SIMULATION OF FROST RESISTANCE OF WINTER WHEAT IN EUROPE BETWEEN 1975 AND 2005

Lazar C., Micale F., Genovese G.

AGRIFISH, IPSC – JRC Ispra, Italy Email catalin.lazar@jrc.it

Abstract
Frost damage is very important especially for Eastern Europe, but in some winters this aspect is of interest also for larger areas of Europe. The effect of the temperature at the crown level (considered as a function of snow and air temperature, Aase and Siddoway, 1979) it is better estimated if the physiological condition of the plant (hardening index) is taken into consideration. The algorithms for simulation of phenology, snow layer thickness, hardening, and frost damages from an older version of CERES Wheat (Ritchie, 1991) were transcribed in VBA and integrated into a system using the weather data base from CGMS (about 4000 grids of 50 x 50 km, starting from 1975) and crop calendars specific for each main agricultural area. In this presentation, the influence of phenology and cultivar dependent frost resistance *per se* is discussed, as well as the overview of the frost damages simulated for the considered period.

Introduction
Winter and facultative wheat cultivars are grown on 75 million ha of the 220 million ha devoted to wheat worldwide. The European wheat market is influenced by cereal production around the Black Sea area (especially Ukraine and the Russian Federation). This area is well known for the high winter kill risk for wheat crops (Braun et al., 1998). On the other hand, even if the wheat crops from other regions of Europe (especially in the northern part of the continent) are damaged by frost only with a low frequency, this perturbation may affect considerably the performances of crop growth monitoring.

The estimation of the frost impact is complicated because, besides the meteorological factors like air temperature and snow depth, one must take into consideration also the physiological status of the plant. Wheat model, the gradual increase of plant resistance to frost during the exposing of low but positive temperatures (process known as hardening) and the losing of this capacity (dehardening) at temperatures higher than 10°C (Gusta and Fowler, 1976).

The current WOFOST version used in the Crop Growth Monitoring System of AGRIFISH unit was not designed to take into account these aspects (Supit et al., 1994; Van Diepen, 2003) and in order to compensate this gap an auxiliary system (Fig.1) for estimation of frost damages was developed (Lazar et al., 2004). This work presents the results of running the new software all over Europe for different years.

Materials and method
The daily weather data (minimum and maximum temperature, precipitation, solar radiation and snow depth) for each 50 x 50 km cell grid of Europe were extracted from MARS-STAT DB (1975-2005) and used for calculation of a "meteorological" frost risk (coincidence of temperatures below -8, -12 or -18°C and snow cover depths lower than 1, 3 or respectively 10 cm) and a "physiological" frost risk based on the model mentioned in introduction.

The model is able to simulate the crop phenology using the sowing date provided by one of the two crop calendars available in CGMS (Willekens, 1998; Kucera and Genovese, 2004) and the cultivar dependent parameters from CERES v3.0 for Bezostaya. Using the calculated temperature at crown level (considered as a function of snow and air temperature, Aase and Siddoway, 1979), the hardening index was estimated (Gusta and Fowler, 1976). Although it is possible to simulate the snow depth, the observed data were preferred for calculus of temperature at crown level. The hardening index was converted into killing temperatures at crown level for each winter day.

A reduction coefficient for the reduction of the existing leaf area index was also calculated and it is used to produce qualitative maps of leaf area reduction.

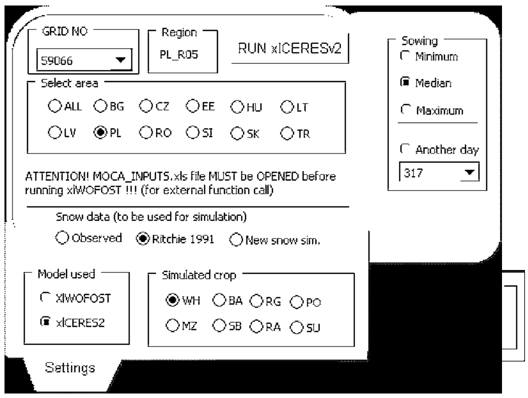

Fig. 1 The user interface

Results
The outputs were used to produce maps for the year of interest. In comparison with the previous maps for frost risk based on the occurrence of low temperatures in the areas with insufficient snow insulation, the new elaborations are additionally taking into account the dynamics of physiological status of the crop (hardening index) and provide separate insights on plant survival and damage to foliar apparatus.

Genetic differences regarding the maximum level of frost resistance that could be obtained by a given cultivar

are not yet taken into consideration but once the information at European scale will became available it will be very easy to take them into account at the level of conversion of hardening index into critical (killing) temperature. Now the system is setup to reduce the simulated number of plants per square metre only when the frost is able to affect cultivars with a good frost resistance *per se*. In this way the risk of false positive results (false alarms) is reduced. Complementary, simulated leaf area reduction and the "classical" approach based on the intersection of low temperatures with poor snow cover are minimizing the risk of false negative results (missing events).
All methods analyzed are sensitive at snow cover depth and the quality of this parameter is very important.

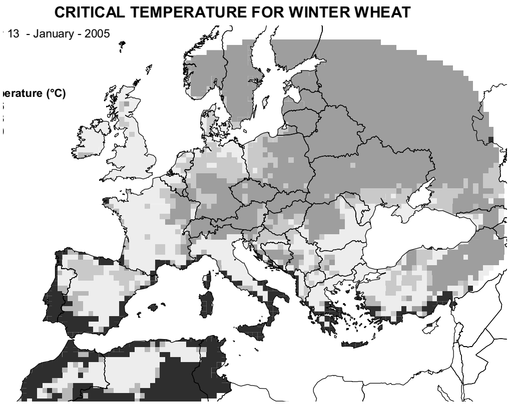

Fig. 2. Example of map for critical temperature

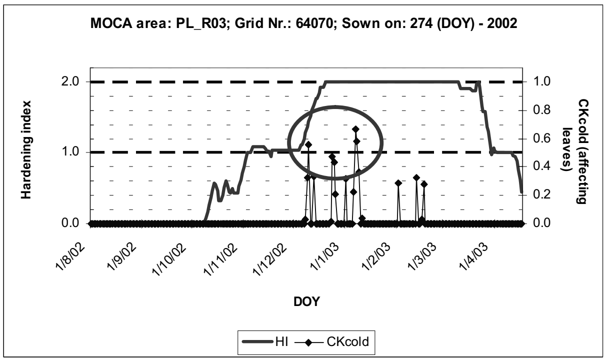

Fig 3. Example of dynamics of hardening index (HI) and reduction factor for leaf area index (CKcold)

Conclusions

This system proved to be useful for detection of potential direct problems induced by low temperatures but it is rather complementary to the "classical" agrometeorological analysis. Quality check of the snow cover data is necessary.

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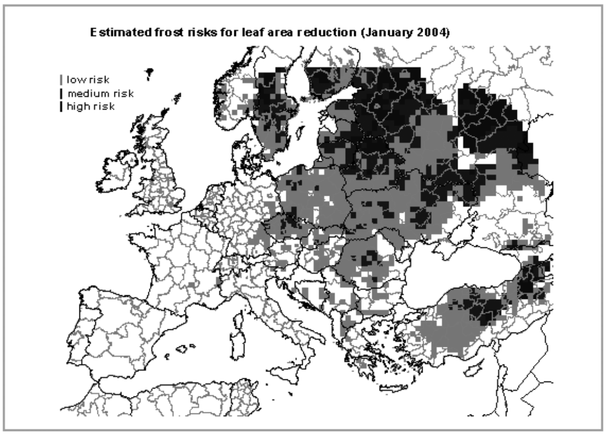

Fig 4. Example of map for risk of leaf area reduction.

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