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Yield of biomass and essential oil of dill (*Anethum graveolens* L.) grown under irrigation

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Summary: Dill (*Anethum graveolens* L.) is a one-year herbaceous, spicy plant, which has aromatic smell and taste. One of its important ingredients is essential oil. The experiment showing the effect of irrigation on essential oil and biomass yield of dill was conducted in rainy 2016 and dry 2017 in two variants: control (without irrigation) and variant with irrigation. Favourable water balance of the soil was provided by applying drop-by-drop irrigation method. The average yield of fresh biomass was 8,252 kg ha^{-1} (10,194 kg ha^{-1} under irrigation and 6,310 kg ha^{-1} in control). Under irrigation, the yield of biomass was higher than the control variant by 78.59% in 2017 and 47.41% in 2016. Under irrigation, essential oil content and yield were higher than the control by 10.73% and 95.97% in 2017, respectively, and 3.93% and 54.06% in 2016, respectively.
Key words: biomass, dill, essential oils, irrigation, soil water regime, yield

Introduction

Dill (*Anethrum graveolens* L.) is a one-year herbaceous plant with young juicy branches and leaves that are used. It is one of the most important spices in the food industry (Leung & Foster, 2003; Orhan et al., 2013). European dill (*Anethum graveolens*) is one of annual aromatic and medicinal plants belonging to the *Apiaceae* (*Umbelliferae*) family, commonly known as vilayati saunf in India. The major constituents of European dill seed oil are carvone (34.5%), dihydrocarvone (12.0%), limonene (10.0%), terpinene (6.0%), carveol (4.0%), dillapiole (3.0%) and some other compounds in traces. Higher carvone and limonene and negligible dillapiole content in dill seed oil shows its good quality (Guenther, 1949). It significantly increases antimicrobial, diuretic, antispasmolic, and anticancer activities and has a laxative effect (Tucakov, 1997; Hosseinnzadeh et al., 2002; Koppula & Choi, 2011; Peerakam et al., 2014; Stanojević et al., 2016). Dill is a local plant in the Mediterranean, South-eastern Europe and Central and South Asia (Kaur & Arora, 2010), but it is also successfully cultivated in the province of Vojvodina, Serbia.

Vojvodina belongs to the climatic area with variable, unstable and unpredictable weather conditions, primarily precipitation, both by quantity and by schedule (Bošnjak, 2002; Popović, 2010; Pejić et al., 2017). Since agricultural production takes place under the open sky and it is largely unprotected, the risk of occurrence of some harmful events (hail, flood, drought, cold, storm, fire, etc.) is increased (Marković and Kokot, 2018).

Although dill has low water requirements and only in the germination and sprout stage is sensitive to lack of moisture in the soil, a favourable aquatic and air regime of soil is required for successful plant production. The average daily air temperature in central Vojvodina shows a growing trend (Maksimović et al. 2018). Thirty years in the period 1987-2016 were warmer by 5.7% than

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the period 1948-1990 in the area of Bački Petrovac, central Vojvodina. Such conditions increase plant water consumption which leads to a deficiency of water in the soil and a decrease in the genetic potential of cultivated plants by 50 to 90%, depending on the intensity of the drought (Dragović et al., 2005).

Soil properties are significant indicators of its fertility and quality (Milunović et al., 2017). The main hydrological property of soil is water permeability. Water permeability is highly dependent on other soil properties. There are multiple factors that influence soil water permeability: soil porosity, mechanical composition, structure, presence of crack and channels. Additionally, chemical composition, length of humidification, agro-technical and ameliorative measures belong to this group. Mechanical composition conditions number, size, shape and continuity of pores; but shape of particles, set of particles, and stability of structural aggregates of soil affect the same characteristics (Miljković, 1996). The application of various cultivation practises, such as irrigation or drainage, can affect the elements of water regime and soil balance, which significantly increases fertility and quality of the land, as well as the yield and quality of cultivated plants (Dragovic et al, 2005a; Maksimović et al, 2018b), so it is useful to apply them wherever possible.

For this reason, dill was examined under irrigation in order to regulate the soil water regime and determine the effect of irrigation on the yield of fresh dill biomass and essential oils.

Materials and Methods

The trial was conducted during 2016 and 2017 at experimental field of the Institute of Field and Vegetable Crops in Novi Sad, Serbia, at the Department for Alternative Crops and Organic Production in Bački Petrovac, Serbia (φ N 45° 20`, λ E 19° 40`). It was carried out on chernozem soil, with low humus (2.68%), calcareous, $CaCO_3$- 3.38%, moderately alkaline, pH in KCl - 7.61, high in P_2O and K_2O (37.2% and 34.10%, respectively). After the autumn ploughing at the depth of 0.3 m and pre-sowed preparation of soil in the spring, sowing was carried out by manual sowers on 9 May 2016 (due to the cold spring) and on 5 April 2017, with 10 kg ha^{-1} seed in both years. The area of parcel was 21 m^2 (3 rows at a distance of 0.7 m, length 10 m). The plants were harvested on 17 August 2016 and 1 August 2017. Fresh biomass yield of dill was calculated in kg ha^{-1}. After drying in a solar dryer, the content of essential oils was analyzed according to the standard procedure (Ph. South, V, 2000) in the accredited laboratory of the Department and calculated in the yield of ethereal oil in kg ha^{-1}.

The study included two variants: a variant with irrigation (drop-by-drop method) and control as non-irrigated variant. The watering time was determined by the basis of water balance method using reference evapotranspiration (ETo) and crop coefficient (kc). ETo values (mm day^{-1}) were calculated by Hargreaves method (Hargreaves & Samani, 1985), and downloaded from the Republic Hydrometeorological Service of Serbia website (www.hidmet.gov.rs), and kc from the FAO organization website (www.fao.org). The watering norm was 30 mm. Soil water balance was monitored by examining the soil moisture on both variants, twice a month to 60 cm depth, by probe sampling and applying the thermo-gravimetric method, drying in the dryer at 105 °C to a constant mass, before the mathematical calculation of the soil moisture.

Data reported for the yield of raw dill mass and essential oil yield were assessed by analyses of variance (ANOVA) and Fischer`s LSD test which was used for any significant differences at the $P < 0.05$ levels between the means. All the analyses were conducted using software package statistics STATISTICA 12 (StatSoft Inc. USA). Significance of difference between calculated average values of investigated factors (year and irrigation) were tested by using a two-factorial analysis of variance.

Analysis of data from the meteorological station in Bački Petrovac, located in the immediate vicinity of the field of test, determined that the average daily air temperature in growing period was 18.6 °C in the thirty-year period (1987-2016). Precipitation was 370.7 mm (Maksimovic et al., 2018). There was a large percentage of dry years with precipitation that does not meet plant requirements for water, with the increase in mean monthly air temperatures 83.3% in July and 86.6% in August (Maksimović et al., 2017).

Results and Discussions

Meteorological data

Growing periods of the analysed years differed in long.term average values, according to meteorological parameters. According to the Republic Hydro-meteorological Service of Serbia in 2016, the northern part of the country, in the Vojvodina region of Serbia had average precipitation and an mean deviation of average daily air temperatures of 1.4 °C (www.hidmet.gov.rs/podaci/agro/ciril/AGROveg2016.pdf). The year of 2017 was warmer in the territory of Vojvodina by 0.4 °C, with a lower precipitation compared to the long-term average (www.hidmet.gov.rs/podaci/agro/godina.pdf). The average long-term temperature was 11.6 °C and the total precipitation was 615.1 mm. In the first year, the average temperature was 12.4 °C and total precipitation was 727.1 mm (Figures 1 and 2).

In the growing period in 2016, the amount of precipitation was higher than the average long-term values, amounting to 439.7 mm and 69.0 mm more than the expected values. Air temperatures in central Vojvodina (Bački Petrovac) were 0.8 °C higher than the long-term average (Fig. 1).

In the second year, the average temperature was 12.7 ° C and total precipitation was 360.2 mm. During the

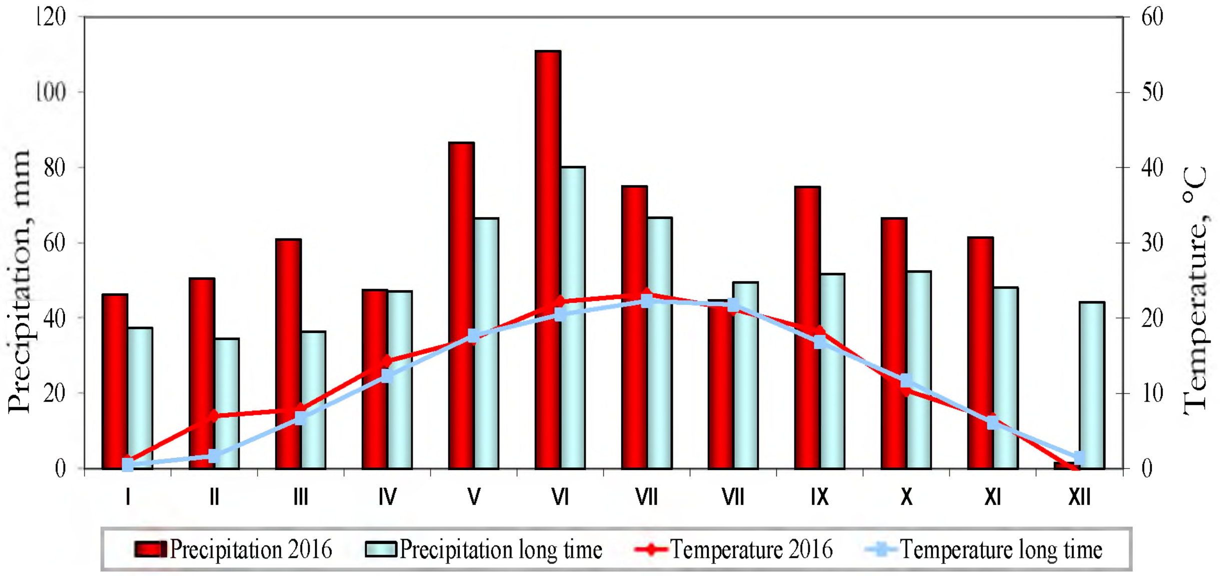

Figure 1. Average temperature (°C) and total precipitation (mm) in Bački Petrovac in 2016

growing period in 2017 total precipitation was 219.0 mm, which is lower by 152.0 mm than the annual average of 370.7 mm, while the average temperatures were 20.1 °C and were higher than the long-term temperature by 1.5 °C (18.6 °C), as shown in Figure 2.

Soil Water Balance

By monitoring soil water balance, the time of watering was determined when the quantity of easily accessible water in the rhizosphere layer was up to 40 cm deep. In the first year of the test, there were 4 waterings with 110 mm irrigation norm, while in dry 2017 there were 8 waterings with 240 mm irrigation norm (Fig. 3). It was found that dill water requirements, or potential evapotranspiration (ETc), during 110 to 117 days of growing were similar, i.e. 378 mm in rainy 2016 and 374 mm in dry 2017 (Fig. 3 and 4).

Soil moisture

Soil moisture was determined by monitoring the soil moisture by thermo-gravimetric method up to 60 cm depth (Fig. 5), and the irrigation had a very significant effect in the increase of fresh dill biomass yield (Tab.1).

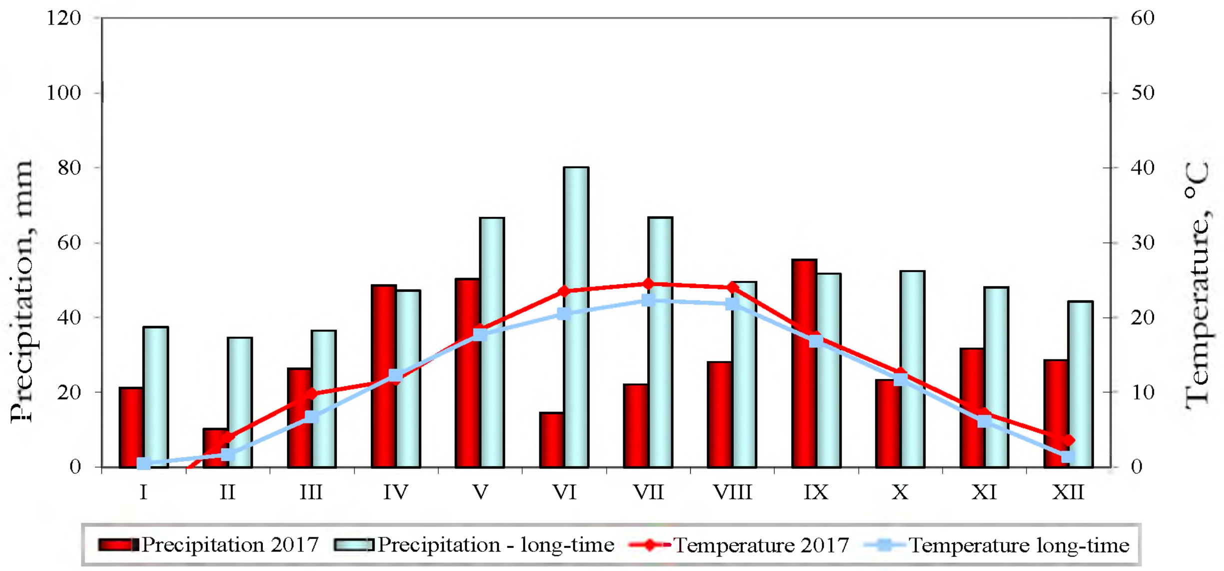

Figure 2. Average temperature (°C) and total precipitation (mm) in Bački Petrovac in 2017

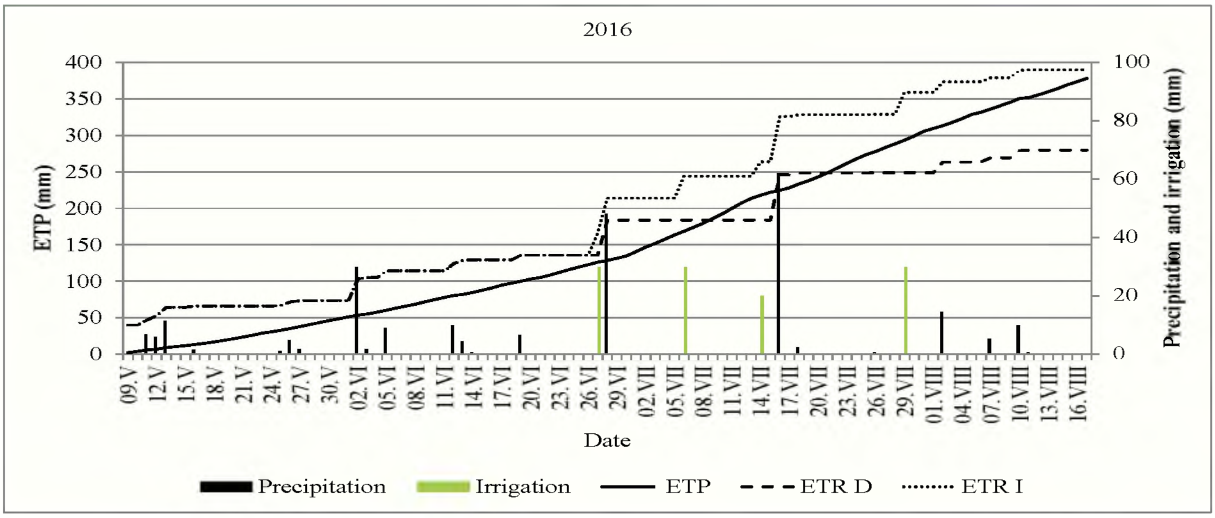

Figure 3. Water balance of soil under dill (mm), potential evapotranspiration (ETP) and actual evapotranspiration (ETR) in dry and in irrigation variant in 2016

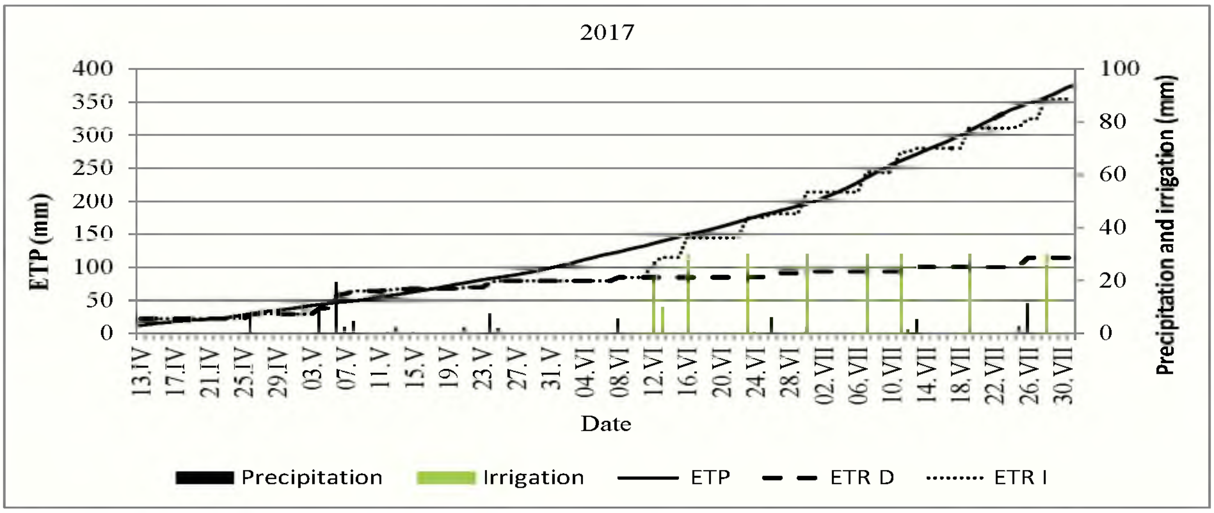

Figure 4. Water Balance balance of Soil soil under the dill (, mm), ETP-potential evapotranspiration (ETP) and ETR – actual evapotranspiration (ETR) in dry and in irrigation variant in 2017

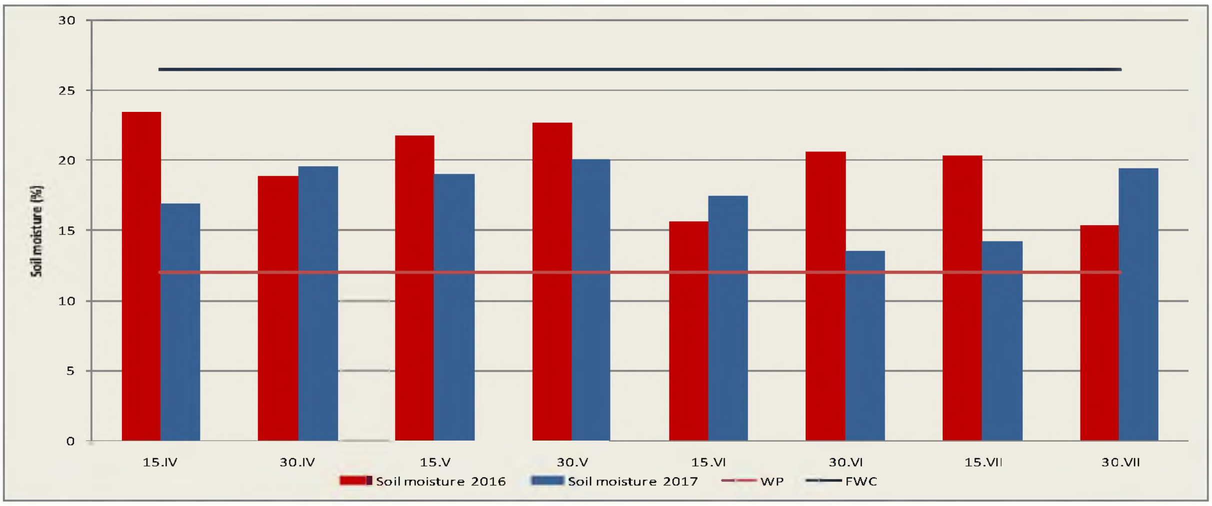

Figure 5. Soil moisture, Witching Point (WP) and Field Water Capacity (FWC, in mm) under dill in 60 cm depth

Table 1. Irrigation effect on the fresh biomass yield (kg ha^{-1}), dill essential oil (%), and essential oil yield (kg ha^{-1}) in 2016-2017

Parameter	Year	Control	Irrigation	Average	Difference	Effect (%)
Yield of fresh biomass (kg ha^{-1})	2016	6,893	10,161	8,527	3,268	47.41
	2017	5,726	10,226	7,976	4,500	78.59
	$\bar{x}$	6,309	10,194	8,251	3,884	61.58
	Std. Dev.	1,262	899	2,268	-	-
Essential oil content (%)	2016	1.78	1.85	1.82	0.19	3.93
	2017	1.77	1.96	1.87	0.13	10.89
	$\bar{x}$	1.78	1.91	1.84	0.05	7.30
	Std. Dev.	0.14	0.11	0.14	-	-
Essential oil yield (kg ha^{-1})	2016	24.38	37.56	30.97	13.18	54.06
	2017	20.62	40.41	30.52	19.79	95.97
	$\bar{x}$	22.50	38.99	30.75	16.94	73.29
	Std. Dev.	5.18	3.71	9.56	-	-

Parameter	Yield of fresh biomass		Essential oil content		Essential oil yield	
LSD	0.05	0.01	0.05	0.01	0.05	0.01
Year	1186.33	1668.45	0.144	0.202	4.891	6.878
Irrigation	1186.32	1668.44	0.144	0.201	4.891	6.878
Y × I	1677.72	2359.54	0.201	0.284	6.917	9.728

Biomass yield and quality of dill

The average yield of dill fresh biomass was 8251 kg ha^{-1} for the period 2016-2017. In the irrigated variant, the yield of dill green biomass was 10,194 kg ha^{-1}, which is statistically significantly higher than in the control variant (6,310 kg ha^{-1}). The effect of irrigation amounted to 61.55% in the period 2016-2017.

The average yield of dill fresh biomass was 7976 kg ha^{-1} in 2017. Irrigation had a statistically significant effect on the yield of dill fresh biomass. In rainy 2016 the yield of green biomass was significantly higher, 8,527 kg ha^{-1}. The irrigation effect in 2016 was 47.41%. Standard deviation for biomass yield was 2268 and the standard error was 567 (Table 1).

In the irrigated variant in 2017 yield of dill fresh biomass was 10,226 kg ha^{-1}, which is statistically significantly higher than in the control variant (5,726 kg ha^{-1}). The yield of fresh biomass was higher in the irrigated variant than in the control by 4,500 kg ha^{-1} which is a difference of 78.59% (Tab. 1).

The average essential oil content was 1.84% for the analysed period 2016-2017. In the irrigated variant, the content of essential oil was 1.91%, which is statistically significantly higher than the control variant (1.78%), Table 1.

The average essential oil content in 2016 was 1.82%. In the irrigated variant, statistically significantly higher essential oil content (1.85%) was achieved than in the control variant (by 1.78%), as shown in Table 1.

Irrigation had a statistically significant effect on essential oil yield. The average yield of essential oil was 30.75 kg ha^{-1} and varied from 22.50 kg ha^{-1} in non-irrigated variants to 38.99 kg ha^{-1} in irrigated variants. In the irrigated variant, the yield increased by 16.49 kg ha^{-1} compared to the non-irrigated variant, which is a difference of 73.29% (Table 1).

The year did not have a significant effect on the tested parameter yield. The average essential oil yield was 30.52 kg ha^{-1} in 2017 and 30.97 kg ha^{-1} in 2016. The standard deviation for essential oil yield was 9.56 (Table 1).

The year 2016 was favourable for fresh biomass yield and 2017 was favourable for essential oil content.

Dill essential oil is present in all plant parts, but its content is highest in the seed (2-5%) (Leung & Foster, 2003). The food industry often uses essential oil instead of dill leaves and seeds (Pino et al., 1995) due to its characteristic aroma and flavour (Jirovetz et al., 2003). El-Zaeddi et al. (2017) had similar results and found the highest dill yield in intermediate conditions of both irrigation dose (ID0) and plant density (PD0). During seed development, the environment is a major determinant of seed quality, particularly for seed vigour. Sufficient water for plants during seed filling is necessary to produce high quality dill seed, especially for delayed sowings (Zehtab-Salmasi et al., 2006). Vineeta et al. (2018) suggested that European dill could be irrigated with 100 mm CPE depending on rainfall.

Conclusions

Based on the two-year results of the dill trial under irrigation in central Vojvodina, the following can be concluded:

Irrigation had a statistically significant impact on fresh biomass yield, the content and yield of essential oil.

In the irrigated variant, the average fresh biomass yield was higher by 61.55%, while essential oil content (1.85%) and yield (30.75 kg ha^{-1}) were higher than in the control variant by 7.30% and 73.29%, respectively.

Although dill has low water requirements, irrigation is necessary in dry years for successful plant production, by which high yields of improved quality can be achieved.

References

Bošnjak, Đ. (2002). Potrebe, stanje i perspektive navodnjavanja u Vojvodini. (Needs, condition and perspectives of irrigation in Vojvodina). Tematski zbornik radova: Melioracije i poljoprivreda. Novi Sad, 147-155.

Dragovic, S., Maksimovic, L., Milic, S., Radojevic, V. (2005): Drought intensity in Vojvodina Province and impact on field crop production. *Savremena poljoprivreda,* 54 (1-2), 384-389.

Guenther, E. (1949). *The Essential Oils.* Vol. III.D. Van Nostrand Co. Inc., New York, 640-676.

Hargreaves, G.H., Samani, Z.A. (1985). Reference crop evapotranspiration from temperature. *Applied Engineering in Agriculture,* 1, 96-99.

Dragovic, S., Maksimovic, L., Radojevic, V., Cicmil, M. (2005a). Irrigation Requirements and their Effects on Crop Yields in Serbia and Montenegro. ICID 21st European Regional Conference, Frankfurt (Oder) and Slubice – Germany and Poland, 1-9.

El-Zaeddi H., Martínez-Tomé J., Calín-Sánchez Á., Burló F., Carbonell-Barrachina ÁA. (2017). Irrigation dose and plant density affect the volatile composition and sensory quality of dill (*Anethum graveolens* L.). *J. Sci. Food Agric.* 97 (2), 427-433.

Hosseinnzadeh, H., Karimi, G.R., Ameri M. (2002): Effects of *Anethum graveolens* L. Seed extrats on experimental gastric irritation models in mice. *BMC Pharmacology,* 2 (21), 1471-2210.

Jirovetz, L., Buchbauer, G., Stoyanova, A.S., Georgiev, E.V., Damianova, S.T. (2003). Composition, quality control and antimicrobial ativity of the essential oil of long-time stored dill (*Anethum graveolens* L.) seeds from Bulgaria. *Journal of Agricultural and Food Chemistry,* 51 (13): 3854–3857.

Kaur, G.J., Arora, D.S. (2010). Bioactive potential of *Anethum graveolens*, *Foeniculum vulgare* and *Trachys permumammi* belonging to the family *Umbelliferae* – Curent status. *Journal of Medicinal Plants Research*, 4 (2), 87-94.

Koppula, S., Choi, D.K. (2011). *Anethum graveolens* Linn (Umbelliferae), Extract Attenuates Stress-induced Urinary Biochemical Changes and Improves Cognition in Scopolamine induced Amnesic Rats. *Tropical Journal of Pharmaceutical Research,* 10 (1): 47–54.

Filipović, V., Glamočlija, Đ., Radivojević, S., Jaćimović, G. (2010): The demand for fresh spice herbs in the world and in Serbia. *6th Conference on Medicinal and Aromatic Plants of Southeast European Countries*, Antalya, Turkey. pp. 120-120.

Leung, A.Y., Foster, S. (2003). *Encyclopedia of common natural ingredients (used in food, drugs and cosmetics)*, 2-Edition,A John Wiley & Sons, Inc., Hoboken, New Jersey. 649-649.

Maksimović, L., Dragović, S., Pejić, B., Milić, S., Mačkić, K., Živanov, M. (2017). Occurrence of drought and needs for irrigation in central Vojvodina. *2nd International and 14th National Congress of Soil Science Society of Serbia „Solutions and Projections for Sustainable Soil Management"*, Novi Sad, 246-253.

Maksimović, L., Popović, V., Stevanović, P. (2018). Water and irrigation requirements of field crops grown in central Vojvodina, Serbia. *Agriculture & Forestry,* 64 (1), 133-144.

Maksimović, L., Adamović, D., Pejić, B., Popović, V., Mačkić, K. (2018a). Variation of yield biomass dill and contents essential oils depending of irrigation. *22nd International Eco-Conference 2018: Safe food,* 26-28.9.2018, Novi Sad; 219-225.

Maksimović, L., Adamović, D., Pejić, B., Dragović, S., Marjanović-Jeromela, A., Milošević, D., Popović, V. (2018b). Effects of irrigation on production and quality of dill, marigold and basil in different weather conditions. *Green Room Sessions 2018 International GEA (Geo Eco-Eco Agro) Conference,* Book of Abstracts, 51-52.

Madadi Bonab, S., Zehtab Salmasi, S., Ghassemi Golezani, K. (2012). The effect of irrigation and nitrogen fertilizer on morphological characteristics and essential oil percentage and yield of dill (*Anethum graveolens* L.). *Journal of Agricultural Science*, 22 (2), 91-100.

Marković, T., Kokot, Ž. (2018): Whole farm revenue insurance as a new model of risk management in agriculture *Ratar. Povrt.*, 55(1), 22-28.

Milunović, K., Nešić, Lj., Vasin, J., Ćirić, V., Belić, M., Pejić, B., Pavlović, L. (2017). The effect of land use on soil permeability in Vojvodina. Ratar., 54 (1), 8-12.

Miljković, N. (1996). *Osnovi pedologije. (Basics of pedology).* Novi Sad: University of Novi Sad, Faculty of Sciences, Institute for Georgraphy. Novi Sad.

Orhan, E.I., Senol, F.Z., Ozturk, N., Celik, S.A., Pulur A., Kan, Y. (2013). Phytochemical contents and enzime inhibitory and antioxidant properties of *Anethum graveolens* L. (dill) samples cultivated under organic and conventional agricultural conditions. *Food and Chemical Toxicology*, 59, 96–103.

Peerakam, N., Wattanathorn, J., Punjaisee, S., Buamongkol, S., Sirisaard , P. , Chansakaow S. (2014). Chemical profiling of essential oil composition and biological evaluation of *Anethum graveolens* L. (seed) grown in Thailand. *Journal of Natural Sci. R.,* 4 (16): 34–41.

Pejić, B., Adamović, D., Maksimović, L., Mačkić, K. (2017). Effect of drip irrigation on yield, evapotranspiration and water use efficiency of sweet basil (*Ocimum basilicum* L.). *Ratar. Povrt.,* 54, 3: 124-129.

Pino, J.A., Rosado, A., Goire, I., Roncal, E. (1995). Evaluation of flavor characteristic compounds in dill herb essential oil by sensory analysis and gas chromatography. *Journal of Agricultural and Food Chemistry*, 43 (5): 1307–1309.

Popović V. (2010): Agro-technical and agro-ecological influence on the production of wheat, maize and soybean seeds. Doctoral dissertation, University of Belgrade, Faculty of Agriculture, Zemun, 1-145.

Stanojević, Lj., Stanković, M., Cvetković, D., Danilović, B., Stanojević, J. (2016). Dill (*Anethum graveolens* L.) seeds essential oil as a potential natural antioxidant and antimicrobial agent. *Biologica Nyssana*, 7 (1), 31-39.

Tucakov, J. (1997). *Lečenje biljem*, (Treatment plants). RAD. Belgrade. RAD-Beograd. Beograd

Vineeta, Vishwanath, Kewalanand and Vandana (2018). Oil constituents of European dill (*Anethum graveolens L.*). Affected by irrigation and FYM Levels and storage conditions. *Journal of Pharmacognosy and Phytochemistry.* SP1: 841-844.

Zehtab-Salmasi S., Ghassemi-Golezani K., Moghbeli S. (2006). Effect of Sowing Date and limited Irrigation on the Seed Yield and Quality of Dill (*Anethum graveolens* L.). *Turk J Agric For.* 30, 281-286.

Prinos etarskog ulja i biomase mirođije (*Anethum graveolens* L.) gajene u uslovima navodnjavanja

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Sažetak: Mirođija (*Anethum graveolens* L.) je jednogodišnja zeljasta, začinska biljka, aromatičnog mirisa i ukusa čiji je najvažniji sastojak etarsko ulje. Eksperiment pokazuje efekat navodnjavanja na prinos etarskog ulja i biomase mirođije, a izveden je tokom vlažne 2016. i sušne 2017. godine u dve varijante: kontrola, bez navodnjavanja i varijanta sa navodnjavanjem. Povoljan vodni bilans zemljišta obezbeđen je primenom navodnjavanja metodom kap po kap. Prosečan prinos sveže biomase mirođije iznosio je 8.252 kg ha^{-1} (10.194 u navodnjavanju i 6.310 kg ha^{-1} na kontroli). U varijanti sa navodnjavanjem prinos biomase bio je veći u odnosu na kontrolnu varijantu za 78,59% u 2017. godini, dok je u 2016. godini ostvarena razlika od 47,41%. U varijanti sa navodnjavanjem, sadržaj i prinos etarskog ulja bio je veći u odnosu na kontrolnu varijantu za 10,73% i 95,97% u 2017. godini, dok je u 2016. godini ostvarena razlika od 3,93% i 54,06%.

Key words: biomasa, etarsko ulje, mirođija, navodnjavanje, prinos, vodni režim zemljišta

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