Hydrophytometeorological indexes of Virginia type tobacco

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Abstract

The field trial of Virginia type tobacco (Hevesi-9) was set in irrigation conditions, in the vicinity of Brzi Brod village, Nišava river’s valley, on the alluvium soil type. Water consumption for evapotranspiration, at the irrigated variant and the control one, was calculated for each month and the whole vegetation period, by making the balance between water consumption from the soil layer to 2 m under the ground, total precipitation amount in the vegetation and water added by irrigation. Hydrophytometeorological indexes of Virginia type tobacco were calculated in regard to air temperature, relative air humidity, air humidity deficiency, sunshine duration and global radiation. Among the six meteorological elements (the above mentioned five and wind speed) analyzed in the studied period, the highest level of correlation with tobacco ETP was shown by air temperature ($r=0.88$), so the use of hydrophytometric index could be recommended for calculation of potential evapotranspiration in irrigation practice.

Key words: tobacco, irrigation, evapotranspiration, hydrophytometeorological indexes

Introduction

Tobacco production is aimed to obtain leaves, that have to meet specific physical, chemical, and quality requirements, in order to be a good raw material for cigarette production. Water deficiency during vegetation of Virginia type tobacco affects the balance between carbohydrate and nicotine content, which causes a poor tobacco quality. Proper water supplies during vegetation period, obtained by irrigation, can stabilize leaf yield and quality of Virginia type tobacco and keep them within desired limits.

Water balance becomes more and more important in irrigation practice as the base for drenching regime, because of possibility to make a daily balance of available water content in the zone of active rhizosphere, in regard to water incomes and losses, and with the aim of determining irrigation terms and schedule. Water balance as the base for drenching regime requests a good knowledge of daily potential evapotranspiration (ETP), which can be calculated by hydrophytometeorological indexes and given meteorological elements.

The base for use of bioclimatic methods in our country was set by Vučić (1971, 1973), who applied hydrophytometric index to calculate potential ETP, and that index showed how many mm of water was spent by plants on ETP for each °C of mean daily temperature. Application of bioclimatic method for ETP calculation is based on the high established correlation coefficient between meteorological elements and potential ETP.

In the conditions of Serbia, the following average values of hydrophytometric indexes for the vegetation period are previously established: in maize 0.15 (Vučić, 1971; Bošnjak et al., 1983), soybean 0.17 (Vučić and Bošnjak, 1980), apple trees 0.17 (Vučić et al., 1981), second-crop silage maize 0.17 (Lugonja, 1983), alfalfa 0.20 (Bošnjak, 1992), sunflower 0.16 (Bošnjak, 1993), potato 0.19 (Bošnjak, 1994) etc.
Material and methods
The field trial of Virginia type tobacco (Hevesi-9) was set in irrigation conditions, in the vicinity of Brzi Brod village, Nišava river’s valley, on the alluvium soil type. Irrigation was scheduled and dosed according to soil humidity, which was observed weekly by thermogravimetric method in drying chamber at 105-110°C. Tobacco planting was done within optimal terms, and a modern production technology for this crop was applied. The trial was set in random block design, adapted for irrigation conditions, and the experimental plot area was 35 m². Field water capacity (FWC) was determined at the location of field trial. Irrigation was done by sprinklers, and the term was determined in regard to soil humidity to the depth of 60 cm.

Meteorological elements (air temperature, precipitation, relative air humidity, air humidity deficiency, wind speed, sunshine duration, global radiation) of the trial area were analyzed in Meteorological Station in Niš. Precipitation amount was also measured at the experimental field. Water consumption for evapotranspiration, at the irrigated variant and the control one, was calculated for each month and the whole vegetation period, by making the balance between water consumption from the soil layer to 2 m under the ground, total precipitation amount in the vegetation and water added by irrigation (Bošnjak, 1999).

After evapotranspiration value was determined at the experimental field, hydrophyto-meteorological indexes was calculated by the equation:

$$h_i = \frac{ETP}{Me}$$

$hi$ – hydrophyto-meteorological index for specific meteorological element (air temperature, relative air humidity, air humidity deficiency, sunshine duration, global radiation);

$ETP$ – water demand of plants for total vegetation period or some sub period;

$Me$ – sum of average daily values of the given meteorological element for total vegetation period or some sub period.

Results and discussion
Plant water demand, i.e. $ETP$, at the optimal soil humidity are in the direct dependency on environment, that mainly are characterized by meteorological elements (table 1).

| Months | Air temperature (°C) | Air relative humidity (%) | Wind speed (m/s) | Air saturation deficiency (mb) | Sunshine duration (h) | Global radiation (MJ m²) | ETP (mm) |
|--------|----------------------|---------------------------|-----------------|-------------------------------|----------------------|-------------------------|----------|
| V      | 18.8                 | 62.7                      | 1.4             | 8.4                           | 7.5                  | 18.1                    | 2.4      |
| VI     | 21.4                 | 63.0                      | 1.3             | 9.7                           | 8.9                  | 19.4                    | 4.4      |
| VII    | 23.4                 | 61.7                      | 1.4             | 11.7                          | 8.8                  | 19.0                    | 4.8      |
| VIII   | 23.3                 | 61.7                      | 1.3             | 11.9                          | 8.5                  | 18.3                    | 4.5      |
| IX     | 16.6                 | 70.7                      | 1.2             | 5.8                           | 5.8                  | 15.7                    | 2.3      |

Linear regression analysis showed that, among the six analyzed meteorological elements (Table 2), air temperature gave a highly significant correlation coefficient ($r=0.88$) with the observed $ETP$, as well as the highest determination coefficient ($r^2=0.774$), which means that potential $ETP$ was explained by the effect of this meteorological element at the level of 77.4%. Bošnjak (1986), in environmental conditions of Vojvodina, also found a highly significant correlation between maize $ETP$ and air temperature. Calculation of $ETP$ based
on the effect of specific meteorological elements for Virginia type tobacco can be done by the regression equations (tab. 2), that are suitable for agroecological region of southern Serbia or similar soil and climatic conditions.

**Table 2: ETP dependency on meteorological elements in Virginia type tobacco during the studied period**

| Meteorological elements         | Regression equation                                                | r   |
|--------------------------------|---------------------------------------------------------------------|-----|
| Air temperature (°C)           | ETP = 79.07 - 12.27 t + 0.64 t² - 0.01 t³                            | 0.88|
| Air relative humidity (%)      | ETP = 305.41 + 15.43 rh - 0.25 rh² + 0.001 rh³                       | 0.50|
| Wind speed (ms⁻¹)              | ETP = -408.41 + 904.67 w - 658.01 w² + 158.5 w³                     | 0.56|
| Sunshine duration (h)          | ETP = 24.98 - 9.65 s + 1.33 s² - 0.005 s³                           | 0.70|
| Global radiation (MJ m⁻²)      | ETP = 3.53 - 1.01 gr + 0.18 gr² - 0.006 gr³                          | 0.71|

Complexity of the meteorological factors influence on the observed evapotranspiration during the investigated period was demonstrated through multiple regression analysis, and the obtained correlation coefficient (r=0.936) pointed to their strong effect on ETP. The observed highly significant multiple correlation between Virginia type tobacco’s ETP and meteorological elements is in accordance with the previous reports; e.g. Bošnjak (1982, 1986) observed a highly significant effect of meteorological elements on ETP (r=0.869; r=0.941), and Balogun(1974) found a highly significant multiple correlation between meteorological elements (air temperature, solar radiation and wind speed) and ETP (r=0.82).

The multiple regression equation based on five meteorological elements was established (air temperature, air humidity deficiency, average wind speed, global radiation, and relative air humidity), and it can be used for reliable estimation of Virginia type tobacco’s ETP.

\[
\text{ETP} = 4.62 + 0.69t - 0.58sd - 1.83w + 0.15gr - 0.12rh
\]

Calculated hydrophytometeorological indexes of Virginia type tobacco are given in the table 3. Among the five analyzed meteorological elements during the studied period, the highest correlation coefficient is observed between tobacco ETP and air temperature (r=0.88), which is pretty constant within a region, so data of the nearest meteorological station can be used for calculations. Therefore, the use of hydrophytotermic index could be recommended in irrigation practice for calculation of potential ETP, which is the base for making balance of available water in soil.

**Table 3. Hydrophytometeorological indexes of Virginia type tobacco (2001-2003)**

| Months            | Hydrophtometeorological indexes in regard to | Hydrophytometeorological indexes in regard to |
|-------------------|---------------------------------------------|---------------------------------------------|
|                   | Air temperature | Air saturation deficiency | Air relative humidity | Sunshine duration | Global radiation |
| V                 | 0.13            | 0.29                       | 0.04                  | 0.33              | 0.30              |
| VI                | 0.20            | 0.46                       | 0.07                  | 0.50              | 0.47              |
| VII               | 0.21            | 0.41                       | 0.08                  | 0.55              | 0.53              |
| VIII              | 0.19            | 0.39                       | 0.08                  | 0.55              | 0.55              |
| IX                | 0.14            | 0.39                       | 0.03                  | 0.40              | 0.40              |
| Vegetation mean   | 0.17            | 0.40                       | 0.06                  | 0.47              | 0.45              |
| June, July and August means | 0.20            | 0.43                       | 0.08                  | 0.53              | 0.52              |
Conclusions
Multiple correlation coefficient between the observed meteorological elements and calculated tobacco ETP was highly significant, which made possible to establish a multiple regression equation based on five meteorological elements (air temperature, air humidity deficiency, average wind speed, global radiation, and relative air humidity). That equation can be used for reliable estimation of Virginia type tobacco’s ETP in the conditions of southern Serbia.

Hydrophytometeorological indexes of Virginia type tobacco were calculated in regard to air temperature, relative air humidity, air humidity deficiency, sunshine duration and global radiation. The use of hydrophytometeorological indexes offers a simpler way of ETP calculation for Virginia type tobacco.

This study suggests few different approaches for daily calculation of water consumption for ETP of Virginia type tobacco in the conditions of southern Serbia, which is important for successful realization of irrigation regime by water balance method.

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Hidrofitometeorološki indeksi duhana tipa Virdžinija

Sažetak
Eksperimentalna istraživanja poljskim pokusom, u uvjetima navodnjavanja duhana tipa Virdžinija (Heveši-9), obavljena su u blizini sela Brzi Brod, u dolini rijeke Nišave, na aluvijalnom tipu tla. Utrošak vode na evapotranspiraciju, u kombinacijama navodnjavanja i kontroli bez navodnjavanja, utvrđivan je za mjeseci i vegetacijski period u cjelini, bilancom potrošnje vode u rezervi iz sloja tla do 2 m dubine, oborina u periodu vegetacije i norme navodnjavanja. Utvrđeni su hidrofitometeorološki indeksi za duhan tipa Virdžinija u odnosu na temperaturu zraka, deficit zasićenosti zraka, relativnu vljušćnost zraka, dužinu insolacije i globalno zračenje. Analizom meteoroloških elemenata za istraživani period konstatiran je najviši stupanj korelacije ETP duhana sa temperaturom (r=0.88), stoga se u praksi navodnjavanja preporučuje korišćenje hidrofitotermičkog indeksa za obračun potencijalne evapotranspiracije.

Ključne riječi: duhan, navodnjavanje, evapotranspiracija, hidrofitometeorološki indeks