EFFECT OF TEMPERATURE ON THE VIABILITY OF BUCKWHEAT (CV. KORA) SEEDS

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Summary. The purpose of this work was to study an influence of temperature (10°C, 20°C, 25°C, 30°C) on germination of Kora variety buckwheat seeds. Temperature plays a significant role in determining the essential parameters of the germination process, such as germination ability and germination speed. Simulation model was used to interpret the experimental results and a growth equation was used for curve-fitting and analysis of germination process. The fitting was obtained for germination temperature 10°C and 25°C.

Key words: buckwheat, germination, temperature, simulation model.

INTRODUCTION

Germination is a specific form of a plant growth process during which the rootlet breaks through the seed coat and the sprout emerges. The beginning of the germination process is conditioned by adequate moisture and temperature levels as well as by access to fresh air. The first two factors play a dominant role because they initiate biochemical reactions conditioning all the life phenomena [Esan 1960, Grzesiuk and Kulka 1981]. Temperature is a key consideration in the process of seed imbibition and germination. Early growth of seedlings is important because seedlings that appear early will dominate those which develop at a later stage, and those differences will deepen with time [Birhuizen 1974, Lack and Evans 2003]. The range of temperatures that support germination covers three cardinal thermal points, namely the minimum and maximum temperature (below and above which germination stops) and the optimum temperature at which the most rapid growth is observed.

Buckwheat is a spring, thermophilous plant species. In wet soil, buckwheat seeds begin to germinate at the temperature of 7-8°C [Hryncewicz 1992]. According to other authors [Grzesiuk and Kulka 1981], buckwheat's minimum germination temperature is 3-5°C. Under field conditions, buckwheat seeds do not germinate at 0 to 4°C [Ruszkowska 1981]. The optimum germination temperature was observed at 25-26°C [Płatek and Oleś 2000, Ruszkowska 1981], while other sources claim that buckwheat growth is most rapid in the temperature range of 20-25°C [Hryncewicz 1992] or 25-31°C [Grzesiuk and Kulka 1981]. The maximum germination temperature for buckwheat is difficult to determine. Some authors claim that the upper temperature threshold falls within the

35-45°C range [Grzesiuk and Kulka 1981], while others point to a maximum of 31°C [Ruszkowska 1981] as seedlings wither and seeds cease to take up water above this temperature limit.

The requirements for evaluating seed germination are set by the International Seed Testing Standards [1995] and Polish Standards [Dorywalski 1964]. One of the main evaluation criteria is viability, namely the seed's ability to go through active and latent development stages. The evaluation process involves the determination of germination capacity by biochemical (biological), biophysical and physiological methods [Grzesiuk and Kulka 1981]. Viability (which is dependent on genotype and storage conditions) is supported by low ambient temperature and the presence of hard seed coats which are impermeable to substances that activate the growth of the seed embryo [Kopcewicz and Lewak 2002].

The objective of this study was to determine the viability of buckwheat (cv. Kora) seeds germinating at various temperatures and to describe the above process mathematically with the application of a simulation model.

MATERIALS AND METHODS

The experimental materials comprised buckwheat cv. Kora seeds harvested in 1993. Seed germination was observed at four temperature settings: 10° C, 20° C, 25° C and 30° C. Every experimental group was represented by 600 seeds sown on Petri dishes lined with filter paper in 6 samples of 100 seeds each. Petri dishes were placed in a thermostatic oven at a stable temperature controlled with the precision of $\pm 1^{\circ}$ C. Prior to seed sowing, Petri dishes and filter paper were sterilized for 30 minutes at 150°C and cooled to 20°C. The germination process took place without a light source. Germinating seeds were counted at intervals of several hours. Seeds which formed sprouts of minimum 1 mm were regarded as sprouted. Filter paper was regularly dampened with distilled water to maintain the desired moisture level.

RESULTS AND DISCUSSION

The germination capacity of seeds is usually determined by physiological methods which are used to observe the germination process under laboratory conditions. Germination capacity Z_k can be expressed as the percentage of seeds which germinate normally under given conditions over a sufficient period of time:

$$Z_{k} = \frac{n}{n_{c}} \cdot 100\%, \tag{1}$$

where: *n* is the number of sprouted seeds, n_c is the total number of seeds. Germination rate E_k , i.e. the percentage of seeds which germinated normally under the set conditions and in a given period of time, usually the moment of the first recalculation of germinating seeds, is described by the following equation:

$$E_{k} = \frac{n(t_{1})}{n_{c}} \cdot 100\%, \tag{2}$$

where: $n(t_p)$ is the number of sprouted seeds during the first recalculation; n_c is the total number of sown seeds. Seed viability may also be expressed by Pieper's coefficient t_p [Duczmal and Tucholska 1994, Grzesiuk and Kulka 1981], i.e. the average time required for one seed to germinate:

$$t_{p} = \frac{\sum_{i=1}^{n} n_{i} \cdot t_{i}}{\sum_{i=1}^{n} n_{i}},$$
(3)

where: n_i is the number of seeds germinating within a given time interval: i=1,2,3,...,n; t_i is the seed germination time. Table 1 presents the values of germination capacity Z_k , germination rate E_k and time t_p , calculated based on the conducted experiment at four temperature settings. The highest germination capacity values at Z_k =91.67% were reported in respect of the group germinating at 10°C, while the lowest germination capacity of Z_k =50% was noted at 30°C (the highest experimental temperature). Similar germination capacity Z_k values of 81.67% and 83.83% were observed at the temperature of 20°C and 25°C, respectively. Germination rate was the highest (E_k =71%) at T=25°C, and the lowest values (E_k = 38.33%) were noted with buckwheat seeds germinating at the temperature of T=30°C. The data on the first sprouts' emergence and time of the experiment are presented in Table 2. The lowest experimental temperature (10°C) significantly prolonged the sprout emergence time (to 57 hours) as well as the time of the entire experiment (268 hours). An increase in temperature decreased the experimental time, which reached 158 hours at 20°C, 131 hours at 25°C, while only 96 hours were needed to germinate the maximum number of seeds (50%) at the temperature of 30°C. The optimum temperature for the germination of buckwheat seeds was 25°C.

T [°C]	Z _k [%]	E _k [%]	t _p [h]
10	91.67	68.17	81.4
20	81.67	63.50	47.7
25	83.83	71.00	33.3
30	50.00	38.33	30.8

Table 1. Germination capacity Z_k , germination rate E_k and average Pieper's coefficient calculated for buckwheat seeds germinating at the temperature of: 10°C, 20°C, 25°C and 30°C

Table 2. T	ime required	for the firs	t sprouts to	emerge	(t_0) and expe	erimental time	(t _e)

T [°C]	t _o [h]	t _e [h]
10	57	268
20	23	158
25	14	131
30	12	96

The time elapsed from the emergence of the first sprouts was significantly shorter (by 9 hours) than the experimental time at the temperature of 20°C, and it was insignificantly longer (by 2 hours) than the experimental time noted at 30°C. Experimental temperature of 30°C stimulated the rate of germination, but it led to a drop in germination capacity values. Figure 1 presents the number of sprouted seeds as a function of time at the temperature of 10°C, 20°C, 25°C and 30°C. The obtained results suggest that germination takes place at various time intervals subject to temperature, and that temperature significantly affects germination capacity.



Fig. 1. Number of sprouted seeds (%) as a function of time (h) at a temperature of 10°C, 20°C, 25°C and 30°C

The germination process was described mathematically with the use of a simulation model [Gładyszewska and Koper 2002a, Gładyszewska and Koper 2000b, Gładyszewska 1998] based on the assumption that germination has three distinctive stages: physical, biochemical and physiological. It was assumed that the germination process involves gradual evolution through the successive stages at a given level of probability. In its analytical form, the model can be expressed by the following equation:

$$n(t) = n_{k} \cdot \left(1 - \frac{\alpha \cdot e^{-\lambda_{2}(t-\alpha_{0})} + \beta \cdot e^{-\lambda_{2}(t-\alpha_{0})} + \gamma \cdot e^{-\lambda_{3}(t-\alpha_{0})}}{\alpha + \beta + \gamma}\right), \tag{4}$$

where:

 $\begin{aligned} \alpha &= \lambda_2 \cdot \lambda_3 \cdot (\lambda_2 - \lambda_3), \\ \beta &= \lambda_3 \cdot \lambda_1 \cdot (\lambda_3 - \lambda_1), \\ \gamma &= \lambda_1 \cdot \lambda_2 \cdot (\lambda_1 - \lambda_2). \end{aligned}$

Parameters λ_{p} , λ_{z} , λ_{z} indicate the probability of the seed's transition from one development stage to another; n(t) is the number of seeds sprouted at a given time; n_{k} is the final number of sprouted seeds; t – is the germination time (h); t_{0} – is the time required for the seed to emerge from the latent development stage and to enter the sprout formation stage.

Table 3. Parameters for fitting the simulation model to experimental pointsat a temperature of 10°C, 20°C, 25°C and 30°C

Simulation model					
T [°C]	λ_1	λ_2	λ ₃	t _o [h	n _k
10	0.06	0.84	0.88	57.4	540
20	0.06	0.82	0.86	23.8	490
25	0.14	0.46	0.48	15.0	503
30	0.07	0.4	0.45	12.2	300



Fig. 2. Experimental germination curves (o) and model curves (-) determined based on the simulation model at a temperature of a) 10°C, b) 20°C, c) 25°C, d) 30°C

Table 3 presents the parameters for fitting simulation model curves to experimental data. Figure 2 suggests that the simulation model is a highly accurate tool for describing the experimental curves.



Fig. 3. Changes in "emergence time" values subject to germination temperature.



Fig. 4. Final number of sprouted seeds as a function of temperature

The final number of sprouted seeds as a function of temperature, as presented in Figures 3 and 4, leads to a number of observations. The average time required for the seed to emerge from the latent development stage (calculated based on a simulation) decreases with an increase in germination temperature. The longest time (54.4 h) was reported at the temperature of 10°C, and the shortest (12.2 h) – at 30°C. A rapid drop in "emergence time" values was noted in the temperature range of 10°C-20°C (Fig. 3), implying that an increase in temperature stimulates the germination process. Changes in the final number of sprouted seeds as a function of temperature are presented in Figure 4. The highest number of sprouted seeds was noted in the experiment conducted at 10°C. The number of seeds decreased with an increase in temperature, reaching the lowest value at 30°C.

CONCLUSIONS

The following conclusions can be drawn from an analysis of experimental results:

1. Temperature contributes significantly to the germination process.

2. The highest germination capacity (Z_k =91.67%) was reported with seeds germinating at the temperature of 10°C, and the lowest values (Z_k =50 %) were noted at 30°C.

3. The optimum temperature for buckwheat seed germination is 25°C.

4. The temperature of 30°C significantly shortens seed germination time, but it has an adverse effect on germination capacity and the rate of germination.

5. Simulation models are a highly accurate tool for describing experimental points at four germination temperature levels.

6. The best fitting between the simulation curve and the experimental curve was reported at the temperature of 10° C and 25° C.

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WPŁYW TEMPERATURY NA ŻYWOTNOŚĆ NASION GRYKI ODMIANY KORA

Streszczenie. W pracy przedstawiono wyniki badań nad wpływem temperatur: 10°C, 20°C, 25°C i 30°C na żywotność nasion gryki odmiany Kora. Na podstawie otrzymanych wyników stwierdzono, że w zależności od temperatury kiełkowanie nasion przebiegało w różnych przedziałach czasu, a zdolność i szybkość kiełkowania była w dużym stopniu od niej zależna. Krzywe doświadczalne otrzymane na podstawie eksperymentu opisano za pomocą modelu symulacyjnego. Najlepsze odwzorowanie punktów uzyskano w doświadczeniu prowadzonym w temperaturze 10°C i 25°C.

Słowa kluczowe: gryka, kiełkowanie, temperatura, model symulacyjny.