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Cardinal Temperatures of *Brassica sp*. and How to Determine It

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ABSTRACT

Cardinal temperatures consist of minimum, optimum and maximum of plant growth, and might be able to be determined by assessing effect of temperature on seed germination. An experiment of seed germination was conducted in laboratory, using thermal gradient plate for ten days. To test hypothesis that rapeseed genotypes vary in their response to temperatures. The design of this experiment was a split plot with four replications. The main-treatments were 14 different temperatures: 0.4°C, 3.3°C, 7.8°C, 11.6°C, 13.3°C, 15.0°C, 16.8°C, 18.3°C, 20.9°C, 21.1°C, 25.6°C, 29.0°C, 33.0°C and 36.3°C. Sub-treatments were 6 brassica genotypes: *Brassica napus* genotypes (Tatyoon and Marnoo); *B. campestris* (Jumbuck and Chinoli B); *B. juncea* (No. 81797 and Zero Erusic Mustard (ZEM) 2). Each treatment was using 50 seeds. Germinations were observed daily for ten days and data were analyzed with regression and correlation. Genotypes responded differently to temperatures with Jumbuck the most sensitive to low temperature with minimum temperature (7.90°C), then respectively followed by Chinoli B (6.36°C), ZEM 2 (4.77°C), Tatyoon (4.63°C), No. 81797 (2.59°C), and Marnoo (1.00°C). For high temperature the most sensitive was No. 81797 with maximum temperature 38.61°C. and then respectively followed by Marnoo (39.76°C), Chinoli B (42.93°C), Tatyoon (43.79°C), Jumbuck (44.58°C) and ZEM 2 (45.88°C). Optimum temperatures were for Jumbuck was 24.56°C, ZEM 2 (26.95°C), Tatyoon (27.12°C), No. 81797 (28.12°C), Chinoli B (29.74°C) and Marnoo (30.48°C).

Key words: cardinal temperature, *Brassica* sp., thermal gradient plate.

INTRODUCTION

Rapeseed (*Brassica sp.*) seeds are very small (±3mg/seed) and reduces their chances of germination at low temperature. And so, low temperature causes late and low seed germination and then causes low plant establishment. Germination percentages vary between genotypes of *Brassica campestris*, but were satisfactory for *B. napus* at all level of temperatures (2° C – 25°C) that have been tested (Anonymous, 1983).

Based on the variability of seed germination for rapeseed at low temperature, Acharya, *et al.*, (1983) conducted an experiment for selection and heritability of rapeseed at 10°C. They found that germination and rate of growth of brassica genotypes, decreased with the decreasing temperature, however, their results were variable in the genotypes (*B. napus* genotypes Midas, Regent and DI-820; *B. campestris* genotypes Torch and Candle) that they used.

The results of such experiments could be used to determine planting time based on the suitability of temperature for the seed to germinate. Besides effects on seed germination, temperature also influences the growth of roots and the hypocotyls and so emergence should be closely correlated with germination response to temperature.

For cotton, Arndt (1945) reported variation of primary roots, hypocotyls length and culture period in response to temperature (10°C-39°C). The optimal temperature for germination of cotton seed within the range of 33°C-36°C, minimal temperature probably about 16°C–17°C and maximal temperature was above 39°C. Cole and Wheeler (1974) showed that speed and percent of germination of cotton seed, with preconditioning in water and gibberellic acid (10^{-3} M), were higher at 30°C than that at 10°C. Then, in 1975 Cole and Christiansen found that cotton seeds with chilling treatment (5°C) for 16 and 32 days were very low in seed viability and germination compared with lower periods.

For soybean, Hatfield and Egli (1974) developed equation for predicting time to 50% emergence as a function of soil temperature and planting depth. They concluded that hypocotyl elongation of soybean was extremely slow at 10°C and the seed did not germinate at 40°C. The maximum rate of hypocotyls elongation was at approximately 30°C. Littlejohns and Tanner (1976) found that there were differences in emergence among soybean cultivars at 10° C, and at seedling stage, cold tolerant cultivars had higher fresh weight at 10°C. Priestley and Leopold (1980) explained that the differences in chilling sensitivity between pea (chilling insensitive) and soybean (chilling sensitive) was not related to the major lipid components of the seed membranes.

In a range temperature of 10°C–24°C, experiment for sugar beet, Cole and and Campbell (1985) found significant differences in vigor indices based on germination among sugar beet cultivars, but below 10°C germination were limited for all cultivars.

Poor emergence of maize in tropical low lands was used by high soil temperature (Riley, 1981). That case was related to the tolerance of the embryo to high temperature (about 37°C).

Blacklow (1972) found that shoot and radicle elongation of corn seedlings were approximately linear function of time, with the greatest growth rate at 30° C and effectively all growth ceased at 9°C and 40°C. Studies of Garcia-Huidubro *et al*. (1982) showed that the cardinal temperatures for germination of pearl millet can be obtained by a linear model of germination rate expressed as the reciprocal of the time to 50% germination versus temperature. The hypothesis in this study, that rapeseed germination also confirms to this model and that it can be used to characterize germination response of rapeseed genotypes to temperature and then for determining the cardinal temperatures of rapeseed.

For lesquerella (*Lesquerella sp*.) the base (minimum) temperature of the dormant seed was < 3°C, but the base temperature of the non dormant seed was > 7°C and the optimal temperature for both seeds was 28°C (Adam *et al*., 2007).

Alvarado and Bradford (2002) observed that both seed germination rates and germination percentages were decreased at temperature above the optimum temperature.

Estimation of cardinal temperature, including base or minimum temperature, optimum temperature and maximum or ceiling temperature is essential because the rates of development increases between base and optimum and decrease between optimum and maximum and ceases below base and above maximum temperature (Shafii and Price, 2001).

The coefficients yielded by the cardinal temperature models, could be used for screening germplasm, for a certain temperature of the field for the crop plantation (Hardegree, 2006).

Cardinal temperatures (base or minimum temperature = Tb, optimum temperature = To and ceiling or maximum temperature = Tc) of seed germination of three medicinal plants: medicinal pumpkin (*Curcubita pepo* convar. *pepo* var *styriaca*), borago (*Borago officinalis* L.) and black cumin (*Nigelia sativa* L.) were found by Ghaderi *et al*. (2008) respectively as follows: Tb = 5.9°C, 5°C and 5°C; To = 37.7°C, 29.9°C and 28.6°C and Tc = 45°C; 39.9°C and 35°C.

Monk *et al.* 2009, found for pasture, that the base temperature was 0°C for all species tested except ripgut with base temperature 4°C and the maximum temperature for all species were ≥ 35°C. Pourreza and Bahrani (2012) found that the cardinal temperatures of milk thistle (*Silybum marianum*) were 1.35°C for the base temperature, 20.51°C for the optimum temperature and 41.81°C for the ceiling temperature.

Cardinal temperatures for germination of three millet specieses (*Panicum miliaceum*, *Pennisetum glaucum* and *Seteria italica*) were found by Kamkar *et al.*(2006) as follows: for *P.miliaceum* Tb = 9.9°C, To = 40.2°C, Tc = 47.8°C; for *P. glaucum*, Tb = 7.7°C, To = 38.9°C, Tc = 46.0°C ; for *S. italica*, Tb = 9.3°C, To = 37.0°C, Tc = 45.0°C.

Since studies on rapeseed germination are still meagre, review of literature is done for various seed germination. By this way various seed germination response to temperature could be compared to each other. So, the principles of seed germination response to temperature could be pointed out and by this way cardinal temperatures of a plant as an importance subject in plant science could be calculated.

MATERIALS AND METHODS

A seed germination experiment was conducted on thermal gradient plate in laboratory for ten days in relation to determine cardinal temperatures for rapeseed. Seeds were placed on three pieces filter paper in petri dishes with diameter 9 cm. Each petri dish contain 50 seeds.

The design of this experiment was a split plot, replicated four times. The main-treatments were 14 different temperatures: 0.4°C, 3.3°C, 7.8°C, 11.6°C, 13.3°C, 15.0°C, 16.8°C, 18.3°C, 20.9°C, 21.1°C, 25.6°C, 29.0°C, 33.0°C and 36.5°C. The sub-treatments were six rapeseed genotypes: *Brassica napus* genotypes Tatyoon and Marnoo; *B.campestris* genotypes Jumbuck and Chinoli B; *B. juncea* selection No. 81797 and Zero Erusic Mustard (ZEM) 2. Germination of the seeds were oberved daily for ten days. Seed was counted as germinated if the length of the radicle has been about 2 mm or more. Germination percentage was calculated based on equation as follows:

$$\frac{\text{No. of seeds that germinated}}{\text{No. of seeds per petri dish}} \times 100\% \quad \text{.....(Eq.1)}$$

To prevent the infestations of fungi, Captan 83% was used with dose 1.25 g Captan/m^2 surface with a concentration of 1.25 g Captan/l of water. Petri dishes were watered as needed to ensure that water was not limiting.

The data was analyses by using linear regression and correlation for each genotype and then cardinal temperatures for each genotype was determined.

RESULTS

The results of this experiment were consisted of cumulative germination, time to 50% germinated, and relationship between rate of germination and temperature.

Cumulative germination percentage. The cumulative germination percentages for the six rapeseed genotypes of ten days are shown in Table 1. The germination percentages at 0.4°C and 3.3°C in this experiment was negligible. From 7.8°C to 36.3°C germination percentage varied among gynotypes. Appreciable germination did not take place until 7.8°C at which Tatyoon reached 91% compared to the local genotype Jumbuck, only 18.62% Tatyoon reached 100% at 11.6°C, but Jumbuck died not reach 100% until at 15°C, with other genotypes being intermediate in response to temperature.

Time to 50% germinated. Time to 50% germinated was used for analyzing the rate of germination (Garcia-Huidubro *et al.*, 1982). This term was used in order to get ample points for the analysis and fit with linear regression model (Little, and Hills, 1978). Variation in time taken for 50% germinated among the six rapeseed genotypes are shown in Table 2, with the local recommended genotype Jumbuck being appreciably slower than the other genotypes tested.

Table 1. Cumulative of seed germination percentages at 10 days of the six rapeseed Genotypes

Temperature	Genotype					
(°C)	Tatyoon	Marnoo	No.81797	ZEM 2	Jumbuck	Chinoli B
0.4	0	0	0	0	0	0
3.3	2.50	0	0	0	0	1.00
7.8	91.00	85.00	80.63	51.61	18.62	56.50
11.6	100.00	99.00	87.50	71.20	66.90	95.50
13.3	100.00	100.00	91.25	82.58	66.90	96.50
15.0	100.00	100.00	91.25	86.94	99.14	97.50
16.8	98.50	99.00	98.13	76.78	88.45	98.50
18.3	100.00	100.00	93.13	92.58	92.76	98.50
20.9	99.50	100.00	98.13	89.52	95.52	100.00
21.1	99.50	99.50	88.13	97.58	87.76	100.00
25.6	99.50	98.50	70.00	81.94	87.07	99.00
29.0	100.00	99.50	61.25	74.84	76.55	99.50
33.0	98.50	98.00	60.63	69.04	55.87	99.00
36.3	79.50	49.50	40.63	38.06	6.90	86.50

Table 2. Time to 50% germinated of six rapeseed genotypes.

Temperature	Time (days) to 50% of seeds germinated for six rapeseed genotypes					
(° C)	Tatyoon	Marnoo	No. 81797	ZEM 2	Jumbuck	Chinoli B
0.4	*	*	*	*	*	*
3.3	*	*	*	*	*	*
7.8	6.81	5.86	7.00	7.89	*	0.21
11.6	4.07	3.60	4.23	5.19	6.70	3.75
13.3	2.52	3.49	3.44	4.54	6.83	3.08
15.0	2.50	2.00	2.60	3.51	4.11	2.00
16.8	1.58	1.86	2.21	3.43	3.87	1.80
18.3	1.58	1.48	2.02	2.73	3.25	1.48
20.9	1.51	1.26	1.72	1.99	2.21	1.20
21.1	1.46	1.46	1.64	1.80	2.46	1.260.80
25.6	1.09	1.40	1.69	1.95	2.14	0.60
29.0	1.00	1.30	1.71	1.88	2.19	0.88
33.0	1.31	1.27	1.82	1.93	3.50	2.26
36.3	3.38	*	*	*	*	*

Note: * = Not germinated or germinated less than 50%.

Relationship between rate of germination and temperature. There was a close relationship between rate of germination and temperature for all genotypes. Those relationships could be modeled as a linear regression of rate of germination versus temperature (able 3).

Table 3. Time to 50% germinated, and germination rate of B. napus genotype Tatyoon at various temperatures

Temperature (°C)	Time to 50% seeds germinated (days)	Germination rate
7.8	6.81	0.147
11.6	4.07	0.246
13.3	2.52	0.397
15.0	2.50	0.400
16.8	1.58	0.633
18.3	1.58	0.633
20.9	1.51	0.662
21.1	1.46	0.685
25.6	1.09	0.917
29.0	1.00	1.000
33.0	1.31	0.763
36.3	3.38	0.296

An example of this relationship for Tatyoon are as follows:

For the lower temperatures regime the equation was:

$Y = -0.199 + 0.052\ X$ with $r = 0.967^{**}$ ..... (Eq.2)

. For the higher temperatures regime the equation was:

$Y = 2.540 - 0.058\ X$, with $r = 0.860^{*}$. ..... (Eq.3)

Where Y = germination rate (1/time to 50% germinated in days), X = temperature (°C), r = Correlation coefficient. From equation (2) for Y = 0, the value of X = 4.63 = Minimum temperature in °C for Tatyoon. From equation (3) For Y = 0 the value of X = 43.79 = Maximum temperature in °C for Tatyoon. To find optimum temperature Eq.2 = Eq.3. So, 0.199 + 0.052 X = 2.540 – 0.058 X, so, X = 27.12 = Optimum temperature in °C for Tatyoon.

By that way cardinal temperatures for all rapeseed genotypes tested were determined. Cardinal temperatures for the six rapeseed genotypes are shown in Table 4.

Table 4. Cardinal temperatures (°C) of six rapeseed genotypes.

Genotype	Cardinal temperature (°C)		
	Minimum	Optimum	Maximum
Tatyoon	4.63	27.12	43.79
Marnoo	1.00	30.48	39.76
No.81797	2.59	28.12	38.81
ZEM 2	4.77	26.95	45.88
Jumbuck	7.90	24.56	44.58
Chinoli B	6.36	29.74	42.93

DISCUSSION

Germination rate of rapeseed increases linearly from minimum temperature to optimum temperature and then decreases linearly from optimum temperature to maximum temperature in accordance with the model of Garcia-Huidubro *et al*. (1982).

There were Variations in response of rapeseed genotypes to low or high .temperature. For example Tatyoon was tolerant to low temperature (Table 1) and ZEM 2 was tolerant to high temperature (Table 4). These characters may be important for breeding purposes, especially for producing seed for areas that pose low or high temperature problems.

Data in Table 4 show that the most sensitive genotype to low temperature was Jumbuck and then followed by Chinoli B, ZEM 2, Tatyoon, No, 81797 and Marnoo respectively. For high temperature the most sensitive was No. 81797 and then respectively followed by Marnoo, Chinoli B, Tatyoon, Jumbuck and ZEM 2. The optimum temperatures of the six rapeseed genotypes vary from 24.56°C up to 30.48°C (Table 4).

These results indicated that genotypes have different response to temperatures besides seed quality might be also as another factor to influent these responses.

CONCLUSIONS AND SUGGESTION

From the results of this study could be pointed out, that the effects of temperature on seed

germination of six rapeseed genotypes as follows: Genotypes had different sensitivity response to temperature. So, their cardinal temperatures also varied. The results of this study confirm theory of Garcia *et al.* (1982), on how to determine cardinal temperature of a plant. For determining cardinal temperatures of a plant, a study on effect of temperature on seed germination could be used due to seed germination is one of the growth phase of a plant.

Genotypes responded differently to temperatures with Jumbuck the most sensitive to low temperature with minimum temperature (7.90°C), then respectively followed by Chinoli B (6.36°C), ZEM 2 (4.77°C), Tatyoon (4.63°C), No. 81797 (2.59°C), and Marnoo (1.00°C). For high temperature the most sensitive was No. 81797 with maximum temperature 38.61°C. and then respectively followed by Marnoo (39.76°C), Chinoli B (42.93°C), Tatyoon (43.79°C), Jumbuck (44.58°C) and ZEM 2 (45.88°C). Optimum temperatures were for Jumbuck was 24.56°C, ZEM 2 (26.95°C), Tatyoon (27.12°C), No. 81797 (28.12°C), Chinoli B (29.74°C) and Marnoo (30.48°C).

From the results of this study could be suggested that further studies should be done to avoid cardinal temperatures of a plant determined by assumption or prediction,

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