The relationship between seed coat color and seed quality in watermelon Crimson sweet

K. Mavi

Department of Horticulture Antakya, Faculty of Agriculture, Mustafa Kemal University, Hatay, Turkey

Abstract

Mavi K., 2010. **The relationship between seed coat color and seed quality in watermelon Crimson sweet**. Hort. Sci. (Prague), *37*: 62–69.

This work was carried out to determine the relationship between seed coat color and seed quality in Crimson sweet watermelon. Seed lots (1, 2, 3, and 4) were prepared taking into consideration seed coat colors in fresh seeds with naked eye. The color parameters of these prepared seed lots were determined using Minolta colorimeter. To determine quality differences between the seed lots, standard germination test, seed weight, water uptake ratio, mean germination time, emergence percentage, mean emergence time, seedling fresh weight, seedling dry weight and electrical conductivity values were determined. The seed weight (57.22 mg), germination percentage (86.5%), emergence percentage (77.5% total and 76.5% normal), seedling fresh weight (978.7 mg), and dry weight (64.7 mg) of the brown seed lot (Lot 1) were markedly higher than lots having lighter seed coat (2, 3, and 4). On the other hand the mean emergence time (7.7 days) and electrical conductivity value (128.8 µS/cm g in 24 h) of the brown seed lot (Lot 1) were lower than lots having lighter seed coat (2, 3, and 4). The obtained data indicated that seed quality differences can be determined according to the seed coat color of Crimson sweet seeds. It was found that seed lot 1 had higher seed vigor and viability than seed lots 2, 3, and 4. Color parameters b^*, C^*, L^*, and $H°$, determined by Minolta colorimeter, showed significant correlation with seeds quality parameters.

Keywords: seed coat color; watermelon; seed quality; seed germination

Turkey, with its annual production of 3,445,441 t, is the second largest watermelon producer after China (Anonymous 2007). Total amount of watermelon seed production required for watermelon production in Turkey is 22,255 kg. 14,600 kg (65.6%) of this production consists of Crimson sweet cv. (Anonymous 2008). Quality in seed production is more important than the quantity of produced seeds; it means that seed producing firms guarantee company reliability and the producers get their money's worth when each seed grow into seedling.

Even in the same growing period, watermelon seeds may have different seed coat colors (Demir et al. 2004). It was reported that for a quality seed, watermelon fruits should be harvested 40–45 days after anthesis (Nerson 2002, Demir et al. 2004). In watermelon production performed by the seed producers, seeds of the fruits of different growing periods are collected and mixed. In this mixture, the seeds which are different in color are used in combination.

It was reported that seed coat affected various factors, such as water uptake by the seed (De Souza, Marcos-Filho 2001), seed dormancy (Baskin et al. 2000), seed quality due to color pigments in seed coat (Abdullah et al. 1991) and germination (Nerson 2002).

I found no information in the literature on the relationship between seed coat color and seed qual-

Fig. 1. Seed samples from prepared seed lots and color differences in seed coat (1 – brown, 2 – light-brown, 3 – dark-yellow, and 4 – light-yellow)

ity during seed development stage. However, the changes in seed coat colors in seed development were subjectively observed by Demir et al. (2004) with naked eye. It was reported that seeds of different colors can be found among the fruits in the same development stage.

The objective of this study was to determine a relationship between seed coat color and seed quality using watermelon seed lots, which are estimated to be in different development stages, and to determine whether this relationship can be distinguished by naked eye-judging from seed coat color in watermelon cv. Crimson sweet.

MATERIAL AND METHODS

The seed lots obtained from Crimson sweet watermelon fruits produced in 2008 were used in the study. Seed lots were prepared taking into consideration seed coat colors in fresh seeds with naked eye. Seed samples of prepared seed lots (1 – brown, 2 – light brown, 3 – dark yellow, and 4 – light yellow) are given in Fig. 1. The seed moisture content of seed lots after drying process varied between 6.8 and 6.3%. Seed moisture content was determined by drying in oven (130°C, 1 h). Seed lots were kept at 5°C until utilization. The viability of seed lots was determined by a standard germination test.

Table 1. Changes in color, seed moisture content and seed weight of the seed lots

Lot	Seed m.c. (%)	Color	Seed weight (mg)
1	6.8	brown	57.52 ± 1.28^{a}
2	6.8	light-brown	54.43 ± 0.79^{a}
3	6.6	dark-yellow	48.21 ± 1.09^{b}
4	6.3	light-yellow	39.92 ± 2.18^{c}

The difference between the averages indicated in the same column with different letters are statistically significant ($P < 0.05$)

To determine the quality differences between seed lots, water uptake ratio (%), seed weight, mean germination time (MGT, h), emergence percentage (%), mean emergence time (MET, day), seedling fresh weights (mg), seedling dry weights (mg), electrical conductivity values (4, 20, and 24 h, µS/cm g), and seed color values (L^*, a^*, b^*, C^*, and $H°$; using Minolta CR 300 colorimeter) were determined.

Twenty five seeds whose initial weights were measured were left to uptake water in moist paper in four replications at 25°C. The seeds were weighed in 1 h intervals (except between 9 p.m. and 7 a.m.). The study was ended when germination started. Amounts (%) of water uptake were calculated according to Demir et al. (2008) as follows:

$$W_2 = (100 - A/100 - B) \times W_1$$

Where:

W_2 – indicates final seed weight
W_1 – indicates initial seed weight
A – indicates initial seed moisture content
B – indicates the final seed moisture content that seed lots reached

Seed weight (mg) was determined by weighing in precision balance (+/– 0.0001 g) using 4 × 25 seeds. Standard germination test was conducted by keeping 4 × 25 seeds in germination paper (200 × 200 mm) for 14 days at 25°C. Seeds producing a 2 mm radicle were counted as germinated. In germination test 4 countings were made at every 4 h starting from 8 a.m and mean germination time was determined in h (Ellis, Roberts 1980). Emergence test was carried out in humidity chamber in 280 × 200 × 80 mm

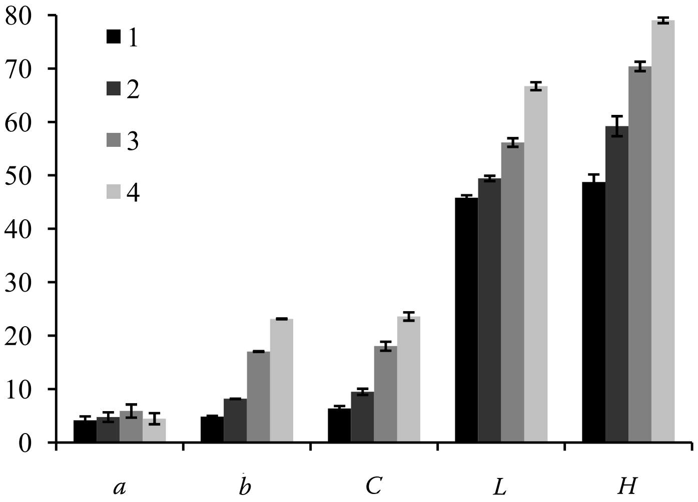

Fig. 2. Changes in watermelon cv. Crimson sweet seed lots in a^*, b^*, C, L^*, and $H°$ values determined by Minolta colorimeter (darker to lighter shades in bar colors was used to simulate the color change in seed lots)

plastic seedling trays at 20°C, under 12 h of light and 12 h of dark conditions. The test lasted for 22 days and at the end of the test percentages of normal (whole and healthy seedling) and abnormal seedlings were determined by ISTA seedling evaluation handbook (Ista 2003). Mean emergence time was also determined by sprouts counting, made on daily basis. At the end of the emergence test, fresh and dry weights of the seedlings (10 seedlings × replication) cut out from peat surface were determined. To determine dry weight, the seedlings were kept at 80°C for 24 h and weighed. Electrical conductivity test was set up using 4 × 10 seeds in 40 ml distilled water at 20°C. The conductivity of seed soak water was measured after 4, 20, and 24 h using a conductivity meter (Schott-Gerate GmbH, Hofheim) and was expressed in µS/cm g. Seed lots were grouped according to their colors. Then seed colors were measured by the colorimeter (Minolta CR300). Total of 5 × 10 seeds in 3 replications were used for color measurements. The L^* value indicates the changes in color brightness, a^* value indicates color change from green (negative values) to red (positive values). The b^* value indicates color change from yellow (positive values) to blue (negative values). $H°$ parameter indicates hue angle value (0 – red-purple, 90 – yellow, 180 – bluish green, 270 – blue) and C^* (chroma) indicates color density.

To indicate the difference between seed lots, variance analysis was made in SPSS (9.05, The Predictive Analytics Company) package program. Differences between seed lots were determined by the Duncan's multiple range test at $P = 0.05$. Percentage values were subjected to angle transformation prior to the analysis. Correlation analysis in SPSS package program was made for color and seed qualities.

RESULTS

Initial seed moisture content and seed weight

Initial seed moisture content of the seed lots which were grouped according to seed coat color varied between 6.8 and 6.3%. The seed lot having light yellow seed coat (Lot 4, 39.92 mg) had the lowest seed weight, while the seed lot having brown seed coat color (Lot 1, 57.52 mg) showed the highest seed weight. Statistical analysis indicated that seed lots (excluding Lot 1 and 2) fell into statistically different groups in terms of seed weight (Table 1).

Seed coat colors in seed lots

Checking of seed lots, grouped according to seed coat colors, indicated that all color values, excluding a^* value, gradually increased from dark-colored

Table 2. Changes in emergence percentages, mean emergence time (MET), seedling fresh weight (SFW), and seedling dry weights (SDW)

Lot	Emergence (%)		MET (day)	SFW(mg)	SDW (mg)
	total	normal			
1	77.5^a	76.5^a	7.7^a	978.7^a	64.7^a
2	49.0^b	49.0^b	9.7^a	677.5^b	39.9^b
3	42.5^b	37.0^{bc}	10.1^a	431.0^c	24.9^c
4	38.5^b	24.5^c	14.5^b	245.3^d	15.4^d

The difference between the averages indicated in the same column with different letters are statistically significant ($P < 0.05$)

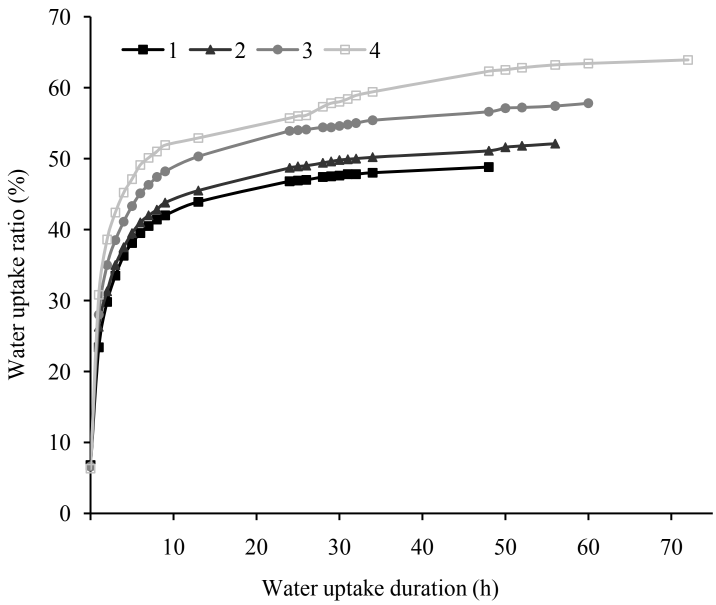

Fig. 3. Differences in water uptake ratios of seed lots

lot to light-colored lots. It was true especially for *b** value, which ranged from 4.82 units in brown lot (Lot 1) to 23.15 units in light yellow lot (Lot 4). *L** value, which indicates brightness, was found to be the highest in light-colored seeds (Lot 4). Seed lot 1 had the lowest *H*° value, while seed lot 4 had the highest *H*° value (Figs. 1 and 2).

Water uptake ratio (%)

Water uptake ratios of seed lots were differentiated. The seed lot with light yellow seed coat (Lot 4) had the highest water uptake, while brown seed lot (Lot 1) had the lowest water uptake ratio. Fast water uptake (I. phase) was completed in all lots in 10 h. However, water uptake amounts of seed lots showed variations depending on seed coat color. In the phase II, when water uptake is slower, water uptake in dark-colored seed lots was slower (Lot 1, 48 h); water uptake was completed in the longest time in light yellow-colored lot (Lot 4, 72 h). In this phase, light yellow-colored seed lot (Lot 4) absorbed approximately 15% more water than brown seed lot (Lot 1) (Fig. 3).

Standard germination percentages and mean germination time

Initial germination percentage of seed lots decreased from dark-colored seed lot to light- colored seed lot. In seed lot 1, germination percentage was 86.5%; in seed lot 4, 37.5%. In terms of germination ratios, seed lots 1 and 2 fell into the same group, while lots 3 and 4 fell into another group. Also mean germination time increased from dark-colored seed lots to light-colored seed lots (Fig. 4).

Electrical conductivity test

Seed membrane damage of different color seed lots was investigated by recording the electrical conductivity after 4, 20, and 24 h of soaking in deionized water. Parallel to the color changes of seed lots, electrical conductivity (EC) values was found to decrease from light-colored to dark-colored seeds. The lowest EC in all three durations was found in brown seed lot (Lot 1), while the highest EC was found in light yellow seed lot (Lot 4). Seed lot 1 (brown) and 2 (light brown) fell into the same group for all three durations, while seed lot 3 (dark yellow) and 4 (light yellow) fell into different groups than lot 1 and 2 (Figs. 4 and 5).

Emergence percentage and mean emergence time (MET)

Emergence test indicated that brown seed lot (Lot 1) had the highest emergence percentage (total 77.5, normal 76.5), while light yellow seed lot (Lot 4) the lowest. Parallel to emergence percentages, mean emergence time (MET) decreased from dark-colored seed lot to light-colored lot. Light yellow seed lot (Lot 4) completed its emergence 7 days later than brown seed lot (Lot 1) (Table 2).

Table 3. Correlation (*r*) coefficients between seed coat color and vigor tests in seed lots

		Color values					Seed weight	Germination			Water uptake ratio	Electrical conductivity			Emergence		MET	SFW	SDW
		*a**	*b**	*C**	*L**	*H°*		total	Nor.	MGT		4 h	20 h	24 h	total	Nor.			
Color values	*a**	1.00	0.34	0.36	0.18	0.41	–0.21	–0.57	–0.42	0.20	0.28	0.51	0.34	0.28	–0.56	–0.45	0.02	–0.44	–0.50
	*b**		1.00	1.00***	0.98*	0.98*	–0.99**	–0.97*	–0.99**	0.98*	0.99**	0.98*	0.99**	0.99**	–0.84	–0.93	0.92	–0.97*	–0.94
	*C**			1.00	0.98*	0.98*	–0.98*	–0.97*	–0.99**	0.98*	0.99**	0.98*	0.99**	0.99**	–0.84	–0.93	0.91	–0.97*	–0.94
	*L**				1.00	0.97*	–1.00***	–0.91	–0.97*	1.00***	0.99**	0.93	0.98*	0.98*	–0.80	–0.91	0.97*	–0.95*	–0.91
	H°					1.00	–0.97*	–0.97*	–0.99**	0.97*	0.98*	0.98*	0.99**	0.96*	–0.92	–0.98**	0.92	–0.99**	–0.98*
Seed Weight							1.00	0.92	0.97*	–0.99**	–0.99**	–0.94	–0.99**	–0.98*	0.81	0.92	–0.96*	0.96*	0.92
Germination	total							1.00	0.98*	–0.92	–0.95*	–0.99**	–0.96*	–0.95*	0.89	0.94	–0.81	0.97*	0.96*
	normal								1.00	–0.97*	–0.98**	–0.99**	–0.99**	–0.98*	0.88	0.96*	–0.90	0.98*	0.97*
	MGT									1.00	0.99**	0.94	0.98*	0.98*	–0.83	–0.93	0.97*	–0.96*	–0.98*
Water uptake ratio											1.00	0.97*	0.99**	0.99**	–0.84	–0.95*	0.95*	–0.97*	–0.94
Electrical conductivity	4 h											1.00	0.98*	0.96*	–0.88	–0.95*	0.85	–0.98*	–0.96*
	20 h												1.00	0.98*	–0.86	–0.95*	0.93	–0.98*	–0.96*
	24 h													1.00	–0.78	0.89	0.92	–0.94	–0.90
Emergence	total														1.00	0.98*	–0.78	0.94	0.97*
	normal															1.00	–0.89	0.99**	0.99**
MET																	1.00	–0.91	–0.87
SFW																		1.00	0.99**
SDW																			1.00

*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$

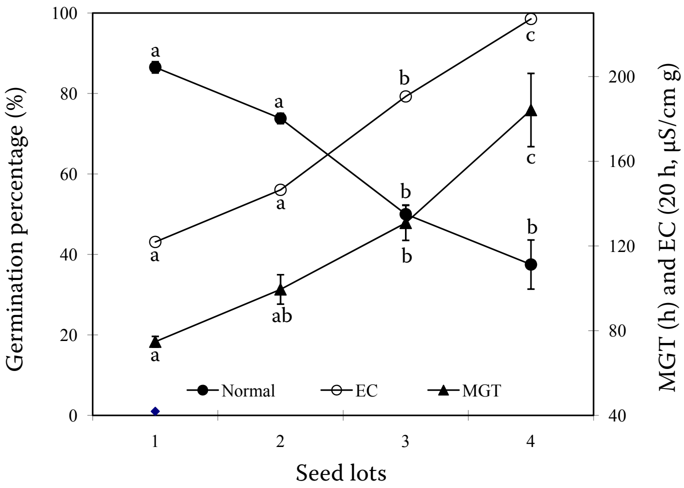

Fig. 4. Changes in germination percentage (●, %), mean germination time (MGT, ▲, h), and electrical conductivity (EC, ○, 20 h) values in seed lots, for germination percentage and mean germination time, different letters on the lines in the same direction indicate that the difference between the averages is statistically significant ($P < 0.05$)

Seedling fresh and dry weight

Seedling fresh weights were found to be 978.7 mg in seed lot 1 and 245.3 mg in seed lot 4. Seeds of lighter coat color showed lower fresh weight. Dry weight of seedling changed parallel to the fresh weight. The seed lot having brown seed coat color (Lot 1) had the highest (64.7 mg) seedling dry weight, while the lot having light yellow seed coat (Lot 4) had the lowest (15.4 mg) seedling dry weight (Table 2).

Correlation coefficients between seed coat color and vigor tests

Correlation analysis indicated a high and significant correlation between color values (excluding *a**) and seed weight, germination percentage, MGT, water uptake ratio, electrical conductivity test (20 and 24 h) and seedling fresh weight tests. In addition, giving a significant correlation coefficients with 14 of 17 properties in correlation analysis, *H*° value was the most successful in color values. *b** and *C** giving significant correlation coefficients with 12 properties were the second most successful color values (Table 3).

DISCUSSION

It was found that in Crimson sweet watermelon seeds, there were differences in terms of seed quality in the seed lots grouped according to seed coat colors. It was found that seed lots 3 and 4 had

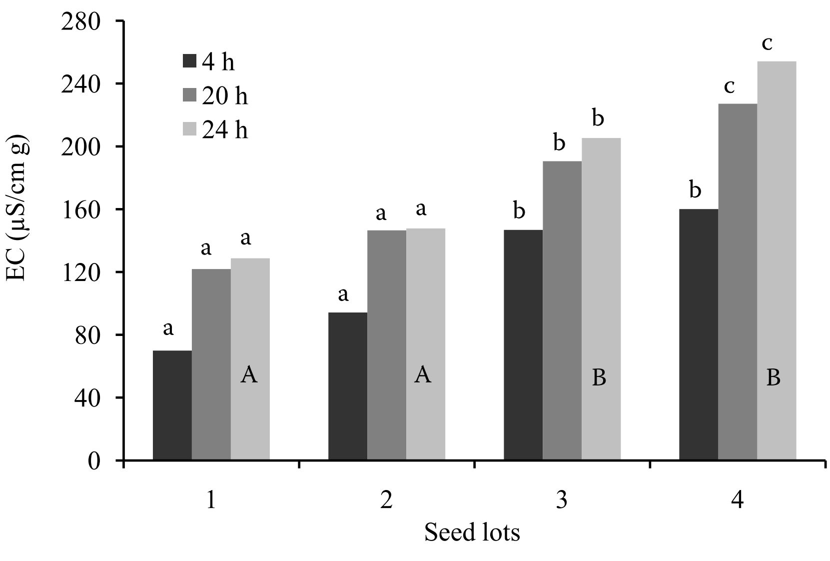

Fig. 5. The changes in electrical conductivity test (EC, 4, 20, and 24 h) EC measurements of seed lots formed by considering color differences (lower case letters in the bars indicate statistical significance in the same durations, while capital letters indicate the statistical significance ($P < 0.05$) between the averages of the seed lot)

a lower vigor than lots 1 and 2. Correlation analysis indicated that this was also related to the color differences (Tables 1, 2, 3, and Fig. 1).

Conductivity increased after the seeds were subjected to deterioration and seed maturation. The conductivity increased due to membrane deterioration, mitochondrial changes, chromosomal aberrations and free radicals in seed lots. As seed deterioration increased, cellular membranes lose their selective permeability, permitting the cytoplasmic metabolites to leach into the intercellular spaces. Membrane degradation occurs from both hydrolysis of phospholipids by phospholipase and phospholipids oxidation. Therefore, the studies should continue to determine suitable test conditions for electrical conductivity test of seed lots (Figs. 4 and 5).

The effect of seed coat on germination in watermelons was analyzed in diploid (Nerson 2002), triploid (Duval, NeSmith 2000) and tetraploid (Jaskani et al. 2004) watermelons. However, these studies pointed out to the limiting effect of seed coat on germination and proposed that seed coat should be removed. This method does not seem to be practical. For this reason, it was important to harvest the seed lots in the most suitable period in such a way to eliminate the negative effect of seed coat. Besides, seed lots having different seed coat colors should not be used in the same lot. It is possible to identify the differences in seed coat color with naked eye. These differences can also be determined using colorimeter as a simple method. In addition, it was found that $H°$ value can be used to classify the unprocessed seeds in the same lot (Table 3 and Fig. 2).

Seed lots of flax (Dana, Ivo 2008) and *Ambrosia trifida* (Sako et al. 2001) were classified according to seed coat colors using image analysis method. Based on the obtained findings, I think that this method can be applied for watermelon seed lots as well.

It is known that differences in the amount of some color pigments in seed coat result in color differences of seed coats. For example, it was found that in rapeseed, water uptake and tolerance to excessive water was significantly correlated with seed coat color and melanin pigment amount. Seed lots having red and black seed coat were found to have higher melanin pigment. In addition, colored types had a slow water uptake, low electrical conductivity value and high tolerance to slow water uptake. In yellow-colored seeds, lower melanin content and faster water uptake were observed (Zhang et al. 2006, Zhang et al. 2008). Nerson (2002) found that immature seeds of watermelon cv. Sugar Baby uptake more water than mature seeds, however the study presented no data on seed coat color. Water uptake ratios (Fig. 3) in our study were found to be similar to those of Nerson (2002).

Consequently, the seed weight (57.22 mg), germination percentage (86.5%), emergence percentage (77.5% total and 76.5% normal), seedling fresh weight (978.7 mg) and dry weight (64.7 mg) of the brown seed lot (Lot 1) were fairly higher than those of light-colored seed lots (3 and 4). Light yellow seed lot (Lot 4) completed its emergence 7 days later than brown seed lot (Lot 1). The data show that brown seed lot (Lot 1) was more vigorous than other seed lots. For this reason, sowing of brown color seeds must be performed in more favorable soil moisture and temperature conditions compared to light-colored seed lots (3 and 4). In addition, it was found that the differences in seed coat color can be used as a quality indicator in Crimson sweet watermelon. Color values b^*, C^*, L^*, and $H°$ (Fig. 2) were significantly correlated with the properties used to identify the differences in seed quality (Table 3). It was concluded that removing the seeds with the seed coat color typical to seed lots 3 and 4 would increase the quality of seeds in Crimson sweet watermelon.

References

Abdullah W.D., Powell A.A., Matthews S., 1991. Association of differences in seed vigour in long bean with testa colour and imbibition damage. Journal of Agricultural Science, *116*: 259–264.

Anonymous, 2007. Food and Agriculture Organization of the United Nations. FAOSTAT. Available at: http://faostat.fao.org/site/526/default.aspx (accessed November 11, 2008)

Anonymous, 2008. Ülkesel Tohumluk Tedarik, Dağıtım ve Üretim Programı. Tarım ve Köyişleri Bakanlığı, Tarımsal Üretim ve Geliţtirme Genel Müdürlüğü, Tohumculuk Dairesi Başkanlığı (Territorial Seed Supply, Distribution and Production Program. Ministry of Agriculture and Rural Affairs, General Directorate of Agricultural Production and Development, Seed Department), Ankara.

Baskin J.M., Baskin C.C., Li X., 2000. Taxonomy, anatomy and evolution of physical dormancy in seeds. Plant Species Biology, *15*: 139–152.

Dana W., Ivo W., 2008. Computer image analysis of seed shape and seed color for flax cultivar description. Computers and Electronics in Agriculture, *61*: 126–135.

Demir I., Mavi K., Kenanoglu B.B., Matthews S., 2008. Prediction of germination and vigour in naturally aged commercially available seed lots of cabbage (*Brassica ol-*

eracea var. capitata) using the bulk conductivity method. Seed Science and Technology, *36*: 509–523.

Demir I., Mavi K., Oztokat C., 2004. Changes in germination and potential longevity of watermelon (*Citrullus lanatus*) seeds during development. New Zealand Journal of Crop and Horticultural Science, *32*: 139–145.

De Souza F.D., Marcos-Filho J., 2001. The seed coat as a modulator of seed-environment relationships in Fabaceae. Revista Brasileira de Botanica, *4*: 365–375.

Duval J.R., NeSmith D.S., 2000. Treatment with hydrogen peroxide and seedcoat removal or clipping improve germination of Genesis triploid watermelon. HortScience, *1*: 85–86.

Ellis R.H., Roberts E.H., 1980. Towards a rational basis for testing seed quality. In: Hebblethwaite P.D. (ed.), Seed Production. London, Butterworths: 605–635.

Ista, 2003. Handbook on seedling evaluation. 3rd Ed. Bassersdorf, The International Seed Testing Association.

Jaskani M.J., Kwon S.W., Kim E.J., Ko B.R., 2004. Polyploidy affects fruit characteristics, seed morphology, and germination in watermelon. Korean Society for Horticultural Science, *5*: 233–237.

Nerson H., 2002. Effects of seed maturity, extraction practices and storage duration on germinability in watermelon. Scientia Horticulturae, *93*: 245–256.

Sako Y., Regnier E.E., Daoust T., Fujimura K., Harrison S.K., McDonald M.B., 2001. Computer image analysis and classification of giant ragweed seeds. Weed Science, *49*: 738–745.

Zhang X.K., Yang G.T., Chen L., Yin J.M., Tang Z.L., Li J.N., 2006. Physiological differences between yellow-seeded and blackseeded rapeseed *(Brassica napus* L.) with different testa characteristics during artificial ageing. Seed Science and Technology, *34*: 373–381.

Zhang X.K., Chen J., Chen L., Wang H.Z., Li J.N., 2008. Imbibition behavior and flooding tolerance of rapeseed seed (*Brassica napus* L.) with different testa color. Genetic Resources Crop Evolution, *55*: 1175–1184.

Received for publication August 31, 2009
Accepted after corrections December 8, 2009

Corresponding author:

Dr. K. Mavi, Mustafa Kemal University, Faculty of Agriculture, Department of Horticulture, 310 34 Antakya, Hatay, Turkey
phone: + 90 326 245 5845/1089, fax: + 90 326 245 5832, e-mail: kazimmavi@yahoo.com