Acta Agrophysica, 2002, 77, 111-116

RED/FAR-RED LIGHT EFFECTS ON THE ELECTROCONDUCTIVITY OF PEA SEEDS TEST SOLUTION

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Summary. Gravimetry, osmotic stress experiment and electroconductivity were combined to characterize water uptake in pea seeds. Red light irradiation decreases while far-red light increases the water uptake rate compared to seeds germinated in darkness. Electroconductivity of the test solution measured after 24 hours of preliminary imbibition increases after far-red and decreases after red light irradiation. This fotoreversibility indicated that the observed effect is phytochrome – mediated reaction.

Keywords: germination, fotoreversibility, phytochrome, electroconductivity.

INTRODUCTION

Germination can be defined as the processes that begins with water uptake by the seed and ends with the initiation of elongation by the embryonic axis and the radicle penetration of the structures surrounding the embryo [1]. Most seeds contain less than 20% water, as opposed to about 80% in growing tissues and most of the water in seeds is bound to macromolecules, so that little is available for metabolic reactions. In these conditions water flow is disorganized. Because the water potential of seeds is extremely low, they are capable of drawing water from soil and as the seed imbibes water cell membranes reorganize and metabolism begins.

The imbibition process in seeds is determined by two mechanisms. The first is the water entry into seed's cells that occurs not only because of the physical conditions, but also as a result of the biological forces operation. Effect of these forces is manifested in the activity of the cell mechanisms that regulate the entry of water into seeds and removes the water from the cell compartments. The second is the water addition to biological exchange substance in cells which leads to dynamic changes in physical, chemical and technological properties of seeds.

The most sensitive and technically the simplest indicator of seeds quality is an electroconductivity of the solution in which seeds are soaked. The electroconductivity, is inversely correlated with the field viability of the seeds [11].
Since low-quality seeds often leak more exudates than high-quality seeds during the first hours of imbibition, the conductivity test has become an important approach to monitoring seed quality. It was demonstrated that the degree of the seed leakage during imbibition was affected by the stage of the seed maturation, degree of seed aging and incidence of imbibition damage [5]. Ram and Wiesner[6] showed that artificial aging increased membrane permeability and enhanced loss of seeds' electrolytes in wheat. However, there are precedents where conductivity has not been helpful in assessing seeds quality. There is considerable evidence that soybean seeds at high moisture content developed a resistance to leakage [10]. Herter and Burris [2] reported that the length of seedlings of corn seed exposed to drying injury showed small changes over a wide range of conductivity values, suggesting that the membrane disruption could be only one of the factors responsible for drying injury.

Because light is one of the most important factors influencing seed development and because, under laboratory conditions, seeds vigor can be estimated by electro-conductivity test, a relationship between the light treatment and electroconductivity of the solution in which seeds are immersed, was the main aim of the paper presented herein.

MATERIAL AND METHODS

Pea seeds cv. Szesciotygodniowy harvested in 2000 year were used in all experiments. Five groups of 20 seeds were placed on three layers of blotting paper in Petri dishes, moistened with water and incubated at 294 K. Irradiation with red and far red light was performed at suitable time after sowing and the water uptake was measured afterwards.

A source of red light was an air-cooled 1500 W incandescent lamp equipped with a system of interference filters (λ = 658 nm, half width 8 nm, λ = 725 nm, half width 12 nm). Electroconductivity was measured with Orion conductometer in deionized water in which the seeds previously irradiated after preliminary imbibition were soaked at 20^0C for 24 hours.

Cell expansion can be described by the following mathematical equation:

$$\frac{1}{v}\frac{dv}{dt} = \frac{mL}{m+L}\left(GP - \Pi_0\right),$$

where dv/dt represent rate of volume growth (water uptake), m - the cell-wall extensibility (cell-wall yielding coefficient), L - the hydraulic conductance, GP - germination potential and Π_0 osmotic pressure of the internal medium, respectively. Presented formula is a modification of the equation first derived by Lockhart [3,8]. The term $mL/(m+L)$ is often referred to as the growth coefficient k_G.

The term (GP - Π_0) is the driving force of cell expansion. In another expression $GP \doteq \Delta\Pi$-Y where $\Delta\Pi$–difference in osmotic pressure between tissue and medium and Y-yield threshold i.e. the turgor pressure which must be exceeded for cell expansion.

Steady-state water uptake kinetics of seeds incubated in a series of osmotic test solutions were used for constructing curves relating water uptake rates to osmotic pressure of the external medium. Both k_G and GP may be estimated from these curves as the slope and the intersection with the base line, respectively.
The water flux rates as a function of osmotic pressure were determined by incubating seed batches in osmotic test solutions, which were adjusted to defined values of osmotic pressure using the Michel and Kaufmann formula [4].

RESULTS AND DISCUSSION

Water sorption kinetics in irradiated pea seeds, obtained by an approximation of the experimental data by sigmoidal runs, are presented in Fig.1. For the points above the 25 imbibition hours the difference are statistically significant for the risk error of 0.05. As can be seen, water uptake rate for seeds irradiated with far-red light is higher than in red light pretreated seeds. As follows from the data in Fig.2 (obtained by nonlinear regression method), the red-light reduces the GP parameter but has no detectable effect on the growth coefficient k_G (the slope of these curves is approximetly equal). A decrease in GP may be induced either by a decrease in $\Delta\Pi$ or by an increase in Y. The far-red light treatment induces the opposite effect on the Π_0 dependence of water uptake. Because the slope of the curves obtained is almost the same, there is no indication that irradiation with red or far-red light involves regulatory changes in the parameters m and L of the Lockhart's equation. At the same time the parameter GP is reduced to a value of 0.6 MPa for the seeds irradiated with red light and to 1.2 MPa for the seeds irradiated with far-red light. It is interesting to note that similar effect was observed in photoinhibition of radish seeds germination, but under far-red light treatment [8]. Electroconductivity measured 24 hours after far-red irradiation was higher than after red light treatment (Tab. 1).

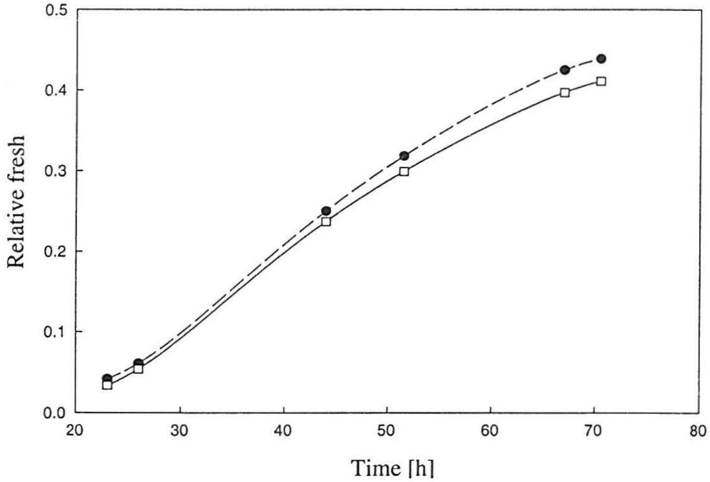

Fig. 1. Effect of red (solid line) and far–red light (dashed line) on water uptake kinetic in pea seeds.

The observed fotosensivity indicated that observed effect is a phytochrome-mediated reaction. Phytochrome is now known to be a small family of photoreceptors whose apoproteins are encoded by different genes. Phytochrome B (phy B) is present in dry seeds and affects germination of dark imbibed seeds. Other phytochromes could also be involved.

Table 1. Electroconductivity of pea seeds test solution after red and far-red irradiation with different time of preliminary imbibition of seeds.

	ELectroconductivity after red light treatment $\mu S\ cm^{-1}\ g^{-1}$	Elelectroconductivity after far-red light effect $\mu S\ cm^{-1}\ g^{-1}$
Preliminary imbibition		
21 h	56	64
22 h	50	56
23 h	58	73

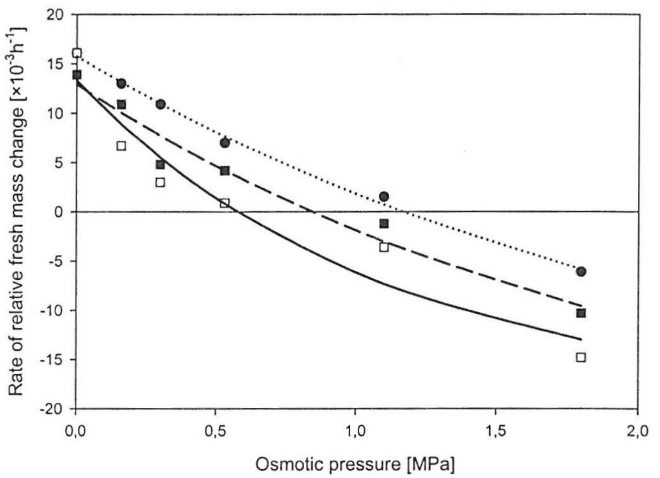

Fig. 2. Effect of osmotic pressure on the rate of water uptake /loss by pea seeds irradiated with red light (solid line) and far-red light (dotted line). Short dash curve represents dark control.

Further improvement in the conductivity test may come from a better understanding of the nature of the compounds leaked from the investigated cell. For example, it was reported that exudates from bean seeds contained sugars, amino acids, phosphorus and potassium ions, and dehydrogenase enzymes [7]. Taylor [9] found that the predominant amino acid leaked from various non-germinable vegetable seeds included alanine, while tomato and pepper seeds leaked only small amounts of amino acids. The detection of leakage of specific compounds may provide a more sensitive appraisal of conductivity of seeds test solution and observed correlation with seeds vigor in future.

CONCLUSIONS

A study of water sorption kinetics in germinating pea seeds has shown that red light decreases the water uptake by seeds, whereas far-red light has the opposite effect. From the analysis of the general equation of volumetric cell growth, it can be concluded that the predominant effect of light treatment is a modification of the *GP* parameter by variation in the osmotic pressure of the cellular medium or in the yeld treshold *Y*. Electroconductivity of the seeds test solution is also under phytochrome control as seen from its fotoreversibility.

We can not estimate is the higher electroconductivity the effect of imbibitional damage accompanied with the greater water flow or it is a result of the complex enzymatic processes in germinating seeds.

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WPŁYW ŚWIATŁA CZERWONEGO I DALEKIEJ CZERWIENI NA ELEKTROPRZEWODNICTWO ROZTWORÓW TESTOWYCH DLA NASION GROCHU

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S t r e s z c z e n i e. Metodę grawimetryczną, pomiar poboru wody w warunkach stresu osmotycznego oraz pomiar elektroprzewodnictwa zastosowano łącznie do scharakteryzowania sorpcji wody przez nasiona grochu. Światło czerwone powoduje obniżenie poboru wody przez nasiona podczas gdy światło dalekiej czerwieni zwiększa pobór wody w odniesieniu do nasion kontrolnych, hodowanych w ciemności. Elektroprzewodnictwo roztworów testowych również zmienia się pod wpływem działania światła czerwonego (bliskiej i dalekiej czerwieni).

S ł o w a k l u c z o w e: kiełkowanie, fotoodwracalność, fitochrom, elektroprzewodnictwo.