Germination of Watermelon Seeds at Low Temperature

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The Cucurbitaceae comprise more than 700 species of herbaceous crops plants with about 90 genera. They provide vegetables, fruits, oils, and several other useful products. The fruits are a pepo (fleshy berry-like structures with a rind and spongy seed interiors), but sometimes a papery, bladdery pod. The seeds are usually flat and plate-like.

Watermelon (*Citrullus lanatus* (Thumb.) Matsum. and Nakai) was formerly *Citrullus vulgaris*. Commercial cultivars are classified as *Citrullus lanatus* var. *lanatus*, and wild accessions are *Citrullus lanatus* var. *citroides*. It has been cultivated for thousands of years as indicated by the fact that it has a name in Sanskrit. Watermelon is grown throughout the world as a staple food (edible seeds), a dessert food (edible flesh), and for animal feed, although it is primarily eaten fresh. It is also eaten as a cooked vegetable in Africa. In Russia, watermelon is a staple food eaten pickled and used for production of syrup by boiling the sugary flesh. In China, firm-fleshed cultivars are cut into strips and dried for use as pickles or glace candy.

In the U.S., watermelon is a major vegetable crop that is grown primarily in the southern states. The major watermelon producing states in the U.S. are Florida, California, Texas, Georgia, and Arizona. Total area under production in the U.S. in 1998 was 76,629 ha, with a total production of 36,731 Mg (U.S.D.A., 1998).

Early-planted watermelons often have difficulty with seed germination and emergence. Cultivars selected for cold germination ability would provide growers with better stands for crop production.

The seeds of cucurbitaceous crops are non-endospermic and germination is epigeal. Dormancy can be a severe problem in some species. It is comparatively easy to induce dormancy by testing the seeds for germination in unfavorable environments. Ellis et al. (1985) provides specific germination information and test recommendations.

Poor field emergence and erratic stands lead to increased variation in plant development, which can result in yield reductions. The survival and performance of seeds after sowing is affected by physical, mechanical, chemical and biotic factors. Temperature, light, drought, flooding and gaseous environments are physical factors which influence seedling emergence (Khan et al., 1979; Hegarty, 1979; Thomas, 1981). Low temperature after the sowing of many warm-season vegetables can lead to asynchronous seedling emergence (Kotowski, 1962; Thompson, 1974). This asynchrony is consistently observed where spring temperatures fluctuate dramatically.

For crops harvested once-over by machine, non-uniform emergence is of particular concern. Cucurbit seeds require high temperatures for successful germination and seedling emergence (Harrington and Minges, 1954; Hegarty, 1973). For instance, cucumber (*Cucumis sativus* L.) seeds germinated rapidly at 20°C, but the time to 50% germination at 14°C decreased substantially (Simon et al., 1976; Nienhuis et al., 1983), and below 11°C only a small percentage of the seeds germinate (Simon et al., 1976). Germination of watermelon seeds (*Citrullus lanatus* (Thumb.) Matsum. and Nakai) was improved at 15°C after priming with inorganic osmotica (Sachs, 1977). Several treatments of cucumber seeds did not improve germination, however (Staub et al., 1989).

Nilsson (1968) reported that in cucumber there was genetic variation among cultivars for germination at 12, 14, 17 and 23°C, with 'Rhenskdruv', P5261 and 'Favor' best and 'Hokus' and 'Rea' worst. Seget (1966) reported that in two cucumber cultivars at soil temperature below 12°C, depression of emergence was caused mainly by the direct effect of low temperatures of 12 to 16°C on the plants. It was due to mainly to the effect of pathogenic and parasitic micro-organisms. With a prolongation of the low temperature effect, emergence was markedly reduced. Except in extreme cases, the soil moisture content had no significant effect on emergence at low temperatures. Emergence was higher in sterilized than in unsterilized soils, and seed treatment was always beneficial.

Hall et al. (1989) reported that water-imbibed watermelon seeds provided faster crop establishment than dry seeds at temperatures below the optimum (15.7°C). Mozumder et al. (1970) reported that conidia were germinated at three temperatures in media in which available water, expressed as water activity, was controlled at three levels. Rate of germination in the basal medium (0.9964 water activity) was most rapid at 25°C and was inhibited at 15 and 30°C. Lowering the water activity at particular temperatures decreased the rate of germination. However, at a low water activity (0.9778) germination rate was greater at 30 than at 25°C. Thus the effect of temperature on germination appeared to be dependent on the water activity of the medium.

Milotay et al. (1991) reported that the germinating capacity of seeds of 15 cultivars and lines was studied in the laboratory at constant and fluctuating temperatures ranging from 15°C. Temperature affected both the time required to start germination and the initial growth of the seedlings. At 17°C, significant differences among cultivars were found for germination percentage and radicle growth, and starting date was more variable. Germinating capacity decreased drastically with temperature. At 17 to 25°C, a positive correlation was found between 1000-seed weight and germination percentage. Uniform germination could be expected above 17°C, and therefore early sowing in cold soil should be avoided. It was possible to measure the growth rate and calculate vigor by germinating seeds in vertically-placed filter paper rolls.

Jennings and Saltveit (1994) reported that cucumber seeds ('Dasher II' and 'Poinsett 76') were imbibed and germinated at 10 to 30°C, and seeds germinated at 25°C for 24h were chilled at 2.5 for 0 to 144h. Both cultivars responded similarly to the treatments in terms of fresh weight increases, time to radicle emergence and root growth. In comparison, seeds from an aged (1989) lot of 'Poinsett 76' responded very differently from the 1992 seed lots in all experiments. The chilling tolerance levels of germinating 'Poinsett 76' seeds varied with seedling age as measured by resumption of root growth. The results suggest that some factor that confers chilling tolerance is gradually lost during the early stages of germination following imbibition.

Roeggen (1987) reported that cultivars of bean, cucumber and tomato were tested with the aim of finding any differences in minimum germination temperature. A variation in minimum germination temperature from 7.0 to 10.5°C in tomato cultivars. Pesticide treatment of the seeds of the bean cultivar 'Processor' had a restrictive effect on germination.

The objectives of this study were to determine the optimum temperature for testing watermelon seeds for cold germination ability. In addition, we were interested in whether there were genetic differences among cultivars for cold germination ability.

Methods. Two experiments were run, the first to determine the optimum temperature to use for cold germination tests. Four temperatures were used, based on previous experience, and a review of the literature: 10, 14, 18, and 22°C (Table 1). The second experiment was to screen a diverse set of cultivars for germination speed at the chosen temperatures.

For the cultivar experiment, 44 diverse cultivars were chosen (Table 2). Seeds were treated with a fungicide (captan) to prevent surface organisms from rotting the seeds during the test. Germination data was recorded daily. Data were used to calculate percentage germination, actual days to germinate (for seeds that actually germinated), and total days to germinate (for all seeds). For total days to germinate, seeds that failed to germinate by the end of the test (approximately 30 days) were considered to have germinated on the last day.

Seeds were germinated in controlled temperature chambers in the Phytotron at North Carolina State University (Downs and Thomas, 1983). Temperatures were set at 10, 14, 18, or 22°C. Each treatment combination consisted of 10 seeds in one plastic Petri plate (100 mm diameter). Each plate had two pieces of filter paper wetted with 1.5 ml of water (equilibrated to the chamber temperature).

Seeds were placed in the chambers on 13 October (replications 1 to 4) or 7 November (replications 5 to 8) 2000 for the temperature experiment. Seeds were placed in the chambers on 30 October for the cultivar

Table 1. Germination percentage and speed of two watermelon cultivars tested at four temperatures in the growth chamber.[z]

Temperature (°C)	Cultivar name	Days to actual germination	Days to total germination	Percentage germination
10	Charleston Gray	-	-	0
	Petite Sweet	-	-	0
14	Charleston Gray	19.4	26.4	46
	Petite Sweet	19.3	26.8	44
18	Charleston Gray	11.7	15.4	83
	Petite Sweet	11.3	17.7	70
22	Charleston Gray	5.9	10.3	84
	Petite Sweet	8.4	13.6	79
LSD (5%)		*2.2*	*2.6*	*15*
CV (%)		*17*	*12*	*29*
Mean	Charleston Gray	12.3	17.4	71
	Petite Sweet	13.0	19.7	64
Correlation (% germ. vs. days to germ.) = -0.68				
Correlation (days to actual vs. days to total) = 0.91				

[z] Data are means of 2 seeding dates of 4 replications of 10 seeds each, tested for 32 days. Data for 10°C were excluded from the means since there was no germination. Seeds were considered germinated when the radicle emerged 10 mm out of the seed coat. Actual days to germinate was calculated for seeds that actually germinated. Total days to germinate was calculated for all seeds (seeds that failed to germinate by the end of the test were considered to have germinated on the last day).

Table 2. Germination percentage and speed of 44 watermelon cultivars tested at two temperatures in the growth chamber.[z]

	14°C chamber			18°C chamber		
Cultivar	Total	Actual	%	Total	Actual	%
Starbrite	10.8	8.2	90	7.0	5.6	95
Blackstone	14.2	12.9	95	5.6	5.6	100
Crimson Sweet	18.5	10.1	65	5.1	5.1	100
AU-Jubilant	19.1	14.2	75	10.4	6.4	85
Sultan	20.1	8.7	55	5.1	5.1	100
AU-Golden Producer	20.7	14.7	70	5.5	5.5	100
Jubilee	21.4	13.0	60	12.8	5.7	75
Jubilee II	23.7	18.6	70	8.9	6.1	90
Fiesta	24.5	11.0	40	4.4	4.4	100
Dixielee	24.5	10.0	40	9.6	8.5	95
Orangeglo	24.5	10.1	40	18.0	7.1	60
AU-Sweet Scarlet	24.7	13.2	45	7.5	7.5	100
Dixie Queen	24.9	18.8	60	10.2	7.7	90
Sugar Baby	25.8	10.5	35	5.5	5.5	100

Stars-N-Stripes	26.3	12.0	35	8.5	5.6	90
Klondike Striped #11	26.7	12.8	35	5.6	5.6	100
Super Sweet	27.2	11.4	30	7.6	6.2	95
Big Crimson	29.4	18.7	30	5.5	5.5	100
Minilee	30.5	10.8	15	5.6	5.6	100
Desert King	30.6	22.2	20	5.7	5.7	100
Petite Sweet	31.0	23.8	30	22.3	12.7	55
Graybelle	31.4	7.5	10	6.6	5.1	95
Calhoun Gray	31.4	28.4	35	9.6	9.6	100
Calsweet	31.5	28.1	40	5.7	5.7	100
Bush Jubilee	31.5	26.1	35	18.8	13.8	75
Peacock Shipper	31.7	18.3	15	5.6	5.6	100
Kleckley Sweet	32.5	18.5	10	11.4	5.7	80
Sugarlee	32.8	30.1	45	14.1	9.0	80
Regency	32.9	12.0	5	7.2	7.2	100
Peacock WR60	32.9	22.5	10	20.3	12.9	65
Long Crimson	33.0	14.0	5	9.2	6.5	90
Black Diamond YF	33.0	13.0	5	14.5	10.9	85
Sweet Princess	33.4	21.0	5	18.5	13.0	70
Louisiana Sweet	33.7	28.0	5	18.0	15.2	85
Super Gold	33.8	32.8	20	5.4	5.4	100
Tendergold	33.9	33.0	10	8.2	6.9	95
Chubby Gray	33.9	33.0	15	9.6	8.3	95
Black Diamond YB	34.0	33.0	5	5.3	5.3	100
Tastigold	34.0	33.0	5	20.8	10.0	55
Mickylee	-	-	0	5.3	5.3	100
AU-Producer	-	-	0	6.0	4.5	95
Golden Honey	-	-	0	16.8	9.5	65
Yellow Crimson	-	-	0	22.7	14.4	50
Verona	-	-	0	22.9	11.8	50
LSD both temp. (5%)				*4.1*	*3.6*	*8.1*
CV both temp. (%)				*20*	*28*	*31*

Correlation (% germ. vs. days to germ.) = -0.66**
Correlation (days to actual vs. days to total) = 0.79**
Correlation (days to actual at 14°C vs. days to actual at 18°C) = 0.39*
Correlation (days to total at 14°C vs. days to total at 18°C) = 0.40*
Correlation (% germ at 14°C vs. % germ at 18°C) = 0.41*

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[z] Data are means of 2 replications of 10 seeds each, tested for 32 days. Seeds were considered germinated when the radicle emerged 10 mm out of the seed coat. Actual days to germinate was calculated for seeds that actually germinated. Total days to germinate was calculated for all seeds (seeds that failed to germinate by the end of the test were considered to have germinated on the last day).

experiment. The studies were ended after 32 days. Seeds not germinating by day 32 were considered germinated on day 33.

Data were analyzed as means for each treatment combination (petri plate) using the Means, Correlation, and ANOVA procedures of SAS (SAS Institute).

Results. The first experiment was designed to determine optimum temperature for cold germination tests. Maximum germination percentage (84 and 83%) was observed at 22 and 18°C, respectively (Table 1). The minimum germination percentage (44%) was observed at 14°C. In the first experiment, 'Charleston Gray' had 71 % germination compared to 64% for 'Petite Sweet'.

The second experiment was to screen a diverse set of cultivars for germination speed at the chosen temperatures. In this experiment, 44 cultivars were tested at two different temerature, 14 and 18°C in the growth chamber. The maximum germination percentage (100%) was obtained for 17 cultivars: Blackstone, AU-Golden Producer, AU-Sweet Scarlet, Big Crimson, Black Diamond Yellow Belly, Calhoun Gray, Calsweet, Desert King, Fiesta, Klondike Striped II, Mickylee, Minilee, Peacock Shipper, Sugar Baby, Sultan F1, Super Gold, and Crimson Sweet (Table 2). Black Diamond Yellow Belly and Mickylee had high percentage germination (100%) at 18°C, but very low (0 to 5%) at 14°C.

At 14°C, 'Blackstone' and 'Starbrite' had the highest germination percentage (90 to 95%), while the other cultivars were below 80% (Table 2). Low germination percentage at low temperature has been reported in cucumber at 14°C (Harrington and Minges, 1954; Hegarty, 1977).

The watermelon cultivars used in this study were able to germinate at 14°C, but not at 10°C, during the 30 days used for the testing method. Some cultivars germinated rapidly, and with a high percentage at 14°C. If the trait is heritable, it could be transferred into elite cultivars to provide growers with more safety in early spring plantings. Improved cold germination ability may also provide better germination of triploid hybrids.

In the future, a larger collection of germplasm should be screened for germination at low temperature. Also, temperatures between 10 and 14°C should be evaluated to determine whether the best watermelon accessions can germinate below 14°C.

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