EVALUATION OF THE RAPESEED FROST RESISTANCE BY A DIELECTRIC METHOD

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In the usual agricultural practice, the evaluation of frost resistance is based on the data characterizing the wintering of selected samples. This evaluation however often includes a series of additional factors e.g. bacterial infections, damage of cultures by pests etc (Segeťa, 1965). The obtained results then do not reflect the true resistance of crop to low temperatures and are largely distorted by other factors. The laboratory tests used in plant breeding practice do not allow to determine so called critical values; these can be found only indirectly after extrapolating the results obtained at various temperatures. The tests are time-consuming and generally require considerable manual work.

The attemps to simplify the evaluation of frost resistance have led to methods based on physical principles. The new experience of botany in physiology of frost resistance in plants (Tumanov,1979), studies on plant water regimes (Sedych,1970), as well as some experiments carried out with NMR and DTA methods (Burke et al.,1975) suggest possibilities of the evaluation of frost resistance on the basis of water binding in plant tissues. The results indicate that the adaptation to low temperature causes an increase of the proportion of bound water (on structural proteins etc.). These changes are exceedingly pronounced in resistant plants and may be indicated by measuring the dielectric properties of plant tissue in certain frequency regions (Mládek,Stuchly,1977). The measurements of the dielectric properties can even reflect the dynamics of

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changes in the spring season when plants can be damaged even by mild frost (Fábry,1975)

MATERIAL AND METHOD

Since a determination of the dielectric properties in a broad frequency range is of interest, the coaxial technique should be employed. The sample holder is formed by a section of the coaxial transmission line ended by a shunt capacitor in which the sample under investigation is placed. The originally propcsed method (Stuchly et al.,1974) was modified by Nývlt (1982) for measurements of the loss factor of biological materials. The instrumentation can cover the range between 5 Hz and 2 GHz, tissue samples can be tempered in the range from -25 to 30 °C. After some check measurements and the determination of the optimum frequency range, most measurements were performed at frequencies from 10 to 450 MHz and at a temperature of 20 °C.

In the period 1977 - 1982, a comprehensive study of the dielectric properties of plant tissues in many varieties of winter rape were carried out simultaneously with their parallel evaluation on the basis of field tests, laboratory freezing tests and other biological aspects. The measurements involved mostly the tissue of growth apex. The samples cut from this tissue were discs of diameter 3 mm and thickness 0.5 mm. The details on the sample holder, relations for the calculation of both components of the complex permittivity and measurement uncertainties, as well as for the statistical evaluation of plant groups representing individual genotypes, have been published elsewhere (Nývlt,1982).

RESULTS AND DISCUSSION

The values of the complex permittivity ($\varepsilon_r^* = \varepsilon_r' - j\varepsilon_r''$) show a characteristical decrease in the winter season. This decrease is especially well pronounced in imaginary part ε'' denoted as the loss factor. The typical results are shown in Fig.1. The average values of the loss factor were determined in a period from November to April. In agreement with some former measurements (Havlíček et al.,1980), the hardening of plants is accompanied by the water activity decrease which is manifested in the values of loss factor ε_r''. This decrease is deeper in more resistant genotypes having a better ability to bind water. That is evident from the comparison of ε'' values for varieties Brink and S1-20. Their differences in the frost resistance were confirmed by

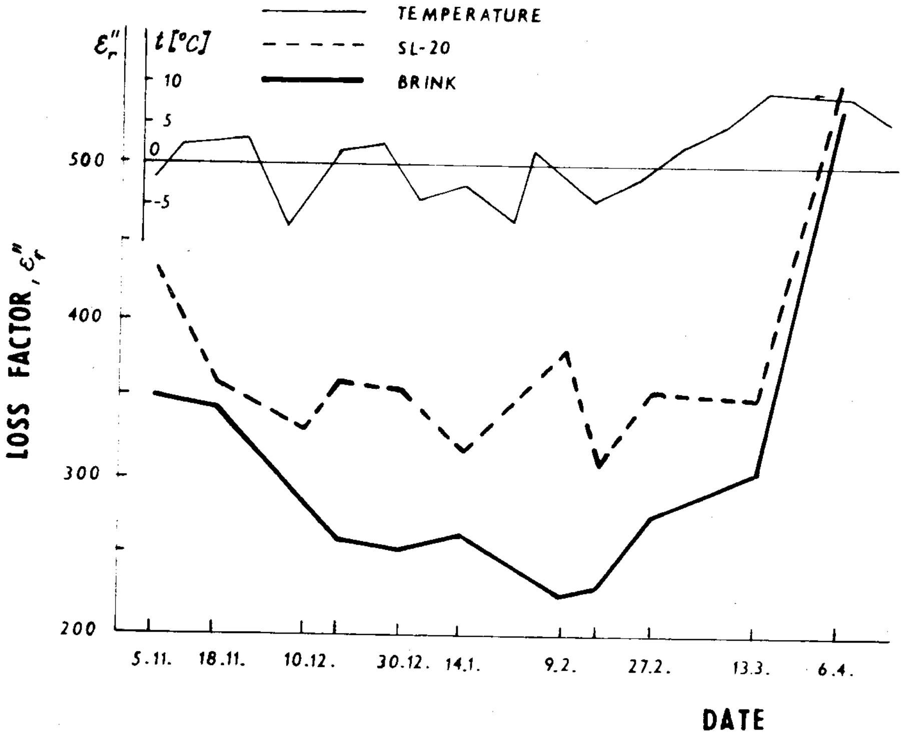

Fig.1 The loss factor at 50 MHz as a function of time for rape varieties with a different resistance to cold (season 1980/81)

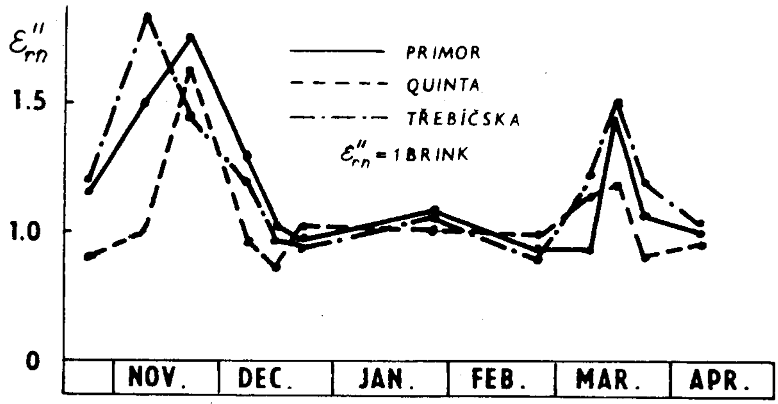

Fig.2 Normalized values of the loss factor at 50 MHz (season 1978/79)

biological as well as by freezing tests. The average week temperature in the region of experimental plots is given for comparison.

The decrease of permittivity values is not a single characteristic reflecting the relation with the frost resistance. The rate of reaching this minimum, or vice versa the rate of disappearing this hardening are also of a great importance. Generally it involves the rate of reaction of plants in a certain developmental stage to the external temperature. Even when the differences are obvious from Fig.1, it is useful to introduce so called normalized values ε''_{rN}. The classification of a selected varietal assortment is illustrated in Fig.2. The normalized values, ε''_{rN}, are defined as a ratio of the actual values of loss factor ε''_r of investigated and reference varieties. In Fig.2 the reference is variety Brink. The figure shows that certain varieties are more active both in fall and spring seasons. The delayed reaction to the fall drop of temperature and on the other hand the rapid increase of activity in early spring (e.g. variety Primor) evidence a lower frost resistance compared with variety Brink. These differences are disappearing in further vegetation phases in late spring. Therefore, the early spring is the season with optimum conditions for the evaluation of individual genotypes. However the time with these optimum conditions is relatively short and can be easily passed by.

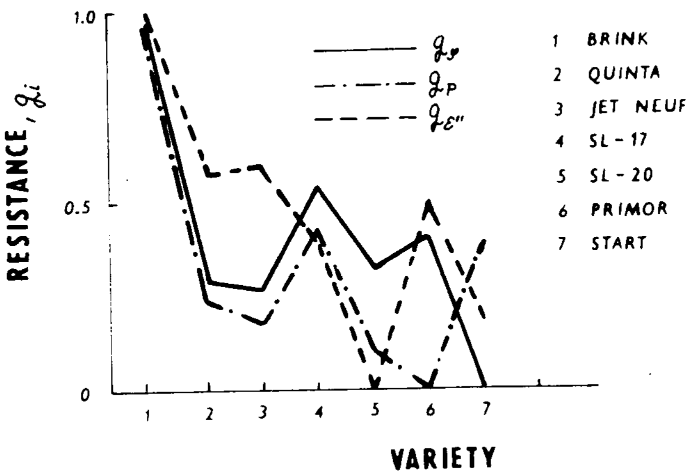

Fig.3 Coefficients of the relative frost resistance calculated from dielectric measurements and field tests (season 1980/81)

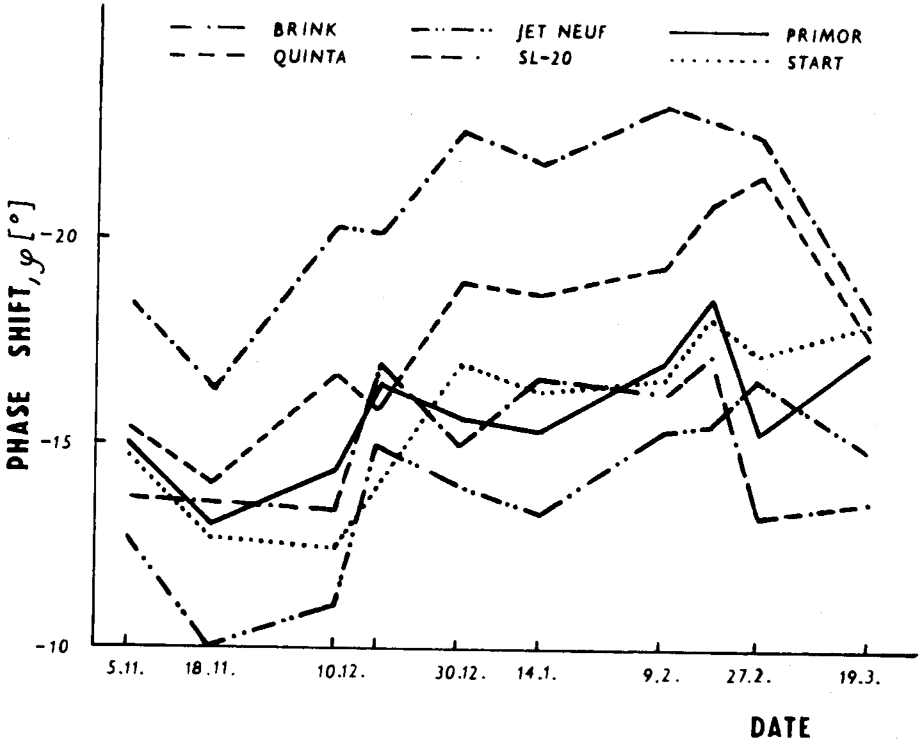

Fig.4 The phase shift of the impedance of different rape varieties(season 1980/81)

In an attempt to express the differences between varieties, we tried to find an objective and reliable criterion. Therefore, the non-dimensional coefficient, q_i, defined by the following expression was introduced.

$$q_i = (\varepsilon''_{rmax} - \varepsilon''_{ri}) / (\varepsilon''_{rmax} - \varepsilon''_{rmin})$$

ε''_{ri} is the average value of the loss factor for the i^{th} variety over a testing period and ε''_{rmax} and ε''_{rmin} are the extreme values in a group under investigation. This equation transforms values ε''_r into interval from 0 to 1. The variety with the highest frost resistance being classified by $q_i = 1$, while the variety with the lowest frost resistance by $q_i = 0$. The distribution of q_i represents the scale of relative frost resistance among varieties under investigation. An example of the frost resistance evaluation is illustrated in Fig.3. The figure shows also the results based on field tests (q_p). The evaluation according to the loss factor ($q_{\varepsilon''}$) as well as according to the phase shift (q_φ) are in a relatively good agreement with field tests. For illustration Fig.4 shows the time dependence of the phase shift from which the comparison was done.

Using the dielectric principle, we developed a prototype frost resistance meter to be applicable in practice. The sensor is designed as a needle electrode and the evaluation is performed by statistical processing. The advantage of the dielectric method can be of a special value in winters with above normal temperature when this method gives a better sensitivity and more reliable results than field tests.

CONCLUSIONS

Measurements of the dielectric properties of plant tissues can fairly well indicate changes related to the adaptation in winter seasons. The experiments confirmed relations between the permittivity of the growth apex tissue of winter rape and its frost resistance. The method as well as the developed meter have all pre-requisites to become an effective tool for plant breeding practice.

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