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Research Article

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Research on the ultra-weak luminescence of maize seeds

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ABSTRACT

The ultra-weak luminescence (UWL) feature of plant seeds is investigated. Before UWL measurement, the maize seeds are moistened in distilled water for various periods, which are 2h, 4h, 6h and 8h. And then the seeds are dried to the mass they had before moistened. The UWL measurements are made before and after distilled water injects into measured samples. A kind of double exponential function is proved fitting the tested data well as the coefficient of determination of fitting is above 0.97. It is observed that UWL properties of different samples have obvious regularities. The dry seeds contain a large number of hydrophilic pores, so water quickly permeates into maize seeds and forces the seeds to produce stress UWL after water injection. The intensity of UWL depends on the structure of seeds and the time of moistening. Over a period of time, the different UWL intensity of samples decays to the same level as the seeds without moistening. The study results contribute to the understanding of relationships between the structure of seeds and metabolic activity and its UWL specialties. The paper provides a new idea for nondestructive testing of plant seeds.

Key words: Ultra-weak luminescence, maize seeds, structure of seeds, moisture treatment, water stress

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INTRODUCTION

Ultra Ultra-weak luminescence (UWL: Ultra-Weak Luminescence) is the phenomenon of life organ-isms exist objec tively, closely related to various life activities. Light level can reflect the dynamic indices of growth metabolism of organisms [1-3]. Biological ultra-weak luminescence contains biological spontaneous luminescence and external inducedluminescence, which induced by exogenous ultra weak luminescence is called stress luminescence.

Colli L conforms that the luminous intensity of germinated seed of corn, wheat, lentils, and beans is between 250 and 700 photons/ (s • cm^2). Its spectrum ranges from 400 to 600nm, the peak is about 550nm [4]. S.Tryka researches the influence of water stress on wheat seed ultra weak luminescence, confirming that the ultra weak luminescence (UWL) of the wheat seeds is influenced by the structure of wheat and soaking time [5]. Xi Gang et al analyzes the ultra weak photon emission of soybean callus induced by UV – -B and the influence of extremely low frequency high-voltage pulsed electric field of the germinated maize seeds, proving that the structure of soybean callus cell is damaged by UV UV-B radiation and that spontaneous luminescence and stress luminous intensity of germinated maize seeds are promoted by extremely low frequency high voltage pulse electric field[6-7] .Yu Yong researches the relationship between the UWL of osmanthus flower seedlings and its grow environment, finding that the base environment factors (such as light, temperature, humidity and moisture) influence ultra weak luminescence differently [8]. ZHAO Dan-ying confirms that UWL rise with the degree of chilling injury, furthermore UWL go up remarkably [9].
Corn is one of the most important crops in the world. In this paper, the interest of this study is focus on the action to research the measurement of UWL from imbibing maize seeds and wheat grains moistened previously in water for

several given periods of time. The investigation has scientific significance in the field of ultra-weak bioluminescence.

EXPERIMENTAL SECTION

Autumn maize seed (Zheng Dan 958) and wheat grain (Zheng Mai 7698) harvested in 2013 were used. Five 10g portions of maize seeds and five 10g portions of wheat grain were chosen for the measurement. These samples are weighted with accuracy to a mass of one seed. Four samples of maize seeds were socked in distilled water for 2, 4, 6 and 8h. One sample of wheat grain was soaked in distilled water for 2h. The wet maize seeds and wheat grains were next spread on sheets of paper and dried at a temperature of 25ºC to the mass they had before soaking. One set of maize sample which had not been soaked, was used as control material. All the samples were then placed in small airtight containers and kept in a thermostatic box at a temperature of 28ºC until the measurements of UWL were taken.

UWL was measured twice, before and during imbibe of seeds. Spontaneous UWL from air-dried seeds was detected for 20min and then the induced emission of UWL was generated by adding 15ml of distilled water to the sample cup. Measurements of UWL from imbibing grain were continued for 640min. In both case, UWL was recorded at 28ºC. To avoid recording the light-induced luminescence from prepared samples, they were kept for 30min in darkness before the start of UWL detection. All the manipulations were also done in a dark chamber.

UWL was measured by BPCL-ZL-TGC system. The system schematic is shown in Fig.1. The measurement system mainly consists of UWL detection cell, optical-electronic converter, photon counting pulse amplification circuit, intelligent data measuring and recording system, high stability and high voltage power supply. Bio-photon from samples hits the photocathode of the photoelectric converter (the core device is photomultiplier tubes) and then generated electrical pulses. Electrical impulses amplified, filtered and counted through a photoelectric counting pulse amplification circuit. The results are stored and displayed by dedicated software. Measurement results can be processed further.

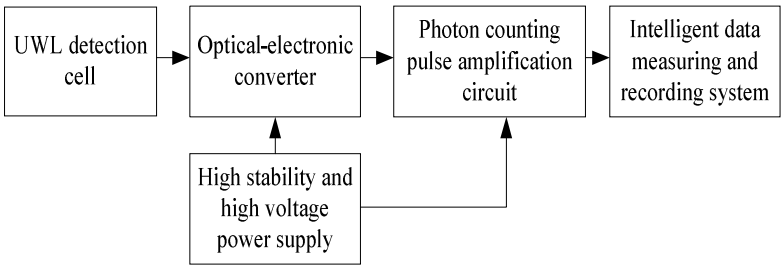

Fig.1 Measurement system schematic

Measured data include biological photon signals of samples and background noise of the measuring device. Background noise mainly comes from the dark current of photomultiplier tube. The temperature of the detection system is rising with the time .And the noise increases with the temperature. To maintain low noise count, the semiconductor refrigeration device of measuring equipment can make the photoelectric converter cathode temperature around 10 ℃ lower than the room temperature. Working voltage of the instrument is 1036 V (use C-13 for calibration to be sure higher measurement efficiency).In order to make background noise stable, measuring instrument preheats 1 h before measuring [9].Pulses counted upon 1 min periods and corrected for background counts were taken of UWL intensity, so that the counts per minute were the intensity unit.

RESULTS AND DISCUSSION

Kinetics of UWL from the 2h moistened maize seeds and 2h moistened wheat grain are compared in Fig.2. The "+" indicates a point as the background noise (similarly hereinafter). Before injection, spontaneous UWL level of maize seed is lower than that of wheat seed. After the dry seeds were placed in water, UWL suddenly increased, giving maximum reading in the first minute of imbibitions. Then UWL from maize seed and wheat grain decrease continuously during the measurements period. After 600 minutes, the intensity of UWL goes down to the stable level. Having 200 minutes for boundaries, the whole process can be divided into two stages. Stage one is rapid decay phase and the stage two is the slow decay stage for UWL level. The results in Fig.2 show that UWL from the maize seeds was higher than from the wheat grain. Compared with the wheat seeds, maize seeds belong to the bigger seed, which seed embryo accounts for one third of the hole volume .The embryo organization is loose and contains more hydrophilic which make it easier to absorb water, so the internal structure of seeds are more likely to change

[10-12].The Fig.2 shows that UWL from maize seeds and grain seeds are significantly different.

Kinetics of UWL from the not-moistened and moistened maize seeds is compared in Fig.3. At the first few hours of imbibe, the shapes of the curves illustrate a sharper decrease of UWL from not moistened maize seeds. However, the UWL had been influenced by previous periods of wetting. Immediately after addition of water the highest UWL was noted if the maize was not moistened. Then during subsequent 200min it obtained the level of UWL from the moistened maize. It is worth noting that this UWL kinetic curve is similar in shape to that obtained for the not moistened and moistened maize seeds in Fig.3. Relatively small but observable differences showed that as the times of wetting the maize were longer, lower levels of UWL emission occurred. But there are exceptions, such as soaking 6h sample has lower UWL intensity instead of soaking 8h seeds. Maybe longer periods (for more than 6h) of moisture treatments did not influence significantly the internal structure of the maize seeds.

Comparing these results to those obtained for the moistened and not-moistened maize seeds, we may deduce that not-moistened maize seeds take the water more quickly at the initial period of imbibe. However, in this period the absorption rate of water is greater and the UWL intensity level is higher as the time of moisture treatment was shorter.

Analyze the data quantitatively by means of data fitting methods. It can be proved that kinetic of UWL emission from imbibing maize seeds can be well described by double exponential equations:

$$I(\mathrm{t})=I_1(t_0)*\exp(k_1*t)+I_2(t_0)*\exp(k_2*t)$$

In the equation, $I_1(t_0)$ and $I_2(t_0)$ indicate UWL intensities at t=0 and are related to the fast attenuation and to the slow attenuation phase respectively. k_1 and k_2 represent the two phase decay kinetic constant rates.

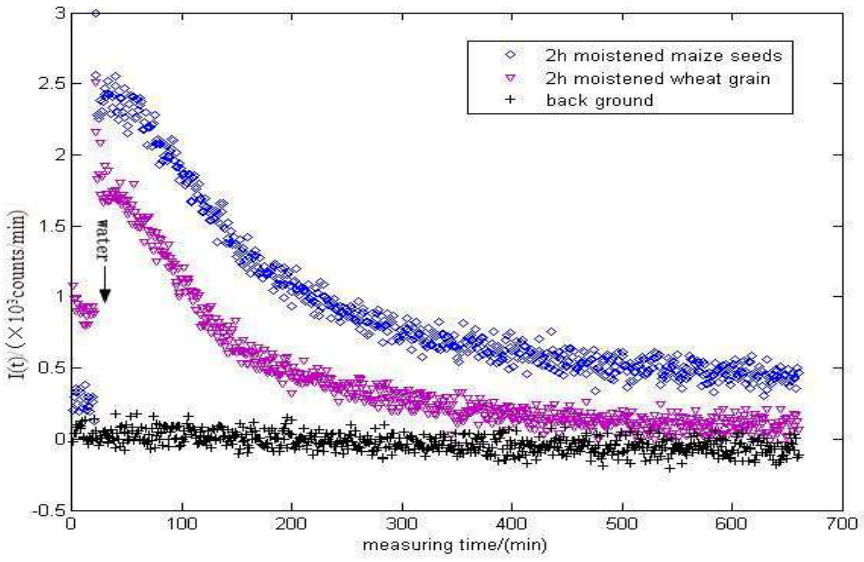

Fig.2 Comparison of UWL from 2h moistened maize seeds and 2h moistened wheat grain before initiation and during 640min period of imbibitions

Tab.1 Curve fitting situation of exponential Function

sample	$I_1(t_0)$	$I_2(t_0)$	k_1	k_2	R
not moistened	11	0.7417	-0.01653	0.0008852	0.9926
2h moistened	6.273	0.4825	-0.012	0.001573	0.9867
4h moistened	5.377	1.201	-0.0182	-0.00095	0.9811
6h moistened	5.3	1.31	-0.0215	-0.00269	0.987
8h moistened	5.593	1.353	-0.0207	-0.00179	0.9756

Values of the estimated parameters are listed in Table 1. The correlation coefficients R, calculated for the data presented in linear semi-logarithmic coordinate system, are given in the last column of this table. If the values of R (greater than 0.9756) is higher, it indicated that kinetic of UWL emission from imbibing maize seeds can be well described by double exponential equations.

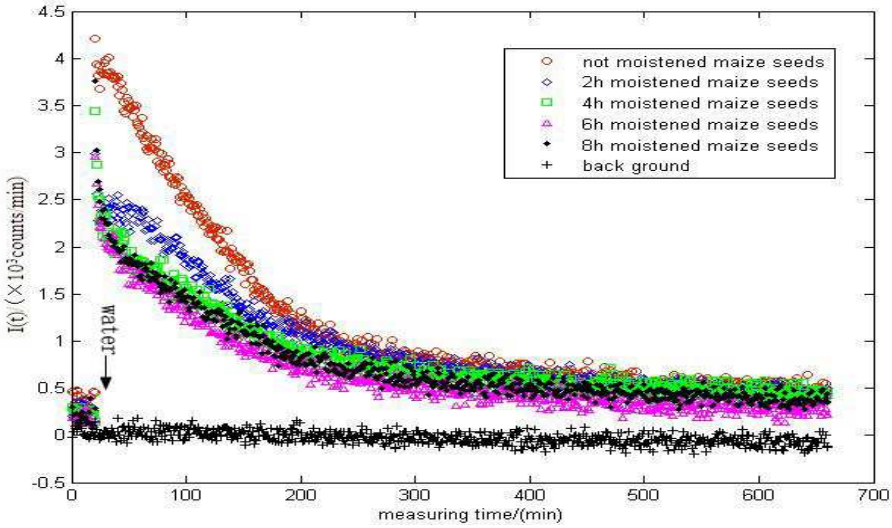

Fig.3 Comparison of UWL from not moistened and moistened maize seed before initiation and during 640min period of imbibe

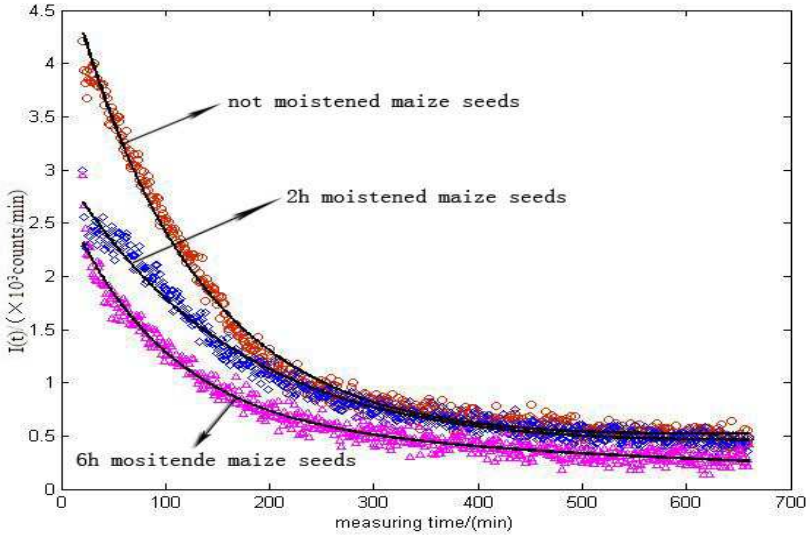

Fig.4 The fitting curve of not moistened maize seeds and 2h、6h moistened maize seeds

Fitting results of UWL from the not-moistened, 2h moistened and 6h moistened maize seeds are compared in Fig.4. The fitted curves for the data tally with the initial data. It confirmed that stress luminescence from imbibing maize seeds can be well described by the curve.

As it has been shown in Table 1 values of $I_1(t_0)$ and k_1 decreased and $I_2(t_0)$ increased with the immersion time increasing. The greatest $I_1(t_0)$ and k_1 values were computed for the not moistened maize seeds and the greatest $I_2(t_0)$ values were computed for the 8h moistened maize seeds. Value of k_2 showed no obvious regularity. The higher k_1 values indicate a more quick decay of the processes generating UWL emission in the initial phase of not moistened maize seeds imbibe.

It can be described that moistened treatment makes structure of maize seed change. When they imbibe moisture again after dried in free air, it will affect the water absorption dynamics process of maize seeds. The internal structure of maize seeds changes with different immersion time. It can be expected that different water absorption capacity of each sample will appear with the change of immersion time. The change will influence the intensity of UWL.

Typically, there is a lipid molecular structure in biological membranes of maize seeds. A hexagonal structure is formed by the lipoid molecular that the hydrophilic end toward the water molecule. The middle part of hexagonal structure is porous hole that water molecules can pass through it freely. Before water injection, the internal system of seed kept a non-balance steady state. After water injection, water is absorbed by seeds quickly through hydrophilic

water hole. The internal biological system of seed deviates forms its steady state when cell metabolism is strengthened. The energy state of most biological molecules is from high into lower. Then the seeds radiated photons and the level UWL are enhanced quickly. The arrangement of the construction of the lipid molecule is turned from hexagon to normal lipid bilayer with the water content increasing. The hole, which water molecule can freely pass through, disappeared so that the water-absorbing rate slowed down. The internal biological system of the seeds returns to the stable state. Then the UWL intensity of seeds is reduced and the level of UWL intensity is decreased. Compared with moistened maize seeds, a hexagonal structure, which can make hydrophilic substance pass freely, is formed easily by the not-moistened maize seeds, so it can absorb water easily and then generate lots of excited electron. UWL level could be seen as indicators of the intensity of cell metabolism[13-18].

The first stage of water-absorbing of dry maize seeds depends on the physical absorption of protoplasmic colloid imbibing. After a period of time，the protoplasm colloid of the soaking maize seeds turn from gelatum to collosol, making the broken cell organelle and inactivated polymer in the dry seeds stretched and repaired, and then recover the original structure and function. The degree of hydration of the protoplasts tends to saturation after the first stage of rapid absorption. The turgor pressure increases and hinders further absorption of cell. Moreover, the increasing volume of the seed is bound by the seed coat so that there is a slow water absorption stage before seed germination. The total UWL intensity of not-moistened maize seeds is higher than the moistened. The UWL intensity of seeds varies inversely with immersing time.

CONCLUSION

Research the UWL characteristics of plants seed in the paper. As it shown, soaking time significantly influenced the photons emission during the period of imbibing. It can help us understand seeds metabolic activity by measuring the UWL level and analyzing the characteristics of seeds. This paper provides a new idea for the nondestructive testing of plant seeds quality.

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