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ULTRASONICS IN AGRICULTURE: CATALYTIC INFLUENCE ON WHEAT GERMINATION

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Abstract: An attempt has been made to study the influence of ultrasonic energy on the germination of wheat by the method of ion efflux from the knowledge of specific conductance of the imbibition medium. The apparent energy of activation and percentage germination for different exposures of ultrasound were determined. The optimum duration appears to be species specific. It has been noticed that ultrasound may be used as an effective catalyst in promoting germination of wheat.

1 - INTRODUCTION

The progress of ultrasonic biophysics has been more rapid towards the medical applications rather than botanical or agricultural aspects which is obvious from published literature /1/. The reports on interaction of ultrasound with seed systems are not so numerous. Pearl Wienberger and El'Pienar /2/ have found clear differences between irradiated and non-irradiated seeds.

It has been reported that bleached pea seeds gave relatively high values of electro-conductivity and germinated poorly compared to unbleached seeds /3/. The kinetics of efflux of electrolytes has been studied and the Arrhenius activation energies have been determined from a knowledge of conductivity of the external medium /4/. The apparent activation energies for cotton seed in the autocatalytic and linear regions by the method of water uptake have been determined by Dewez /5/. The influence of ultrasonic energy on imbibition of Bengal gram seeds has been studied using the water uptake method /6/.

Here an attempt has been made to study the influence of ultrasonic energy on the imbibition of wheat by the method of ion efflux rather than by the water uptake method /7/. From a knowledge of specific conductance of the imbibition medium, the autocatalytic ion efflux constants and the apparent energies of activation are calculated for different exposures of ultrasound to wheat.

2 - THEORETICAL CONSIDERATIONS

The rate of ion efflux by the seeds into the imbibition medium has been viewed as an autocatalytic reaction which could be described by the differential equation.

$$\frac{d\sigma}{dt} = k_i \sigma (\sigma - \sigma_e)$$  (1)

where $\sigma$ is the specific conductance at any time, and $\sigma_e$ is the specific conductance at an infinite time. No processes other than those governed by an auto catalytic rate law were assumed to be operating during imbibition.

At time $t = 0$, $\sigma = \sigma_o$  (2)

where $\sigma_o$ is the specific conductance of distilled water and the proportionality constant $k_i$ is the autocatalytic ion efflux constant. Integration of equation (1) gives

$$\sigma = \frac{\sigma_o \sigma_e}{\sigma_o + (\sigma_e - \sigma_o) \exp (-k_i \sigma_e t)}$$  (3)
From eqn. 3, a plot of log \( \frac{\sigma - \sigma_t}{\sigma} \) against time \( t \) gives a straight line from the slope of which the value of \( k_t \), the autocatalytic ion efflux constant may be calculated.

The rate of a chemical reaction increases considerably with increase in temperature. The Arrhenius equation is given by

\[
K = Ae^{-\frac{E_a}{RT}} \tag{4}
\]

where \( A \) is the Arrhenius factor, \( K \) is the specific reaction rate, \( T \) is the absolute temperature, \( E_a \) is the energy of activation which represents the minimum energy required for collision between molecules to be effective and determines the influence of temperature on reaction velocity. The specific conductance of the imbibition medium at the end of a fixed interval of time, at different temperatures, was used as a measure of the rate of reaction for determining the activation energy for control and exposed seeds here.

3 - EXPERIMENTAL METHODS

An Indian cultivar of commercial wheat named Bansi has been chosen for this study. The experiment was carried out in three parts: (a) exposure to ultrasonic radiation (b) measurement of ion efflux and (c) determination of the percentage germination.

a) 2 gms. of seed was weighed accurately on a sensitive electrical balance taking care to include only whole seeds. Exposure to ultrasonic field was carried out on the sample in 10ml of distilled water using an ultrasonic interferometer (Mittal Enterprises) operating at a fixed frequency of 3 MHz. The seeds were carefully transferred into a beaker along with the imbibition medium and 40ml of distilled water was added to make the total volume of the imbibition medium to 50ml. The samples were exposed to 5, 10, 15 and 20 minutes of ultrasound. A control was also set without exposure for comparison. Each exposure was replicated thrice.

b) The specific conductance of the imbibition medium for control as well as exposed seeds were determined at regular intervals of one hour. The extent of increase in specific conductance is expressed as a percentage of the specific conductance of pure distilled water. In order to obtain the apparent energy of activation, the procedure outlined above for exposure was followed and imbibition was carried out at three different temperatures viz., -5°C, 11°C and 29°C. The specific conductance was determined at the end of two hours for the above three temperatures.

c) After exposure, the seeds were tested for germination by using the conventional method of recording the radicle emergence after 24 hours. All values reported are the mean of three trials.

4 - RESULTS AND DISCUSSION

Fig.1 presents typical ion efflux curves for control and exposed (to ultrasonic radiation for 5, 10, 15 and 20 minutes) wheat seeds. It can be seen from these that the value of specific conductance for 20 min. exposure is less than that of control seeds at the end of one hour as well as at the end of 5 hours. These ion efflux curves are analysed for obtaining the autocatalytic ion efflux constants. The asymptotic value of the ion efflux curves, \( \sigma_t \), after the onset of linear phase is a characteristic of the seed. Exposure to the physical agent, namely ultrasound is reflected in this parameter and hence \( \sigma_t \) is different for control and exposed seeds. The semi logarithmic values of \( \frac{\sigma}{\sigma_t - \sigma} \) versus time \( t \) are plotted for each exposure, the slope of which yields the autocatalytic ion efflux constants. There is a correspondence between low ion effluxes and high values of autocatalytic ion efflux constants.

A plot of the logarithmic value of specific conductance at the end of 2 hours for three different temperatures and the reciprocal of absolute temperature yields a straight line (eqn.4). From the slope, \( E_a \) the activation energy can be calculated for each exposure as shown in Fig.2. \( E_a \) represents the energy required to move the solute from the seed into the external medium in the present context.

When the autocatalytic ion efflux constant is high, the activation energy decreases. From Table-1 it can be seen that a 20 min. exposure to ultrasound gives low activation energy of 6.4 Kcal/mole compared to 7.1 Kcal/mole for control indicating a possible catalytic action for this duration of exposure. Perhaps the influence of exposure to ultrasonic energy can only be detected when seeds are irradiated for optimum durations. However this optimum duration appears to be species specific. Further work by varying the frequency may be useful in understanding what influences the rate of the reaction (ion efflux) between the seed and the imbibition medium to explain the interaction of ultrasound with the seed system.
Table 1: Variation of germination percentage, apparent energies of activation and autocatalytic ion efflux constants with exposure to ultrasonic energy.

<table>
<thead>
<tr>
<th>Exposure time (min)</th>
<th>Germination (%)</th>
<th>Apparent Energy of activation (KCal/mole)</th>
<th>Auto catalytic ion efflux constant (hr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>88</td>
<td>7.1</td>
<td>2.6</td>
</tr>
<tr>
<td>5</td>
<td>78</td>
<td>8.4</td>
<td>2.3</td>
</tr>
<tr>
<td>10</td>
<td>94</td>
<td>8.4</td>
<td>2.1</td>
</tr>
<tr>
<td>15</td>
<td>96</td>
<td>8.0</td>
<td>2.1</td>
</tr>
<tr>
<td>20</td>
<td>94</td>
<td>6.4</td>
<td>3.0</td>
</tr>
</tbody>
</table>

REFERENCES

Fig. 1: Ion efflux curve as a function of time for Wheat.

Exposure time = 20 min

Time in hours

Fig. 2: Arrhenius plot for the determination of apparent activation energy for Wheat.

Exposure time = 10 min

Exposure time = 15 min