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WATER FOOTPRINT OF PROTEIN YIELD OF FIELD CROP SPECIES BASED ON EVAPOTRANSPIRATION PATTERNS

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ABSTRACT
Water availability is one of the major physiological factors influencing plant growth and development. An assessment study has been done at the Szent István University, Gödöllő to evaluate and identify the water footprint of protein yield of field crop species.
Six field crop species (sugar beet *Beta vulgaris*, winter barley *Hordeum vulgare*, winter wheat *Triticum aestivum,* maize *Zea mays*, potato *Solanum tuberosum*, and alfalfa *Medicago sativa*) were involved in the study. Evapotranspiration patterns of the crops studied have been identified and physiologically reliable protein ranges within crop yields were evaluated.
The results obtained suggest, that water footprint of cereals proved to be the lowest, however maize values were highly affected by the high variability of protein yield. Alfalfa, potato and sugar beet water footprints were in accordance with their evapotranspiration patterns.

Keywords: water footprint, evapotranspiration, protein, field crop species

INTRODUCTION

The water footprint shows the extent of water use in relation to consumption by people (HOEKSTRA AND CHAPAGAIN, 2007). The water footprint of an individual, community or business is defined as the total volume of fresh used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in water volume consumed (evaporated) and/or polluted per unit of time. A water footprint can be calculated for any well-defined group of consumers (e.g., an individual, family, village, city, province, state or nation) or producers (e.g., a public organization, private enterprise or economic sector), for a single process (such as growing crop plants) or for any product.
Traditionally, water use has been approached from the production side, by quantifying the following three columns of water use: water withdrawals in the domestic and agricultural and industrial sector. While this does provide valuable data, it is a limited way of looking at water use in a globalised world, in which products are not always consumed in their country of origin. International trade of agricultural and industrial products in effect creates a global flow of virtual water, or *embodied water.* Recently, the water footprint concept was introduced in order to have a consumption-based indicator of water use that could provide useful information in addition to the traditional production-sector-based indicators of water use. It is analogous to the ecological footprint concept introduced in the 1990s. The water footprint is a geographically explicit indicator, showing volumes of water use and pollution, and also the locations. Thus, it gives a grasp on how economic choices and processes influence the availability of adequate water resources and other ecological realities across the globe (and vice versa).
In a UNESCO study series water footprint of various food and feed products have been evaluated (MEKONNEN AND HOEKSTRA, 2010). The research results give an evidence on the diverse amount of water used for production of food and feed. The differences between

vegetables, cereals and meat products may have a 1:10:100 x ratio concerning water usage; e.g. 1 kg of vegetable may be produced with some 300 litres of water while bovine meet would require about 15000 litres. The specific values were much smaller if exact nutritional indicators like calories, protein or fats were evaluated. In this comparison the water footprint differences were within a five-fold range.

Climate change research results in Hungary have highlighted the variation induced by water availability on protein formation of field crops (KASSAI ET AL., 2016; ESER ET AL., 2017; JOLÁNKAI ET AL., 2018).

Crop water use, consumptive use, and evapotranspiration are terms used interchangeably to describe the water consumed by a crop. This water is mainly used for physiological processes; a negligible amount is retained by the crop for growth. Water requirements for crops depend mainly on environmental conditions. Plants use water for cooling purposes, and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the same weather conditions (VÁRALLYAY, 2008; PEPÓ, 2010).

The present study is dealing with the identification of water footprint of some field crops. The hypothesis of the work was not to rely on yield figures only, but rather the nutritional value of that. In our study the protein yield of various crop species has been evaluated in the context of evapotranspiration.

MATERIAL AND METHOD

The materials and methods of the present study cover a rather broad field, since there are various topics of the research work done by the Szent István University, Crop Production Institute, Hungary (SIU). Most of the results are based on experimental research, however, some evaluations were implemented by using national public data, or observation results published (FM 2017, FAOSTAT, 2017).

An assessment study has been done by the authors to evaluate and identify the water footprint of protein yield of field crop species. Six field crop species (sugar beet *Beta vulgaris*, winter barley *Hordeum vulgare*, winter wheat *Triticum aestivum,* maize *Zea mays*, potato *Solanum tuberosum*, and alfalfa *Medicago sativa*) were involved in the study. Evapotranspiration patterns (ET) of the crops studied have been identified and physiologically reliable protein ranges within crop yields were evaluated.

Regarding water availability impacts, experimental mean values of respective treatments and homogenized bulk yield samples were used only. Precipitation records have been evaluated in relation with yield quantity and quality. Quality characteristics were determined at the Research Laboratory of the SIU Crop Production Institute, according to Hungarian standards (MSZ, 1998). Analyses were done by statistical programmes with respect to the methodology of phenotypic crop adaptation (EBERHART AND RUSSELL, 1966; FINLAY AND WILKINSON, 1963; HOHLS, 1995). The meteorological database of the research referring to precipitation as well as temperature data was provided by the Hungarian Meteorological Service (OMSZ). Statistical evaluations, crop ecological model adaptations, and correlation calculations were done by regular methods (SVÁB, 1981; FINLAY AND WILKINSON, 1963).

The present paper produces results of the ongoing research in relation with weather impacts on crop production. Such an assessment has a diverse nature. Once, it is beneficial regarding the abundance and the duration of baseline data. On the other hand, it is restricted to the available structure and moreover it is bound mainly to available figures giving less chance for deep layer evaluations. However, the study could provide some novel specific information on crop performance in relation with their water footprint.

RESULTS AND DISCUSSION

The results obtained show that the evaluated crops may have ten times differences in their amount of yield built up under almost identical field conditions regarding precipitation, soil conditions and other meteorological factors influencing water availability.

Figure 1 presents data on ET patterns in comparison with the long term precipitation means. In accordance with that it can be stated, that the six species studied have profoundly diverse evapotranspiration patterns concerning water demand, seasonality, and in dynamics as well.

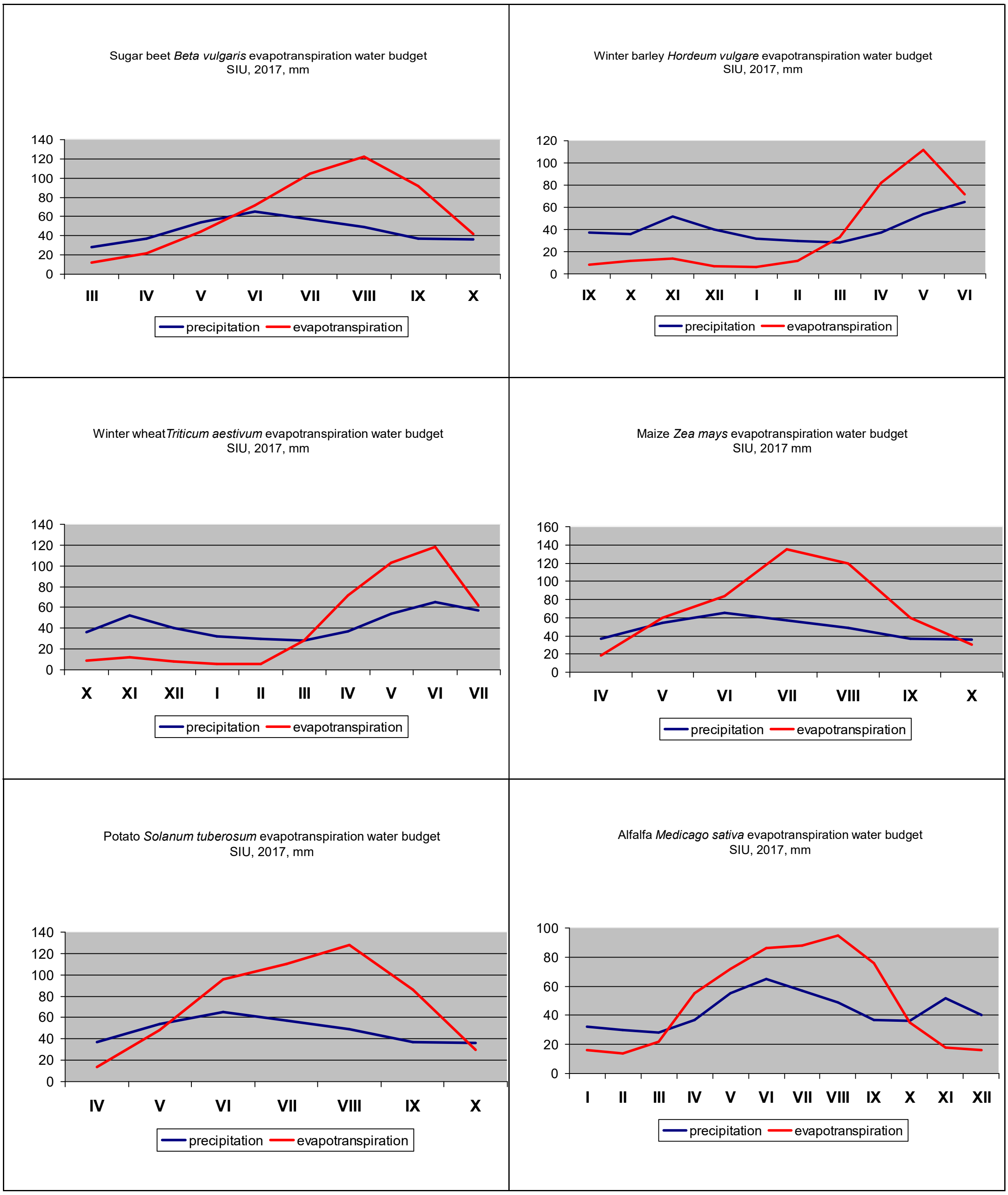

Figure 1. Water budget of field crop species based on evapotranspiration.

Source: SIU, 40 years mean, 2017

The most balanced water budget can be observed in the case of cereal crops like winter wheat and winter barley, where the early development stages are fully supplied by the precipitation and water deficiencies may be experienced mainly during the generative phases and ripening. Maize is the most deficient crop that should be supplied with water either from off season precipitation or irrigation. Similarly to that, the two root and tuber crops are having a negative budget in most of their life cycle. Alfalfa as a perennial crop has more similarities in its ET to that of the cereal species.

The water footprint of the examined crop species proved to be different as it is shown in *Table 1*. The amount of protein of the respective crops ranged from 450 kg to almost 800 kg in the yield of the evaluated species. Root and tuber crops had the lowest protein yield from among the crop species. Grain crops were in the mid-range and definitely alfalfa proved to produce the highest amount of protein.

There were considerable differences in the efficiency of water consumption regarding protein yields. Barley proved to be the most efficient protein producing crop regarding both evapotranspiration and direct water consumption of the crop. Wheat was the next water saving crop concerning protein production. Maize, the third grain crop had almost double specific water consumption in comparison with cereals. Alfalfa had the highest protein yield from among the species examined, however its water efficiency was about half of that of the cereal species.

Table 1. Water footprint of six crop plant species

Crop	Protein (%)	Crop yield (tha^{-1})	Protein yield ($kgha^{-1}$)	Protein kg/ET (mm)	Litre/protein g (l)
Medicago sativa	18.0	4.35*	783	1.32	44.9
Solanum tuberosum	2.0	24.9	498	0.97	52.7
Beta vulgaris	1.1	41.2	453	0.96	49.1
Triticum aestivum	13.0	4.8	624	1.83	23.1
Hordeum vulgare	16.5	4.1	676.5	1.88	18.9
Zea mays	9.5	5.8	551	1.09	46.5

*hay
Source: SIU, 2017

Potato and sugar beet produced the least protein yield within the evaluated crop species. It is quite acceptable since both of them are initiated for the production of carbohydrous substances like starch and sugar rather than proteinous ones. Consequently the water efficiency of these crops proved to be the worst as well.

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REFERENCES

EBERHART, S.A., RUSSELL, W.A. (1966): Stability parameters for comparing varieties. Crop Science 6: 36–40.

ESER, A., KASSAI, M.K., TARNAWA, Á., NYÁRAI, H.F., JOLÁNKAI, M. (2017): Impact of crop year and nitrogen topdressing on the quantity and quality of wheat yield. Columella 4(1) Suppl.: 157-162.

FAOSTAT (2017): www.fao.org/faostat/
FINLAY, K.W., WILKINSON, G.N. (1963): The analysis of adaptation in a plant breeding program. Australian J.f Agric. Res. 14: 742–754.
FM (2017): Statistical data on agriculture. https://www.ksh.hu/hssz_tagok_fm
HOEKSTRA, A.Y., CHAPAGAIN, A.K. (2007): Water footprints of nations: Water use by people as a function of their consumption pattern. Water Resource Management 21: 35–48.
HOHLS, T. (1995): Analysis of genotype environment interactions. South African J. Sci. 91: 121–124.
JOLÁNKAI, M., KASSAI, M.K., TARNAWA, Á., PÓSA, B., BIRKÁS, M (2018): Impact of precipitation and temperature on the grain and protein yield of wheat (*Triticum aestivum* L.) varieties. Időjárás 122(1): 31-40.
KASSAI, M.K., TARNAWA, Á., NYÁRAI, H.F., HORVÁTH, CS., JOLÁNKAI, M. (2016): Water availability and protein formations interrelations. Acta Hydrologica Slovaca 17(2): 260-264.
MEKONNEN, M.M., HOEKSTRA, A.Y. (2010): The green, blue and grey water footprint of farm animals and animal products, Value of Water Research Report Series No.48, UNESCO-IHE.
MSZ 6383 (1998): 824/2000/EK Crop quality standards, Hungary.
PEPÓ, P. (2010): Adaptive capacity of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) crop models to ecological conditions. Növénytermelés 59 Suppl.: 325–328.
SVÁB, J. (1981): Biometriai módszerek a kutatásban (Biometric methods in research - in Hungarian). Mezőgazdasági Könyvkiadó, Budapest. 557 p.
VÁRALLYAY, G. (2008): Extreme soil moisture regime as limiting factor of the plants' water uptake. Cereal Research Communications Suppl. 3–6. https://www.jstor.org/stable/90002626
WICHELNS, D. (2010): Virtual water and water footprints offer limited insight regarding important policy questions. International Journal of Water Resources Development 26(4): 639–651.