# Use of the delayed luminescence test for evaluation of changes in frost-resistance of winter wheat

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#### Abstract

The influence of frost hardening conditions on the frost-resistance of three winter wheat cultivars ('Mironowska 808', 'Grana' and 'Maris Huntsman') was studied. Frost resistance was measured periodically during the autumn and winter season by the delayed luminescence method. Parallelly an electrical conductivity test was performed for comparison. It was found that the temperature which delayed luminescence reaches its maximum  $\langle t_N \rangle$  correlates with  $\langle t_{50} \rangle$  obtained by the conductometric method.

The differences in response of particular cultivars to frost and hardening conditions are described.

#### **INTRODUCTION**

One of the main indices of hardiness of plants is their frost-resistance, a hereditary trait, which comes into play during the autumn-winter period of becoming accustomed to cold. The development of this trait is a dynamic process, variable in time and dependent on the changing ecological conditions  $\langle L \, e \, v \, i \, t \, t$ , 1956; 1972; G r z e s i u k et al., 1974 $\rangle$ .

With frost resistance of plants are connected both the mechanisms which enable the plant to avoid freezing of the tissues and those which protect the tissues from the consequences of freezing, especially from severe dehydration of the cells  $\langle K \ a \ c \ p \ e \ r \ s \ k \ a-P \ a \ l \ a \ c \ z, \ 1970; \ 1978 \rangle$ .

In breeding work for frost-resistance the most reliable results are obtained in field observation under natural conditions. Since severe winters selectioning the material are relatively rare in this country, it is necessary to conduct investigations on frost-hardiness of plants under laboratory conditions  $\langle K \circ c z \circ w \circ k \rangle$  and  $\langle K \circ c \rangle \circ k \circ k \rangle$ . Among the numerous methods of frost-hardiness evaluation  $\langle K \circ c \rangle \circ k \circ k \rangle$  and  $\langle K \circ c \rangle \circ k \circ k \circ k \rangle$  and  $\langle K \circ c \rangle \circ k \circ k \circ k \rangle$ . Ho f f m an et al., 1975 especially noteworthy are the studies utilizing

the detection of delayed luminescence of green plants (B r z ó s t o w i c z et al., 1981). The luminescence methods are of high precision, the measurement time is short and the plants examined may be further used for breeding.

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The phenomenon of delayed luminescence (S t r e h l e r and A r n o l d, 1951) has been utilized for long years both in investigations of the process of photosynthesis itself and of phenomena connected with photosynthesis (E s s e r, 1969; S h u v a l o v and L i t v i n, 1969; A r n o l d and A z z i, 1971; M u r k o w s k i, 1974).

External stress factors disturbing the functioning of the photosynthetic apparatus cause changes in the intensity and character of delayed luminescence emission (D o s k o c h et al., 1976: L a v o r e l, 1969; K i t l a e v and T a r u s o v, 1970; M u r k o w s k i, 1974; T a r u s o v and V e s e-l o v s k i i, 1978). These changes depend on the intensity of the stress factor, its duration and the susceptibility of the plant. This allowed the application of delayed luminescence detection for developing methods of frost-resistance evaluation (D z h a n u m o v et al., 1978; T a r u s o v et al., 1976; T a r u s o v and V e s e l o v s k i i, 1978).

The present authors undertook development and testing in practice of the luminescence method for frost-hardiness evaluation in cereal plants, and part of the results concerning the hardiness of winter wheat is the subject of this paper.

#### MATERIAL AND METHODS

The material consisted of leaves of three winter wheat  $\langle \textit{Triticum} \rangle$  varieties: 'Mironowska 808', 'Grana' and 'Maris Huntsman' from experimental plots in Szczecin Zdroje. The plants were uprooted and transferred to a refrigerator  $\langle \text{fluorescence light of 25 W} \cdot \text{m}^{-2} | \text{intensity, temperature equal to the air temperature on the day of collection of the plants} and the temperature was changed at a rate of <math>1^{\circ}\text{C} \cdot \text{h}^{-1} | \text{down to } 5^{\circ}\text{C}$ . After 24 h segments of leaves 4 cm long were collected for investigation. They were placed in a measuring chamber on the surface of a thermobattery previously cooled to  $0^{\circ}\text{C}$ . After 3 min of adaptation the temperature was depressed within the interval of  $0^{\circ}$  to  $-20^{\circ}\text{C}$  at a rate  $1^{\circ}\text{C} \cdot \text{min}^{-1}$ . In the course of temperature fall the plants were irradiated at minute intervals for 2 s with light of 30 W · m - 2 intensity. Two seconds after switching off the inducing light the intensity of delayed luminesce was recorded during two successive seconds. The measurement cycle was repeated at 1-min intervals. As index of frost-resistance the temperature  $\langle t_N \rangle$  was assumed at which the intensity of delayed luminescence was highest.

Simultaneously frost-resistance was measured by the conductometric method  $\langle K \text{ a c p e r s k a-P a l a c z and D l u g o k e c k a, 1971}, modified by the present authors. In the method used plants without roots were taken and the process of their "complete killing" was run during 16 h at -30°C <math>\langle$  instead of +100°C $\rangle$ . Temperature  $\langle t_{50} \rangle$  at which 50 per cent of the plant tissues is damaged served as index of hardiness.

The material was collected in the middle of each month from November 15, 1981 to March 15, 1982.

All measurements of delayed luminescence (DL) were carried out in four replications, and the conductometric measurements in ten replications. Errors in measurement graphically marked on the diagrams were calculated by the Student-Fisher method for the confidence level 0.95.

#### RESULTS

A block diagram of the measuring system of delayed luminescence is shown in Figure 1, and the results of frost-resistance evaluation of the tested winter wheat cultivars  $\langle A - 'Maris Huntsman', B - 'Grana', C - 'Mironowska 808' \rangle$ 

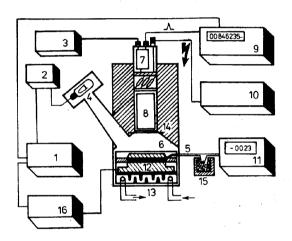


Fig. 1. Block diagram of system for massurements of delayed luminescence intensity of plants at different temperatures: 1 — programming system, 2 — autotransformer, 3 — stabilized power supply, 4 — projection lamp, 5 — thermocouple, 6 — lightproof camera, 7 — amplifier, 8 — photomultiplier, 9 — counter, 10 — high voltage power supply, 11 — voltmetre, 12 — thermoelectric battery, 13 — water cooler, 14 — diaphragm, 15 — vacuum flask with ice, 16 — low voltage power supply

obtained by the luminescence and conductometric methods are shown in Figure 2. As seen, the values  $\langle t_N \rangle$  and  $\langle t_{50} \rangle$  change, reaching minimum in February. This is probably due to the progressing natural adaptation (hardiness development) in the plants, connected with the occurrence of severe frost in this period  $\langle \text{Fig. 3} \rangle$ . In March  $\langle t_N \rangle$  and  $\langle t_{50} \rangle$  drastically increase and their values exceed even the autumn ones. This may be evidence of loss of hardiness by the plants, owing to the temperature rise in the end of February and in March, when the mean diurnal temperature reached as much as  $+8^{\circ}\text{C}$   $\langle \text{Fig. 3} \rangle$ .

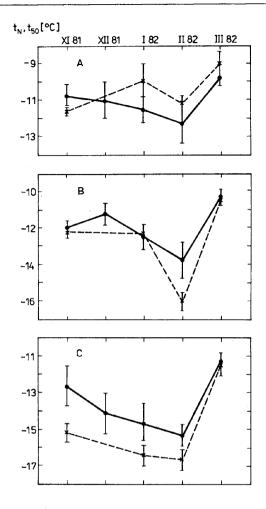


Fig. 2. Average  $t_N \langle -- \rangle$  and  $t_{50}$  values  $\langle -x- \rangle$  measured during autumn and winter season 1981/82 for wheat winter cultivars: A - 'Maris Huntsman', B - 'Grana', C - 'Mironowska 808'

The  $\langle t_N \rangle$  and  $\langle t_{50} \rangle$  temperatures were over the whole period of investigation higher for the cultivar 'Maris Huntsman' than for the cultivar 'Grana' and 'Mironowska 808'. This indicates, in agreement with literature data  $\langle D \text{ o l-n i c k i, 1975} \rangle$ , that the cv. 'Maris Huntsman' is unresistant to low temperature, 'Grana' is medium-resistant and 'Mironowska 808' is the most resistant of the tested plants.

The results of evaluation of frost-resistance of three winter wheat varieties obtained by the described, measurement methods show good agreement of the  $\langle t_N \rangle$  and  $\langle t_{50} \rangle$  values for the particular cultivars in the whole autumn-winter period.

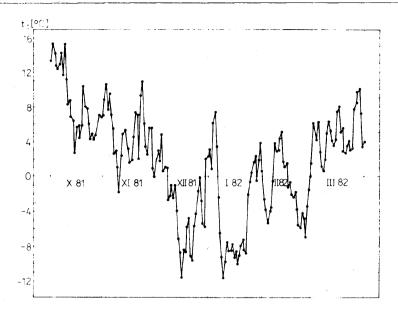


Fig. 3. Average diurnal temperatures  $\langle t_d \rangle$  for autumn and winter season 1981/82

#### CONCLUSIONS

- 1. Measurement of delayed luminescence  $\langle DL \rangle$  demonstrated differences in hardiness of the tested wheat varieties. As expected, the temperature at which maximum DL was observed was lowest for the frost-resistant variety, 'Mironowska 808' and highest for the low-resistance variety 'Maris Huntsman'.
- 2. The investigations showed the usefulness of the luminescence method for evaluation of the frost-resistance of various winter wheat varieties and for observation of their resistance during adaptation to cold.

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## Wykorzystanie testu luminescencyjnego do oceny zmian mrozoodporności pszenicy ozimej

#### Streszczenie

Zbadano wpływ jesienno-zimowego hartowania na mrozoodporność trzech odmian pszenicy ozimej ('Mironowska 808', 'Grana', i 'Maris Huntsman'). Ocenę mrozoodporności przeprowadzano co miesiąc testem luminescencyjnym i metodą konduktometryczną. Jako wskaźnik mrozoodporności w metodzie luminescencyjnej przyjęto temperaturę  $\langle t_N \rangle$ , w której występuje maksimum natężenia opóźnionej luminescencji. Natomiast metodą konduktometryczną wyznaczano temperaturę  $\langle t_{50} \rangle$ , która powoduje uszkodzenia 50% tkanek.

W trakcie hartowania róślin zarejestrowano wyraźne różnice w mrozoodporności badanych odmian oraz obniżanie się  $\langle t_N \rangle$  i  $\langle t_{50} \rangle$ . Stwierdzono również dużą zgodność między wartościami  $\langle t_N \rangle$  i  $\langle t_{50} \rangle$  badanych odmian w ciągu całego hartowania.