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Yield of spring barley in dependence of soil moisture balance

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Abstract

The occurrence of dry periods with a negative impact on field crop production is a significant characteristic of Czech climate. The amount of usable soil water was calculated using the agrometeorological model AVISO at 21 experimental sites for the period 1975 to 2007 (expressed as percentage of available water holding capacity, % AWHC). The mean seasonal % AWHC value during this period varied from 40% (site Žatec) to 77% (sites Pusté Jakartice and Trutnov). A decrease in usable soil water (% AWHC decrease up to 24%) in a growing season was observed at 20 sites in the long-term trend. Statistically significant relationships were found between grain yield of spring barley and % AWHC. The optimum range of amount of usable soil water for the production of spring barley (65-75% AWHC) was defined by long-term calculations of soil water in combination with a series of yield trials. A significant influence of high underground water level with negative effects on yield was found in some sites (even with low precipitation in maize and sugar beet production areas) caused by different moisture regime.

Keywords

Drought, *Hordeum vulgare*, soil moisture, yield

Introduction

The occurrence of meteorological drought, as well as the occurrence of hydrological, agronomic, physiological and other kinds of drought is an important feature of Czech climate. Lack of soil moisture is expected in the main growing season (approx. 200 days) when rainfall does not exceed 340 mm. The figure results from claims of moisture of the main crops given by the transpiration coefficient. In connection with stress effects on yield and quality the most important indication for growers is the presence of agronomic drought. It is defined as a state where the amount of moisture in the soil is less than required by the particular plant (BLINKA 2005). Literature often defines agronomic drought as a decline in soil moisture below the permanent wilting point (i.e. approx. -1.5 MPa) which stops water uptake and, subsequently, plants stop growing. The results of moisture conditions of the Czech Republic for the period of 1961-2000 (KOHUT et al. 2010) show that locations with the lowest sea level (about 300 m) are characterized by long-term values below 45% available water holding capacity (AWHC), whereas typical values for central locations up to 600 m a.s.l. are 60% AWHC (*Figure 1*). The analysis revealed a decreasing trend of soil water reserves. SPITZ et al. (2007) claims that the proportion of usable water in order not to reduce yields vary according to crop type and stage of development between 45 and 75% AWHC. JAMIESON et al. (1995) use soil moisture in the root zone at 65% AWHC as a limit value for barley before it comes to reduction of transpiration. DOORENBOS and PRUITT (1975) suggest a value of 55% AWHC as a qualitative and not stressful value for all growth phases except beginning of flowering (45%) and maturation. Analysing meteorological data from the period of 1961-2000 in 74 districts of the Czech Republic HLAVINKA et al. (2006) found strong episodes of drought in South Moravia associated with a significant decline in yields of winter wheat and spring barley. Specifically, in the Brno-Venkov district, the correlation coefficient between spring barley yield and the Palmer Z drought index was as high as 0.7.

Material and methods

Soil moisture represented by % AWHC was calculated the years 1975 to 2007 using the AVISO agro-meteorological model (KOHUT et al. 2008). The model is based on fully combined Penman-Monteith equation. For simplicity a grass stand was used as the evaporating surface. The calculation itself was done in a modified form with information about AWHC in the area of every grid point of a 10×10 km square grid in the vicinity of the areas of interest. Specification of AWHC for each point according to data of the Research Institute for Soil and Water Conservation (RISWC) was carried out using GIS methods (digital map of AWHC Czech soils with a resolution of five AWHC intervals). In order to determine the effect of moisture on spring barley yields we used long-term yield trial data (1975-2007; lack of data in one year) from 21 experimental stations. The stations are located in all production areas defined by NEMEC (2001), i.e. maize (MPR), sugar beet (SPR), cereals (CPR), potato (PPR) and forage production (FPR). Considering the varieties in a given year within the experiments of the National Variety Office (NVO) it is possible to quantify the impact of weather or soil or their combination on grain yield.

Results and discussion

The AVISO agrometeorological model was used to calculate AWHC for the spring barley growing season (91st to 180th day of the year) in individual years for experimental stations of NVO. The water supply defined as %AWHC was

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calculated for the period 1975-2007 by including a straight trend line into the calculations. For 20 of 21 stations the long-term trend revealed a decrease of % AWHC (*Figure 2*).

The relationship between soil water reserves and grain yield levels of spring barley is demonstrated in *Figure 3*. A statistically significant relationship between spring barley grain yield and soil %AWHC was found.

% AWHC data were related to the annual yield per hectare of the particular NVO station for the period 1975-2007. Statistically significant ($\alpha \leq 0.05$) correlations were found at different growth stages (*Table 1*). This results from different water regimes of individual locations. For several sites, including the less humid ones, a significant negative impact of high groundwater level to yield has been proven.

For the presented analysis the certified and recommended calculation method in combination with the Penman-Monteith's equation was used in a modified form according to MORECS (The Meteorological Office for Rainfall and Evaporation Calculating System) and AVISO (Agrometeorological Calculating and Informative System) models. The calculation of evapotranspiration and water balance of grass growth was realized in the AVISO model for a number of selected climatic stations. Longtime data of the AVISO agrometeorological model have shown significant reductions in soil water supplies during the growing period of spring barley. Optimum range of usable soil water amount for the production of spring barley yield (65-75% AWHC) was defined by evaluation of long-term calculations of soil water in combination with a series of spring barley yield. The average seasonal value of % AWHC for 1975-2007 ranges from 40% (Žatec) to 77% (Pusté Jakartice a Trutnov). Data on soil water supply at each experimental station was related to the annual yield of spring barley. With regard to an uniform ag-

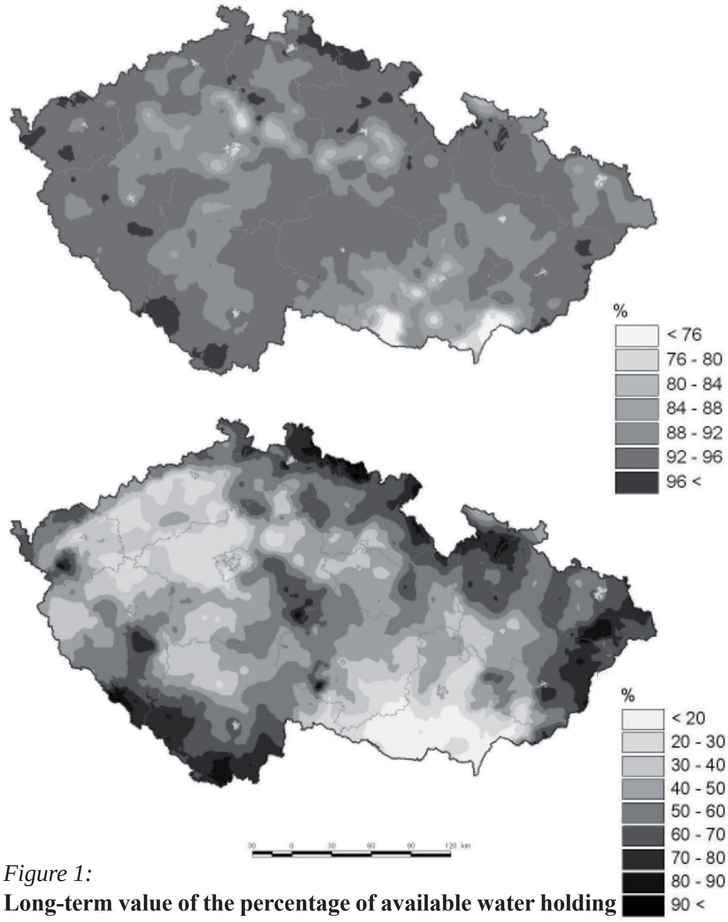

Figure 1:
Long-term value of the percentage of available water holding capacity in Czech soils (top: April 1; bottom: August 31)

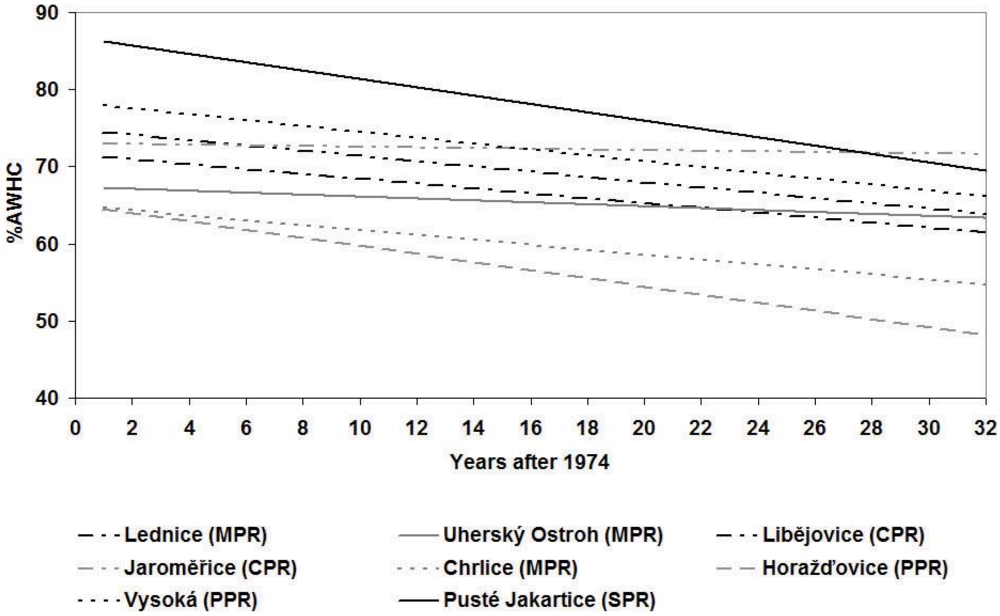

Figure 2: **Development of % AWHC in the period 1975-2007 at selected NVO experimental stations (data interspaced by a linear trend)**

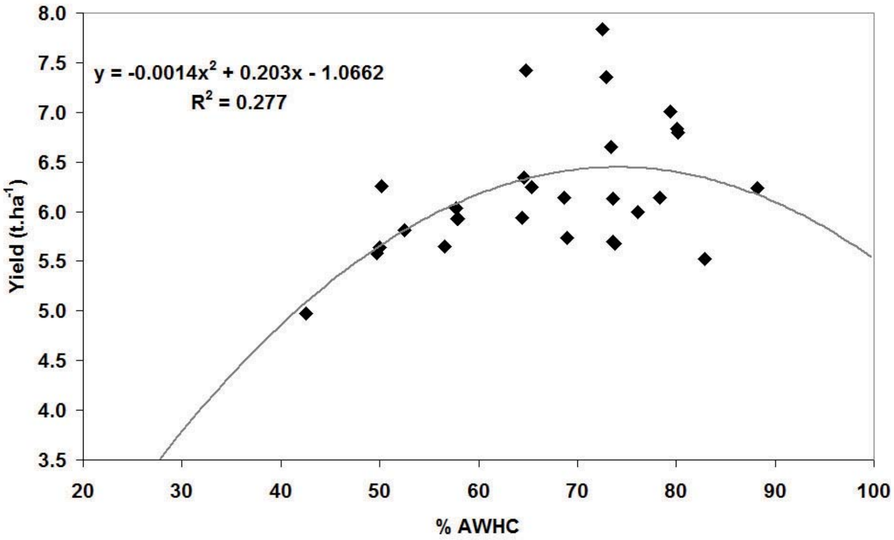

Figure 3: **Relationship between the soil water supply (% AWHC) and potential yield of grain**

Table 1: **Correlation between soil water supply at specific periods of growing days and grain yield of spring barley at selected experimental stations in the period 1975-2007 (*, $P \leq 0.05$; **, $P \leq 0.01$)**

Growing days	Lednice (MPR)	Uh. Ostroh (MPR)	Libějovice (CPR)	Jaroměřice (CPR)	Chrlice (MPR)	Vysoká (PPR)	Žatec (SPR)
91-100	-0.120	-0.565*	0.067	0.236	-0.466	0.154	-0.646
101-110	-0.027	-0.539*	0.193	0.421	-0.573*	0.148	-0.617
111-120	0.141	-0.391	0.297	0.534*	-0.256	0.072	-0.502
121-130	0.286	-0.275	0.438*	0.623*	-0.178	0.198	-0.134
131-140	0.425	-0.210	0.598**	0.625*	-0.132	0.371	0.582
141-150	0.449	-0.213	0.699**	0.614*	-0.136	0.514*	0.003
151-160	0.447	0.056	0.619**	0.393	-0.028	0.523*	0.604
161-170	0.527*	0.205	0.377	0.345	-0.026	0.637**	0.968**
171-180	0.470*	0.302	0.330	0.365	0.002	0.679**	0.504

rotechnical practices (precrop, fertilization) and identical varieties it is possible to quantify the influence of weather or soil and their combination on grain yield. Statistically significant correlations between grain yield and soil % AWHC was observed. Coefficients of correlation for selected experimental stations varied from -0.64 to 0.97. Therefore, the AVISO system can be used to model the influence of weather on yield for any location in the Czech Republic, even for models including scenarios of climate change.

It also allows defining an optimal range of soil water supply for yield formation of spring barley in the country. Statistically significant correlations were found for various growth stages. This is due to differences in water regime of various locations. For some locations, including the ones with poor soil fertility in the maize and sugar beet production region (Chrlice-Svratka, Uherský Ostroh-Morava), a significant negative effect of high groundwater levels after considerable rainfall on barley grain yield was observed.

Acknowledgement

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