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# THE INFLUENCE OF TEMPERATURE ON VARIOUS FIELD CROPS SEEDS GERMINATION

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***Abstract***

*The quality control of the biological material is done systematically through analyses: genetic, physical, physiological and the sanitary conditions, as well as regarding to respect the quality parameters standards. Depending on testing results, the seeds are or not accepted for sowing. The influence of environmental factors on seeds germination for sowing is very important. The temperature influences the activity of involved enzymes in seeds germination metabolism. The minimum, optimal and maximum temperatures differ from one species to another, so this must be taken into account when it is organizing the seeds sowing. The purpose of this paper is to present results of the temperature influence on the seeds germination for sowing, for 10 field crops species, as follows: Triticum aestivum, Hordeum vulgare, Hordeum distichon, Zea mays conv. dentiformis, Zea mays conv. sacharata, Sorghum bicolor var. eusorghum, Brassica napus spp. oleifera. Helianthus annuus, Lupinus albus and Cicer arietinum, from the profile market. The influence of temperature on the germination process showed that there were normal seedlings, which are taken into account to express germination, but there were also abnormal seedlings or dead seeds (that did not germinate). Thus, at exposure for one hour at temperature of 40°C, for the species such as: Triticum aestivum, Hordeum vulgare, Hordeum distichon, Brassica napus ssp. oleifera, germination was reduced with 10-25%. In the experiment with exposure for one hour at temperature of -7°C, the species such as: Helianthus annuus or Lupinus albus, completely lost their ability to germinate.*

***Key words****: field crops, seeds germination, seeds quality, sowing, temperature.*

## INTRODUCTION

Investments in competitive agriculture, increased productivity and high yields can be optimized by farmers' access to high quality seeds for agricultural crops (Balafoutis et al., 2017). The seed is the foundation of the crops, therefore the importance of its quality is decisive in order to obtain a good result from the quantitative and qualitative of production. Seed is the most important natural factor for increasing yields and represents the natural way of transmitting the plants characters from one generation to another, being considered the basis of plant life and the most important link for starting a new cycle production (Bewley et al., 2014). In the embryo, the seed holds a number of valuable components that together with the characteristics of species and sanitary conditions must ensure in the field a uniform emergence and rapid growth of vigorous, healthy plants capable of producing high-yield crops.

In Romania, the Ministry of Agriculture and Rural Development through the Central Laboratory for Quality Seeds and Planting Material and through the Territorial Inspectorates for Seed and Planting Quality certifies batch identity seeds in the field and laboratory testing of the quality of seeds used for sowing, as well and the authorization of economic operators to carry out these specific activities. According to the Romanian legislation in force (Law No. 266/2002 (r2) on production, processing, control and quality certification, seed marketing and planting material, as well as testing and registration of plant varieties, republished in 2014) seed is defined as any material for reproduction or planting: seeds, fruits, planting material produced by any method of propagation, intended for multiplication or for the production of food or industrial consumption.

The certification of the seeds quality for sowing is carried out in the framework organized by the specialized and accredited Laboratories for this purpose by the Romanian Ministry of Agriculture and Rural Development. These Laboratories perform control and verification operations in the main phases of the multiplication process, conditioning, packaging, labelling and sealing of seeds for sowing and ensure that products, processes and services comply with specific official technical rules and regulations.

Food and Agriculture Organization (FAO) in 2011, in "Seeds in Emergencies: a technical handbook" stated that seed testing provides essential information for determining the quality of a shipment of seed and comprises such parameters as germination, physical purity and moisture content. This ensures that it meets the technical specifications of the order and that quality seed is being provided to vulnerable farmers (FAO, 2011). Seed growers need to be aware of the requirements and the technical regulations necessary for the production of a crop intended for obtaining certified seed and to ensure that all operations are carried out strictly in accordance with the specific regulations and in a timely manner.

In this context, seed germination is defined as the test that determines the maximum germination potential of the seeds in the seed lot, which can be used to compare the quality of different lots and also to assess the sowing value in the field (www.incs.ro/activitate.htm).

The ability to germinate can be influenced by a number of factors related to, among others, the genetics and purity of the species tested, the health of the crop from which the seeds come, the harvesting technology, but also by factors such as humidity and temperature, from the moment the seed is sown (Kameswara Rao et al., 2017).

The temperature is one of the main factors conditioning the seeds germination process (Oliveira et al., 2020). It affects the water absorption rate and the biochemical reactions that control germination, influencing both the germination percentage and its speed index. In general, species demonstrate physiological variations when exposed to different temperatures, and for this very reason evaluating this germination aspect is important (Filho, 2017; Araújo et al., 2016). Temperature is one of the primary factors affecting the percentage and speed of germination, which directly works via seed imbibition and the biochemical reactions that regulate the metabolism involved in the germination process (Filho, 2017). The correct assessment of the resistance of plants to high temperatures is particularly important for the rational use of varieties and hybrids, as well as optimization methods for selecting valuable genotypes. This task is becoming more and more important in connection with the danger of global warming.

Therefore, the purpose of this paper is to demonstrate the influence of temperature on seeds germination belonging to different crops.

## MATERIALS AND METHODS

The present experiment of the influence temperature on the seeds germination included the following crops: winter wheat (*Triticum aestivum*), 6-row barley (*Hordeum vulgare*), 2-row barley (*Hordeum distichon*), maize (*Zea mays* conv. *dentiformis*), sweet maize (*Zea mays* conv. *sacharata*), sorghum (*Sorghum bicolor* var. *eusorghum*), sunflower (*Helianthus annuus*), *rape seed* (*Brassica napus* spp. *oleifera*), white lupines (*Lupinus albus*) and chickpeas (*Cicer arietinum*), from the profile market.

The experiments were carried out in the period 2020-2021, within the Field Crops Production Laboratory, Faculty of Agriculture, University of Agronomic Sciences and Veterinary Medicine of Bucharest.

The sampled seeds were stored at a temperature of 10-12°C until the date of the experiment and they were produced in 2020. The experiment started after minimum 3 months after harvesting of each species.

Temperature, like the other factors influencing the seeds germination, acts within intervals of minimum, optimal and maximum, different for each plant species, variety or hybrid.

To achieve the proposed objective, the seeds germination was tested at different temperature conditions, as follows: minimum germination of each species; optimum temperature

(20-22°C); one hour exposure to thermal shock of -8ºC, then germination at optimum temperature; one hour exposure to thermal shock of +40ºC, then germination at optimum temperature.
In Table 1, it is included the requirements for the minimum germination temperature and the European standards regarding the germination, for the commercialization of the certified seed.

Table 1. Minimum germination temperature (ºC) and Germination Standards (% of pure seeds) (according the Council Directive of 14 June 1966 on the marketing of cereal seed (66/402/EEC) and Council Directive 2002/57/EC of 13 June 2002 on the marketing of seed of oil and fibre plants)

| Species | Minimum germination temperature (ºC) | Standards of minimum germination (% of pure seed) |
|---|---|---|
| *Triticum aestivum* | 1-3 | 85 |
| *Hordeum vulgare* | 1-3 | 85 |
| *Hordeum distichon* | 1-3 | 92 |
| *Zea mays* conv. *dentiformis* | 8-10 | 90 |
| *Zea mays* conv. *sacharata* | 8-10 | 90 |
| *Sorghum bicolor* var. *eusorghum* | 11-13 | 85 |
| *Helianthus annuus* | 6-8 | 85 |
| *Brassica napus ssp. oleifera* | 1-3 | 85 |
| *Cicer arietinum* | 2-4 | 80 |
| *Lupinus albus* | 2-5 | 80 |

The germination substrate was filter paper. Other tools were: Petri dishes, paper towels, labels, tweezers, thermometer, distilled water, germinator, airtight seed containers, magnifying glasses and tweezers. The germination substrate was kept at sufficient humidity without excess. In order to maintain optimum humidity and to avoid further wetting, which can lead to further variation in results, the relative humidity of the air surrounding the seed has been kept as close to saturation as possible. Distilled water was used.
For wheat, barley, rapeseed, sorghum, were counted 4 replications of 100 seeds and for the rest of species with 50 seeds.
Germination test results fall into at least four major categories: normal seeds/seedlings that will develop into healthy plants and all other seeds/seedlings that include abnormal seedlings, dead seed and hard seed (FAO, 2011). Normal seedlings possess the essential structures that are indicative of their ability to produce a normal plant under favourable conditions. These seedlings possess a normal and healthy shoot (hypocotyl, cotyledons or epicotyl) and root (primary and secondary). Abnormal seedlings will not eventually develop into a healthy plant. Abnormal seedlings are all those that cannot be classified as normal. They often lack a shoot and/or a root. Dead seeds are those that absorb water, decay and will not produce a seedling during the germination test. Since these are seeds that do not absorb water, they do not swell and do not start the germination process. This is a problem with a limited number of species that include some legumes.
Germination results are percentage reported in germination capacity of normal seedlings, based on the average of the four replications of 100 seeds. Germination capacity means the percentage of the pure seed with the ability to germinate and that can develop into normal seedlings in 7-8 days, under appropriate conditions of optimum moisture, temperature and light. Germination energy is expressed by the percentage of germinated seeds in a period equal to 1/3-1/2 of the duration established for the germination capacity.
During the experiments, observations were made 3 days after germination of the seeds, to determine the germination energy, at optimal conditions. After 7 days to determine the germination capacity in all experiments.
Seeds were considered to be germinated when the tip of the radical (2 mm) had grown free of the seed coat (Auld et al., 1988).
The Germination Percentage (G%) was calculated by the following formula as described by Association of Official Seed Analysis (AOSA, 1990): Germination percentage (G%) = (Germinated seeds/Total seeds) x 100 and Germinative Energy = (Seeds count on $4^{th}$ day/Total seeds) x 100 (Ikram et al., 2014).

## RESULTS AND DISCUSSIONS

The seeds quality intended for sowing is determined by a whole chain of factors, such as: natural environment conditions, cultivation works, maintenance works, seeds harvesting, conditioning, packaging, storage and marketing. From the moment the seed is received for official testing, it acquires a special biological value, attested by a quality certificate, and finally it acquires an economic value that ensures the economic efficiency that keeps visible any production activity.

**Results for seed germination under minimum germination temperature conditions.** In order to comply with the working protocol, each species was tested according to the minimum germination temperature of EU Council Directives 2002/57/EC and 66/402/EC.

If sowing takes place earlier, the seeds are soaked in water and cannot germinate due to too low a temperature, thus becoming a favourable environment for the development of pathogens and pests, producing uneven and hollow emergence.

If sowing takes place later, moisture can be lost from the surface layer of the soil, which can lead to an uneven and hollow emergence, and on the other hand, the vegetation is delayed, the plants reaching maturity later.

For the success of crop, it is especially important to sow when the minimum germination temperature is reached in the soil.

According to the data in Table 2, all the seeds had the germination capacity over standards minimum germination, except for the chickpea in which no seed germinated even after 8 days.

The best value was determined for 2-row barley (98%), both for germination energy and for germination capacity, where the standard shows that the germination energy must be over 92%.

Tao et al., in 2016, show that final germination of all these varieties of rape seeds was more than 98% and time to final germination was less than 3 days at 23ºC (Tao et al., 2018).

At the seeds of wheat, barley and rapeseed at the minimum germination temperature, the germination energy of 80% and the germination capacity of 91% were obtained. Of the four replications 2-9 seeds did not germinate.

In the case of thermophilic species (maize, sorghum, sunflower) the germination energy was lower (57-68%) than in the winter species, and in the case of lupine the germination energy was about 50%.

For the chickpea seeds no germinating were registered.

Abnormal seedling has also been obtained from sunflower and maize seeds, respectively 1 abnormal seedling. Also, the number of dead seeds ranged from 2-9 (Table 2).

Table 2. Seed germination results under minimum germination temperature

| Species | Minimum germination temperature (ºC) | Germination Energy (after 3 days) (%) | Normal seedlings (number) | Abnormal seedlings (number) | Dead seeds (number) | Hard seeds (number) | Germination Capacity (after 7 days) (%) |
|---|---|---|---|---|---|---|---|
| *Triticum aestivum* | 1-3 | 87 | 97 | 0 | 5 | - | 97 |
| *Hordeum vulgare* | 1-3 | 81 | 91 | 0 | 9 | - | 91 |
| *Hordeum distichon* | 1-3 | 98 | 98 | 0 | 2 | - | 98 |
| *Zea mays* conv. *dentiformis* | 8-10 | 62 | 42 | 1 | 7 | - | 94 |
| *Zea mays* conv. *sacharata* | 8-10 | 68 | 48 | 0 | 2 | - | 96 |
| *Sorghum bicolor* var. *eusorghum* | 11-13 | 65 | 95 | 0 | 5 | - | 95 |
| *Helianthus annuus* | 6-8 | 57 | 47 | 1 | 2 | - | 94 |
| *Brassica napus* ssp. *oleifera* | 1-3 | 83 | 93 | 3 | 3 | - | 93 |
| *Cicer arietinum* | 2-4 | 0 | 0 | 0 | 0 | 50 | 0 |
| *Lupinus albus* | 2-5 | 52 | 42 | 0 | 0 | 8 | 84 |

**Results for seed germination under optimum germination temperature conditions.** At the optimum temperature, which is about 20-22ºC for all species, germination energy was observed about 1-3 days after germination (Table 3). The results showed that the optimal temperature can influence the duration of germination by comparison with the minimum germination temperature, respectively reduces germination time by about 2-3 days. Seed germination proceeds most rapidly at the temperature of 20-22°C.

After 3 days, the germination energy was between 71 and 94%, compared to the result obtained at minimum temperature, when after 3 days, only 2-row barley germinated over 98%.

For this experiment, germination values were obtained above the limits of the EU standards, which proves that the seeds meet the commercial standards as certificated seeds for sowing. The best value was obtained in wheat, on average 99%. Also, legumes have the hard seeds, 50 for chickpea and 8 of lupine.

Table 3. Seed germination capacity results under optimum germination temperature

| Species | Germination Energy (after 3 days) (%) | Normal seedlings (number) | Abnormal seedlings (number) | Dead seeds (number) | Hard seeds (number) | Germination Capacity (%) |
|---|---|---|---|---|---|---|
| *Triticum aestivum* | 87 | 99 | 0 | 1 | - | 99 |
| *Hordeum vulgare* | 81 | 94 | 0 | 6 | - | 94 |
| *Hordeum distichon* | 98 | 98 | 0 | 2 | - | 98 |
| *Zea mays* conv. *dentiformis* | 82 | 48 | 0 | 4 | - | 96 |
| *Zea mays* conv. *sacharata* | 88 | 49 | 0 | 2 | - | 98 |
| *Sorghum bicolor* var. *eusorghum* | 85 | 97 | 0 | 3 | - | 95 |
| *Helianthus annuus* | 87 | 49 | 2 | 0 | - | 98 |
| *Brassica napus* ssp. *oleifera* | 83 | 96 | 0 | 4 | - | 93 |
| *Cicer arietinum* | 0 | 0 | 0 | 0 | 50 | 0 |
| *Lupinus albus* | 84 | 44 | 0 | 0 | 8 | 84 |

**Results for seed germination under one hour exposure to thermal shock of –8ºC, then germination at optimum temperature.** In this experiment, at low temperatures, it observed that the low temperature above –8ºC influences the seeds germination of all species. Thus, among the species, the most resistant proved to be wheat, which had a germination energy of 80%, followed by barley of beer and for forage and lupine, with a germination energy of 60%. The other values were between 30 and 50% (Table 4). Also, the number of deeds seeds was very high, especially for sorghum where the lowest germination of only 35% was recorded. In general, winter cereals and rapeseeds have not been affected by low temperatures, which demonstrate their ability to adapt to very low winter temperatures.

Table 4. Seed germination capacity results under one hour exposure to thermal shock of –8ºC, then germination at optimum temperature

| Species | Germination Energy (after 3 days) (%) | Normal seedlings (number) | Abnormal seedlings (number) | Dead seeds (number) | Hard seeds (number) | Germination Capacity (%) |
|---|---|---|---|---|---|---|
| *Triticum aestivum* | 80 | 95 | 0 | 5 | - | 95 |
| *Hordeum vulgare* | 60 | 90 | 0 | 10 | - | 90 |
| *Hordeum distichon* | 61 | 92 | 0 | 8 | - | 92 |
| *Zea mays* conv. *dentiformis* | 50 | 25 | 0 | 25 | - | 50 |
| *Zea mays* conv. *sacharata* | 30 | 29 | 0 | 21 | - | 48 |
| *Sorghum bicolor* var. *eusorghum* | 40 | 35 | 0 | 65 | - | 35 |
| *Helianthus annuus* | 30 | 35 | 0 | 15 | - | 70 |
| *Brassica napus* ssp. *oleifera* | 30 | 89 | 0 | 11 | - | 89 |
| *Cicer arietinum* | 0 | 0 | 0 | 0 | 50 | 0 |
| *Lupinus albus* | 60 | 44 | 0 | 0 | 6 | 44 |

**Results for seed germination under one hour exposure to thermal shock of +40ºC, then germination at optimum temperature.** It can be appreciated that the high temperature influenced both the germination energy and the germination capacity.

Thus, in the case of lupine, the germination energy was 0%.

The most resistant proved to be wheat and rapeseed, which kept their germination unchanged even in these conditions, 95%, respectively 93%.

It is noteworthy the chickpeas, which in the other cases had a germination of 0, in the case of the shock of +40ºC had a germination of 70%. In the case of the other species it is found that there have been decreases in the value of germination being 10-20% below the standard. Also, 2-row barley has lost its germination energy by about 53% in case of exposure to high temperature. This shows that the embryo suffers from drying temperatures above +40ºC (Table 5).

Table 5. Seed germination capacity results under one hour exposure to thermal shock of +40ºC, then germination at optimum temperature

| Species | Germination Energy (After 3 days) (%) | Normal seedlings (number) | Abnormal seedlings (number) | Dead seeds (number) | Hard seeds (number) | Germination Capacity (%) |
|---|---|---|---|---|---|---|
| *Triticum aestivum* | 75 | 95 | 0 | 5 | - | 95 |
| *Hordeum vulgare* | 40 | 80 | 0 | 20 | - | 80 |
| *Hordeum distichon* | 34 | 78 | 0 | 22 | - | 78 |
| *Zea mays* conv. *dentiformis* | 70 | 38 | 0 | 12 | - | 76 |
| *Zea mays* conv. *sacharata* | 22 | 32 | 0 | 18 | - | 64 |
| *Sorghum bicolor* var. *eusorghum* | 40 | 70 | 0 | 30 | - | 70 |
| *Helianthus annuus* | 40 | 22 | 0 | 28 | - | 44 |
| *Brassica napus* ssp. *oleifera* | 40 | 80 | 0 | 20 | - | 93 |
| *Cicer arietinum* | 20 | 35 | 0 | 0 | 15 | 70 |
| *Lupinus albus* | 0 | 40 | 0 | 0 | 10 | 80 |

## CONCLUSIONS

The experiments showed the major importance of temperature to seeds germination of 10 different field crops species: wheat, 2-rows barley and 6-row barley, maize and sweet maize, sorghum, sunflower, rapeseed, lupine and chickpea.

Of all the species, wheat seeds performed best, regardless of the temperature to which they were subjected, and maintained a germination capacity of over 95%. By comparison, chickpea has a good germination at shock thermic with high temperature, over +40ºC, and in the case of the other cases (minimum and optimal temperature) it did not manifest its germination capacity, the germination being 0%. In this case, it can be argued that sometimes legume seeds need a thermal shock to get out of the dormant phase to germinate. At the opposite pole, lupine lost its germination energy under the conditions of high temperature.

The other species were affected by both high and low temperatures, losing their germination capacity by about 20-30% than in optimal or minimum temperature conditions.


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## REFERENCES


Araújo, A.M., Assis, L.C., Nogueira, W.N., Freitas, R.M.O., Torres, S.B. (2016). Substrates and temperatures for the germination of seeds of *Senegalia tenuifolia* (L.) Britton & Rose. *Revista Caatinga, 29(1),* 113–118.

Association of Official Seed Analysis. (1990). https://www.nist.gov/system/files/documents/2017/04/28/11-appd-11-hb133-final.pdf.

Auld, D.L., Bettis, B.L., Crock, J.E., Kephart, K.D. (1988). Planting data and temperature effects on germination and seed yield of chickpea. *Agron J. 80(6),* 909–914.

Balafoutis, A., Bert, B., Fountas, S., Vangeyte, J., Van Der Wal, T., Soto Embodas, I., Gomez Barbero, M., Barnes, A., Eory, V. (2017). Precision Agriculture Technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability, (8), JRC106659,* 1339.

Bewley, J.D., Bradford, K., Hilhorst, H., Nonogaki, H. (2014). Seeds: Physiology of Development, Germination and Dormancy. *3rd ed. Plenum Press: New York,* USA.

Council Directive of 14 June 1966 on the marketing of cereal seed (66/402/EEC).

Council Directive 2002/57/EC of 13 June 2002 on the marketing of seed of oil and fibre plants.

FAO (2011). Seeds in Emergencies: a technical handbook.

Filho, M. J. (2017). Fisiologia de sementes de plantas cultivadas. *2nd ed. Londrina: ABRATES.*

Ikram, R.M., Tanveer, A., Ata, Z., Saqib, M. (2014). Dormancy studies on *Euphorbia dracunculoides* and *Astragalus* spp.: major weeds of arid areas. *Planta Daninha*, *32*(4), 747–753.

Kameswara Rao, N., Dulloo, M.E., Engels, J.M.M. (2016). A review of factors that influence the production of quality seed for long-term conservation in genebanks. *Genet Resour Crop Evol*.

Ministry of Agriculture and Rural Development of Romania (2014). Law No. 266/2002 (r2) on production, processing, control and quality certification, seed marketing and planting material, as well as testing and registration of plant varieties, republished in 2014.

Oliveira, A.K.M., Fernandes, R.M., Abreu, C.A.A., Pina, J.C. (2020). Effect of different temperatures on the germination of *Callisthene major* (*Vochysiaceae*). *Floresta e Ambiente 2020b*; 27(1): e20170854.

Tao, L., Mengzhu, X., Mohammad, N. K., Liyong, H., Zhenghua, X. (2018). Estimation of Base Temperature for Germination of Rapeseed (*Brassica napus*) using Different Models. *Int. J. Agric. Biol.*, *20.* 524–530.