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ASSESSMENT OF POTENTIAL VIGOUR AND PRODUCTIVITY OF AIR-DRIED CUCUMBER SEEDS BY THE APPLICATION OF LUMINESCENCE METHOD

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ABSTRACT: Delayed luminiscence (DL) from air-dried seeds of different plants have been already observed. It has been noticed that the seed DL level increases with the moisture content decreasing. The seed DL level also increases with the decreasing germination percentage. Therefore it seems reasonable to suggest that the DL level rise with seed ageing is induced by the moisture content reduction. Within the range of 12 to 85% RH all equilibrated viable seeds have a high water content and a low DL level. Dead seeds have a low water content and a high DL level. As the DL method is highly sensitive, it allows measuring of the DL level of both individual seeds and seed lots and therefore allows construction of the seed distribution according to their DL level. There are three maxima (three seed fractions) in the distribution of a seed lot, containing seeds of various germination percentage. The first fraction is the fraction of viable seeds. The second fraction involves viable seeds with a lower vigour while the third fraction encompasses only dead seeds. The distribution of seedlings according to their root length has two maxima (long and short root lenth fractions). The shape and position of these two maxima coincides with that of the distribution curve (the first and the second fractions) of air-dried seeds according to their DL level. The correlation between the potential productivity and the DL level of air-dried seeds has been established in cucumber seeds.

Key words: *accelerated ageing, delayed luminiscence, potential productivity, seeds, unusual (paradoxical) effect*

Abbreviations – *DL – delayed luminiscence, RH – relative humidity*

INTRODUCTION: The yield is determined by numerous factors including both internal and external ones. Seed quality is one of the most essential factors. It is of a great importance in closed ecosystems when it is possible to create the optimal controlled conditions for plant growth. It is not easy to detect the best seeds. Field qualities of seeds are usually estimated by analysing seed samples and extrapolating their parameters to all seeds. Many investigators tired to find such characteristics of air-dried seeds which would correlate the future productivity of plants grown from such seeds.

Based on our results, the registration of air-dried seed DL is a promising method.

Material and Methods

Seeds. The seed samples used in this study belong to cucumber (*Cucumis staivus L.*) and pea (*Pisum sativum L.*). Prior to the DL experiment, the seeds were exposed to the atmospheric RH of 60% up to their constant weight. In the experiment with seeds equilibrated with different RH, the seeds were kept for a month in open desiccator filled with salt solutions at the saturated concentrations providing the following RHs: LiCl – 12% RH, $CaCl_2$ – 29% RH, $MgCl_2$ – 33% RH, K_2CO_3 – 44% RH, $NaNO_2$ – 66% RH, $NaNO_3$ – 76% RH, KCl – 85% RH.

Accelerated ageing. Pea seeds were stored above saturated potassium chloride solution (which gives a relative humidity of 85% between 20 and 50 °C, seed water content being approximately 20% fresh weight), first at 20 °C for three days and then at 41 °C for different periods. Samples of 100 ageing seeds were taken at 1 to 5-day intervals to examine changes in seed germination and vigour (50 seeds) and DL (other group of 50 seeds) during the accelerated ageing. The

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seeds from the second group were air-dried for four weeks on the lab bench up to the constant weight.

Seed germination. Seeds were placed into moist paper rolls and germinated at 20-22 °C for six days. Then germinated seeds were counted according to the methods recommended by ISTA (International Seed Testing Association, 1985). Seedling lenghts were measured and the distribution of seedlings was done according to their root length.

Seed moisture content was determined according to the methods recommended by ISTA (International Seed Testing Association, 1985).

Seed DL was measured as previously described (Veselova et al., 1995a).

Results and Discussion

Delayed luminiscence of air-dried seed. A photo-induced DL, following a visible light excitation, has already been observed in seeds of various plants (bean, pea, soybean, wheat, rye, cucumber, pine, etc., Veselova et al., 1985).

The seed DL level is known to decrease with the increase of their moisture content. There is virtually no luminiscence in the seeds with moisture content amounting to 25%. The DL method provides detection of changes in the seed moisture content as low as 0.1–0.2% in a range of 2–20%. In the range from 12 to 85% RH, all equilibrated viable seeds have a higher water content and a low DL level. Dead seeds have a low moisture content and a high DL level (fig. 1).

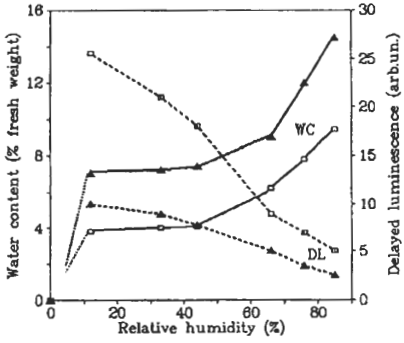

Fig. 1. The water adsorption isotherms (solid lines) and delayed luminiscence levels (dashed lines) from germinated (triangles) and non-germinated (squares) cucumber seeds

Graf. 1. Izoterme adsorpcije vode (pune linije) i nivoi zakasnele luminiscencije (isprekidane linije) za klijalo (trouglovi) i neklijalo (kvadrati) seme krastavca

Fig. 2. shows the correlation between the DL level logarithm and moisture content of these seeds.

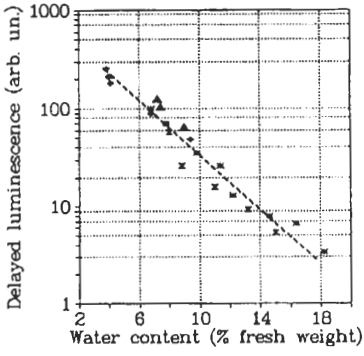

Fig. 2. The correlation of moisture content and logarithm of delayed luminiscence of air-dried seeds of various plants

Graf. 2. Korelacija između sadržaja vlage i zakasnele luminiscencije semena različitih biljaka koje je sušeno na vazduhu

Germination and delayed luminiscence. The DL level increases when the seed viability decreases during natural of accelerated ageing (Veselova et al., 1985, 1988, 1995a, b).

Fig. 3. shows the changes in germinability and emitted DL in seeds as a function of time of accelerated ageing. After 5–7 days of accelerated ageing, the seed germination was lower by 15–20% than the initial one (and DL was accordingly higher). But after 8–10 days, germination was higher than the initial one (and DL was lower) and then it dropped again on the 16th day of ageing. The germination was twofold lower, while DL increased considerably. Thus, it was found out that both, germination and the average DL level of seeds in the process of accelerating ageing, changed in an unusual (paradoxical) way.

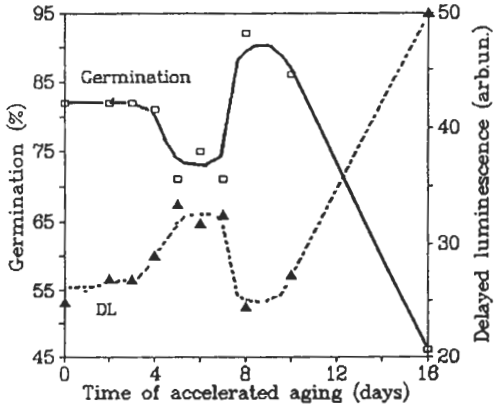

Fig. 3. Time course of the changes in germination and delayed luminiscence of pea seeds after accelerating ageing (41 °C, 80% RH)

Graf. 3. Vreme za koje su se dogodile promene u klijavosti i zakasneloj luminiscenciji semena graška posle ubrzanog starenja (41 °C, 80% RH)

The paradoxical reaction in a phemenon of a stronger damage a smaller action as compared to a moderate action (which acts as a stimulator). This is a well-known fact for active organisms and the phenomenon of stimulation is usually interpreted as a result of reparation process (Wagenbrerh, 1968, Aleksandrov, 1985). In case of seeds, this fact has not been reported yet. A more detailed study should be performed to discuss mechanisms of this phenomenon in seeds.

Seed vigour and delayed luminiscence. The DL method is highly sensitive. It allows the measurements of the DL level from the individual seeds to the group of seeds and therefore a seed distribution according to the DL level (moisture content). Thus, the registration of seed DL provides the evaluation of seed lot heterogeneity.

Fig. 4-A shows the distribution of pea seeds (after accelerating ageing) according to their DL level. The initial seed lot shows a distribution with one maximum (1) and a low depression. The distribution remained the same after three days of accelerating ageing. While it had two maxima after five days. The DL level of the second maximum was approximately twice as great as the initial one. After eight days the distribution had a maximum similar to the initial one, but the dispersion became lower than the initial one. After 15 days, the distribution had a shoulder and two maxima (II and II maxima). The DL levels of the second and third maxima were approximately two and three times higher than the initial one.

The distribution of seedlings according to the root length (fig. 4-B) can be described as almost a mirror image of the distributions of air-dried seeds according to the DL level (I and II fractions). These results show a good agreement with the results on pine seeds (Veselova et al., 1995a, b). The first DL fraction (maximum I) is shown to be a fraction of viable seeds. The third DL fraction (maximum I) is shown to be a fraction of viable seeds. The third DL fraction (maximum III) encompasses only dead seeds, while the second DL fraction involves seeds with lower vigour. The seedling root lengths of these seeds were approximately twice shorter.

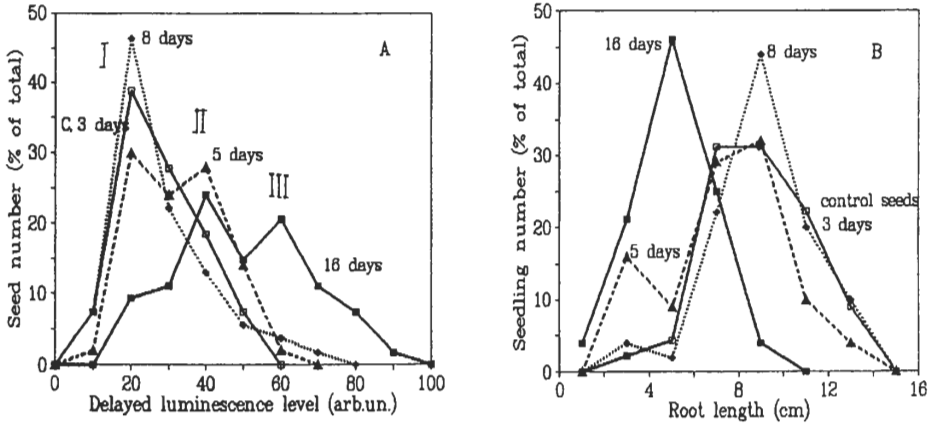

Fig. 4. Distribution of air-dried pea seeds from different lots according to delayed luminiscence (A) and root length (B). Seed were taken on 0th (c=control seeds), 3rd, 5th, 8th and 16th day of accelerated ageing at 41 °C, 80% RH (50 pea seeds were used to construct distributions)

Graf. 4. Raspored semena graška sušenog na vazduhu a iz različitih partija semena prema zakasneloj luminiscenciji (A) i dužini korenaka (B). Seme je uzorkovano nultog (c=kontrola semena) trećeg, petog, osmog i šesnaestog dana ubrzanog starenja na 41 °C, 80% RH (50 semena graška je korišćeno za stvaranje svih rasporeda)

Delayed luminiscence and potential productivity of cucumber seeds. The distribution of cucumber seeds with a high germination ability according to the DL level has one maximum and can be described as a normal distribution (fig. 5). Seeds were sorted into groups according to their DL level. Then cucumber plants were grown and the total weight of cucumber fruits collected during the vegetation period was measured. The results of two greenhouse experiments are shown in tabs. 1 and 2.

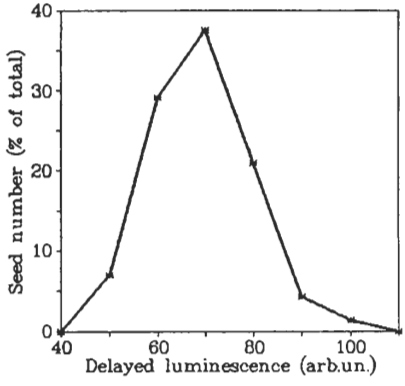

Fig. 5. Distribution of cucumber seeds according to the DL level (400 cucumber seeds were used to construct this distribution)

Graf. 5. Raspored semena krastavca prema nivou ZL (400 semena krastavca je korišćeno za kreiranje ovog rasporeda)

One plant yield was greater when the DL level of air-dried seed was higher (the DL level was not corrected with the seed size and weight). On the soil substrate of the second year the yield obtained from the seeds exhibiting a high DL level significantly increased.

Tab. 1. The correlation between the DL level and yield of cucumber (cv. Gribovchanka) fruits on each plant (soil subrstrate of 1st year)

Tab. 1. Korelacija između nivoa ZL i prinosa ploda krastavca (kultivar Gribovčanka) na svakoj biljci (jednogodišnji zemljišni supstrat)

DL level Nivo ZF	Plant Yield – kg – prinos po biljci		
	1st plant – 1-a biljka	2nd plant – 2-a biljka	3rd plant – 3a biljka
80 ± 5	2.6	3.7	3.7
90 ± 5	3.05	3.65	3.35
100 ± 5	4.3	4.3	4.3
110 ± 5	4.6	4.6	4.6
120 ± 5	4.7	4.9	4.8
130 ± 5	5.5	6.05	5.4
140 ± 5	6.6	6.65	6.8

Tab. 2. The correlation between the DL level and yield of cucumber (cv. Gribovchanka) fruits on each plant (soil substrate of 2nd year)

Tab. 2. Korelacija između nivoa ZL i prinosa ploda krastavca (kultivar Gribovčanka) na svakoj biljci (dvogodišnji zemljišni supstrat)

DL level Nivo ZF	Plant Yield – kg – prinos po biljci		
	1st plant – 1-a biljka	2nd plant – 2-a biljka	3rd plant – 3a biljka
90 ± 5	3.3	3.3	3.3
100 ± 5	5.6	6.65	6.23
110 ± 5	6.25	6.65	6.37
120 ± 5	7.05	6.99	6.85
130 ± 5	7.15	7.25	6.96
140 ± 5	10.9	11.7	11.12

The DL levels of air-dried seeds and production of cucumber plants of two cultivars differing in productivity were compared. The same regularity was observed: when the DL level of air-dried seed was higher, a plant productivity was greater.

Such a correlation between seed DL and plant productivity was confirmed by the three-year experiments on different seed cultivars. This indicates the possibility of employing the DL method for sorting the seeds which will provide a higher yield.

It has been revealed that the initial unimodal distribution of air-dried seeds according to the DL level was transformed during storage (or accelerated ageing) into multimodal one with three major components corresponding to vigorous, non-vigorous and dead seeds. It is assumed that the seed ageing is a stepwise, rather than a gradual transition from a viable to the nonviable state through an intermediate metastable state (Veselova et al., 1995a, b).

The loss of seed vigour during seed ageing seems to be a stepwise rather than a gradual process as well, because the initial unimodal distribution of seedlings according to the root length was transformed during seed ageing into th bimodal one.

It is significant that these transitions occur in seeds with a moisture content of approximately 15–20% fresh weight (bulk water is absent).

A paradoxal effect, the most notable fact during seed ageing, affecting both seed germination and the air-dried seed DL levell, has not yet been detected in seeds.

a phenomenon of stimulation in active ogranisms (algae, plant and animal cells, yeast, etc.) is thought to be due to reparation processes. However it is unclear how reparation processes could take place in seeds in the absence of bulk water.

Conclusion

According to achieved results the following can be concluded:

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PROCENA POTENCIJALNE VITALNOSTI I PRODUKTIVNOSTI SEMENA KRASTAVCA SUŠENOG NA VAZDUHU PRIMENOM METODE SVETLJENJA

by

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REZIME

Zakasnela luminiscencija (ZL) semena sušeno na vazduhu otkrivena je kod različitih biljaka. Nivo ZL u semenu u isteklom elektrolitu se povećava sa snižavanjem procenta klijavosti semena. Prilično dobra podudarnost dve nezavisne fizičko-hemijske pojave (ZL i isticanje elektrolita) je pokazatelj integralnih promena u semenu tokom njegovog starenja i adekvatnost primene ZL metode za ispitivanje vitalnosti semena.

Poznato je da se ZL seme smanjuje sa povećanjem sadržaja vlage. Izgleda razumljivo da se povećanje nivoa ZL sa starenjem semena manifestuje snižavanjem sadržaja vlage. Ovaj metod omogućava otkrivanje promena u sadržaju vlage semena od o,1 do 0,2% u domenu od 2–20%.

Seme visoke vitalnosti ima visok sadržaj vlage i nizak nivo ZL. Mrtvo seme različitih biljaka ima nizak sadržaj vlage i visok nivo ZL.

Metod ZL je velike osetljivosti i dozvoljava merenje nivoa ZL kako pojedinačnog zrna tako i partije semena i stoga omogućava distribuciju semena prema nivou ZL (sadržaj vlage). Stoga se registrovanjem ZL semena može proceniti i heterogenost partije semena.

Partija semena klijavosti 97–100% pokazuje normalnu distribuciju prema nivou ZL sa malom depresijom i niskim prosečnim nivoom ZL.

Distribucija partije semena klijavosti 0% takođe ima jedan maksimum. On nije značajno pomeren ka visokim nivoima ZL, jer je mrtvom semenu koje gubi vodu potreban mnogo viši kapacitet za emitovanje ZL.

U partiji semena koja se sastoji od semena iz partija različitog procenta klijavosti mogu se videti tri maksimuma (tri frakcije). Prvu frakciju predstavlja seme koje klija. Treća frakcija obuhvata mrtvo seme, dok druga frakcija obuhvata seme koje klija, ali sa manjom energijom klijanja. Dužina korenaka klijanaca bila je manja približno za polovinu.

Jasno je da registrovanje ZL omogućava odvajanje semena koje klija i semena koje može da klija, ali sa manjom energijom klijanja, od mrtvog semena.

Seme koje može da klija sa nižim nivoom ZL sporije gubi klijavost tokom vremena (za vreme ubrzanog starenja kao i za vreme prirodnog starenja) u odnosu na seme sa višim nivoom ZL. Registrovanje ZL omogućava određivanje kapaciteta skladištenja semena.

Stoga postoji mogućnost praktične primene zakasnele luminiscencije semena sušenog na vazduhu: praćenjem ZL u semenu moguće je odrediti kvalitet, heterogenost partije semena i kapacitet skladištenja semena.