 - 87.14	81.00 - 86.44
10.1 - 12.5	74.03 - 80.45	75.33 - 80.77
12.6 - 15.0	67.34 - 73.76	69.66 - 75.10
15.1 - 17.5	60.65 - 67.07	63.99 - 69.43
17.6 - 20.0	53.97 - 60.39	58.32 - 63.76
20.1 - 22.5	47.28 - 53.70	52.65 - 58.09
22.6 - 25.0	40.59 - 47.01	46.98 - 52.42
25.1 - 27.5	33.90 - 40.32	41.31 - 46.76
27.6 - 30.0	27.21 - 33.63	35.65 - 41.09
30.1 - 32.5	20.53 - 26.95	29.98 - 35.42
32.6 - 35.0	13.84 - 20.26	24.31 - 29.75
35.1 - 37.5	7.15 - 13.57	18.64 - 24.08
> 37.6	< 6.88	< 18.41

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