ELECTRICAL CONDUCTIVITY OF SOYBEAN SOAKED SEEDS.
I. EFFECT OF GENOTYPE[1]

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ABSTRACT - During the period from October/92 to September/94 experiments were carried out at the Seed Laboratory, FCAV/UNESP, Jaboticabal, SP, Brazil, using soybean seeds of different genotypes in order to evaluate the effect of genotype on the electrical conductivity (bulk conductivity) of soaked seeds. Seed moisture content (105 ± 3°C, 24 h), standard germination (four 50-seed samples, paper towel, 30°C), and vigor-accelerated aging (42°C, 48 h) were first determined. Undamaged soybean seeds were soaked in deionized water (four 50-seed samples, 75 ml, 25°C, 24 h) and electrical conductivity (μmhos.cm^{-1}.g^{-1}) was measured. Significant differences in conductivity were observed among genotypes having the same pattern of germination and vigor. The results have showed that electrical conductivity can be significantly influenced by genotype.

Index terms: *Glycine max*, standard germination, accelerated aging.

CONDUTIVIDADE ELÉTRICA NA SOLUÇÃO DE EMBEBIÇÃO DE SEMENTES DE SOJA.
I. EFEITO DO GENÓTIPO

RESUMO - Durante o período de outubro/92 a setembro/94 foram conduzidos no Laboratório de Sementes do Departamento de Fitotecnia, FCAV/UNESP, Jaboticabal, SP, vários experimentos com sementes de soja, com o objetivo de avaliar o efeito do genótipo sobre a condutividade elétrica na solução de embebição das sementes. Foram determinados: o grau de umidade das sementes(105 ± 3°C, 24 h), a germinação-padrão (quatro repetições de 50 sementes, rolo de papel, 30°C) e o vigor, pelo teste de envelhecimento acelerado (42°C, 48 h) e da condutividade elétrica (quatro repetições de 50 sementes, em 75 ml de água deionizada, 25°C, 24 h). Os resultados de condutividade elétrica mostraram diferenças significativas entre genótipos, cujas sementes apresentaram o mesmo padrão em termos de germinação e vigor (envelhecimento acelerado). Conclui-se que a condutividade elétrica na solução de embebição das sementes pode ser significativamente influenciada pelo genótipo em questão.

Termos para indexação: *Glycine max*, germinação, envelhecimento acelerado.

INTRODUCTION

Over the last few years, the use of electrical conductivity (EC) test has been increasing, mainly among the Association of Official Seed Analysts (AOSA) (Tekrony, 1983) and the International Seed Testing Association (ISTA) (Hampton, 1992) members. In Brazil, a survey of ABRATES (Brazilian Seed Technology Association) members (Krzyzanowski & França Neto, 1991) did not indicate the EC test as one of the tests most used by seed companies. However, recent information of professionals working on seed technology have indicated a rising interest for the EC test, mainly in terms of research.

Among the factors that can affect the EC results, particularly important are seed moisture content (MC), period and temperature of imbibition, species under study, seed size, genotype within the species, and seed age and color (Short & Lacy,1976; Tao, 1978; Loeffler, 1981; Association of Official Seed Analysts, 1983; Loeffler et al., 1988).

Although the effect of genotype within species on EC results has been mentioned, it has not been specifically studied. A detailed analysis of some stud-

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ies which employed the EC as a vigor test evaluating more than one genotype clearly shows that the genetic material does play an important and significant role in the final results of the test.

Results of studies conducted on pea (Caliari & Marcos Filho, 1990), dry bean (Hampton et al., 1992), corn (Bruggink et al., 1991) and soybean (Bergamaschi, 1992; Vieira et al., 1992; Prete et al., 1994) seeds have revealed that seeds of different genotypes within those species did show significantly different EC values, even though similar differences were not observed for standard germination (SG) and vigor evaluated by other tests, especially accelerated aging (AA).

In a study on soybean seeds comparing EC among genotypes, Kuo (1989) observed the existence of variability in seedcoat permeability among genotypes and reported that the EC test proved to be efficient in monitoring seedcoat permeability; thus, he concluded that this is a test that can be employed in genetic improvement programs aiming at the enhancement of physiological seed quality.

Studies conducted on soybean seeds in Japan (Mugnisjah et al., 1987) also demonstrated differences in EC among genotypes. It should be pointed out that these differences were observed among genotypes whose seeds presented the same germination pattern (95-100%) and vigor - AA (96-97%). Among these genotypes, EC values ranged from 33 to 56 μmhos.cm^{-1}.g^{-1}.

The variations in soybean seed EC observed among different genotypes may be related to the variation in lignin content in the seed coat. Differences in seedcoat lignin content among soybean genotypes were observed by Caballero Avarez (1994), who also detected a correlation between seedcoat lignin content and soybean seed resistance to mechanical damage. This fact suggests that a higher lignification of the seedcoat cell wall makes it difficult for seed imbibition process, thus affecting the loss of leached substances.

The EC values of soybean seeds are also influenced by the degree of hardseedness of the genotype. Verma & Ram (1986) observed that the higher the hardseedness percentages the lower the value of soybean seed EC. Studies carried out by Bedford (1974) on pea seeds showed differences in EC among the genotypes used. However, the reasons for these differences were not identified by the authors.

The objective of this study was to investigate the effect of genotype on EC values in soybean seed imbibing solutions.

MATERIALS AND METHODS

This work was carried out in the Seed Laboratory of the Department of Crop Science, College of Agriculture, FCAV/UNESP, Jaboticabal Campus, SP, Brazil, from October/92 to September/94.

Forty-nine soybean genotypes were studied, distributed in the following trials: (1) soybean cultivars whose seeds were hand harvested in the experimental area of FCAV/UNESP in 1992 and 1993; (2) soybean cultivars obtained from seed companies located in the region of Orlândia, SP, in 1992, and (3) soybean genotypes obtained from CPAC/EMBRAPA, Brasília, in 1993.

The seeds were evaluated in the laboratory for the following parameters: (1) moisture content (MC) determined before the beginning of the tests and after seed aging using the oven method (105 ± 3°C) for all trials according to Brasil (1992); (2) standard germination (SG): the test was run using sand as substrate, with four 50-seed samples sown and kept under laboratory conditions (25 - 30°C). Emerged seedlings were counted seven days after sowing. Seedlings were considered to have emerged when their cotyledons were above the substrate surface (Brasil, 1992); (3) vigor-accelerated aging (AA): 42 g of seeds were aged at 42°C for 48 h as previously described (Marcos Filho et al., 1987) and germination was measured as in the SG test (Brasil, 1992); (4) vigor-electrical conductivity (EC): Four samples of 50 seeds each were soaked in 75 ml of deionized water for 24 h at 25°C, after which the conductance of the soaking water was measured with a dip cell (cell constant = 1.0) attached to a Digimed conductivity bridge. Conductivity was measured as described by the Association of Official Seed Analysts (1983) and expressed as μmhos.cm^{-1}.g^{-1}; (5) mechanical damage: for its determination (trial 3) three 50-seed samples of apparently intact seeds were placed into a Petri dish with water for ten to fifteen minutes. During this period the swollen seeds were counted. The results were expressed as percentage of seeds with damaged seedcoats, similarly as the hypochlorite test decribed by Marcos Filho et al. (1987).

The experimental design was a randomized complete block with four replications, and the number of treatments (genotypes) varied according to the trial. The results were subjected to analysis of variance and the means were compared by LSD.

RESULTS AND DISCUSSION

The data (1991/92) for moisture content (MC) before the beginning of the tests, standard germination (SG) and vigor-electrical conductivity (EC) are presented in Table 1. No significant differences among cultivars were detected for MC, but differences were observed for SG and EC. For SG, the cultivar which presented the highest value was Doko (99%) followed by Savana, Davis, Bossier, IAC-17 and FT-2. The lowest value was detected in the cultivar IAS-5 (94%), corresponding to a variation of 5%. Nevertheless, both values showed that the seeds were of high physiological quality.

With respect to EC, there was a reduction from Savana (58 μmhos.$cm^{-1}.g^{-1}$) to FT-2 (42). It should be pointed out that Savana and IAC-17 showed statistically similar EC values, whereas EC was significantly lower for Savana (58 μmhos.$cm^{-1}.g^{-1}$) as compared to IAC-17 (45), Doko (43) and FT-2 (42), even though these values were still within a range indicating high seed vigor (Vieira, 1994).

Table 2 presents data about MC before and after seed aging, SG and vigor, AA and EC for seeds from seven soybean cultivars harvested at two different times (R7 and R8) in 1992/93. Since no effect of harvest time was detected, mean data of the two harvests are presented.

Although the differences were quite small, the MC values before the beginning of the tests were significantly different, ranging from 9.5 to 10.9%, with a maximum variation of 1.3%. In contrast, no significant differences were detected among cultivars when MC was evaluated after seed aging.

The SG value ranged from 96 to 97%, showing no significant difference (Table 2). As to AA, even though the difference between the highest and the lowest values was slight (4%), 'Davis' (93%) differed significantly from 'IAC-17' (97%), which in turn did not differ from the others. Thus, based on SG and AA, it may be stated that the seeds of these cultivars produced in 1992/93 were indeed of high physiological quality, as also noted on the basis of the EC results, which ranged from 62 to 41 μmhos.$cm^{-1}.g^{-1}$ (Table 2).

With respect to EC, the same tendency was observed as in the previous year (Table 1), i.e., there was a significant reduction in EC from 'Savana' (62) to 'FT-2' (41 μmhos.$cm^{-1}.g^{-1}$) (Table 2). Thus, a significant variation in EC was observed within a range in which the seeds are assumed to have a high vigor

TABLE 1. Moisture content (MC), standard germination (SG) and vigor-electrical conductivity (EC) of seeds of seven soybean cultivars. FCAV/UNESP. 1991/92[1].

Cultivars	MC[2]	SG	EC
	%		μmhos/cm/g
SAVANA	9.13	97	58
IAS-5	9.93	94	54
DAVIS	9.68	95	48
BOSSIER	9.79	96	48
IAC-17	9.49	95	45
DOKO	9.57	99	43
FT-2	9.38	95	42
F	1.01[ns]	3.25[*]	80.29[**]
CV (%)	3.93	2.59	3.83
LSD (5%)	2	4	3

[1] The data presented for each cultivar represent the mean of R7 and R8 growth stages of soybean at harvest(Fehr & Caviness, 1977).
[2] MC obtained before the beginning of the tests.

TABLE 2. Moisture content (MC), standard germination (SG), vigor-accelerated aging (AA) and electrical conductivity (EC) of seeds of seven soybean cultivars. FCAV/UNESP. 1992/93[1].

Cultivars	MC		SG	Vigor	
	Before[2]	After[2]		AA	EC
	%				μmhos/cm/g
SAVANA	-[3]	34.2	96	94	62
IAS-5	10.9	33.4	97	96	62
DAVIS	10.9	34.2	96	93	45
BOSSIER	9.6	35.1	97	94	46
IAC-17	10.2	35.2	97	97	45
DOKO	-	35.3	97	94	53
FT-2	10.5	33.1	97	96	41
F	7.69[**]	1.58[ns]	0.54[ns]	4.68[**]	126.83[**]
CV (%)	3.77	5.92	1.94	1.89	3.70
LSD (5%)	1	3	3	3	3

[1] The data presented for each cultivar represent the mean of R7 and R8 growth stages of soybean at harvest (Fehr & Caviness, 1977).
[2] MC before and after seed aging.
[3] Not determined due to the small quantity of seed per plot.

(Vieira, 1994). This difference possibly can be caused by a genotype effect.

MC data (Table 3) showed a significant difference only between 'IAC-11' (13,8%) and all other cultivars prior to the performance of the tests. However, this high MC of 'IAC-11' before seed aging did not affect its MC after seed aging since no significant differences in seed MC were detected among cultivars. Similarly, no significant differences were observed among cultivars in percentage of mechanical damage, SG or AA (Table 3).

However, although within a pattern of EC attributed to seeds with high vigor (Vieira, 1994), significant differences among cultivars were observed. The highest conductivity was shown by IAC-11 (67 μmhos.cm^{-1}.g^{-1}) and the lowest by Doko (38 μmhos.cm^{-1}.g^{-1}). Cultivars IAC-Foscarin-31, IAS-5 and IAC-15 showed intermediate values with 47, 46 and 45 μmhos.cm^{-1}.g^{-1}, respectively. In all three trials, Doko always showed low EC values which ranged from 38 to 53 μmhos.cm^{-1}.g^{-1}.

Table 4 shows that the MC values before the tests, were statistically similar, ranging from 9.5 to 11.7%. However, following seed aging, significant differences were observed, with values ranging from 24.2 to 28.6%. It should be pointed out that neither the lowest nor the highest MC values before the tests corresponded to the lowest and highest values after seed aging (Table 4). For SG, the genotypes with the highest values were MTBR 89-1053 and EMGOPA 309, both with 99%, and the genotype with the lowest value was MGBR 87-42 (87%), corresponding to a variation of 12%.

In relation to AA and EC, significant differences were observed among genotypes. Genotypes whose SG values after seed aging were considered relatively high, such as BR 85-487-88, EMGOPA 313, EMGOPA 309, MTBR 89-1053 and BR 88-10638, showed the least conductivity. In contrast, genotypes such as BR 88-11157 and BRAS 83-2686 which showed AA values similar to those of the first group mentioned above, presented significant differences for EC, indicating a possible genotype effect on electrical conductivity.

An overall analysis of the results of these trials on soybean seeds indicates a clear effect of genotype on conductivity. The MC effect is more related to wide variations among lots or cultivars. In this case, it is known that for the same cultivar, seed lots with MC less than 11% can significantly increase EC without jeopardizing seed vigor (Loeffler et al., 1988; Hampton et al., 1992).

In the present study, MC was below 11% for all cultivars in the two first trials (Tables 1 and 2). Thus, if there was some influence it was general for all seven cultivars. With the concept that a lower MC results in a higher EC and vice-versa, the high MC obtained for 'IAC-11' (Table 3) appeared to be an

TABLE 3. Moisture content (MC), mechanical damage (MD), standard germination (SG), vigor-accelerated aging (AA) and electrical conductivity (EC) of seeds of seven soybean cultivars - CAROL and Sementes Brejeiro. 1991/92.

Cultivars	MC		MD	SG	Vigor	
	Before[1]	After[1]			AA	EC
	%					μmhos/cm/g
IAC-11	13.8	31.8	3	95	84	67
IAC-FOSC.31	10.2	32.0	4	96	79	47
IAS-5	10.8	32.9	2	95	89	46
IAC-15	10.6	31.0	2	96	85	45
IAC-8	10.5	32.5	1	97	85	43
IAC-14	11.2	32.8	2	96	86	41
DOKO	11.2	32.1	2	96	89	38
F	19.49**	1.43^{ns}	2.23^{ns}	1.21^{ns}	1.96^{ns}	39.86**
CV (%)	3.46	3.39	40.79	0.94	5.81	6.40
LSD (5%)	2	3	3	2	12	7

[1] MC obtained before and after seed aging.

TABLE 4. Moisture content (MC), standard germination (SG) and vigor-accelerated aging (AA) and electrical conductivity (EC) of seeds of soybean genotypes - CPAC/EMBRAPA, 1992/93.

Genotypes	MC		SG	Vigor	
	Before[1]	After[1]		AA	EC
	%				μmhos/cm/g
EMGOPA 308	11.0	28.3	96	91	87
BR 88-4135	10.8	26.5	90	87	84
BR 88-11157	11.3	26.7	98	94	84
BRAS 83-2686	10.2	26.1	96	92	82
BR 88-4133	10.1	27.0	92	86	81
DOKO RC	10.5	26.3	90	86	80
BR 88-11360	10.7	27.3	97	89	79
BR 88-4098	10.4	27.1	97	86	79
IAC-8	10.1	28.6	97	95	79
BR-515	10.3	27.0	95	87	79
ESTRELA	10.2	27.8	96	86	79
BR 88-4328	10.4	26.2	97	93	79
BR 86-10460	10.9	26.7	97	94	78
BR-40	10.5	25.6	95	88	78
MTBR 89-3044	10.1	25.4	96	89	78
BR 88-11115	11.0	26.0	94	88	78
BR 88-10964	11.0	26.3	96	89	78
MTBR 89-3929	10.8	27.6	95	94	76
BR 86-9992	11.0	27.5	96	95	75
BR 86-6045	10.5	24.2	97	88	74
BR 88-9154	10.5	25.5	92	87	74
BR 83-819	9.7	26.1	97	93	73
FT-11	10.4	27.5	96	94	69
BR 88-9855	10.3	26.6	95	95	69
BR 88-4324	10.6	27.5	96	86	68
BR88-20872	10.9	25.5	94	93	68
MGBR 88-7828	10.4	25.1	98	93	67
BR 85-17134	11.5	27.1	88	88	67
BR 88-4136	10.2	25.8	98	92	67
MGBR 87-42	10.3	27.9	87	85	67
MGBR 88-9378	9.5	27.2	93	96	66
BR 88-9205	11.2	26.5	96	91	66
BR 88-10122	10.9	27.1	98	89	66
BR 85-487-88	10.9	27.1	98	89	66
EMGOPA 313	10.9	26.1	95	94	64
EMGOPA 309	9.6	27.0	99	93	63
MTBR 89-1053	10.5	27.8	99	97	61
BR 88-10638	11.7	26.3	95	94	57
F	1.02^{ns}	8.58^{**}	5.93^{**}	3.70^{**}	11.83^{*}
CV (%)	6.72	1.92	2.44	4.01	5.83
LSD (5%)	3.00	2.14	6.52	10.21	12.01

[1] MC obtained before and after seed aging.

exception, since instead of reducing EC, this was the cultivar showing the highest value.

For the first two trials (Tables 1, 2 and 3), the cultivars differed significantly from one another, suggesting a genotype effect on EC. This influence is confirmed when we consider the situation of two cultivars, in particular Doko and Savana, which presented the lowest and highest EC in both trials, respectively. This may be the consequence of some genetically controlled traits of these cultivars. The Savana cultivar presented a lower resistance to mechanical damage in comparison to Doko (Carbonell & Krzyzanowski, 1995), a fact possibly related to the lower lignin content in the Savana seed coat compared to Doko (Caballero Avarez, 1994). This characteristic of the seedcoat can have a direct effect on the EC of these cultivars since, according to Calero et al. (1981), the water absorption by soybean seed is controlled by the shape and size of seedcoat pores, and by the amount of wax material present in the epidermic cells.

Comparing white and pigmented lima bean seeds, Kannenberg & Allard (1964) observed that the white ones gained and lost water more rapidly and were more easily damaged. This fact they attributed to the lower lignin content detected in the white seeds.

In our studies, Doko cultivar presented lower EC also in the second trial (Table 3), confirming the observations of the first trial (Tables 1 and 2). Differences in EC among genotypes were also clear (Table 3). In the case of IAC-11, based on available knowledge about MC (Tao, 1978; Loeffler et al., 1988; Hampton et al., 1992), an effect of EC reduction was expected; however, this was not the case, and IAC-11 was the cultivar with the highest conductivity in this trial. On the other hand, this may indicate the influence of multifactors on EC, among them the genetic characteristics of each genotype.

It should be emphasized that the present results are only partially conclusive and that further studies are needed. Seed lots of lower physiological quality should also be included in trials in order to determine to what extent the variation caused by the genotype interfers with the interpretation of the final results of soaked seed conductivity.

CONCLUSION

The seed soak electrical conductivity of soybean is influenced by the genotype.

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