# IMPORTANCE OF LONG-TERM EXPERIMENTS IN STUDYING THE EFFECTS OF CLIMATE CHANGE

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Nowadays, studying the impact of climate change on agricultural crops is of great importance in national and international projects. Research on the effects of climate change on agricultural cultivars is supported by crop growth models. Simulations provide facilities for the low cost investigation of the effects of many factors, both independently of each other and in combination. These models require parameterisation and testing, which can be done using data measurements. In order to test the correctness of the simulations of meteorological and nutrient supply effects, it is necessary to use the results of long-term field experiments with many replicates.

In the present study, the Ceres Wheat and AFRCWHEAT2 winter wheat crop growth models were tested, utilizing the data of a five-year sowing date experiment and the relevant meteorological data. An analysis was made of whether changes in the sowing date were able to influence or eliminate the negative effects of the changing climate. It was found that choosing the optimum sowing date could be the key to adapting to changing conditions.

**Key words:** climate change, modelling, winter wheat, sowing date

## Introduction

Over the last 150 years the surface air temperature of the Earth has risen by 0.6–0.8°C, with certain deviations from one region to another. The climate of Hungary is jointly determined by oceanic, Mediterranean and continental effects, and these, together with the relief features of the Carpathian Basin, lead to very variable weather conditions. Based on current knowledge, it seems likely that in the long term there will be a gradual warming in Hungary, with a reduction in rainfall quantities and an increase in the frequency and intensity of extreme weather events.

With few exceptions, the effects of climate change on crop production are negative. Rainfall deficiencies cause yield losses, high temperature accelerates ripening processes, thus reducing the yield, extreme weather events lead to greater annual yield fluctuations, and new pests, pathogens and fungi may appear.

The correct choice of sowing date could be of outstanding importance in adapting to the probable effects of climate change. The course of plant development depends not only on weather conditions, but also on the variety.

Altering the sowing date also leads to changes in other parameters, such as the heading date, which could also influence the yield level.

An increase in temperature could have a positive effect on the yield, but if it rises too much or is combined with other weather extremes, the result could be a substantial reduction in the yield level. A steep rise in temperature at flowering may lead to a considerable decline in biomass, and particularly in the grain yield. Damage may be caused not only by a rise in temperature, but also by wide fluctuations in temperature values and to the occurrence of dry periods. This is reflected in the Third Assessment Report of the IPCC, which stated that extremes represent the greatest danger, as they are difficult to predict and their effect is also uncertain. This means that the problem of climate change is really a problem of climate variability.

As for all crops, the weather has a decisive influence on the yield of winter wheat. In Hungary there are often cold winters without snow cover, dry springs and drought in summer. Rainfall is not evenly distributed over the season. Nevertheless, the climate throughout Hungary is suited to wheat production, so relatively high yield averages can be achieved if suitable varieties are grown with satisfactory technologies.

## Materials and methods

*Simulation models*

In earlier studies, the Ceres-Wheat (Ritchie and Otter, 1985) and AF2MOD (Porter, 1993; Harnos, 2003) wheat growth simulation models were tested on long-term county yield averages and weather data series for the counties of Győr-Moson-Sopron and Hajdú-Bihar (Harnos and Erdélyi, 2008). The period tested was 1980–1990, as the cultivation technologies used in Hungary had by this time reached a uniformly high standard, so that yield levels depended mostly on the weather. The annual yield and the weather-dependent changes in yield were adequately described by both models for both counties.

*Experiments*

Sowing date experiments were set up on winter wheat in Martonvásár between 1998 and 2004. Twenty varieties were sown at four different dates each year with optimum nutrient supplies. In the course of the experiments data were collected on the heading date and grain yield, and the yield averages of the 20 varieties were used to test the AF2MOD and Ceres-Wheat models. The weather data were obtained from the meteorological station in Martonvásár. The properties of the wheat variety Martonvásári 8, which is widely grown in Hungary, were used to parameterise the model, the damaging effects of pests, diseases and weeds were eliminated using an integrated plant protection technology, and optimum nutrient supplies were ensured.

## Results and discussion

*Effect of weather on yield levels*

As can be seen in Figure 1, two of the five vegetation seasons analysed had extreme weather conditions. In 1999/2000 the weather was considerably cooler than average both in autumn and during the spring-summer period, while the rainfall sum in winter and early spring was above-average. This had no influence, however, on the heading date or yield level. By contrast, the long, hard winter and dry, warmer than average spring in the 2002/2003 season had an unfavourable effect on the yield, which was only 1–2 t/ha, compared with around 7 t/ha in the previous years. The 1998/1999, 2000/2001 and 2003/2004 seasons were average years from the point of view of both rainfall and temperature, so timely sown cereals produced the expected yields.

In Martonvásár the average sowing date for winter wheat is around 10 October. It is clear from Figure 2 that this sowing date resulted in significantly the best yield, even in the least favourable year. Under good weather conditions a 2-week deviation from the optimum sowing date did not result in yield losses, but under extreme weather conditions (2003) it represented a considerable risk. Early heading was observed to result in higher yields. Sowing later than usual led to yield losses in almost every year.

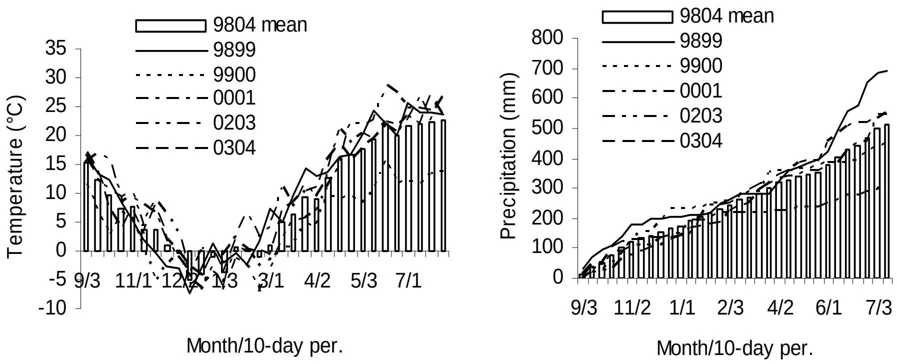


*Fig. 1*. Mean temperature and cumulated rainfall sums measured for 10-day periods between September 1998 and July 2004 at the automatic meteorological station in Martonvásár

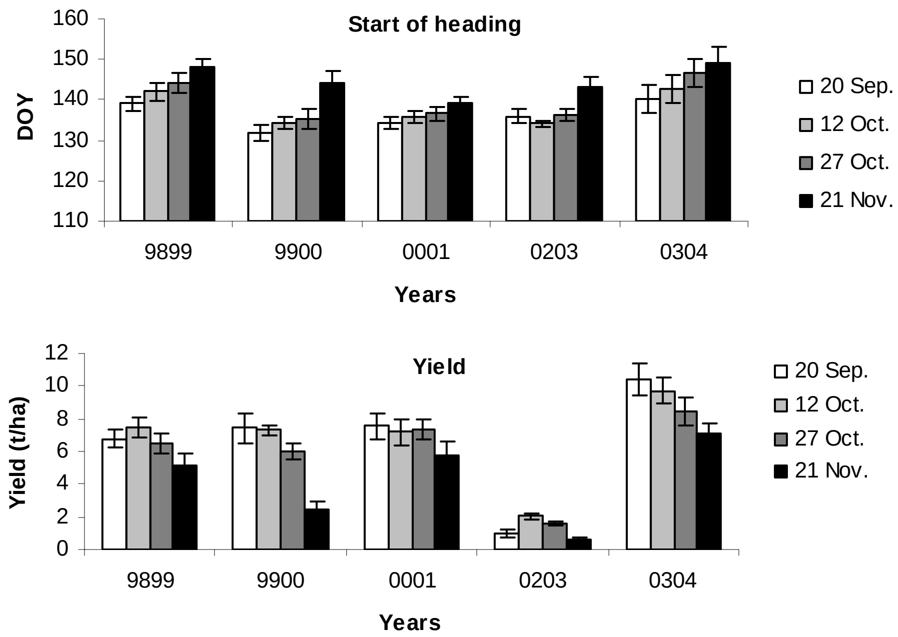


*Fig. 2*. Heading date and grain yield of winter wheat in a long-term sowing date experiment, averaged over 20 varieties

*Evaluation of modelling results*

The models tested were very sensitive to extreme weather conditions. In years with average temperature and rainfall, the models predicted yields close to those actually achieved (Fig. 3). In 2000, however, when the weather was colder than average, the Ceres-Wheat model estimated a lower yield. The effect of the drought experienced in 2003 was reflected in the predictions of both models, though the rainfall sensitivity of the AF2MOD model needs to be corrected.

The aim of model testing was to determine whether the models were capable of giving a satisfactory description of the course of plant development and the grain yield quantity for different sowing dates. In years with average weather, both models gave a good approximation of both the heading date and the grain yield when sowing was carried out in late September or October (Fig. 4). However, further refinements involving new measurement data series will be required if the models are to provide a good description of extreme weather conditions.

In Hungary, scientific research, meteorological data collection and the practical experience of various sectors, including agriculture, all represent an enormous intellectual reserve, but at present they rarely interact. Developments in modelling also offer immense possibilities, but only in the knowledge of experimental results. It seems to be clear that preparations aimed at adapting to climate change should be based on the experience and potential available in Hungary.

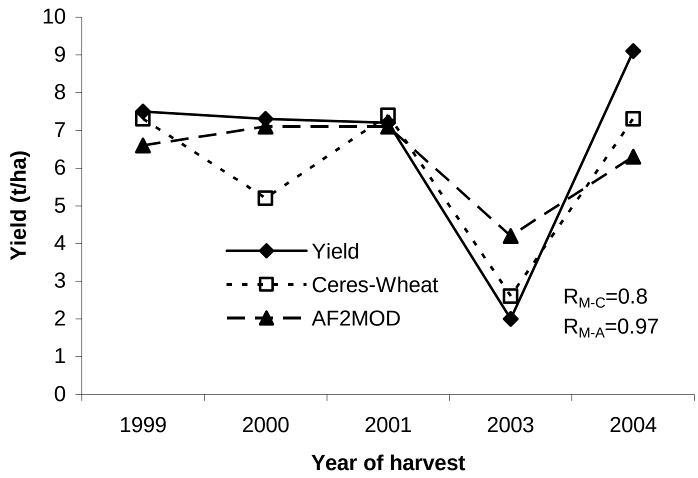


*Fig. 3*. Grain yield of winter wheat sown on 12 October in five years of a long-term sowing date experiment in Martonvásár, and values simulated using the AF2MOD and Ceres-Wheat models. R = Correlation coefficient between measured (M) and modelled (C: Ceres-Wheat, A: AF2MOD) data series

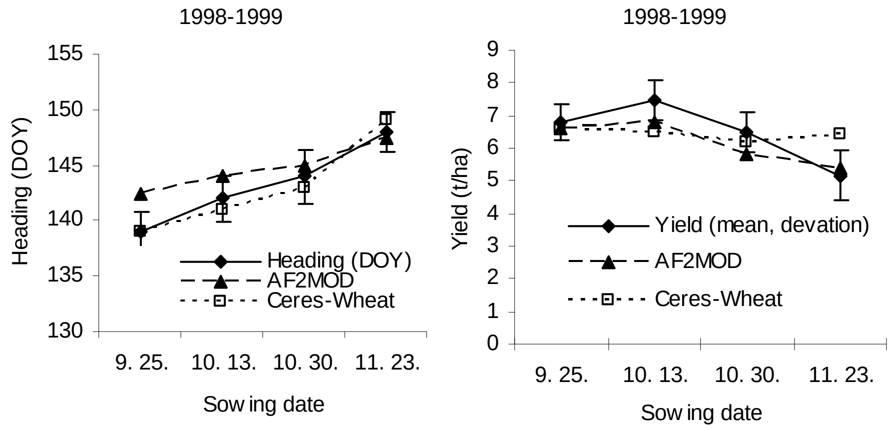


*Fig. 4*. Heading date and grain yield of winter wheat in a long-term sowing date experiment in Martonvásár, and values simulated with the AF2MOD and Ceres-Wheat models

The weather in Hungary is extremely variable, with considerable deviations from year to year. Weather events that are likely to become frequent in coming decades are already experienced today. Data series from long-term experiments would therefore be ideal for the development and testing of simulation models designed to elaborate strategies for adapting to climate change. If preparations are to be successful, closer cooperation is needed between scientists carrying out long-term experiments and those involved in the development and application of simulation models. Only joint efforts based on mutually agreed projects will lead to the desired results.


## Acknowledgements

This work was financed from the EU-FP7-REGPOT 2007-1 project AGRISAFE (No. 203288).


## References


Bartholy, J., Pongrácz, R., Gelybó, G. (2007): Regional climate change expected in Hungary for 2071-2100. *Applied Ecology and Environmental Research*, **5**, 1–17.

Harnos, N. (2003): A klímaváltozás hatásának szimulációs vizsgálata őszi búza produkciójára. (Simulation studies on the effect of climate change on winter wheat production.)*“AGRO-21” Füzetek*, **31**, 56–73.

Harnos, N., Erdélyi, É. (2008): Alkalmazkodási stratégiák őszi búza termelékenységének fenntartásához szimulációs modellek használatával. (Adaptation strategies for maintaining the productivity of winter wheat using simulation models.) pp. 309–328. In: Harnos, Z., Csete, L. (eds.), *Klímaváltozás: környezet – kockázat – társadalom. Kutatási eredmények*. Szaktudás Kiadó Ház, Budapest, ISBN 978-963-9736-87-0.

Porter, J. R. (1993): AFRCWHEAT2: A model of the growth and development of wheat incorporating responses to water and nitrogen. *Eur. J. Agron.*, **2**, 69–82.

Ritchie, J. T., Otter, S. (1985): Description and performance of CERES-Wheat: a user-oriented wheat yield model. pp. 159–175. In: Willis, W. O. (ed.), *ARS Wheat Yield Project. ARS-38*. US Department of Agriculture.