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Effect of drip irrigation on yield and evapotranspiration of fibre hemp (*Cannabis sativa* L.)

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Summary: The experiments showing the effect of drip irrigation on yield and evapotranspiration of fibre hemp (*Cannabis sativa* L.) were conducted at the experimental field of the Alternative Crops Department, Institute of Field and Vegetable Crops, Novi Sad, Serbia. Irrigation was based on the water balance method. Daily evapotranspiration (ET_d) was computed from the reference evapotranspiration (ET_o) and crop coefficient (k_c) 0.5, 0.9 and 1.1 from sowing to 3-4 pair of leaves, from 3-4 pair of leaves to appearance of male flowers and from appearance of male flowers to the end of the season, respectively. ET_o was calculated using Hargreaves equation. The irrigation depth was restricted to the soil depth of 0.4 m. In other words, irrigation started when readily available water in the soil layer of 0.4 m was completely depleted by plants. The irrigation rate was 30 mm at the beginning of the season, 40 mm in the middle of the season, and the amount of water added by irrigation was 320 mm during the entire season. Irrigation significantly affected the yield of fresh stems, fresh leaves, flowers and plant height, but not stem diameter and fibre content. Water used on evapotranspiration in irrigation conditions (ET_m) was 470 mm, while in non-irrigated control variant it amounted to 129 mm (ET_a). These preliminary results could be used as a good platform for hemp growers in the region, in terms of optimizing the use of irrigation water.
Key words: *Cannabis*, evapotranspiration, hemp, irrigation

Introduction

Hemp *(Cannabis sativa* L.) is an annual herbaceous flowering plant indigenous to eastern Asia but now of cosmopolitan distribution due to widespread cultivation. It has been cultivated throughout recorded history, used as a source of industrial fibre, seed oil, food, recreation, religious and spiritual moods and medicine. Each part of the plant is harvested differently, depending on the purpose of its use. Hemp is used to make a variety of commercial and industrial products including rope, clothes, food, paper, textiles, plastics, insulation and biofuel.

Hemp is an annual plant grown in temperate zones. It is mainly present in the eastern hemisphere. In the world industrial hemp is grown on the area of 105,576 ha. The five biggest hemp producing countries in the world are China, North Korea, Chile, France, Germany, and Great Britain. In Serbia industrial hemp occupies the area of about 200 ha (FAO, 2004). Hemp requires a frost-free season of minimum 130 days, middle summer temperatures and a fertile ground (White et al., 1964).

In Vojvodina region, the hemp is cultivated only under rainfed conditions; there is no recorded data on its cultivation under irrigation. Studies conducted in a wide range of environments confirm that irrigation could seriously influence the yield of fibre hemp (Lisson and Mendham, 1998; Di Bari et al., 2004). Hacket (1991) defined water stress as the most limiting factor affecting the fibre yield and quality.

Preliminary step to a more intensive exploitation of the available agroecological conditions or to the development of irrigation schedules for any crop implies a study of crop requirements for water, i.e. the evapotranspiration (ET) for any particular crop. In order to fully utilize the genetic yield potentials of fibre

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hemp and achieve high and stable yields, it is necessary to gain knowledge of the crops capabilities under conditions of dry farming and irrigation. Literature recommendations for the water requirements of fibre hemp are sparse and ambiguous. In growing period, hemp needs 250-350 mm of rainfall (Kišgeci, 1994). In Ukraine, optimum yields are achieved with 250-280 mm of rainfall during the growing season. Van Dam (1995) reported that hemp requires rainfall of at least 650 mm per year in the Netherlands climate. Lisson and Mendham (1998) reported that the highest yield of hemp fibre was obtained with water consumption of 535 mm during growing season in northwest Tasmania in Australia. Bócsa and Karus (1998) reported much higher water requirements of hemp up to 700 mm, especially during the rapid growth phase.

The objective of the study was to get information of how the plants of fibre hemp react to irrigation as well as determination of fibre hemp evapotranspiration in agroecological conditions of the Vojvodina region.

Materials and Methods

The experiment with irrigated hemp was conducted in 2017 at Bački Petrovac experimental field of Institute of Field and Vegetable Crops in Novi Sad, Serbia (N 45° 19`, E 19° 50`) on the calcareous chernozem soil on the loess terrace. In the period 1964-2016, the annual mean air temperature, precipitation and relative humidity were 11.2°C, 598.7 mm and 76% respectively. According to the Hargreaves climate classification system, the study area is classified as arid in the summer period, from June to August (Bošnjak, 2001). Hemp variety Helena was used for the trials. The row spacing was 0.25 × 0.04 m. The size of the experiment unit was 6.75 m² (1.5 × 4.5 m) and was replicated three times.

The trial was established as a blocks design and adapted to technical specifications of drip irrigation system. The plants were irrigated with a lateral placed in every other row with drippers spaced every 0.1 m. The distance between laterals was 0.5 m. Drippers had an average flow of 1.0 l h^{-1} under a pressure of 70 kPa. The trial included irrigated and non-irrigated, control variants. Irrigation was scheduled on the basis of water balance method using reference evapotranspiration (ET_o) and crop coefficients (k_c). ET_o was calculated by Hargreaves equation (Hargreaves and Allen, 2003). Daily water used on plants evapotranspiration (ET_d) was calculated by multiplying ET_o with kc values 0.5 from sowing to 3-4 pair of leaves, 0.9 from 3-4 pair of leaves to appearance of male flowers, 1.1 from appearance of male flowers to the end of the season (Cosentino et al., 2012; García-Tejero et al., 2014). Irrigation started when readily available water in the soil layer of 40 cm was completely absorbed by plants. The irrigation rate was 30 mm at the beginning of the season and 40 mm in the middle season. The volume of irrigation water and the pressure in the system were measured by the flow meter and the pressure gauge installed in the hose nozzle used for irrigation.

$$ETo = 0.0023(T_m + 17.8)\left(\sqrt{T_{max} - T_{min}}\right)R_a$$

ET_o - reference evapotranspiration (mm day^{-1}), T_m - the average daily air temperature (°C), T_{max} -the maximum daily temperature (°C), T_{min} - the minimum daily temperature (°C), Ra - the extraterrestrial radiation (MJ m^{-2} day^{-1})

$$ET_d = ET_o\ k_c$$

All recommended agronomic practices were applied for cultivation and plant protection at the experimental site. Precipitation and air temperature data were obtained from Meteorological Station located at Bački Petrovac experimental field. Data reported for fibre hemp yield were assessed by analysis of variance (ANOVA) and Fisher's LSD test was used to identify significant differences at the $p < 0.05$ levels between the mean values. Different letters indicate significant differences between values.

Results and Discussion

In the growing season of 2017 (from 26 April to 12 August), the mean air temperature and total rainfall were 22.6°C and 99 mm, respectively (Table 1). The amount of water added by irrigation was 320 mm (Figure 1, Table 1). Based on the calculated values of water balance of hemp (Table 1) it can be concluded that irrigation was applied on time with required amount of water and that the deficit of readily available water in the soil was completely eliminated. The amount of irrigation water strongly depends on environment and genotype. In semi-arid Mediterranean environment the irrigation rate for early genotypes is at least 250 mm and 450 mm for late genotypes (Cosentino et al., 2013).

Rainfall shortages is the main problem for successful hemp growth (Hackett, 1991) and therefore irrigation is essential in hemp production as it could overcome deficiencies in both the distribution and the total amount of precipitation over the summer period (Lisson and Mendham, 1998). Di Bari et al. (2004) indicated that in the southern Italy irrigation is indispensable for overcoming the prolonged water deficit which hemp is subject during vegetation season. They highlighted that the best results were obtained with the reintegration of 66% of the water lost through evapotranspiration.

Irrigation significantly affected yield of fresh stems, fresh leaves and flowers and plant height, but not stem diameter and fibre content. (Table 2). Irrigation significantly increased the yield of fresh stem by 48,18%

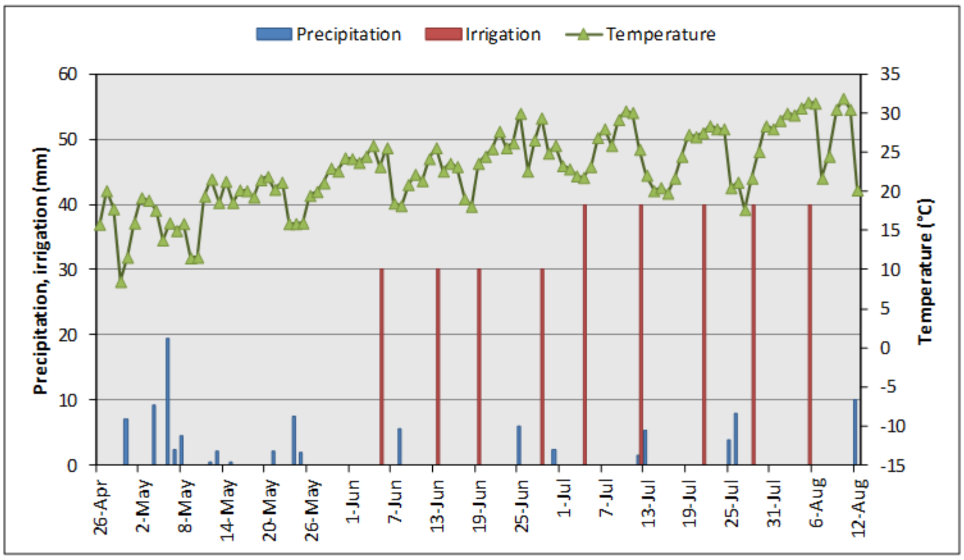

Figure 1. Irrigation schedules, irrigation water applied and meteorological data for the experimental year (daily rainfall and daily average air temperature)

and fresh leaves and flowers by 46,28%, with water consumption of 470 mm. Lisson and Mendham (1998) also pointed out that the stalk yield of hemp, total dry matter, bark percentage and bark yield were significantly higher when compared to rainfed treatment in northwest Tasmania, Australia. Results of fibre content in irrigation conditions of 32.1% are similar to those obtained in Spain, reported by Lioveras et al. (2006).

In years with a pronounced water deficit in Vojvodina, such as 2017, rainfall was not sufficient for hemp production. For this reason, irrigation was needed for acceptable yields of fibre hemp grown in the region.

In order to achieve the full potential of industrial crops, the amount of irrigation water needs to be defined (García-Tejero et al., 2014) with regard to hemp water requirements defined on the basis of evapotranspiration.

Table 1. Water balance of fibre hemp

Elements	Sowing - 3-4 pair of leaves	3 - 4 pair of leaves - appearance of male flowers	Appearance of male flowers - and of the season	Total/Average
	26 IV-1 VI	1VI-1 VII	1VII-12 VIII	26 IV-12 VIII
ET_o (mm)	143	163	165	471
ET_m (mm)	72	147	251	470
Water used on ET_m (%)	15.3	31.3	53.4	100
Duration (days)	36	31	43	110
ET_d (mm)	2.0	4.7	5.8	4.3
Rainfall (mm)	57	14	28	99
Temperature (°C)	18.1	23.9	25.8	22.6
Δ	-15	-15	0	-
r (mm)	30	15	0	-
ET_a (mm)	72	29	28	129
d (mm)	0	118	223	341
s (mm)	0	0	0	0
Irrigation (mm)	0	120	200	320

ET_o – reference evapotranspiration (mm), ET_m – the maximum evapotranspiration – irrigated (mm), ET_d – daily evapotranspiration (mm), Δ ± – difference in rainfall and ET_m represents deficit or suficit after consuming or filling the reserve (r) of readily available water, ET_a – the actual evapotranspiration – rainfed (mm), d – deficit of readily available water (mm), s – suficit (mm)

Table 2. Yield, morphological characteristics, and fibre content of hemp

Treatment	Fresh stem yield ($g\ m^{-2}$)	Fresh leaves and flowers ($g\ m^{-2}$)	Stem diameter (mm)	Plant height (cm)	Fibre content (%)
Irrigated	1950^{a}	866^{a}	5.83^{a}	168.28^{a}	32.10^{a}
Non-irrigated	1316^{b}	592^{b}	5.81^{a}	146.13^{b}	31.95^{a}

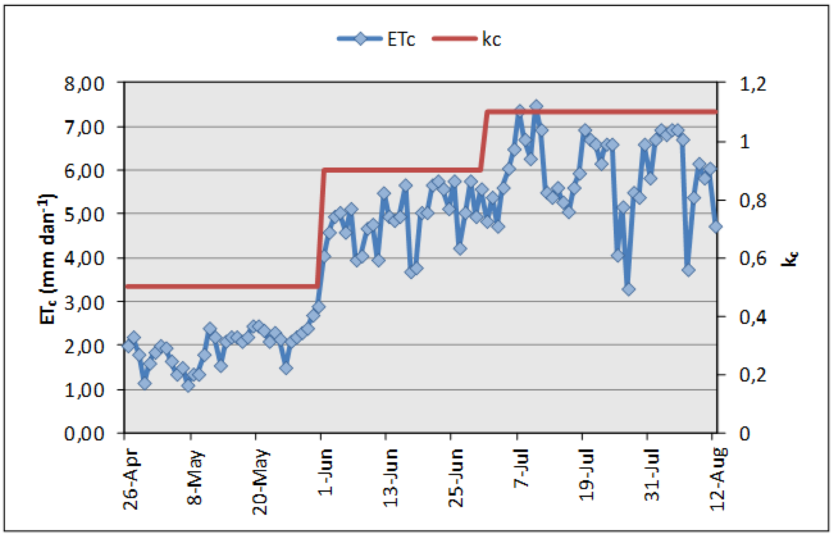

Figure 2. Daily evapotranspiration of fibre hemp

Water used on evapotranspiration in irrigation conditions (ET_m) was 470 mm and 129 mm in non-irrigated control (ET_a) (Table 1). Similar values of water used on hemp evapotranspiration of 535 mm, during growing season in northwest Tasmania, were reported by Lisson and Mendham (1998). Di Bari et al. (2004) found out that 410-460 mm of water consumption was needed for 28-38 t ha^{-1} of hemp green biomass production in southern Italy. The highest evapotranspiration rate in irrigation conditions (ET_m) was obtained for the period from appearance of male flowers to the end of the season and amounted up to 251 mm, or 53.4% of total water used during the entire growing season (Table 1). Merfield (1999) also reported that hemp water demand is concentrated during the rapid growth phase.

Evapotranspiration of hemp is highly dependent on environmental requirements and growth stage. The highest average value of 5.8 mm of daily water used on evapotranspiration (ET_d) was detected in the period of appearance of male flowers to the end of the season, while the average value for the entire growing season was 4.3 mm (Table 1). Maximum daily evapotranspiration value of 7.5 mm was detected on 10 July (Figure 2). These results are in accordance with the results gained by Di Bari et al. (2004) for the maximum values of hemp evapotranspiration of 6 mm in optimum water regime.

Conclusion

Based on the obtained results it can be concluded that irrigation has significantly affected the yield of fresh stems, fresh leaves and flowers and plant height, but not stem diameter and fibre content.

Water used on evapotranspiration in irrigation conditions (ET_m) was 470 mm while 129 mm in non-irrigated control (ET_a). The highest evapotranspiration rate in irrigation conditions (ET_m) was calculated for the period of appearance of male flowers to and of the season and amounted to 251 mm, or 53.4% of total water used during entire growing season. The highest average value of 5.8 mm of daily water used on evapotranspiration (ET_d) was detected in the period of appearance of male flowers to and of the season while the average value for the entire growing season was 4.3 mm.

These preliminary results could be used as a good platform for hemp growers in the region, regarding optimization of irrigation water use.

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Uticaj navodnjavanja kapanjem na prinos i evapotranspiraciju konoplje za vlakno (*Cannabis sativa* L.)

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Sažetak: Eksperimentalna istraživanja o uticaju navodnjavanja kapanjem na prinos i evapotranspiraciju konoplje za vlakno (*Cannabis sativa* L.) su obavljena na oglednom polju Instituta za ratarstvo i povrtarstvo iz Novog Sada u Odeljenju za alternativne biljne vrste u Bačkom Petrovcu. Vreme zalivanja je određivano obračunom vodnog bilansa. Dnevne vrednosti utroška vode na evapotranspiraciju biljaka (ET_d) su obračunate korišćenjem referentne evapotranspiracije (ET_o) i koeficijenata useva (k_c) čije su vrednosti 0,5, 0,9 i 1,1 za potperiode vegetacije konoplje od setve do porasta 3-4 lista, od 3-4 lista do pojave muških cvetova i od pojave muških cvetova do žetve. Referentna evapotranspiracija (ET_o) računata je formulom Hargreaves-a. Zalivanje je obavljano kada su rezerve lakopristupačne vode u sloju zemljišta dubine 0,4 m bile iskorišćene. Zalivna norma je na početku vegetacije iznosila 30 mm, a od sredine vegetacije 40 mm. Navodnjavanjem je ukupno dodato 320 mm vode. Navodnjavanje je signifikantno uticalo na prinos sveže stabljike, svežih listova i cvetova i visinu biljaka, ali ne i na dijametar stabla i sadržaj vlakna. Utrošak vode na evapotranspiraciju biljaka u uslovima navodnjavanja (ET_m) iznosio je 470 mm, a u uslovima bez navodnjavanja (ET_a) 129 mm. Preliminarni rezultati istraživanja mogu biti korišćeni kao dobra osnova za proizvođače konoplje u regionu, u smislu racionalnog korišćenja vode za navodnjavanje.

Ključne reči: *Cannabis*, evapotranspiracija, konoplja, navodnjavanje

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