A comparison of crop evapotranspiration between Hargreaves modified and Penman-Monteith formulas in drip-irrigated autumn sugar beet (Beta vulgaris L.) in Italy

Key words: Sugar beet; Irrigation; Evapotranspiration.

Introduction

AcquaFacile (AF, formerly “EasyWater”), is a Decision Support System (DSS) irrigation software (www.betalitalia.it, developed by BETA and based on the Hargreaves equation (Hargreaves and Samani, 1985). It features reduced Kc, as compared to the reference ones (FAO, 1998), and includes the contribution to ET from the shallow water-table. AF works on both spring and autumn beets, with different parameters.

The dissemination of the software “AcquaFacile” on autumn beet in South Italy was preceded by an intensive work to tune the program algorithms. In this regard, an important reference was the previous calibration work by INEA (National Institute for Agricultural Economy) on the Hargreaves formula (implemented into AF), as well as on the Penman-Monteith formula (INEA, 2001). According to Graph. 1, the value of the fixed term in the Hargreaves formula, 0.0023, brings to a curve that overestimates ET consumptions, compared with the Penman-Monteith’s reference formula.

Methods

In the cropping year 2004-2005, in South Italy (Foggia province) BETA tested three different drip irrigation systems:

- Semi-rigid pipe - Hans Tifo Ø16 mm, thickness 32 ml, with in-line drippers of 2 l/h at 1,035 bar, pitch 40 cm, placed on soil surface every other inter-row (20 cm distance).
- Flexible tape - Toro mod. Aquatraxx Ø16 mm, thickness 6 ml, pressed drippers of 1,16 l/h at 0,7 bar, pitch 30 cm, placed on soil surface every other inter-row (90 cm distance).
- Flexible tape - Toro mod. Aquatraxx Ø16 mm, thickness 15 ml, pressed drippers of 1,36 l/h at 0,2 bar, pitch 30 cm, buried in the soil at a 45 cm depth (sub-irrigation), at a 1,33 m distance between the lines. Tape positioning was performed during soil tillage by a tractor-mounted tool.

A strip-plot design at 6 replications was adopted in the trial, with a common randomized block. Root samples from 13,5 m² plot areas were collected during the harvest campaign, weighted and analysed for the major yield and quality traits.

A parallel study was carried out in order to compare reference evapotranspiration (ET0) and the water balance as calculated by the AF software and by the Penman-Monteith equation.

Results

The results (Table 1) show a significant yield difference between irrigated and non-irrigated crop. In particular, the irrigated plots showed a weight increase of 100-150% and a lower sugar content (-5° as average), although it always remained above 17°. The juice purity (JP), though with lower sugar-content values, was always higher in irrigated plots, thanks to the lower concentration of impurities, especially of nitrogen and sodium. The most interesting data are linked to the sub-irrigation system. In fact, in this case high yields were realised at much lower costs, thanks to the multi-year depreciation involved by this system (Graph. 5).

The correlation coefficients are significant and explain more than 90% of the total variability. In the investigated year, the close resemblance between historical and the year’s ET data suggests that the former might be used as a common reference within the calculations of water balance. This occurrence needs to be confirmed in future research.

The data resulting from the study of the above correlations are confirmed by the fact that, also in this case, the cumulated deficit calculated with “historical AF” corresponds to that calculated with Pen, with a difference of only 1 mm in 4 months.

Conclusion

The trial confirmed the technical-economic effectiveness of sub-irrigation. As for the AcquaFacile software, the reduction of the fixed term in the Hargreaves formula meant a significant correlation of the ETo with Pen-Monteith. This enables to use this software also in areas that are not equipped with automatic weather stations.

Comparison of ET0 formulas

A comparison between the two formulas, over the period January-July, on a ten-days scale, showed the following patterns:

1. ET0 calculated with Penman-Monteith (PM) vs. AF (Hargreaves formula) using historical weather data. (Graph. 6)
2. ET0 calculated with Penman-Monteith (PM) vs. AF (Hargreaves formula) using year 2005 weather data. (Graph. 7)

References