ANALYSIS OF SPRING BARLEY ACTUAL EVAPOTRANSPIRATION

Pozníková G.[1, 2], Fischer M.[1, 2], Pohanková E.[1, 2], Žalud Z.[1, 2], Trnka M.[1, 2]

[1]Department of Agrosystems and Bioclimatology, Faculty of Agronomy, Mendel University in Brno, Zemedelska 1, 613 00 Brno, Czech Republic

[2]Global Change Research Center AS CR, v.v.i., Bělidla 986/4a, 603 00, Brno, Czech Republic

E-mail: g.poznikova@gmail.com

ABSTRACT

Evapotranspiration (ET) represents the main water-loss part of the water balance in agricultural landscape. The reliable quantification of the agricultural field ET is, however, still a challenge. To calculate ET, the Bowen ratio/energy balance (BREB) method was used in this study. It is based on measurements of the temperature and humidity gradients and radiation balance with the soil heat flux. Calculated ET was further used to quantify crop coefficient (Kc). Subsequently, we analysed the crop coefficient of spring barley during one growing season since 7th May 2013 to 30th July 2013. We used the data obtained above 1-ha spring barley field in Bystřice nad Pernštejnem, Czech Republic. In particular, we investigated how Kc correlates to climatic conditions as rainfall and soil humidity and how it reflects Plant Area Index (PAI) during the year during different parts of growing season. The cumulative ET of spring barley was 228.6 mm per investigated period. For reference evapotranspiration (ETo) two different approaches were used. Typically, a reference grass cover 0.12 m high standard for Europe. On the other hand, in the USA it is common to use also alfalfa (0.50 m high). ETo of grass was 296.3 mm and ETo of alfalfa was 351.4 mm. Maximum Plant Area Index occurred in June and its value was 4.1. Mean Kc in May was 1.17 for reference grass and 1.03 for alfalfa. Similarly in June, Kc was equal to 1.16 (grass) and 1.03 (alfalfa). Finally in July, for reference grass Kc was 0.55 and 0.48 for alfalfa. The decline at the end of the growing season was caused by dry weather and ripe stage of spring barley.

Key words: reference evapotranspiration, Bowen ratio/energy balance method, crop coefficient, spring barley, Czech Republic

Acknowledgments: This study was supported by the In-house Grant Agency at FA MENDELU in Brno (IP 10/2013) and was supported by the project of National Agency for Agricultural Research "Crop modelling as a tool for increasing the production potential and food security of the Czech Republic under Climate Change" (project no. QJ1310123), and also by the project InterDrought (no. CZ.1.07/2.3.00/20.0248).

INTRODUCTION

Water balance of the terrestrial ecosystems is of high importance in ecology, agricultural, forestry and related fields. In agriculture, evapotranspiration (ET) represents the main water-loss part of the water balance (Fischer, 2012). The reliable quantification of ET for an agricultural field is, however, still a challenge. The economic reasons do not make scintillometry and eddy covariance commonly affordable methods, although they are considered as the most advanced. In addition, these methods integrate relatively large area and thus it is difficult to apply them in mosaic agricultural landscape (as found throughout Europe) to analyze the differences in crop water use. Alternative group of methods is represented by gradient measurements. One of them is the Bowen ratio/energy balance method (BREB) method using measurements of the temperature and humidity gradients, radiation balance and the soil heat flux (Fischer, 2012). The BREB can be employed very close to the canopy top and thus the area which is seen by the sensors can be substantially reduced. This is advantage especially in small-scale fields which are typical for European agricultural landscape. In this study, we used ET calculated using BREB method to calculate crop coefficient (Kc). While predicting ET from particular vegetation type various characteristics of crop has to be taken into account, e.g. vegetation height, amount of leaf area, amount of soil shaded, an albedo, amount of stomatal control to evaporation, and amount of soil wetness beneath the canopy (Allen, 2003). These are represented by one parameter called crop coefficient. We analyzed the reliability of the ET data measured by BREB above 1-ha spring barley field.

In Europe, it is a common practice to use hypothetical grass cover as a reference. On the other hand, in the USA a typical reference surface is considered to be either grass or alfalfa. We aimed to calculate reference ET using both approaches. Then we looked closer at Kc for different phenological phases and it relation to different climatic conditions.

Our main goal was to:

- quantify actual and reference ET using BREB approach,
- determine and analyse crop coefficient of spring barley during one growing season,
- investigate, whether ET of spring barley will correlate better to ETo of alfalfa than ETo of grass because we assume that it better represents the height of the crop of our interest.

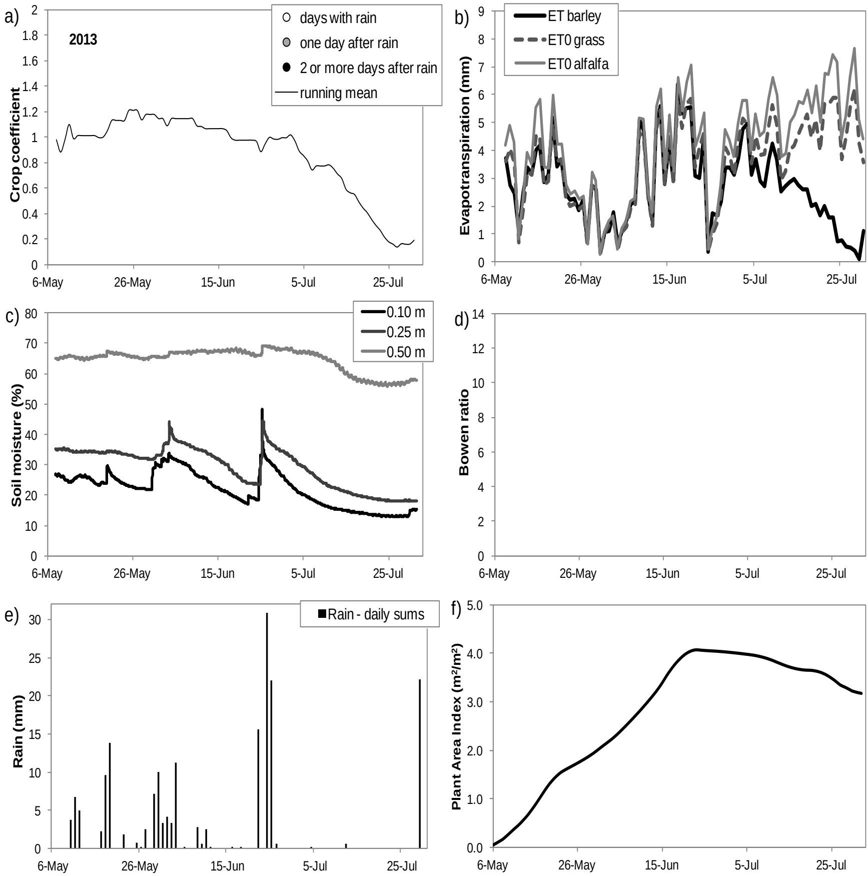
MATERIALS AND METHODS

The data used in this study were recorded during the season 2013 at an experimental field in Bystřice nad Pernštejnem (Czech Republic, 49° 31´ N, 16° 14´ E and altitude 530 m a.s.l.). To gain all necessary data an automatic weather station was placed close to the middle of barley field 7th of May 2013 in order to maximize the distance from the edge downwind with respect to prevailing wind direction. Since then air temperature and humidity at two heights above the canopy (0.2 m and 1.0 m) was recorded as well as net radiation (W/m^2) and soil heat flux(W/m^2). These data were used to calculate actual evapotranspiration (ET) of the spring barley based on BREB method. As a reference, two different hypothetical surfaces were used. Firstly, grassland with standard characteristic for reference crop of 0.12 m high, albedo of 0.23 and a fix surface resistance of 50 and 200 $s.m^{-1}$ for diurnal and nocturnal periods, respectively (Allen *at al.*, 2003). As the second reference crop, alfalfa (0.5 m) with the same albedo and a fix surface resistance of 50 and 200 $s.m^{-1}$ for diurnal and nocturnal periods, respectively, was used. Because alfalfa ETo is more aerodynamically rough, according to Allen *et al.* (2006), values for Kc generally vary less with climate than those based on grass ETo. To calculate reference evapotranspiration (ETo), FAO (Food and Agriculture Organization) Irrigation and Drainage Paper No. 56 was followed (Allen *et al.*, 2006). Subsequently, crop coefficient was calculated as a ratio between actual and reference

ET. During the growing season plant area index (PAI) was measured periodically using ceptometer based system SunScan – Delta-T Devices. PAI is preferred to leaf area index (LAI) if not only leaves but total above ground biomass is included (Bréda, 2003). LAI according to Bréda (2003) is defined as the total one-sided area of leaves per unit ground surface area. The field campaign finished before barley was harvested and so our dataset finishes 31st July 2013.

RESULTS AND DISCUSSION

The results obtained from the survey can be seen in Fig 1. Top left hand side figure (1a) displays crop coefficient of spring barley during the growing season calculated using reference ETo for grass. There are different points distinguishing days with rain, days after rain and two and more days after rain. The Kc of rainy days scatters more from running mean. This was calculated from values of days without rain. Higher divergence is a consequence of higher actual ET of barley after rain when intercepted water with almost zero surface resistance is evaporating intensively. From the shape of the curve of running mean it is obvious that, at the end of the season, ET of spring barley was much lower than ETo as a consequence of dry weather at the end of the season. The distribution of precipitation during the summer is in Fig 1e) showing less rainfall events in July. This is also reflected in soil moisture (Fig 1c). Although it may seem from Fig 1c) that soil moisture is higher in bigger depths, soil water availability in 0.5 m may be comparable to one in 0.1 m. This is because of higher content of clay deeper in the soil. Moreover, it can be also due to the fact that barley was already mature and so not transpiring that much anymore. On the other hand, at the beginning of the growing season most of the surface is represent with bare soil Kc of which is very sensitive to precipitation. There are not many plants to transpire yet. This is quite obvious from PAI curve shown in Fig 1f). But Kc is around 1.0 what can be explained as a result of wet start of the season (also Fig 1e). Although according to literature, Kc of cereals in the initial phase of growth is only 0.3, prevailing surface at that time in the field is bare soil with Kc equal to 1.0 (Allen et al., 2006). In the mid-season period typical value of Kc for barley is 1.15 and 0.25 at the end of the growing season so called late-season (Allen et al., 2006). Following definitions by Allen (2003) the initial period represents the period following planting of annuals until about 10% ground cover. Mid-season extends from “effective full cover” to when plant greenness begin to decrease and the late-season period extends from end of mid-season until harvest or crop death (Allen, 2003). Fig 1b) displays actual and reference ET in mm during the season. First thing to notice, is the decrease of ET at the end of the growing season due to the reasons that have been already discussed. Another point is the difference between ETo for grass and alfalfa. As we expected alfalfa reaches in general higher values of ETo. This is due to higher aerodynamical roughness of alfalfa cover together with lower surface resistance. Last thing to mention is Bowen ratio showed in Fig 1d). The Bowen ratio is the ratio between sensible and latent heat flux (Bowen, 1926). During May and June the values are around 0.5. This refers to higher values of latent heat flux in comparison to sensible heat which is typical for green plants not under stress. Only at the end of season when the soil moisture decreased and plants transpiration was lower the Bowen ratio



values dramatically increased. Subsequently, it dropped again after increased soil moisture.

Fig 1 Results of the survey: a) crop coefficient (Kc) calculated from ETo of grass; b) actual ET of spring barley and reference ETo for both grass (dashed line) and alfalfa (solid gray line); c) soil moisture in three depths under spring barley; d) Bowen ratio calculated for spring barley; e) daily sums of precipitation during whole growing season; f) Plant Area Index of spring barley.

Further, ET rate (mm/hour) for particular months was quantified and is shown in Fig 2. Due to wet beginning of the growing season the difference between actual and reference ET in May and June is not so pronounced. However, ETo calculated for alfalfa shows systematically higher values. In contrast to this, in July the ET for barley is significantly lower than ETo. Our assumption that ET will correlate better with ETo of alfalfa was not confirmed. Values of Kc for individual months can be seen in Tab 1. However, the hypothesis was possibly not confirmed due to relatively low vapour pressure deficit (VPD) at our site (in average 0.75 kPa during daytime).

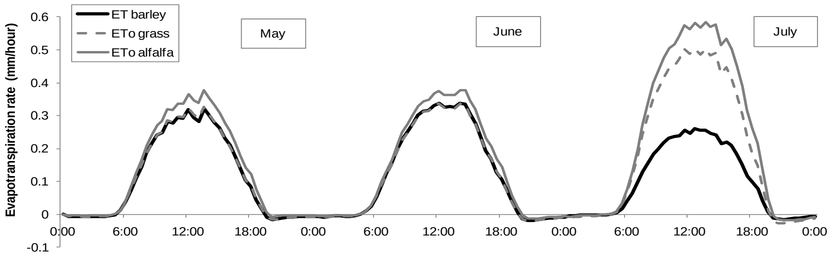


Fig 2 Mean actual (ET) and reference (ETo) evapotranspiration rate (mm/hour) of grassland and alfalfa for individual months.

Tab 1 Mean Kc of barley for particular months calculated for grass and alfalfa and the correlation coefficient describing the relation between actual and reference ET.

	Kc (ETo grass)	Kc (ETo alfalfa)	r – grass x barley	r - alfalfa x barley
May	1.17	1.03	0.92	0.91
June	1.16	1.03	0.96	0.96
July	0.55	0.48	0.65	0.61

CONCLUSIONS

The crop coefficients for spring barley were calculated and analyzed in this study. We can conclude that at the beginning of growing season the Kc reflected more bare soil that real crops. This was mainly due to rainy weather in May and June. On the other hand, dry July together with lower transpiration of ripe crops caused decrease in ET of barley. Potential ETo was, however, high and so Kc declined. Our assumption that ET will correlate better with ETo of alfalfa was not confirmed. However, further study is planned to determine whether Kc calculated using ETo of alfalfa will be more stable that the one of grass. The object of further study remains also, correlation of the differences between ETo based on grass and alfalfa to VPD or ratio between VPD and aerodynamic resistance.

REFERENCES

Allen R. G., Pruitt W. O., Wright J. L., Howell T. A., Ventura F., Snyder R., Itenfisu D., Stedutoh P., Berengena J., Yrisarry J. B., Smith M., Pereira L. S., Raes D., Perrier A., Alves I., Walter I., Elliott R. (2006): A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method. Agricultural Water Management 81: 1–22.

Allen R. G. (2003): Crop coefficients. Encyclopaedia of Water Science, DOI: 10.1081/E-EWS 120010037.

Bowen I.S. (1926): The ratio of heat losses by conduction and evaporation from any water surface. Physical Review, 27: 779–787.

Bréda N. J. J., (2003): Ground-based measurements of leaf area index: a review of methods, instruments and current controversies. Journal of Experimental Botany, 54 (392): 2403–2417.

Fischer M. (2012): Water balance of short rotation coppice, Mendelu Brno. Ph.D. thesis: 261 pp.