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EVALUATION OF THE MOISTURE CHANGE ABILITY OF SELECTED CROP SEEDS

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ABSTRACT

The objective of the paper was to investigate the moisture change ability of bean, broad bean, pea, lupine, radish, beetroot, winter wheat, maize, cucumber, pumpkin and sunflower seeds. Seeds absorbed water in the system for measurement of the water absorption kinetics with the capillary and weighting method. The research results were presented in the form of plots of the relation of kinetics of the moisture change of seeds in the time for the first and second stage of the process which precedes germination. Moreover, the water content in seeds for the time of the end of the second stage of water absorption was determined and the maximum water absorption speed coefficient and the time of its obtaining was calculated. The water content for the end of the 2nd stage of its collection was the highest for seeds which include a hard caryopsis and for broad bean plant seeds. The maximum water absorption speed coefficient was the highest for seeds with low initial moisture - radish, beetroot, cucumber and pumpkin. The measurement of the water absorption speed with the use of the capillary and weighting method enabled investigation of seeds with a varied size, construction of a seed coat and chemical composition for a long period of time to the moment seedlings were obtained.

Introduction

In the environment, water occurs in three physical states: volatile (gas) solid and liquid. Water is one of the basic components of living organisms (Grzesiuk and Kulka, 1981). It may occur in the form of real, colloidal solutions, suspensions and as water related to various substances whose distribution in caryopisis may be investigated with non-invasive methods NMR (Lukas et al., 2007) and MR imaging (Horrigane et al., 2013). In the air-dry caryopses the water level is recognized as an organized system which combines biopolymers, cytomembrane, proteins and polysascharides with variety of caryopsis capillars (Reichert, 2003).

In the process of water penetration, three stages may be distinguished ((Milthorpe et al., 1979; Grzesiuk and Kulka, 1981; Kopcewicz et al., 2002).

Testing the process of moisture change during water absorption by seeds takes place for various temperatures (Resio et al., 2005) in order to investigate the structure of seeds, fissures and damages (Genkawa et al., 2011) often with a description of the process with the use of mathematical models (Miano et al., 2015). Usually two methods of water absorption are applied − through a contact of seeds with a moist base (the so-called matri-conditioning), at a full air access for seeds soaked in water without air access (the so-called hydro-conditioning). A common feature of these treatments is subjecting seeds to the process of expanding during which they have a direct contact with water (Grzesik and Nowak, 1998; Grzesik and Janas, 2011; Grzesik et al., 2011; Kubala et al., 2013ab; Nawaz et al., 2013). Unfortunately, these methods are not precise enough, which may cause many measurement errors (Verma et al, 1999; Maskan, 2001; Bello et al., 2004).

The objective of the paper

The objective of the paper was application of a capillary and weighting method for the measurement of the changes in the moisture level of crop seeds which differ with the structure of a seed coat, size and chemical composition and for determination of the sizes which characterize the process.

Materials and methods

Measurements were carried out for seeds: spring wheat ‘Pasteur’ cultivar, beetroot ‘Czerwona kula' cultivar, radish ‘Carmen’ cultivar, triticale ‘Fidelio’ cultivar, broad bean ‘Dragon’ cultivar, bean ‘Aura’ cultivar, yellow lupine ‘Taper’ cultivar, pea ‘Brutus’ cultivar, sunflower, giant pumpkin ‘Amazonka’ cultivar, cucumber ‘Rufus’ cultivar and corn ‘Handle F1’ cultivar. The research was carried out in the water absorption system with the capillary and weighing method (Kornarzyński et al., 2000, 2002a, 2002b) in the temperature 20ºC, the schematic representation in fig. 1.

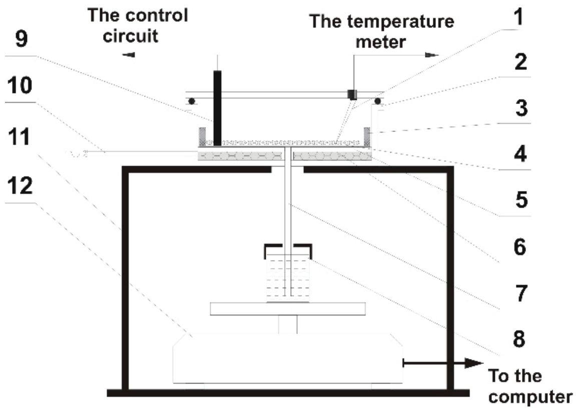

Figure 1. Schematic representation of the measurement system: 1 – thermocouple, 2 – thermostatic container with seeds, 3 – form with seeds, 4 – seeds, 5 – blotting paper mounted to the form, 6 – heater, 7 – capillary, 8 – water container, 9 – Pt–100 sensor, 10– heaters supply, 11– table, 12 – electronic weight

The capillary and weighting method consisted in registering the change of water mass in a standing beaker on the scales. Water collected by seeds was registered with electronic scales, which after connection to a computer collected measurement data in cycles for a long period of time which lasts even to several days. Schematic representation of the measuring system is presented in figure 1. Seeds were placed in a tight, thermostatic container (2) where a constant temperature was ensured by a thermostat control RE65A215 which supplies a heater (6) and cooperates with a sensor Pt–100 (9). A blotting paper (5) placed in the bottom part of the container strictly adhered to the bottom of the container, to which a glass capillary (7) with a diameter φ_{wewn} = 1.0 mm sticking to the bottom of the container, where temperature was measured with the use of a thermocouple (1). The second end of the capillary was in the water container (8) which rested on the electronic scales WPS 360/C (12) which weighted with a precision of 0.001 g connected to a computer which collected measurement data with the use of WAGAWIN program (RADWAG).

The change of the water content in a sample ΔZ_K for k-measurement in specific time t was calculated from the relation:

$$\Delta Z_K = \frac{(m_{PW} - m_{KW}) - m_{PAR}}{m_{PZ}} \tag{1}$$

where:

m_{PW} – initial weight of water in a beaker in the moment of starting the measurement, (kg)

m_{KW} – water weight in a beaker for k-measurement, (kg)

m_{PZ} – initial weight of a seed in the moment of starting measurements, (kg)

m_{PAR} – water mass, which evaporated from the beaker through a ring container in a cover (kg), was measured and accepted: $\Delta m_{PAR} = 50\ \mathrm{mg \cdot h^{-1}}$

Coefficient of water absorption speed S_K was determined from the following equation:

$$S_K = \frac{\Delta Z_K}{\Delta t_K} \tag{2}$$

where:

ΔZ_K – water collected for the range Δt_K

Δt_K – time between two neighbouring weights of collected water

The research was carried out for the sampling time of 300 s. Particular descriptions for the investigated seeds were obtained as an average value from three curves. Description of water absorption, namely change in seeds moisture was made for the first and the second stage of the process which precedes germination. The time of the end of the second stage of water absorption was determined based on the measurements of seeds germination kinetics on a petri dish.

Research results and discussion

Results of the research on the water absorption kinetics with the capillary and weighing method were presented in the form of diagrams in figure 2.

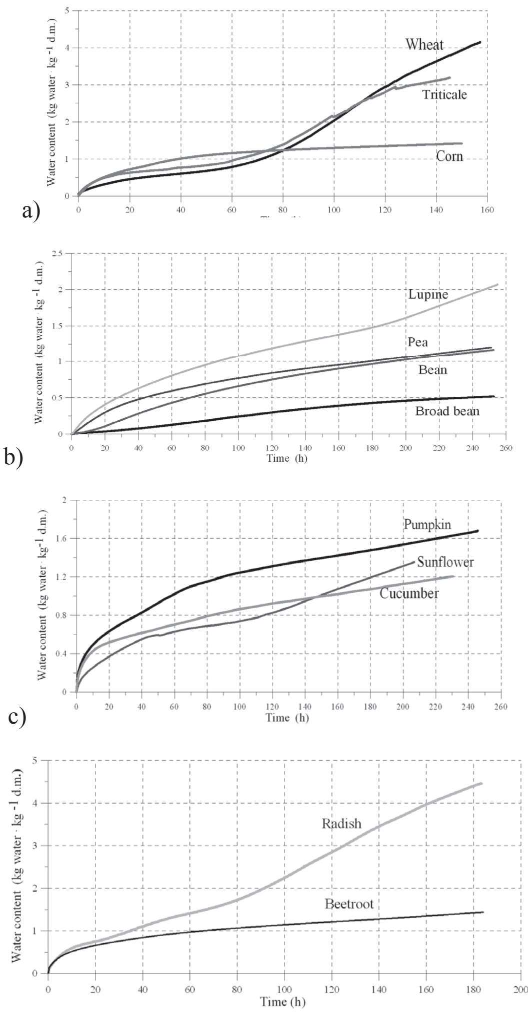

Figure 2. Change in the water content in seeds of the selected crop species in the unit of time: a – seeds of cereal plants (spring wheat, triticale, corn), b – seeds of broad bean plants (yellow lupine, broad bean, bean, pea), c – seeds with hard seed coats (sunflower, giant pumpkin, cucumber), d – remaining seeds - non-expending (beetroot, radish)

Figure 3 presents descriptions of the relation of the coefficient of the absorption speed as a function of time. Table 1 presents results of water content in seeds (Z_w) and in a single caryopsis (Z_{wwpz}) for the times of the end of the second stage of water absorption, namely at the beginning of seeds germination (t_{pocz}). The value of standard deviation was determined for the values read out from water absorption tables based on which plots were prepared. Table 2 includes the values of the maximum coefficient S_K and the time of its obtaining t_u.

Table 1.
Water content in seeds for the time of the end of the second stage of water absorption

	Winter wheat Triticale Corn Bean			
Number of seeds 150	150	90	30	
t_{pocz} (h)	35	50	55	60
Z_w (kg water · kg $^{-1}$ d.m.)	0.57 ± 0.034	0.83 ± 0.043	1.13 ± 0.087	0.4 ± 0.019
Z_{wwpz} (kg water · kg^{-1} d.m.)	3.82×10^{-3}	5.53×10^{-3}	12.6×10^{-3}	14.3×10^{-3}
	Broad bean Pumpkin Sunflower Cucumber			
Number of seeds 18	40	60	150	
t_{pocz} (h)	60	45	50	50
Z_w (kg water · kg $^{-1}$ d.m.)	0.13 ± 0.007	0.88 ± 0.041	0.59 ± 0.022	0.66 ± 0.03
Z_{wwpz} (kg water · kg^{-1} d.m.)	7.22×10^{-3}	22×10^{-3}	9.83×10^{-3}	4.4×10^{-3}
	Yellow lupine Pea Radish Beetroot			
Number of seeds 90	80	450	250	
t_{pocz} (h)	55	50	35	45
Z_w (kg water · kg $^{-1}$ d.m.)	0.76 ± 0.058	0.54 ± 0.022	1.01 ± 0.084	0.87 ± 0.033
Z_{wwpz} (kg water · kg^{-1} d.m.)	8.44×10^{-3}	6.75×10^{-3}	2.24×10^{-3}	3.48×10^{-3}

d.m stands for 'dry mass' namely mass of dry seeds

Table 2.
Maximum coefficient of water absorption speed and time of its obtaining

	Winter wheat Triticale Corn Pea			
$S_{K\,MAX}$ (kg water·kg $^{-1}$ d.m.·h $^{-1}$)	0.0718(1) 0.0628(2)	0.1298	0.2505	0.00912
t_u (h)	0.1667(1) 105.5(2)	0.0833	0.0833	27.3
	Broad bean Pumpkin Sunflower Cucumber			
$S_{K\,MAX}$ (kg water· kg^{-1} d.m.· h $^{-1}$)	0.0081(1) 0.0035(2)	0.331(1) 0.619(2)	0.088	0.507
t_u (h)	0.0833(1) 91.9(2)	0.0833(1) 0.5(2)	0.25	0.0833
	Yellow lupine Pea Radish Beetroot			
$S_{K\,MAX}$ (kg water· kg^{-1} d.m.· h $^{-1}$)	0.0327	0.021	0.752	0.663
t_u (h)	0.166	6.5	0.166	0.333

Digits (1) and (2) next to wheat, broad bean and pumpkin seeds stand for two maximum values of water absorption speed coefficient $S_{K\,MAX}$

Based on the obtained results and the course of characteristics of kinetics of water penetration to seeds, it may be stated, that beetroot, radish, pumpkin and maize seeds take water in the shortest time and bean, pea and broad bean seeds in the longest time which proves the maximum values of the water absorption speed coefficient $S_{K\,MAX}$ placed in table 2.

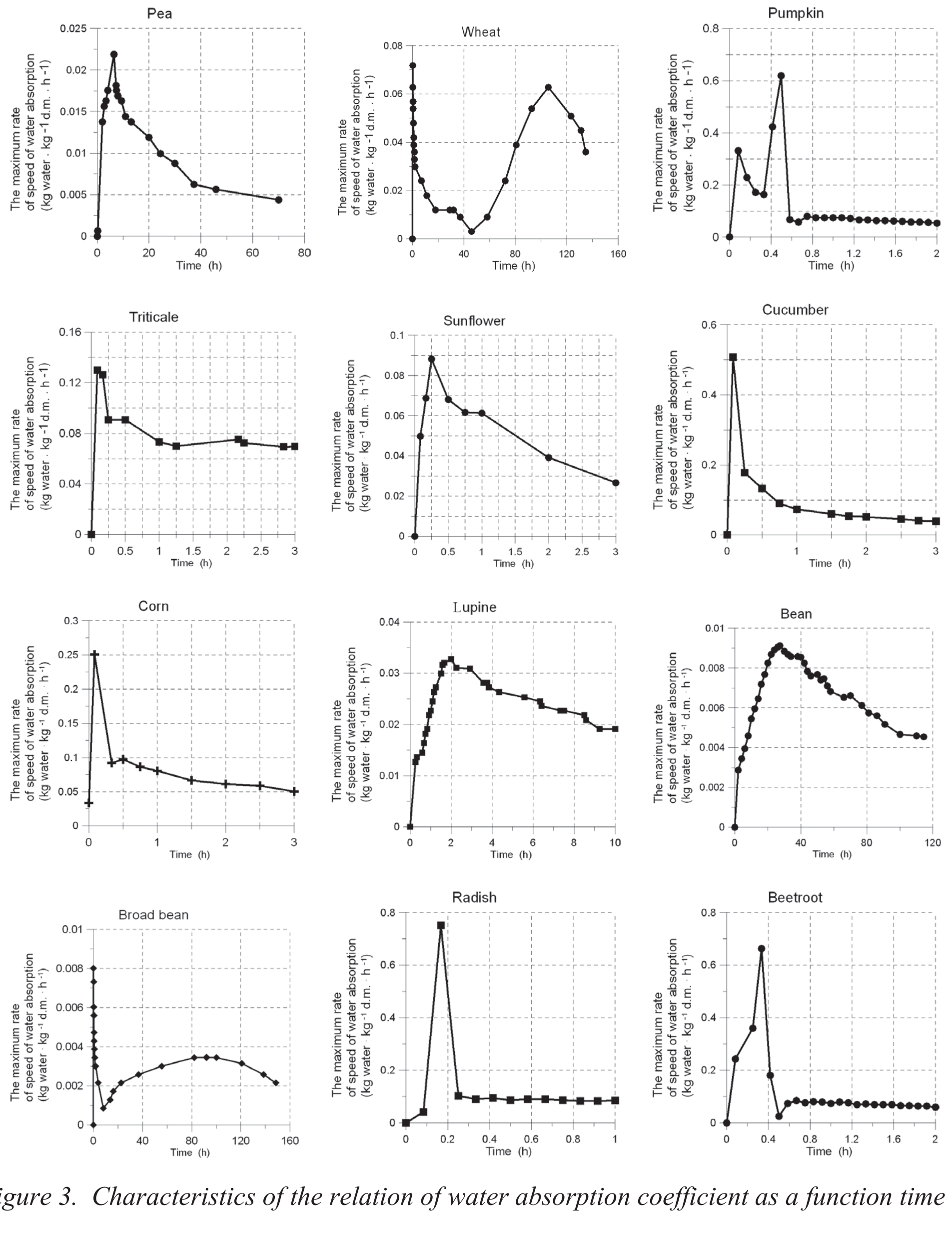

Figure 3. Characteristics of the relation of water absorption coefficient as a function time

In case of water included in seeds under the end of the second stage of its penetration, the biggest differences occurred for seeds of radish, winter wheat, triticale and pumpkin, which was reflected in figure 2. The time of obtaining the maximum value of the water absorption speed coefficient t_u was varied for the seeds with various structures of a seed coat and chemical composition. For the majority of non-expanding seeds (radish and beetroot) the time of obtaining $S_{K\ MAX}$ value is very short, namely these seeds achieve the maximum speed of water absorption from the beginning of the germination process, namely before entering the 3rd stage of water absorption.

For caryopses of winter wheat and broad bean and pumpkin seeds two time values for each were obtained, for which these seeds achieved the maximum coefficient of speed S_K (Table 2, Fig. 3). Most probably, it results from the fact that seeds got hydrated to the extent which allowed initiation of metabolic activity, sufficient enough to initiate the germ growth and pricking of the seed coat by a germ axis and formation of the germ root, which directly influenced the speeding of the water absorption kinetics.

In the future, one should think whether the capillary and weighting method should be developed in such a way that it should be used to determine the end of the second stage - not with the method of observation of the emerging germ root but based on the data obtained from the relation of the water absorption speed. Thus, in the future, it is planned to modernize the applied water absorption method by means of registration of seeds germination by counting germs and measurement of crops dimensions (height, leaves spread) with time-lapse footage and determination of fresh and dry mass of roots and stalks of the investigated crop species which may enable obtaining significant parameters which define the investigated seeds in the future.

Majority of the research concerning the change in the seeds moisture is carried out in the conditions without air access (the so-called hydra-conditioning) often with the use of various water solutions. Amarantus seeds were soaked in water and water solution SO_2 with a low concentration in the temperature of 30-60°C without air access (Resio et al., 2006). Similarly Bello et al., (2004) soaked raw rice in water solutions of ClH, CH_3COOH and PO_4H_3. Research was carried out where barley seeds were hydrated in temperatures from 10ºC to 25ºC within 32 hours by modelling of the process which may lead to shortening of the time and costs of hydration (Montanuci et al., 2014). Moreover, kinetics of hydration of andean lupine in the temperature of 23ºC and 60ºC (Miano et al., 2015) for which, after the hydration process, micro-structural analysis with the use of a scanning electron microscope was carried out. It was found out that the increase of the temperature of the process caused the increase of water absorption, shorter time of hydration and higher final moisture for which mainly a seed coat is responsible, which was confirmed by the analysis of the seed structure.

Similarly, Kornarzyński and Pietruszewski (2000) investigated moisture of beetroot, wheat, pea and radish seeds comparing water absorption method for seeds soaked in water and with a capillary and weighting method. Based on the course of characteristics it was stated that the highest increase of moisture is in case of sugar beet seeds and the lowest in case of bean seeds for both methods of water absorption, which is confirmed by the results obtained in the presented paper. Similar results, which confirm the results presented in this paper, were obtained for wheat, broad bean and pea seeds, which absorbed water during soaking in temperatures of 20, 30 and 40ºC, where they were simultaneously weighted - obtaining the highest increase of mass for the seeds of wheat (Kornarzyński et al., 2001).

The capillary and weighting method was also used for various distribution of wheat seeds (Kornarzyński et al., 2002a) and triticale (Kornarzyński and Łacek, 2002b) during water collection from moist blotting paper. Tests prove that seeds absorb water in he shortest time by a germ and in the longest time by a beard which was confirmed by the results obtained with various methods by other authors (Daoud et al.,1977; Cierniewska, 1978; Tryka, 2001).

The increase of seeds moisture has a considerable impact on the germination speed. Grzesik and Janas (2011) investigated the impact of four methods of hydra-conditioning of carrot seeds "Amsterdamska" cultivar in various temperatures on their sowing value. The obtained results indicate that carrot seeds hydrated to 40% of water content have a high vigour, germinate faster and seedlings obtained therefrom germinate and grow faster than seedlings from control seeds. 2011; Kubala et al., (2013 ab) in their review article stated that during seeds conditioning the structure of an endosperm is loosened and hydrolysis of stored substances included therein takes place. The system of internal membranes and their phospholipid composition is reconstructed. Moreover, during such a treatment repair processes are induced, which are responsible for the removal of damages collected during seeds storing. In case of Wirginia mallow seeds, which germinate very weakly when values of the temperature are low - the highest number of seeds (30-50%) germinates in the temperature of 20-35ºC. Hydro-conditioning which was carried out favourably influenced the speeding, increase and levelling of their germination and the increase and development of plants derived from them. (Grzesik et al., 2011).

Conclusion

Based on the course of characteristics of the change of moisture of the selected cultivars of crop seeds during water permission and based on determination of the selected parameters of this process one may assume that the speed of water absorption through seeds resulted from the structure of the seed coat and the size of seeds as well as on the chemical composition. The use of the capillary and weighting method for measurement of the water uptake kinetics allows research on this process together with the possibility of determination of energy and dynamics of germination, as a result of which the information obtained therefrom for purposeful improvement of sowing material (conditioning – hydro or matriconditioning) in order to include them during seeds treatment designed for the food industry.

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OCENA ZDOLNOŚCI ZMIANY WILGOTNOŚCI WYBRANYCH NASION ROŚLIN UPRAWNYCH

Streszczenie. Celem pracy było badanie zdolności zmiany wilgotności przez nasiona fasoli, bobu, grochu siewnego, łubinu żółtego, rzodkiewki, buraka ćwikłowego, pszenicy ozimej, pszenżyta, kukurydzy, ogórka, dyni i słonecznika. Nasiona pobierały wodę w układzie do pomiaru kinetyki pobierania wody metodą kapilarno-wagową. Wyniki badań przedstawiono w postaci wykresów zależności kinetyki zmiany wilgotności nasion w czasie dla pierwszej i drugiej fazy procesu poprzedzającej kiełkowanie. Wyznaczono również zawartość wody w nasionach dla czasu końca drugiego etapu pobierania wody oraz maksymalny współczynnik szybkości pobierania wody i czas jego uzyskania. Zawartość wody dla czasu końca II etapu jej pobierania była najwyższa dla nasion zawierających twardą okrywę nasienną oraz dla nasion roślin bobowatych. Maksymalny współczynnik szybkości pobierania wody był najwyższy dla nasion o niskiej wilgotności początkowej - rzodkiewki, buraka, ogórka i dyni. Pomiar szybkości pobierania wody przy wykorzystaniu metody kapilarno-wagowej umożliwił badanie nasion o różnej wielkości, budowie okrywy nasiennej i składzie chemicznym przez długi okres czasu, aż do momentu uzyskania siewek.

Słowa kluczowe: nasiona, pobieranie wody, metoda kapilarno-wagowa, zawartość wody