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EFFECT OF ANTI-HAIL NETS ON DESIGN OF IRRIGATION SYSTEMS

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Summary: *Design of irrigation systems is not possible without a reliable calculation of evapotranspiration. In order to ensure production of high quality fruit, the latest technological solutions are applied in the field of irrigation, protection from bacteria, rodents and birds, protection from weeds, effects of hail, frost and excess rain. Today, the use of anti-hail net is considered as one of the most effective ways to protect orchards from the hail. In addition, it has the role of protecting from birds and insects, wind and the strong solar radiation. There are changes in the microclimate conditions due to the anti-hail net. The changed parameters in the orchards such as intensity of light, air temperature, relative humidity, and wind velocity depend on the characteristics of the anti-hail nets (the quality and thickness of the fiber, color, openings size). All that directly affects the evapotranspiration of orchards and should be taken into account when designing the irrigation systems. This paper presents estimation of evapotranspiration using the FAO-56 Penman-Monteith method. Based on the results, it is clear that the evapotranspiration of the orchard covered by anti-hail nets decreases compared to the orchard that is not protected by the anti-hail nets.*

Keywords: *Design, irrigation systems, anti-hail net, evapotranspiration, FAO-56 Penman-Monteith*

1. INTRODUCTION

Irrigation is a hydraulic engineering measure comprising transporting water to the crops, for the purpose of obtaining high and stable crop yields, irrespective of the weather conditions. Water is supplied in the amounts and timing required for the crops. These conditions suggest that one of the most important elements in design of the irrigation systems is definition of the crop water demand, which determine the relevant water flow needed for design [1].
Crop water demand is expressed through evapotranspiration of the crops (ET_c) which is detrermined on the basis of the value of reference evapotranspiration (ET_0) and the crop

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coefficient (k_c). Evapotranspiration of a particular crop is different from the reference evapotraspiration to the extent to which the degree of land coverage, surface and aerodynamic resistancs of that culture are different from the reference crop (grass). Coefficients of fruit crops in the warmest season of the year range between 0.8 and 1.2. This difference is irrelevant for the scope of this paper, thus only the reference evapotranspiration calculation is performed in the paper.
Anti-hail nets represent the most efficient means of protecting orchards from hail, recommended for regions with frequent hail incidents [2]. The existing protection system, i.e. anti-hail rockets does not reduce the need for anti-hail nets. In fact, the two are mutually complement and comprise a unique system. They are applied for highly prized and high-yield fruit species, i.e. in crops, which show great potential, and whose fruit is used fresh [2].

The anti-hail nets are built from materials (high-density polyethylene) with highly valued physicochemical, thermal and electrical properties. Therefore, in addition to the fundamental role of protecting the orchard from hail, the networks also have the role of protection against insects, birds, wind and strong sun radiation. The net also has an impact on the change in microclimatic conditions inside the orchard itself. Namely, under the effect of the net, inside the orchard, there are changes in the insolation, air temperature of the plant and soil, air and soil humidity, as well as wind speed [3-7]. Changes in these parameters lead to changes in the fertility, productivity and fruit quality, the reduction of scorching, and even a better fruit color.
This paper contains solely the analyses of the elements, which have a direct impact on the change of evapotranspiration, which the orchard irrigation system design is dependent on, i.e. air temperature, humidity, vapor pressure, sunshine hours and wind.

The impact of anti-hail nets on the climatic parameters used for the calculation of evapotranspiration and its impact on the system of irrigation were also considered, in order to be able to consider the changes in designing the size of the system of the experimental field near Hum village, close to Nis. The evapotranspiration calculation was performed using the FAO-56 Penman-Monteith method.

2. MATERIALS AND METHODS

For the calculation requirements of the reference evapotranspiration outside the area covered by anti-hail nets, the information used in this paper was taken from the Meteorological Annual for the city of Nis (longitude 21°53’46”, latitude 43°19’09”, elevation 195 m) for the period from 2001 to 2010, for the months of June, July and August. Due to the lack of the measured values, the value of the reference evapotranspiration under the anti-hail nets was determined by reducing the values of meteorological parameters corrected according to the measurement results published in papers (Table 1.) [3-5, 7]. Figure 1 shows the corrected values of the maximum and minimum air temperature, wind speed at 2 m height, vapor pressure and sunshine hours for Nis in June.

According to [3, 5], there was an increase in the minimum air temperature in the orchard of 1 °C and the decline of the maximum air temperature of 1 to 3 °C during warm and hot days. The increase in the pressure of water vapor below the anti-hail nets, compared to the area outside the nets, ranged from 2 to 5 % [7]. It is stated in [3] that the wind speed below the nets dropped by approximately 50 %. The decrease in the level of lighting depends on the characteristics of the network, especially the color of the network. In case of the black nets, it can be from 18 to 25 %. For the white ones, it can range from 8 to 12%, for the gray ones from 15 to 17 %, while the values for the green-black ones, it can be 15 to 16 % [3, 4].

Table 1. Illustration of the change in climatic parameter values

Parameter name	Parameter designation	Change
Minimum air temperature	T_{min}	+ 1 °C
Maximum air temperature	T_{max}	- 3 °C
Vapor pressure	VP	+ 5 %
Wind speed at 2 m height	U_2	- 50 %
Sunshine hours	n	- 15 %

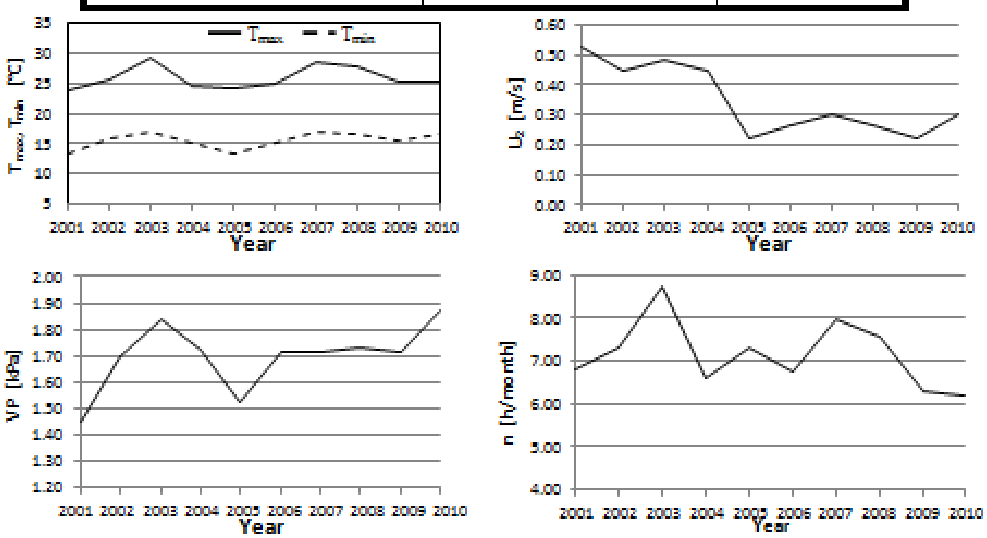

Figure 1. Corrected values of the considered parameters for June

Calculation of the reference evapotranspiration was performed based on the Penman-Monteith formula (Eq. 1), with the aid of the software for the calculation of the reference evapotranspiration with minimum climatic parameters [8-10]:

$$ET_0 = \frac{0.408 \cdot \Delta \cdot (R_n - G) + \gamma \cdot \frac{900}{T + 273} \cdot U_2 \cdot VPD}{\Delta + \gamma \cdot (1 + 0.34 \cdot U_2)} \qquad (1)$$

where: ET_0– reference evapotranspiration (mm day^{-1}); Δ - slope of the saturation vapor pressure function (kPa °C^{-1}); R_n – net radiation (MJ m^{-2} day^{-1}); G – soil heat flux density

(MJ m^{-2} day^{-1}); γ – psychometric constant (kPa °C^{-1}); T – mean air temperature (°C); U_2 – average 24 h wind speed at 2 m height (m s^{-1}) and VPD – vapor pressure deficit (kPa).

3. RESULTS AND DISCUSSION

Figure 2. shows the monthly values of the reference evapotranspiration for June, July and August in the period from 2001 to 2010 for the city of Nis, below and outside the anti-hail nets. The selected months are considered as these are the months in which the irrigation system sustained the greatest load.

When the values evapotranspiration are considered for June, the highest value was calculated in 2003. It was 155 mm/month outside the area coverd by the net and 133 mm/month inside the area covered by the net. The reference evapotranspiration below the net decreased by 16.6 % in comparison to with the evapotranspiration outside the net in June 2003, and this was also the greatest decrease in the evapotranspiration in the reviewed period.

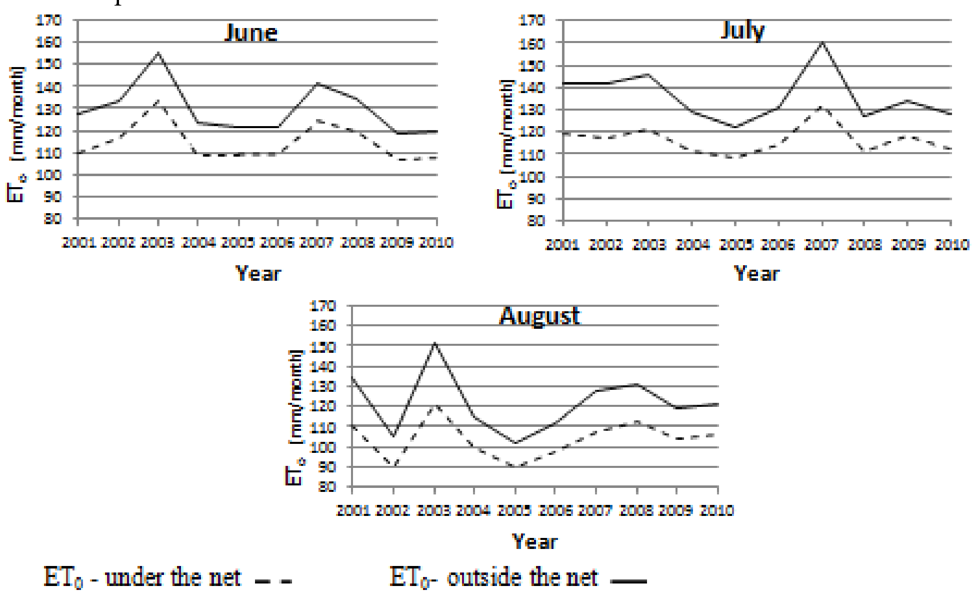

Figure 2. Values of ET_0 for June, July and August

The maximum evapotranspiration for July, outside the anti-hail net, equaled 160 mm/month, while it is was 132 mm/month inside the net, and these values were determined in 2007. Furthermore, the greatest decline in the reference evapotranspiration was also recorded in 2007, equaling 21.3 % between the evapotranspiration outside and inside the area covered by the anti-hail net.

The values obtained in August show that the greatest value of the reference evapotranspiration outside the net was obtained in 2003, amounting to 151 mm/month. The greatest evapotranspiration value inside the anti-hail net amounted to 121 mm/month, and it also occurred in 2003. Year 2003 also saw the greatest percentage in the reference evapotranspiration value decrease, both outside and inside the areas covered by the net, equaling 24.2 %. By comparing the reference evapotranspiration, there was a decline in the evapotranspiration inside the anti-hail net, when compared to the values of evapotranspiration outside the network, i.e. it was 15.7 % for the total reviewed period. The average reference evapotranspiration decline for the total reviewed period was 13.2 % for June, 16.8 % for July, and 17.1 % for August.

4. CONCLUSION

Apart from the primary function of the anti-hail net to protect the crops from the harmful effects of the hail, it also has a significant impact on the microclimate of the orchard, which, among other things, causes the decrease of the reference evapotranspiration, as was shown in this paper. The reduction of evapotranspiration of the crops is proportional to the reduction of reference evapotranspiration and has an impact on the decrease of the necessary irrigation water quantities. Delivery of lower quantities of water, governed by the microclimate of the land, has a considerable impact on the crop and the soil, as there will be no water logging, creation of crust on the surface and plant rotting due to the surplus water. The new microclimate will bring about savings of the irrigation system, such as the reduction of the necessary pump power, which leads to direct energy savings, and the reduction in the water supply pipe diameter.
Based on the results of the research, it can be concluded that the average decrease in reference evapotranspiration was 13.2 % for June, 16.8 % for July and 17.1 % for August. Future work will be aimed at the research of the influence of anti-hail nets of various colors and types of texture on the evapotranspiration of orchards, which will be calculated with the modified Hargreaves method.

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УТИЦАЈ ПРОТИВГРАДНИХ МРЕЖА НА ПРОЈЕКТОВАЊЕ СИСТЕМА ЗА НАВОДЊАВАЊЕ

Резиме: *Пројектовање система за наводњавања није могуће без поузданог прорачуна евапотранспирације. Како би се омогућила производња производа високог квалитета у воћарству се примењују најсавременија технолошка решења у области наводњавања, заштите од бактерија, глодара и птица, заштите од корова, дејства града, мраза и вишка кише. Коришћење противградне мреже се данас сматра једним од најефикаснијих начина заштите воћњака од града. Осим тога има улогу заштите од птица и инсеката, ветра и од јаког сунчевог зрачења. Постављањем противградних мрежа долази до промене микроклиматских услова. У зависности од карактеристика мреже (квалитет и дебљина влакана, боја, величина отвора) долази до промена у воћњаку и то: квалитета и интензитета светлости, температуре ваздуха, влажности ваздуха и брзине ветра. Све се то директно одражава на евапотранспирацију воћњака и треба узети у обзир при пројектовању система за наводњавање. У раду је урађен прорачун евапотранспирације по методи FAO-56 Penman-Monteith. На основу добијених резултата јасно се уочава да су вредности евапотранспирације за воћњак који је покривен противградним мрежама ниже у односу на воћњак који није заштићен од дејства града.*

Кључне речи: *Пројектовање, системи за наводњавање, противградне мреже, евапотранспирација, FAO-56 Penman-Monteith*