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

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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 electrical conductivity test method for seed vigor test in sorghum, to recognize relationship between electrical conductivity test and potassium leakage, and to recognize relationship between electrical conductivity test and other variable on seed vigor. This study have two step experiments. The objective of Experiment I was to determine accurate combinations of water volume and amount seed of the electrical conductivity test for seed vigor test in sorghum. Completely Randomized Design of 15 seed lots with 3 replications were used to determine electrical conductivity method with different vigor. Experiment II were to test electrical conductivity method of 21 seed lots of sorghum without accelerated aging test and 21 seed lots of sorghum were given accelerated aging test. Completely Randomized Design of 21 seed lots with 3 replications were used in Experiment II. The variable were observed : 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 this experiments showed that electrical conductivity test method with 150 ml water volume and 75 seed count was accurate and suitable for sorghum seed vigor test; electrical conductivity test showed 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.

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

INTRODUCTION

Seed vigor test is more sensitive index of seed quality than germination test, any of the events which precede loss of germination could serve as vigor tests. Seed vigor testing has reached increasing importance to rank seed lots according to their physiological potential. One of the main concerns regarding seed vigor evaluation is obtaining reliable result 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 be a measurement of 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 the development of seeds prior to physiological maturity, seed desiccation before harvest, and during imbibition prior to germination (ISTA 1995). As seed rehydrates during early imbibition, the ability of its cellular membranes to reorganize and repair any damage that may have occurred will influence the extend 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 damages to a greater extend, than lower vigor seeds. Consequently, electrolyte leakages measured from high vigor seeds are less than that measured from low vigor seeds. Low vigor seeds have been shown posses decreased membrane integrity as a result of storage deterioration and mechanical injury. However, there are no suggested or recommended procedures for electrical conductivity sorghum seed vigor tests are available in the handbooks of vigor test from the International Seed Testing Association (AOSA 1983; ISTA 1995).

The research reported here is aimed at: to obtain electrical conductivity test method for seed vigor test in sorghum, to recognize relationship between electrical conductivity test and potassium leakage, and to recognize relationship between electrical conductivity test and other variable on seed vigor.

MATERIALS AND METHODS

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

Seed water content

Was determined at 130°C for 2 hours in duplicate samples of grinded 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 at four and teen days after seeding, evaluated for normal development, and results were expressed as percent normal seedlings for each lot.

Germination first count

Was performed simultaneously to the germination test and percent normal seedlings was recorded four days after seeding.

Speed of Germination

The normal seedlings are evaluated on daily basis starting from 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 distilated 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 method (Table 1) and held in a germinator at 20°C. After 24 hours, the electrical conductivity of leachates was determined. The electrical conductivity of leachates of each replication was measured by using conductivity meter (Type Cond 330i) and conductivity per gram of seed weight was calculated (µS $cm^{-1}g^{-1}$) and recorded.

Potassium leakage

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

Table 1. Eight combination 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 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

Completely Randomized Design of 15 seed lots with 3 replications were used to determine electrical conductivity method with different vigor levels ranging from 39-94% as determined by standard germination. Completely Randomized Design of 21 seed lots with 3 replications were used to explore relationship between electrical conductivity test and other variable test on the physiological quality of seed. The quality of selected seed lots were determined by standard germination, field emergence, first count, speed of germination, conductivity and potassium leachate. Analysis of variances were 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 have 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 seed lots of commercially accepted germination.

Although germination and vigor are closely associated, seed vigor is highly complex compared to standard germination and provides additional information to assist in differentiation of the physiological potential of seed lots, seed storability and potential field performance. It is desirable that practical vigor tests 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 on most seed testing laboratories with minimum expenditure for equipment and training of personnel. Physically injured and mechanical damaged seeds can influence the results.

In order 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 method and several vigor tests. Correlation coefficients among all the tests were observed.

Highly significant correlation (r = 0.90) was observed between standard germination and field emergence 21 days test are shown in Table 2. Recent studied (Baskin et al. 1993) relationship between standard germination test 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 condition the field emergence percent ranged from 69% to 97% with a mean of 86.5% and highly significant correlation (r = 0.825**) was observed with standard germination test. Under unfavorable field condition (cold wet 69 soil condition) the mean field emergence percent decreased to 65.9% and low correlation coefficient (r = 0.501**) was observed between 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 combination the electrical conductivity method, the highest correlations with field emergence 21 days (r = -0.78), first count (r = -0.79) and standard germination (r = -0.89) determine by electrical conductivity method with 150 ml deionized water and 75 seed count. According to conductivity test with 150 ml deionized water and 75 seed count, potassium leakage also showed 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 preliminary recommendation for sorghum seed vigor test.

Negative correlations were always observed between conductivity test and standard germination test and other seed vigor tests. This is because low germination and vigor seeds give high amount of leakage of electrolytes (measured in µS cm-1g-1), in contrast high vigor seeds give 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). Conductivity test is rapid, simple and do not need personal skill 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, germination respiratory metabolism, and leaching in cotton seeds. The deterioration of membranes due to weathering was confirmed by electron microscopy of cotyledon's lipids and proteins bodies and correlated well with conductivity measurements.

The electrical conductivity test is based on measurement of resistance to flow of an electric current imposed upon the seed steep water. Resistance is a function of the amount of electrolytes in 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 is presumably an indication of 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 combination 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 has been shown to be 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 of the electrical conductivity test with the additional advantage of producing results in a considerable shorter period of time. In addition, it focus on a specific ion, while the electrical conductivity test evaluates a set of electrolytes release (Miguel and Filho 2002. Potassium leachate and electrical conductivity tests yielded similar results in the ranking of physiological potential of seed lots. The electrical conductivity test, based on the same principle, provides results only after a 24 h imbibitions period when performed under current procedure.

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

Our results showed that electrical conductivity method with 150 ml deionized water and 75 seed count could predict standard germination and field emergence and could be used as seed vigor test in generally recommended sorghum seeds. But before the conductivity test is being standardized by seed agencies or sorghum seed centers, verifications of electrical conductivity method needs to be done especially for different sorghum types.

According to the highest correlation coefficients (r) showed among standard germination, first count, field emergence 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. Twenty one seed lots of fifteen sorghum varieties were used in experiment to verify the recommendations made from the results.

Seed sources and quality of twenty one lots determined by standard germination, first count, field emergence 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 mean of 75.39 %. The standard germination showed very highly significant differences among seed lots. Highly significant differences among twenty one seed lots were also observed in first count, field emergence, speed of germination, 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 as found in above experiment to determine electrical conductivity method were also observed in this experiment to verify the recommendations made from the results above. Correlation coefficients among first count, standard germination, field emergence 21 days, speed of germination, 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 lower correlation was observed between electrical conductivity test with field emergence (r = -0.53) and speed of germination (r = -0.66).

All test result compared in accelerate aging treatment test to survey for possibility of alternative sorghum seed vigor tests. This test provided information comparable to the other vigor tests performed between sorghum seed given accelerated aging treatment and seed sorghum as control.

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

The germination percentages after accelerated aging test ranged from 4.50 to 92.33% and germination percent mean was 61.71%. The germination percentages after accelerated aging test showed very highly significant differences among seed lots (Table 6). Highly significant differences among twenty one seed lots were also observed in first count, field emergence, speed of germination, conductivity test and potassium leakage results.

Accelerated aging test developed by (Delouche and Baskin 1973) to measure seed storability and evaluate vigor. The technique involved the exposure of seeds to adverse levels of temperature (40-45ºC) and 100% R.H. for varying length of time followed by regular germination test. 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 declined in seed vigor, respiration rate, phosphatase activity and sugar content accompanied by a complete declined of alpha amylase activity are noticeable. The concentration and the number of amino acids and the RNA and DNA contents also show a similar reduction with higher RNAse activity. Rise in respiration rate, phosphatase activity and sugar content accompanied by a complete decline of alpha amylase activity and RNA, DNA and protein content were noticeable in rice during seed deterioration (Zhoe et al. 2002).

Conductivity test can predicting the field emergence and standard germination. The electrical conductivity test has been proved as indicator of seed vigor in wide range of crop species and has been successfully related to field emergence and stand establishment. Analysis of linier regression was used to estimate field emergence and standard germination (Table 6).

In conclusion, based on the experiments and data collected from all test, the following conclusions can be drawn : Electrical conductivity test method with 150 ml water volume and 75 seeds count was accurate and suitable for sorghum seed vigor test; electrical conductivity test showed 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

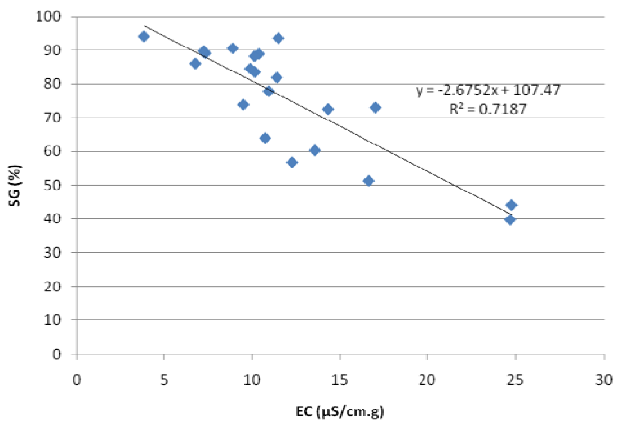

Figure 1. Linier regression between electrical conductivity (EC) and standard germination (SG)

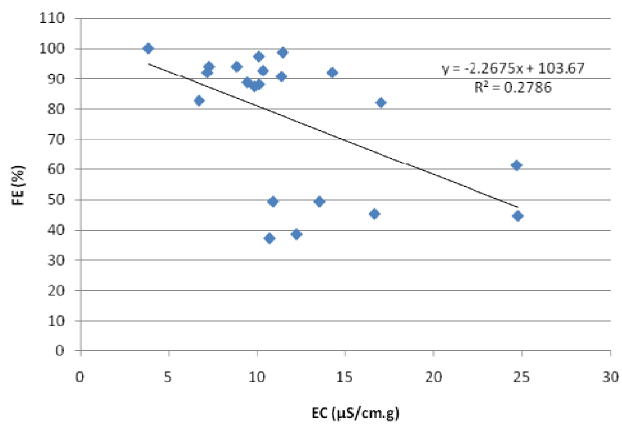

Figure 2. Linier regression between electrical conductivity (EC) and field emergence (FE)

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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