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WATER BALANCE OF COASTAL REGION IN SLOVENIA

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Within the scope of evaluation of water saving irrigation practices in olive orchards, a detailed water balance evaluation of west Slovenian coastal region has been prepared for years 2014 – 2016. The Slovenian Istria is facing increased risk of drought and heat stress. Due to more frequent occurrence and intensity of agricultural droughts, soil water regime management with irrigation is becoming an inevitable element of agricultural practice in Slovenian Istria.

KEY WORDS: water balance, drought, irrigation

VODNÁ BILANCIA POBREŽNEJ OBLASTI V SLOVINSKU. V rámci hodnotenia zavlažovacích postupov, ktoré sú zamerané na šetrenie vody v olivových sadoch, sa v rokoch 2014 – 2016 pripravilo podrobné vyhodnotenie vodnej bilancie pobrežia západného Slovinska. Slovinská Istria čelí zvýšenému riziku sucha a tepelného stresu. V dôsledku častejšieho výskytu a intenzity poľnohospodárskeho sucha sa stáva riadenie pôdneho vodného režimu pomocou zavlažovania nevyhnutným prvkom poľnohospodárskej praxe na Slovinskej Istrii.

KĽÚČOVÉ SLOVÁ: vodná bilancia, sucho, závlahy

Introduction

Irrigation is a measure, applied to avoid water deficits that reduce crop production, and the largest single consumer of water on the planet (Fereres and Soriano, 2007). While olive trees have been traditionally cultivated under rainfall conditions due to their known resistance to drought (Moriana et al., 2003; Fernandez and Moreno, 1999) and other environmental stresses (Gucci et al., 2012; Fernandez, 2014), in order to ensure steady, quality yield in intensive production practices implementation of irrigation is needed (Naor, 2014). Applied water has a large influence on olive tree growth, tree water relations and yield (Grattan et al., 2006), and with suitable water status management, alternate bearing behavior can be reduced and quality of the yield increased (Fernandez and Moreno, 1999; Caruso et al., 2014).

Experiences from most arid areas with intensive olive production, where due to water scarcity and subsequent high water prices, water can be a limiting factor (Bhat et al., 2012), show that implementation o f water savings measures, such as deficit irrigation techniques (Pereira et al., 2002) is necessary and successful. Deficit irrigation can aid as a tactical measure in situations where supply is restricted by reducing the amount of irrigation water use (Fereres and Soriano, 2007). Slovenia's coastal region on the north Adria coast experienced severe drought conditions during summer months in the past two decades (Pogačar et al., 2016). Precipitation improves soil water conditions through occasional storm rain showers during vegetation periods. However, for stable yield with high value characteristics of olives for further processing, supplement irrigation is necessary (Zupanc et al., 2016).

Water balance is a useful tool for rough estimation of soil water status in plant production. For water savings irrigation techniques, additional water deficit measurement may be needed to ensure both water savings and good plant status. In the paper, evaluation of water supply based on water balance calculation and soil water status under rain-fed conditions is assessed for olive orchard in Slovenian Istria, north Mediterranean for 2014 – 2016.

Material and methods

For coastal region of Slovenia, water balance status has been evaluated for standard meteorological station, Portorož (Table 1) for three consecutive years 2014 – 2017. Reference evapotranspiration has been calculated using Penman Monteith method (Allen et al., 1998), applying k_c for the olive tree in Slovenian Coastal region (winter and spring 0.7, summer 0.5-0.58, autumn 0.65-0.69), for the calculation of crop evapotranspiration (Zupanc et al., 2016). Meteorological data (precipitation, air temperature T, reference evapotranspiration ET), for the local meteorological station in nearby Portorož, Slovenia, were used (latitude 45°28'09", longitude 13°37'09", 2 m a.s.l.). Number of days with T over 20 °C, extremely hot days (T_{max} over 35 °C) has been analyzed. Water balance has been compared with 30 year period (1981 – 2010) for Portorož. Data were retrieved from the Slovenian Environment Agency (ARSO). In addition, precipitation data of three precipitation stations Seča, Strunjan and Dekani (Table 1) have been evaluated the distribution of days with precipitation over 20 mm.

Soil water conditions were evaluated for olive orchard (*Olea europaea* L., cv. 'Istrska belica') on a terraced hilly area (latitude 45°32'38", longitude 13°48'37", 25 m a.s.l.). Soil water retention characteristics were determined on undisturbed soil samples by evaporative method (Schindler et al., 2010), field capacity of the soil was determined at 32 volumetric % (−0.02 MPa), wilting point at 18 % (−1.5 MPa). Soil water content (volumetric %) has been measured by TDR in the root zone at 30 cm on eight points for rain-fed conditions (i.e. no supplement irrigation was applied). Soil has loam – clay loam texture, has been classified as Anthroposol, with occasional occurrence of rocks and large stones. Evaluated were measurements from May 2015 – December 2016.

Results and discussion

In the evaluated period, coastal region of south west Slovenia experienced a very wet year (2014, 1462.4 mm total annual precipitation), a dry year (2015, 595.1 mm), and a year with a slightly above 30yr average precipitation (2016, 1028.2 mm, Table 2).

In spite of extremely high precipitation amount in 2014 (over 500 mm more than 30 year average, Table 2), water balance was negative twice, first in early spring (March 2014, −8 mm) and early summer (−38 mm, June 2014). As described by Zupanc et al., 2016, the following year 2015 was very dry and hot, with eight months of water deficit, whole vegetation season, and a total annual deficit of −130 mm (Table 2). The year 2016, with precipitation amount above 30 years average, had negative water balance in four months (April −39.7 mm, July −87.1 mm, August −55.1 mm and September −20.2 mm) during vegetation period and in December 2016 (−18.1 mm).

Even though the beginning of 2016 was wet with positive water balance in January (57.3 mm) and particularly in February (155.3 mm), water balance was already negative in April (−38.7 mm). This was also reflected in soil water status in the olive orchard (Figure 1). Still, in 2016 soil water balance was positive in May and June, which indicated somewhat better conditions for olive production under rain-fed environment than 2015. Even though water balance was negative in December 2016 (Table 2), high precipitation amount in October and November 2016 supplied sufficient water amount and wilting point was not reached.

In the winter and early spring months of 2015, precipitation was below long year averages of thirty years set 1981–2010 (45.3 mm vs 60 mm, 30.3 mm vs 54 mm, 41.9 mm vs 62 mm and 29.4 mm vs 66 mm in January, February, March and April, respectively, Table 2). Lower total precipitation was not sufficient to fill the depleted soil water storage, in spite of extremely wet year 2014, during which annual precipitation exceeded thirty year average for approximately 500 mm (Table 2). Due to negative water balance in the winter 2014/2015 and the spring months 2015, soil water storage had already been depleted at the beginning of the vegetation period May – September 2015 (Zupanc et al., 2016). Initial soil water content measured on 30 cm was close to the −1.5 MPa matrix potential (Figure 1).

Table 1. Description of meteorological station Portorož and precipitation stations Seča, Dekani and Strunjan: altitude, geographical coordinates and surrounding land use

Tabuľka 1. Popis meteorologickej stanice Portorož a zrážkových staníc Seča, Dekani a Strunjan: nadmorská výška, zemepisné súradnice a využívanie pôdy

Station	Altitude (m a.s.l)	Longitude, latitude	Area description
Portorož	2	13.6160, 45.4753	Peri-urban, next to the seaside, flat area
Seča	2	13.6073, 45.4939	Urban to peri-urban, close to the salt panes, next to the seaside, on the foothill
Dekani	80	13.8105, 55.5489	
Strunjan	30	13.6096, 45.5317	Urban/peri urban, hilly area

Table 2. **Monthly precipitation (P, mm) for two thirty year sets (1971 – 2000, 1981 – 2010), and study years 2014 – 2016, olive reference evapotranspiration (ET, mm) and water balance (WB, mm) for meteorological station Portorož, north Istria, Slovenia**

Tabuľka 2. **Mesačné zrážky (P, mm) pre dve tridsaťročné obdobia (1971-2000, 1981-2010) a roky 2014-2016, referenčná evapotranspirácia pre olivy (ET, mm) a vodná bilancia (WB, mm) pre meteorologickú stanicu Portorož, severná Istria, Slovinsko**

P	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
71-00	56.3	47.1	61.3	65.3	68.8	85.8	57.6	78.1	123.8	120.5	91.3	75.3	931.2
81-10	60	54	62	66	75	86	56	86	118	112	106	88	969
2014	87.6	171.7	47.4	124.1	89	55	264.7	94.5	208.5	115.4	139.3	65.2	1462.4
2015	45.3	30.3	41.9	29.4	38.6	71.8	61.2	48.2	69.9	133.8	24.7	0	595.1
2016	75.7	181	99.6	26.3	88.4	109.9	16.2	41.3	54.8	140.2	194.6	0.2	1028.2
ET													
2014	16.9	23.2	55.4	57.1	83.9	93.0	77.9	76.2	57.3	41.7	20.8	20.2	623.6
2015	22.1	29.1	51.4	72	92.1	99.3	115.6	91.4	80.4	39.1	21.7	11.1	725.2
2016	18.4	25.7	50.2	65.0	88.1	79.4	103.3	96.4	75.0	37.1	23.3	18.3	680.2
WB													
2014	70.7	148.5	-8.0	67.1	5.1	-38.0	186.8	18.3	151.2	73.7	118.5	45.0	838.8
2015	23.2	1.2	-9.5	-42.6	-53.5	-27.5	-54.4	-43.2	-10.5	94.7	3	-11.1	-130.1
2016	57.3	155.3	49.4	-38.7	0.3	30.5	-87.1	-55.1	-20.2	103.1	171.3	-18.1	348.0

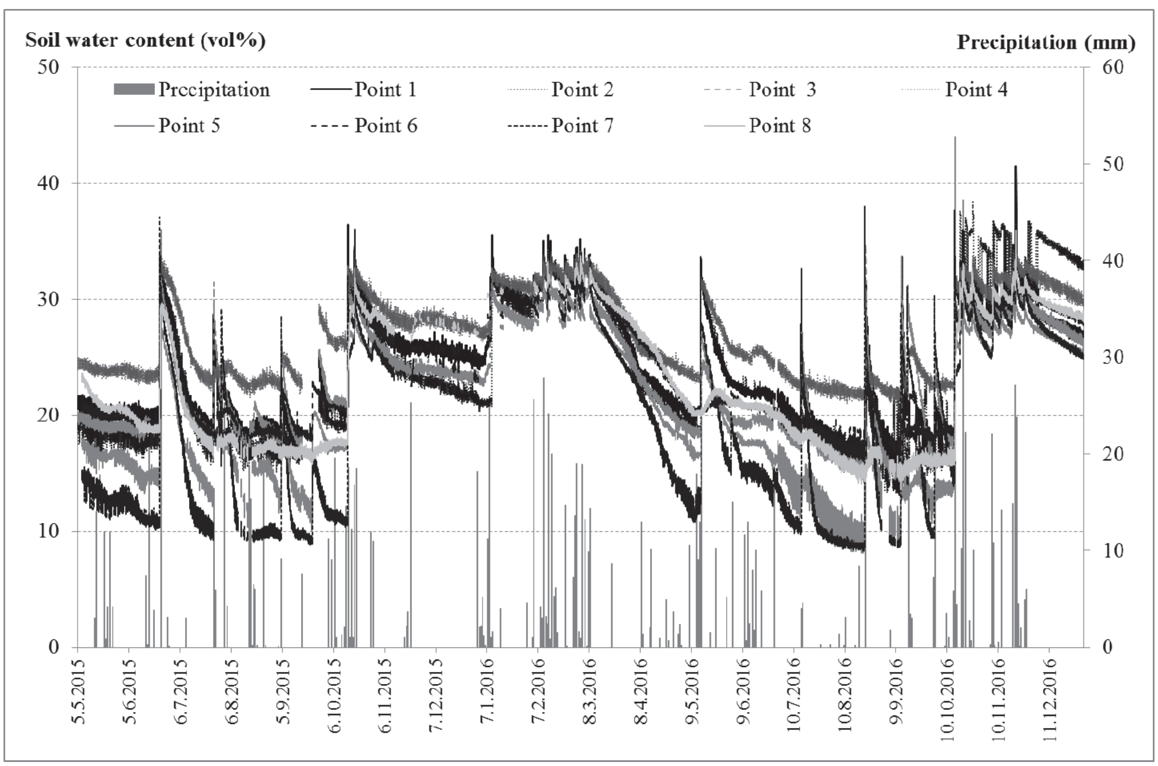

Fig. 1. Soil water content at 30 cm for eight measuring points in olive orchard in north Istria and precipitation for meteorological station Portorož for May 2015 – December 2016.
Obr. 1. Obsah vody v pôde v 30 cm pre osem meraných bodov v olivovom sade v severnej Istrii a zrážky z meteorologickej stanice Portorož v období máj 2015 – december 2016.

Similarly, water deficit in soil occurred also in 2016. Interestingly, this was in spite of precipitation at the beginning of the year, which contributed to positive water balance for three consecutive months, January, February and March 2016. This would imply that under rain-fed conditions olive trees experienced water stress during early spring months, March and most notably April (Table 2, Figure 1), which could affect the next year's olive tree performance (Moriana et al., 2003, Rapoport et al., 2012).

Comparing the number of days with T_{max} over 20 °C, year 2014 had the highest occurence among evaluated years (179, Table 3). Though in the wet year, there were only 12 days over 30 °C, comparing to 52 days with T_{max} over 30 °C in 2015 and 2016. However, in 2015 nine (9) days exceeded 35 °C.

Year 2015 had roughly a half of the days with precipitation over 20 mm comparing to 2014 and 2016. Number of days with precipitation over 20 mm was comparable for the evaluated coastal precipitation stations for individual year. Exception is station Dekani that had only 15 days with precipitation over 20 m in 2016, comparing to 19 days in Portorož and 18 days in Seša and Strunjan (Table 3).

Table 3. Days with precipitation over 20 mm for Portorož, Seča, Strunjan, Dekani stations and days with temperature over 20 °C for 2014 – 2016 in north Istria, Slovenia

Tabuľka 3. Dni so zrážkami nad 20 mm pre stanice Portorož, Seča, Strunjan, Dekani a dni s teplotou nad 20 °C pre roky 2014 – 2016 v severnej Istrii, Slovinsko

2014	Portorož	Seča	Strunjan	Dekani	T interval	Portorož
20 - 24.9 mm	4	4	5	6	20 - 24.9 °C	95
25 - 29.9mm	6	7	2	4	25 - 29.9 °C	72
30 - 34.9 mm	1	1	3	7	30 - 34.9 °C	12
35 - 39.9mm	3	2	5	1	>35 °C	0
40 - 44.9 mm	1	2	1	1	Total days T >= 20 °C	179
45 -49.9mm	0	0	0	0		
> 50 mm	4	6	4	3		
total days P >= 20 mm	**19**	**22**	**20**	**22**		

2015	Portorož	Seča	Strunjan	Dekani	T interval	Portorož
20 - 24.9 mm	4	3	3	6	20 - 24.9 °C	56
25 - 29.9 mm	2	4	3	2	25 - 29.9 °C	56
30 - 34.9 mm	0	1	0	1	30 - 34.9 °C	43
35 - 39.9 mm	0	0	1	1	>35 °C	9
40 - 44.9 mm	0	0	0	1	Total days T >= 20 °C	164
45 -49.9 mm	1	2	2	0		
> 50 mm	1	0	0	0		
total days P >= 20 mm	**8**	**10**	**9**	**11**		

2016	Portorož	Seča	Strunjan	Dekani	T interval	Portorož
20 - 24.9 mm	9	8	12	7	20 - 24.9 °C	67
25 - 29.9 mm	3	5	2	6	25 - 29.9 °C	50
30 - 34.9 mm	5	2	2	0	30 - 34.9 °C	52
35 - 39.9 mm	0	1	0	0	>35 °C	0
40 - 44.9 mm	1	1	1	0	Total days T >= 20 °C	169
45 - 49.9 mm	0	0	1	1		
> 50 mm	1	1	0	1		
total days P >= 20 mm	**19**	**18**	**18**	**15**		

Except for winter time, soil water content under rain-fed conditions remained between 20 and 10 %, which is below −1.5 MPa point (Figure 1) during the most of the observed period. In spite precipitation during vegetation season (Table 2), soil water content remained below permanent wilting point (Figure 1), with short lasting improved soil water conditions immediately after rain events. In the evaluated period, soil water content exceeded water holding capacity of the soil on all measuring points four times. Soil water content over field capacity was measured in June and October 2015, January and February 2016, October and November 2016 (Figure 1).
Generally, soil water measurements on 30 cm show that under rain-fed conditions olive trees experienced water stress, as predicted for Mediterranean area (Tanasijevic et al., 2014). Most notable is the initial low soil water content in late spring in both 2015 and 2016 in the shallow depth, indicating that olive growers should closely monitor olive tree water status to see if early spring irrigation to ensure the following year's optimum olive growth.

Conclusion

In the studied period, 2014 was a wet year, followed by a dry year 2015 with high temperatures (over 35 °C) and negative water balance. Positive water balance on shallow depth provides only for short term water supply. Therefore, in intensive orchards with more emphasis on water supply from shallower roots, irrigation is needed, as water shortage may occur in spite of positive water balance.

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VODNÁ BILANCIA POBREŽNEJ OBLASTI V SLOVINSKU

Vodná bilancia je užitočným nástrojom na odhad stavu pôdnej vody v rastlinnej výrobe. Pri technikách zavlažovania, ktoré sú zamerané na šetrenie vody, je potrebné dodatočné meranie deficitu vody, aby sa zabezpečila úspora vody a dobrý stav rastlín. V príspevku sa vyhodnocuje zásobovanie vodou pre olivový sad na základe výpočtu vodnej bilancie a stavu pôdnej vody v Slovinskej Istrii, severnom Stredozemí v rokoch 2014 – 2016. V sledovanom období bol rok 2014 vlhký, potom nasledoval suchý rok 2015 s vysokými teplotami (nad 35 °C) so zápornou vodnou bilanciou. Kladná vodná bilancia, ktorá je v malej hĺbke, poskytuje iba krátkodobé zásobovanie vodou. V intenzívnych sadoch, kde je väčší dôraz na prívod vody k plytším koreňom je veľmi dôležitá závlaha, pretože pri kladnej vodnej bilancii môže dôjsť k nedostatku vody.

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