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Determination and Modeling of Seed Characteristics in Some Soybean Cultivars*

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Abstract: The aim of this study was to determine the modeling of seed characteristics in some soybean cultivars. The size of the seeds, shape index, testa color, 100-seed-weight, germination and emergence tests and the values of the testa rates, water imbibitions and electrical conductivity were determined as seed characteristics in 75 soybean cultivars. According to the results, it was found that the differences among cultivars were significant in terms of the seed length (6.79-8.45 mm), the seed width (5.27-7.60 mm), the seed thickness (4.93-6.37 mm), shape index (1.03-1.32), testa color (23.3-36.6 b), 100-seed-weight (14.49-24.82 g), the speed of germination (4-100 %), the power of germination (28-100%), the rate of emergence (12-100%), testa rate (1-1.9%), water imbibitions (62-99.3%), seed moisture (9.7-13.5%) and electrical conductivity (5.19-18.28 mSc mg/seed). According to the mathematical modeling results there was a close relationship between actual and predicted seed characteristics for all cultivars. The regression coefficients of the new produced equations for seed characteristics in the tried soybean cultivars changed from 60% (100-seed-weight) to 99% (emergence rate) as a result of model adaptation.

Key words: Soybean, seed characteristic, water imbibitions, electrical conductivity, modeling

Introduction

Today, soybean (*Glycine max* (L.) Merr.) is the world's leading source of oil as well as being a product rich in protein. Besides its oil contents, other fractions and derivatives of the soybean seed have substantial economic importance in a wide range of industrial, food, pharmaceutical and agricultural products (Smith and Huyser, 1987). It is an important cash crop throughout different production areas of the world. Planted area was reached 83.61 million ha and resulted in 189.53 million ton production in worldwide during 2003 (Anonymous, 2004). And also, soybean ranks in the top five crops for hectares planted and total cash receipts generated in US (Freeborn, 2000). This information clearly demonstrates the importance of soybean, as well as the potential economic benefits possibly realized from productivity increases.

Plant genetic resources play an important role in the improvement of cultivated plants along with the preference of cultivars for crop production. It has been determined that soybean producers are not conscious about choosing the cultivar and supplying the seed (Freeborn, 2001). Besides ecological factors, some seed characteristics are effective in producing legumes in order to obtain a desirable fertility and quality (Ceylan, 1996). To author's knowledge, there are no published reports documenting the variation among soybean cultivars in term of selected seed characteristics. Due to the

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**Originally Published in International Journal of Agricultural Research, 2006* lack of such information, the present study focused on determining the variation of seed characteristics in 75 soybean cultivars.

There have been a marked interest by many workers in modeling plant growth and development in recent years and mathematical models make our assessments and predictions in ecology as well as plant structure more objective and reliable (Gertsev and Gertseva, 2004). The development and application of crop modeling is well established in studying crop response to change in cultivar, soil, weather, climatic patterns and management practices (Robertson *et al*., 2001). At the same time, this paper describes models of soybean cultivars with some seed characteristics.

Materials and Methods

Material

The research was carried out at Ondokuzmayis University, Faculty of Agriculture and Department of Field Crops during 2003 in Samsun, Turkey. The names of soybean cultivars used in the research were shown in Table 1. In the experiment, the seeds produced in 2002, were used.

Methods

On examining the characteristics of the seeds, the characteristics of evaluating the bean cultivars improved by UPOV were used (Ellis and Roberts, 1980). The characteristics examined are given in detail:

The Length (L) and Width (W) of the Seed (mm)

With the help of digital compass, length and width of the seeds were measured. One hundred seeds randomly chosen from every cultivar were used in the experiment.

The Thickness (T) of the Seed (mm)

With the help of digital compass, the thickness values in 100 seeds from hylum of the seed were measured.

The Weight of 100-seed (G) (100-SW)

One hundred seeds randomly chosen were counted four times and were weighed in an oversensitive scale (0.0001). The averages of weight values were recorded as 100-seed-weight.

The Shape Index (SI)

The classification of the seeds' shape was arranged in the light of various researchers' results (Sehirali, 1971; Akcin, 1974; Balkaya, 1999). With this purpose, in 100 seeds the rates of the length and width were determined by measuring the length and width with digital compass.

Testa Color (TC)

Surface colors of soybean cultivars were measured by MINOLTA, CR300 series Chromameter. 3-dimensional scale L*, a* and b* is used in Minolta Chromameter. The L* is lightness coefficient, ranging from 0 (black) to 100 (white). The a* value is purple-red (positive a* value) and blue-green (negative a* value). The b* represents yellow (positive b* value) or blue (negative b* value) color (Changrue *et al*., 2004; Ozcan, 1990).

Germination Experiment (%) (GS and GP)

The 100 seeds were put into the petri dishes and covered with drying sheets. For each cultivar, the practice was done four times repeatedly at 20°C. The rates of the normal germination counted at the end of the 7th day were described as the speed of germination (GS) and the rates of the germination at the end of the 10th day were also described as the power of germination (GP) (Sehirali, 1997).

Testa Rate (%) (TR)

In order to determine the coat rate, the weight of 20 seeds randomly chosen from each cultivar was determined. These seeds were boiled in water bath for 15 min. After that seed coats were separated with the help of pliers and dried in oven. Testa rate was expressed as dried seed coat weight/total seed weight.

Emergence Experiment (%) (ER)

In emergence tests, the seeds emerging during 20 days were counted daily. According to the following formula, emergence time of the bean seeds was calculated (Ellis and Roberts, 1980). The average of the emergence time = $(n \times D)/\bullet_n$ where $\bullet_n$: total number of the germinated seeds, D: The number of the days the seeds germinated, n: seedling emerged in counting of D days. The percentage of the seeds that was appeared from the beginning of the first emergence of the seeds till the end of the 20th day was calculated as the emergence rate.

Water Imbibitions (%) (WI)

After weighed, 10 seeds randomly chosen from each cultivar were put into distilled water at 20±2°C for 24 h. Before the seeds were weighed, the moisture of the seeds was wiped with drying paper. We needed to know the seed weight before putting it into the water. Water imbibitions of the seed were calculated as percentage (Deakin, 1974; Kantar and Guvenc, 1995).

Electrical Conductivity (mSc mg/seed) (EC)

After weighed, 20 seeds for each cultivar were put into 50 mL deionized distilled water at 20±2 with two replications. After the seeds were taken out of the water, the electrical conductivity of the water in jams was measured with the electrical conductivity fire-rake HD 8706. To prevent the loss of water imbibitions, the seeds were held for 24 h in an environment with high rational moisture before putting into water. Electrical conductivity was determined as micro siemens/cm-g (Demir *et al*., 1994).

Correlation analysis was made to determine the relationship among some seed characteristics in soybean cultivars. Models were made by using the multiple regression analysis and graphics were made with Excel 2003 computer programs.

Results and Discussion

Determination of Seed Characteristics

According to the results of measurement, the seed lengths of the soybean cultivars were between 6.79 mm (JMS-2382) - 8.45 mm (Ozzie). The seed widths of the cultivars were between 5.27 mm (AP-2292)-7.6 mm (Pella). The thickness values of the seed were between 4.3 mm (Leflore)-6.37 mm (NE-3297) (Table 1).

In the research, the values of shape index were determined according to length/width rates. At the end of the classification, it was seen that the seeds of Keller and SGI-1108 (1.28) had got the highest shape index (Table 1). One Hundred-seed weight is an important character in terms of seed quality. This characteristic has always been considered both agricultural and commercial point of view (Sagsoz, 1990). It was desired that 100-seed-weight was much in the types to use in production. 100-seed-weight was between 14.49 g (SA-88) - 24.82 g (Ware) and big differences were seen among the types regarding weight of the seeds. It was determined that Ware (24.82 g), Pella (24.63 g) and Pella-86 (23.05 g) had the highest values of seed weight (Table 1). Testa colors were measured by MINOLTA, CR300 series Chromameter. 3-dimensional scale L*, a* and b* is used in Minolta Chromameter. Testa colors of all cultivars are positive b* value. It represents yellow color. The values

Table 1: The names of soybean cultivars used in the experiment and their some morphologic and physiologic characteristics

Cultivars	L (mm)	W (mm)	SI (L/W)	T (mm)	100-SW (g)	TC (+b)	GS (%)	GP (%)	ER (%)	WI (%)	TR	EC (mS cmg/seed)
A-1937	7.93	6.81	1.16	5.97	18.94	31.66	60	68	55	98.4	1	10.06
A-3127	7.17	6.41	1.11	5.60	16.96	25.34	16	32	11	96.8	1.2	10.25
A-3237	7.45	6.82	1.09	5.57	18.26	31.43	100	100	95	99.5	1	17.21
A-3935	7.50	7.09	1.05	6.04	20.03	23.68	68	72	65	96.1	1.3	5.74
Amcor	7.41	6.05	1.22	5.34	18.04	28.79	72	78	70	97.2	1.2	16.40
Amsoy-71	7.78	6.46	1.20	5.93	17.64	27.00	4	32	4	98.0	1.1	10.94
Anthow	6.99	6.56	1.06	5.47	18.34	25.46	32	54	30	98.0	1.2	7.79
AP-2292	7.00	5.27	1.32	5.28	15.91	26.52	8	32	7	94.3	1	9.17
AP-240	7.53	6.45	1.16	5.50	18.46	33.74	92	96	92	95.2	1	8.99
Apollo	8.18	6.45	1.26	5.35	16.28	29.00	20	46	15	90.0	1.2	9.64
Athow	7.82	6.93	1.12	5.55	17.02	32.32	48	54	48	89.0	1.3	10.10
Beason	7.58	6.56	1.15	5.62	18.69	29.39	84	92	80	89.2	1.4	6.52
Beeson	8.40	6.39	1.31	5.64	20.16	25.52	8	28	8	88.3	1.4	7.34
Brim	7.21	5.97	1.20	5.43	15.84	30.91	96	100	92	99.2	1	9.91
BSR-301	7.74	6.82	1.13	5.55	18.09	30.99	80	88	80	95.6	1	8.78
Builison	7.89	6.71	1.17	6.11	20.25	26.79	88	92	80	95.5	1.1	6.96
Century	8.27	6.77	1.22	5.93	19.35	31.74	64	72	60	95.6	1.3	7.49
Chippewa	7.06	6.42	1.09	5.34	15.92	32.96	64	74	63	99.3	1	10.42
Chippewa-64	7.74	6.86	1.12	5.93	17.54	29.23	64	70	62	94.6	1.2	6.38
Clark-73	7.66	6.58	1.16	5.45	18.24	33.13	72	82	70	94.5	1.2	11.60
Conorta	7.92	6.97	1.13	5.66	18.30	33.99	84	92	80	91.0	1.3	6.66
Crawford	7.31	6.45	1.13	5.60	18.98	26.55	64	72	60	95.7	1.4	13.90
Cumberland	8.15	7.13	1.14	5.88	20.18	29.81	8	28	7	95.0	1.1	8.47
Cutler	7.88	7.20	1.09	6.23	22.64	29.91	100	100	96	99.1	1	8.03
CX-411	7.63	6.88	1.10	5.93	19.13	29.55	100	100	98	99.5	1	11.29
CX-434	7.80	6.86	1.13	6.12	22.31	33.79	32	56	30	88.6	1.4	5.19
Dare	7.35	6.48	1.13	5.71	18.47	36.20	100	100	95	89.9	1.5	6.06
Dawson	7.64	6.60	1.15	5.54	17.48	34.07	32	44	30	78.0	1.6	8.86
Dougles	7.50	6.31	1.18	5.14	16.42	28.67	72	76	70	76.5	1.7	18.28
Drina	7.67	6.81	1.12	5.88	19.90	30.61	72	76	72	84.1	1.4	8.09
Elgin	7.69	6.19	1.24	5.55	19.16	25.78	56	68	56	78.3	1.9	8.61
Evans	7.86	6.51	1.20	5.54	18.57	30.26	60	68	59	77.5	1.8	10.49
Farol	7.88	7.05	1.11	5.82	21.57	29.90	100	100	94	92.0	1.2	5.28
Fayette	7.90	6.82	1.15	5.65	19.78	33.30	68	72	65	88.2	1.6	7.33
Flayer	7.32	6.64	1.10	5.63	18.54	25.23	84	92	81	81.0	1.6	7.98
Flint	7.11	6.10	1.16	5.33	15.54	24.77	48	56	44	76.3	1.8	9.39
General	7.51	6.53	1.15	5.32	20.27	28.17	92	92	90	95.2	1	12.77
Granite	7.44	6.14	1.21	5.23	20.72	36.60	80	86	78	89.3	1.3	7.28
Hardin	7.89	7.07	1.11	6.19	19.08	26.78	24	48	22	64.9	1.9	7.23
Harlan	8.19	6.92	1.18	5.88	21.19	29.50	92	92	90	93.7	1	6.89
Hill	6.91	6.65	1.03	5.69	16.47	31.78	16	44	14	89.3	1.2	10.68
Hodgson	7.70	6.77	1.13	5.69	18.39	30.04	40	56	40	66.3	1.9	17.86
Iroglous	7.44	6.57	1.13	5.40	17.41	28.43	100	100	91	88.9	1.5	5.39
Iroquois	7.66	6.92	1.10	5.62	19.27	31.12	96	96	96	92.1	1	10.38
JMS-2382	6.79	6.06	1.12	5.38	15.38	34.06	84	84	84	86.5	1.4	11.18
Keller	8.21	6.41	1.28	6.13	21.25	32.38	96	96	92	92.6	1	5.55
KS-4895	7.16	6.41	1.11	5.37	15.54	26.28	20	44	21	69.8	1.8	15.31
Leflore	7.23	6.06	1.19	4.93	14.99	23.30	80	86	81	88.8	1.4	10.34
Logan	7.54	6.80	1.10	5.85	18.87	33.42	100	100	100	94.8	1	7.63
Macon	8.09	6.82	1.18	5.62	18.43	30.52	64	64	56	74.0	1.7	9.87
Mitchell	7.44	6.61	1.12	5.64	19.50	26.76	64	64	61	66.0	1.9	7.58
Nathan	7.02	6.23	1.12	5.36	15.02	26.13	40	56	40	67.3	1.9	17.64
NE-3297	8.05	7.19	1.11	6.37	19.64	33.67	92	92	92	95.8	1	8.14
NE-3399	7.35	6.88	1.06	5.73	17.71	27.55	80	84	79	81.2	1.3	8.41
Ozzie	8.45	7.46	1.13	6.29	22.10	29.55	92	92	88	87.0	1.5	14.29
Pella	8.40	7.60	1.10	6.23	24.63	25.81	68	68	65	75.0	1.7	9.50
Pella-86	7.73	6.74	1.14	5.48	23.05	30.60	92	92	90	90.0	1	5.92
Pena	7.33	6.44	1.13	5.34	15.57	32.15	80	80	82	90.1	1	6.37
Resnik	7.26	6.43	1.12	5.59	18.08	28.46	76	82	75	76.4	1.7	8.07

Table 1: Continued

Cultivars	L (mm)	W (mm)	SI (L/W)	T (mm)	100-SW (g)	TC (+b)	GS (%)	GP (%)	ER (%)	WI (%)	TR	EC (mS cmg/seed)
SA-88	6.99	6.35	1.10	5.35	14.18	27.85	36	56	36	66.0	1.8	12.05
SGI-1108	7.16	6.31	1.28	5.40	15.57	28.75	76	76	76	77.2	1.7	17.21
SGI-1109	8.29	7.22	1.11	5.99	20.57	31.14	100	100	100	99.0	1.0	16.72
SGI-3129	7.86	6.55	1.19	5.85	21.16	32.96	92	92	90	97.0	1.0	7.79
Sloan	7.53	6.54	1.10	5.20	15.69	29.27	64	72	60	77.2	1.6	10.38
Spacer	8.07	7.22	1.18	6.02	22.68	35.45	20	56	21	66.2	1.9	7.27
Stafford	7.29	6.23	1.12	5.31	16.33	30.29	84	84	80	78.9	1.8	8.81
Stride	8.25	6.91	1.12	5.91	19.85	34.94	92	92	85	88.0	1.2	6.80
TNS-95	6.88	5.86	1.11	5.26	14.49	34.96	8	32	5	62.0	1.7	10.21
Victoria	7.93	6.77	1.06	5.95	19.14	30.90	72	72	72	75.1	1.7	9.66
Ware	8.23	7.33	1.13	6.06	24.82	31.05	40	40	36	66.9	1.9	5.96
Weber	6.82	6.46	1.10	5.49	14.67	27.35	96	96	90	98.0	1.0	10.83
Wells	7.65	6.21	1.14	5.33	16.25	32.83	100	100	100	99.1	1.0	17.87
Williams-79	7.35	6.12	1.13	5.37	20.23	29.56	96	96	88	76.4	1.5	10.47
Williams-82	7.71	6.63	1.12	5.69	19.41	30.99	76	76	75	77.2	1.6	10.97
Woodworth	7.13	6.90	1.10	6.17	18.46	26.17	8	32	69	66.4	1.9	6.93

L: Length, W: Width, SI: Seed Index, T: Thickness, 100-SW: 100-seed-weight, TC: Testa Color GS: Speed of Germination, GP: Power of Germination, ER: Rate of Emergence, WI: Water Imbibition, TR: Testa Rate, EC: Electrical Conductivity

change between 23.3 +b* (Leflore) and 36.6 +b* (Granite) (Table 1). The rates of germination speed of soybean cultivars tested differed between 4-100%. It has been observed that A-3237, Cutler, CX-411, Dare, Farol, Iroqlous, Logan, Wells and SGI-1109 (100%) had higher germination speed values than all other cultivars. The lowest germination speeds were observed in Amsoy-71 (4%), AP-2292 (8%), Beeson (8%), Cumberland (8%), TNS-95 (8%) and Woodworth (8%). It was observed that the values of the germination power were similar to these of germination speed. The changes happened in the seed have influenced the growth of plant and especially the emergence and seedling (Demir and Gunay, 1994) (Table 1). The rates of germination power of soybean cultivars differed between 28-100%. It was observed that A-3237, Brim, Cutler, CX-411, Dare, Farol, Iroqlous, Logan, Wells and SGI-1109 (100%) had higher germination power values than all other cultivars. A-3127 (32%), Amsoy-71 (32%), AP-2292 (32%), Woodworth (32%), Beeson (28%) and Cumberland (28%) had the lowest germination power (Table 1). In the experiment of the emergence tests made in the greenhouse, it was determined that emergence time of the cultivars was between 7-12 days. When we examined the values of emergence rates in Logan, SGI-1109 and Wells (100%) had the highest emergence rates. The lowest emergence rate were observed in A-3127 (11%), Amsoy-71 (4%), AP-2292 (7%), TNS-95 (5%), Beeson (8%) and Cumberland (7%) (Table 1). Testa rate is an important seed characteristic especially in term of water imbibition of seeds. Results of the study revealed that testa rates for cultivars tested were between 1.0-1.9% and there was no difference among the cultivars. Water imbibition was determined as higher in A-3237 (99.5%), Cutler (99.1%), CX-411 (99.5%), SGI-1109 (99%) and Well (99.1%) when compared to other cultivars (Table 1). The values of electrical conductivity were examined and the highest ones were determined in Wells (17.87 mSc mg/seed), Hodgson (17.86 mSc mg/seed), SGI-1108 (17.21 mSc mg/seed) and SGI-1109 (16.72 mSc mg/seed) while AP-2292 (9.17 mSc mg/seed), Keller (5.55 mSc mg/seed), Woodworth (8.93 mSc mg/seed) and Beason (6.52 mSc mg/seed) gave the lowest ones (Table 1).

Modeling of Seed Characteristics

Multi-regression analysis was used to determine the best fitting equation for estimation of selected seed characteristics in soybean cultivars evaluated. These seed criterions were 100-seed-weight, water imbibition, emergence rate, germination power and germination speed.

Table 2: The equations of seed characteristics in some soybean cultivars

Seed characteristics	Equations and standard errors	R^2
100-seed-weight	(-8,28±3.494***)+[(2,608±0.528***)×L]+[(3.002±0.704***)×T]	0.6077
water imbibition	(128.99±2.287***) + [(-31.06±1.625***)×TR]	0.8334
Emergence rate	(3.5±2.1***) + [(0.924±0.029***)×GS]	0.9933
Germination power	(26.115±1.225***) + [(0.722±0.017***)×GS]	0.9703
Germination speed	(-2.38±2.585***)+[(0.873±0.081***)×GP]+[(0.372±0.06***×ER]	0.9740

(L: Length, T: Thickness, TR: Testa Rate, GS: Germination Speed, GP: Germination Power and ER: Emergence Rate)
***p<0.001

Table 3: The relations among some seed characteristics in the soybean cultivars tested

	The power of germination	The rate of emergence	Water imbibition	Testa rate	Electrical conductivity
100-seed weight	0.188	0.187	0.065	-0.069	-0.367
The power of germination		0.959**	0.812*	-0.822*	-0.081
The rate of emergence			0.849*	-0.870*	-0.90
Water imbibition				-0.914**	-0.159
Testa Rate					0.169

SD: 5 r: 0.05 0.811, r: 0.01 0.910, *p<0.05, **p<0.01

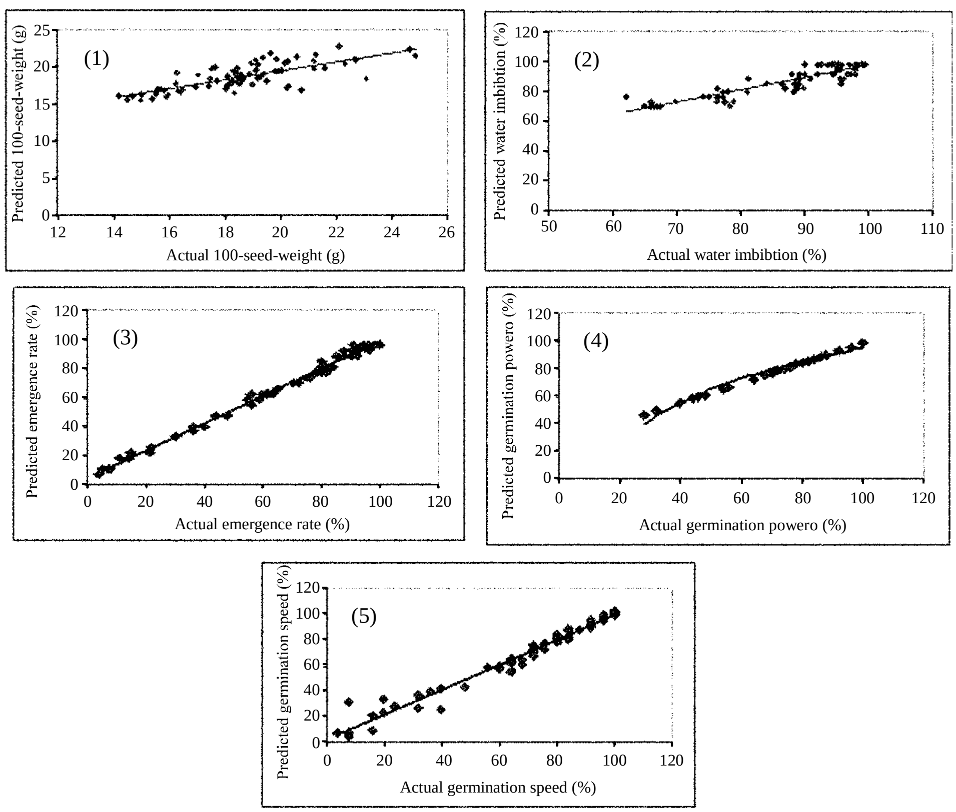

Fig. 1: Relationship between actual and predicted 100-seed-weight (1), water imbibtion (2), emergence rate (3), germination power (4) and germination speed (5) for all soybean cultivars

We found that there was close relationship between actual and predicted seed characteristics for all soybean cultivars tested. As seen in Table 2, the regression coefficients of the new produced equations for seed characteristics changed from 0.60 (100-seed-weight) 0.99 (emergence rate) as a result of model adaptation.

The results of the multi-regression analysis showed that the effect of 100-seed-weight on seed length and thickness were much more important than the other possible effective parameters at the probability 60%.

Water imbibition was affected testa rate at the probability 83%, emergence rate and germination power were affected by germination speed at the probability 99 and 97%. Also germination speed was effected germination power and testa rate at the probability 97%.

The relationship between actual and predicted seed characteristics by the new produced equations were also investigated in order to find out their prediction performances (Fig. 1).

It was determined that there was a significant and positive relationship between the power of germination and the rate of emergence, water imbibitions and the rate of emergence, water imbibitions and the power of germination. Also, there was a significant and negative relation between testa rate and the rate of emergence. Electrical conductivity was found to be insignificant statistically (Table 3).

Consequently, results from the current study indicate that of all cultivars tested, Ozzie, Pella, Keller, SGI-1108, Ware, Pella-86, A-3237, Cutler, CX-411, Dare, Farol, Ioqlous, Logan, Wells, SGI-1109, Brim and Hodgson were the most superior ones in term of the seed characters evaluated here. Also, JMS-2382, AP-2292, Leflore, SA-88, Amsoy-71, Beeson, Cumberland, TNS-95, Woodworth and A-3127 had lower performance when compared to the others. It may be concluded that this kind of comparison and modeling of the seed characters in soybean will make cultivar selection easier and more reasonable as well as the potential economic benefits possibly realized from productivity increases.

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