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INDEXES OF TOLERANCE OF TOMATO (*Lycopersicon esculentum* Mill.) SEEDS FOR GERMINATION AT LOW TEMPERATURES

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Abstract. Sixteen tomato (*Lycopersicon esculentum* Mill.) cultivars from Poland and China were tested on their seed tolerance to germinate at low temperatures: 15ºC and 10ºC. Their responses were evaluated based on 4 characters: germination energy, germination capacity, maximum germination and fresh weight of 100 normal seedlings, calculated then into 6 different indexes. All of proposed indexes include the optimal temperature of germination (20ºC). There is a possibility to use the suggested indexes to evaluate seed tolerance of various tomato cultivars to germinate at low temperatures. The tested low temperatures decreased the germination energy of the seeds of the tested tomato cultivars. Three cultivars were found with a satisfactory germination at 15ºC, but at 10ºC the germination of all tested cultivars was poor. The biggest tolerances of seeds to germinate at 15ºC was found for the cultivars: `Kibic`, `Maliniak` and `Etna $F_1$`, the smallest – for the cultivars: `Bai Guo Qiang Feng` and `Sheng Li 919`. The biggest tolerances of seeds to germinate at 10ºC was found for the cultivars: `Batory $F_1$` and `Korsarz`, whereas the smallest – for the cultivars: `Etna $F_1$`, `Poranek`, `Maliniak`, `Kora`, `Bursztyn`, `Sheng Li 919`, `Ju Huang 83-3` and `Bai Guo Qiang Feng`.

Key words: germination, low temperature, seeds, tomato, *Lycopersicon esculentum* Mill.

INTRODUCTION

There has been a vast research on improving tolerance of many warm-season crops to low temperatures (Lamprecht, 1941; van der Berkmortel, 1980; Levit, 1980; Hołubowicz and Dickson, 1989). Much less attention is paid though to the tolerance of their seeds to germination at low temperatures. Seeds of the majority of the tomato cultivars grown today in Poland cannot germinate well at the temperatures below 20ºC (Korohoda, 1974). In the field condition of commercial tomato production through direct sowing or in unheated, plastic tunnels, such soil temperature is rarely reached. So, there is a need for tomato seeds with ability to germinate at lower temperatures. This problem refers to all species of this group and can be solved either by breeding (Kooistra, 1971; Michalik, 2000; Bralewski and Hołubowicz, 2003a) or seed conditioning (Bralewski and Hołubowicz, 2003b; Halmer, 2000; Tylkowska and Dorna, 2000).

Results concerning seeds tolerance to low temperatures are usually given through energy and capacity of their germination. This way of presentation, however, is not always giving full information about the seeds germination at optimal temperature. The goal of this research was to find out indexes, which would describe this character for several tomato cultivars better than a single parameter.

MATERIALS AND METHODS

Seeds of 16 tomato cultivars (*Lycopersicon esculentum* Mill.) - 13 Polish and 3 Chinese ones – were germinated at 3 different temperatures: 20ºC (check), 15ºC and 10ºC. The seeds were placed on plastic Petri dishes (9 cm diameter), 50 seeds on each, on the blotter paper soaked with the distilled water. There were 6 replications of 50 seeds each for each treatment.

The energy of germination was counted after 7 days and its capacity of germination, maximum germination and 100 normal seedlings fresh weight – after 14 days. The last character was evaluated in 3 replications. Based on this data, the indexes of seed germination at 10ºC and 15ºC were calculated. They were as follows:

$$ITge = \frac{\text{germination energy at } 10^{o}C \text{ or } 15^{o}C\ (\%)}{\text{germination energy at } 20^{o}C\ (\%)}$$

$$ITgc = \frac{\text{germination capacity at } 10^{o}C \text{ or } 15^{o}C\ (\%)}{\text{germination capacity at } 20^{o}C\ (\%)}$$

$$ITmg = \frac{\text{maximum germination at } 10^{o}C \text{ or } 15^{o}C\ (\%)}{\text{maximum germination at } 20^{o}C\ (\%)}$$

$$ITfw = \frac{\text{fresh weight of 100 seedlings at } 10^{o}C \text{ or } 15^{o}C\ (g)}{\text{fresh weight of 100 seedlings at } 20^{o}C\ (g)}$$

$$IT_{10^{o}C} = \frac{ITge_{\,10^{o}C} + ITgc_{\,10^{o}C} + ITmg_{\,10^{o}C} + ITfw_{10^{o}C}}{4}$$

$$IT_{15^{o}C} = \frac{ITge_{\,15^{o}C} + ITgc_{\,15^{o}C} + ITmg_{\,15^{o}C} + ITfw_{15^{o}C}}{4}$$

The received results were subjected to the statistical variance analysis and the smallest significant differences were calculated based on the Duncan`s test for $\alpha = 0.05$.

RESULTS AND DISCUSSIONS

The carried out research showed variability in seed tolerance of the tested cultivars to germinate at 10ºC and 15ºC. The germination evaluation was based on the results of their energy, capacity and maximum germination, as well as the fresh weight of the seedlings in comparison to the results received at optimal temperature, i.e. at 20ºC.

Low temperature significantly decreased the seeds germination energy and the fresh weight of the seedlings received from such seeds (Tab.1). At the same time, they increased the number of abnormal seedlings and healthy, ungerminated seeds.

The temperature 15ºC did decrease the germination energy of the tested cultivars and germination capacity for the majority of the tested cultivars. Seeds of the 3 cultivars: `Etna $F_1$`, `Kibic` i `Ryton` germinated the same as the check ones. In 8 cultivars lower maximum germination was observed (Tab.1).

Based on the calculated indexes, thought, the biggest tolerance of seeds to germinate at 15ºC was found for the seeds of the cultivars: `Kibic`, `Maliniak` and `Etna $F_1$`, the smallest – for the seeds of the two Chinese cultivars: `Bai Guo Qiang Feng` and `Sheng Li 919` (Tab. 2).

Table 2

Indexes of tolerance of the selected tomato cultivars to germinate at 15ºC

Cultivar	Indexes				
	$ITge_{15ºC}$	$ITgc_{15ºC}$	$ITmg_{15ºC}$	$ITfw_{15ºC}$	$IT_{15ºC}$
Etna F_1	0 a*	0.973 cd	0.997 e	0.290 abc	0.567 fgh
Batory F_1	0 a	0.855 bc	0.933 bcde	0.240 a	0.507 bcde
Wiola F_1	0 a	0.937 cd	0.977 de	0.310 abc	0.557 efgh
Koneser F_1	0 a	0.957 cd	0.973 cde	0.250 ab	0.543 efgh
Kibic	0 a	1.017 d	0.975 de	0.363 bc	0.587 h
Poranek	0 a	0.938 cd	0.978 de	0.257 ab	0.543 efgh
Ryton	0 a	0.943 cd	0.960 cde	0.320 abc	0.557 efgh
Maliniak	0 a	0.952 cd	0.980 de	0.393 c	0.580 gh
Korsarz	0 a	0.947 cd	0.990 de	0.290 abc	0.557 efgh
Kora	0 a	0.763 ab	0.883 abc	0.227 a	0.470 abc
Paw	0 a	0.853 bc	0.850 ab	0.210 a	0.480 abcd
Bursztyn	0 a	0.882 bc	0.955 cde	0.2967 abc	0.530 defg
Atma	0 a	0.877 bc	0.952 cde	0.243 a	0.5167 cdef
Sheng Li 919	0 a	0.708 a	0.815 a	0.303 abc	0.4567 ab
Ju Huang 83-3	0 a	0.845 bc	0.8967 abcd	0.310 abc	0.5133 cde
Bai Guo Qiang Feng	0 a	0.767 ab	0.840 a	0.220 a	0.4533 a

* Means in the columns followed by the same letter are not significantly different at $\alpha = 0.05$ level according to the Duncan's test.

None of the tested cultivars was found to have seeds that had satisfactory germinated at 10ºC (Tab.1).

The temperature drastically reduced seed's germination and increased the number of the healthy, ungerminated seeds. Despite poor seed germination, based on the calculated indexes, the biggest tolerance to germinate at 10ºC was found for the seeds of 2 cultivars: `Batory $F_1$` and `Korsarz`, whereas the smallest – for the following cultivars: `Etna $F_1$`, `Poranek`, `Maliniak`, `Kora`, `Bursztyn`, `Sheng Li 919`, `Ju Huang 83-3` and `Bai Guo Qiang Feng` (Tab. 3).

Table 3

Indexes of tolerance of selected tomato cultivars to germinate at 10ºC

Cultivar	Indexes				
	$ITge_{10ºC}$	$ITgc_{10ºC}$	$ITmg_{10ºC}$	$ITfw_{10ºC}$	$IT_{10ºC}$
Etna F_1	0 a	0 a	0.007 a	0 a	0 a
Batory F_1	0 a	0 a	0.128 e	0 a	0.030 c
Wiola F_1	0 a	0 a	0.037 bc	0 a	0.010 b
Koneser F_1	0 a	0 a	0.040 c	0 a	0.007 ab
Kibic	0 a	0 a	0.028 abc	0 a	0.007 ab
Poranek	0 a	0 a	0 a	0 a	0 a
Ryton	0 a	0 a	0.023 abc	0 a	0.003 ab
Maliniak	0 a	0 a	0.010 ab	0 a	0 a
Korsarz	0 a	0 a	0.098 d	0 a	0.023 c
Kora	0 a	0 a	0 a	0 a	0 a
Paw	0 a	0 a	0.015 abc	0 a	0.003 ab
Bursztyn	0 a	0 a	0 a	0 a	0 a
Atma	0 a	0 a	0.008 ab	0 a	0.003 ab
Sheng Li 919	0 a	0 a	0.003 a	0 a	0 a
Ju Huang 83-3	0 a	0 a	0.010 ab	0 a	0 a
Bai Guo Qiang Feng	0 a	0 a	0 a	0 a	0 a

* Means in the columns followed by the same letter are not significantly different at $\alpha = 0.05$ level according to the Duncan's test.

The carried out research showed a possibility of using the proposed indexes to evaluate the tomato seeds tolerance to germinate at low temperatures.

The calculated indexes showed the effect of low temperature on energy (ITge), capacity (ITgc), maximum germination (ITmg) and fresh weight of seedlings (ITfw) in relation to the values received at the optimal temperature.

A general index of tolerance (IT) enables easier and more complete comparision of the different tomato cultivars in terms of the tolerance of their seeds to low temperatures. It includes all of the most important parameters of germination.

Developing a tomato cultivar with tolerance to low temperatures is one of the today's leading directions of breeding works for this species (Michalik, 2000).

The works in these directions have been carried out also for other warm-season crops such as maize (Mock and Bekri 1976), soybeans (Littlejones and Tanner, 1976; Holmberg, 1978) or common bean (Klein 1981; Hołubowicz and Legutko, 1995; Bralewski and Hołubowicz, 2003).

Found in this research various tolerance of the seeds of the tested tomato cultivars to germination at low temperature and pointing out the cultivars with the biggest tolerance brings up the conclusion that in the future it will be possible to receive a tomato breeding line with lower heat requirements. This is in accordance with the results received in other research by Van der Berkmortel (1980) and Hogenboom (1981).

The idea of using mathematical indexes for evaluating the value of seeds is not a new one. Such indexes were used to evaluate seed longevity (Roberts, 1972) and germination (Pietruszewski, 2001, 2002).

CONCLUSIONS

1. There is a possibility to use the suggested indexes to evaluate tolerance of various tomato cultivars to low temperatures.
2. Low temperatures decreased the germination energy of the seeds of the tested tomato cultivars.
3. Three cultivars of tomato were found with a satisfactory germination at 15ºC, but at 10ºC the germination of all tested cultivars was poor.
4. The biggest tolerance of seeds to germinate at 15ºC was found for the cultivars: `Kibic`, `Maliniak` and `Etna $F_1$`, the smallest – for the cultivars: `Bai Guo Qiang Feng` and `Sheng Li 919`.
5. The highest tolerances of seeds to germinate at 10ºC was found for the cultivars: `Batory $F_1$` and `Korsarz`, the smallest – for the cultivars: `Etna $F_1$`, `Poranek`, `Maliniak`, `Kora`, `Bursztyn`, `Sheng Li 919`, `Ju Huang 83-3` and `Bai Guo Qiang Feng`.

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REZUMAT

TOLERANȚA SEMINȚELOR DE TOMATE (*Lycopersicon esculentum* Mill.) LA FRIG ŞI GERMINAREA ACESTORA LA TEMPARATURI REDUSE

Au fost studiate şaisprezece cultivaruri de tomate din Polonia şi China, în ceea ce priveşte capacitatea semințelor de a germina la temperaturi reduse, de 15ºC şi 10ºC. Comportarea semințelor la temperaturi scăzute a fost evaluată pe baza următorilor indici: energia germinativă, capacitatea de germinație, germinația maximă şi masa a 100 de semințe, care pot fi utilizați în scopul estimării toleranței semințelor diferitelor soiuri de tomate la temperaturi reduse. Semințele supuse temperaturilor scăzute au avut o energie germinativă scăzută, însă diferit de la un soi la altul. Trei dintre cultivaruri au prezentat o germinare satisfăcătoare la 15ºC, dar la 10ºC germinarea a fost slabă la toate cultivarurile luate în studiu. Cea mai mare rezistență la temperaturile scăzute au prezentat-o soiurile: Kibic, Maliniak şi Etna $F_{1,}$ iar cea mai mică rezistență soiurile Bai Guo Qiang Feng şi Sheng Li 919. La temperatura de 10°C au rezistat cel mai bine semințele soiurilor Batory şi Korsarz, în schimb soiurile Etna F_1, Poranek, Maliniak, Kora, Bursztyn, Sheng Li 919, Ju Huang 83-3 şi Bai Guo Qiang Feng au avut o toleranță redusă.

Table 1

Effect of low temperatures on seed germination of the selected tomato cultivars – part I

Cultivar	Temperature of germination (ºC)	Germination energy (%)	Germination capacity (normal seedlings) (%)	Deformed (abnormal) seedlings (%)	Diseased seedlings (%)	Dead seeds (%)	Healthy ungerminated seeds (%)	Maximum germination (%)	Fresh weight of 100 seedlings (g)
Etna F_1	20ºC	88.7 b	95.4 b	0.4 a	2.4 b	2.0 a	0.0 a	98.0 b	4.67 c
	15ºC	0.0 a	92.7 b	3.7 b	1.4 ab	1.7 a	0.7 a	97.7 b	1.37 b
	10ºC	0.0 a	0.0 a	0.4 a	0.4 a	16.4 b	83.0 b	0.7 a	0.0 a
Batory F_1	20ºC	84.4 b	90.0 c	0.4 a	6.0 a	3.0 a	0.7 a	96.4 c	4.54 c
	15ºC	0.0 a	76.4 b	6.7 b	6.7 a	4.0 a	6.4 b	89.7 b	1.10 b
	10ºC	0.0 a	0.0 a	10.0 b	2.4 a	18.7 b	69.0 c	12.4 a	0.0 a
Wiola F_1	20ºC	86.7 b	94.0 c	1.4 a	2.0 a	1.0 a	1.7 a	97.4 b	4.98 c
	15ºC	0.0 a	88.0 b	6.7 b	0.4 a	2.0 a	3.4 a	95.0 b	1.54 b
	10ºC	0.0 a	0.0 a	3.4 ab	0.4 a	1.7 a	94.7 b	3.4 a	0.0 a
Koneser F_1	20ºC	97.4 b	98.4 c	0.0 a	1.7 a	0.0 a	0.0 a	100.0 c	5.28 c
	15ºC	0.0 a	94.0 b	2.7 b	0.7 a	0.7 a	2.0 a	97.4 b	1.40 b
	10ºC	0.0 a	0.0 a	2.7 b	1.4 a	10.4 b	85.7 b	4.0 a	0.0 a
Kibic	20ºC	78.3 b	81.0 b	0.4 a	9.3 b	6.4 b	3.0 a	90.7 b	3.50 c
	15ºC	0.0 a	82.0 b	4.4 b	2.0 a	3.0 a	8.7 b	88.4 b	1.27 b
	10ºC	0.0 a	0.0 a	2.7 b	0.0 a	5.4 ab	92.0 c	2.7 a	0.0 a
Poranek	20ºC	82.0 b	90.7 c	0.7 a	2.4 b	1.7 a	4.7 a	93.7 b	4.3 c
	15ºC	0.0 a	85.0 b	5.7 b	1.0 ab	1.0 a	7.4 a	91.7 b	1.1 b
	10ºC	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	100.0 b	0.0 a	0.0 a
Ryton	20ºC	82.4 b	87.7 b	1.4 a	2.4 a	3.7 b	5.0 a	91.4 b	4.50 c
	15ºC	0.0 a	82.4 b	4.0 a	1.0 a	3.4 b	9.4 b	87.4 b	1.43 b
	10ºC	0.0 a	0.0 a	1.0	1.4 a	0.0 a	97.7 c	2.4 a	0.0 a
Maliniak	20ºC	86.0 b	91.0 c	0.0 a	1.7 a	3.4 a	4.0 a	92.7 b	3.15 c
	15ºC	0.0 a	86.4 b	3.4 b	1.0 a	3.0 a	6.4 a	90.7 b	1.23 b
	10ºC	8.8 a	0.0 a	0.0 a	1.0 a	2.4 a	96.7 b	1.0 a	0.0 a

* Means in the columns followed by the same letter are not significantly different at $\alpha = 0.05$ level according to the Duncan's test.

Table 1

Effect of low temperatures on seed germination of the selected tomato cultivars – part II

Cultivar	Temperature of germination (ºC)	Germination energy (%)	Germination capacity (normal seedlings) (%)	Deformed (abnormal) seedlings (%)	Diseased seedlings (%)	Dead seeds (%)	Healthy ungerminated seeds (%)	Maximum germination (%)	Fresh weight of 100 seedlings (g)
Korsarz	20ºC 15ºC 10ºC	93.7 b 0.0 a 0.0a	96.7 c 91.4 b 0.0 a	0.4 a 2.4 b 6.0 c	0.7 a 3.0 a 3.7 a	1.0 a 2.4 a 2.7 a	1.4 a 1.0 a 87.7 b	97.7 b 96.7 b 9.7 a	4.01 c 1.17 b 0.0 a
Kora	20ºC 15ºC 10ºC	42.4 b 0.0 a 0.0 a	93.7 c 71.7 b 0.0 a	0.0 a 14.4 b 0.0 a	3.7 b 0.0 a 0.0 a	1.7 a 1.0 a 0.0 a	1.0 a 13.0 b 100.0 c	97.4 c 86.0 b 0.0 c	2.77 c 0.64 b 0.0 a
Paw	20ºC 15ºC 10ºC	46.4 b 0.0 a 0.0 a	69.0 c 59.4 b 0.0 a	0.0 a 15.7 b 0.0 a	18.7 b 0.0 a 1.4 a	6.0 b 2.4 a 6.0 b	5.7 a 22.7 b 92.7 c	88.4 c 75.0 b 1.4 a	4.94 c 1.0 b 0.0 a
Bursztyn	20ºC 15ºC 10ºC	74.4 b 0.0 a 0.0 a	87.4 c 80.4 b 0.0 a	1.4 a 7.7 b 0.0 a	0.7 a 0.7 a 0.0 a	6.0 b 2.4 a 1.4 a	4.7 a 12.4 b 98.7 c	89.4 b 85.4 b 0.0 a	4.06 c 1.2 b 0.0 a
Atma	20ºC 15ºC 10ºC	68.4 b 0.0 a 0.0 a	88.4 c 77.4 b 0.0 a	2.7 a 8.7 b 0.0 a	0.7 a 1.0 a 0.7 a	5.0 b 3.0 ab 1.7 a	3.4 a 10.0 b 97.7 c	91.7 c 87.0 b 0.7 a	4.37 c 1.07 b 0.0 a
Sheng Li 919	20ºC 15ºC 10ºC	76.7 b 0.0 a 0.0 a	89.8 c 63.7 b 0.0 a	4.0 b 12.4 c 0.0 a	1.5 a 1.7 a 0.4 a	0.4 a 2.4 b 2.0 b	4.4 a 20.0 b 97.7 c	95.4 c 77.7 b 0.4 a	4.80 c 1.4 b 0.0 a
Ju Huang 83-3	20ºC 15ºC 10ºC	70.7 b 0.0 a 0.0 a	90.7 c 76.7 b 0.0 a	3.7 a 8.7 b 1.0 a	1.0 b 0.0 a 0.0 a	1.0 ab 2.0 b 0.0 a	3.7 a 12.7 b 99.0 c	95.4 c 85.4 b 0.4 a	4.54 c 1.4 b 0.0 a
Bai Guo Quiang Feng	20ºC 15ºC 10ºC	35.7 b 0.0 a 0.0 a	85.4 c 71.7 b 0.0 a	80.7 c 61.7 b 0.0 a	3.4 a 10.0 b 0.0 a	1.4 a 0.0 a 0.0 a	3.4 b 0.0 a 0.0 a	11.4 a 28.4 b 100.0 c	4.4 c 0.97 b 0.0 a

* Means in the columns followed by the same letter are not significantly different at $\alpha = 0.05$ level according to the Duncan's test.