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COMPARISON OF APPLE TREE WATER REQUIREMENTS IN THE BYDGOSZCZ (POLAND) AND ISPARTA (TURKEY) REGIONS

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Abstract

The aim of the present research was an attempt to compare apple tree water requirements in the vegetation period in the Bydgoszcz region (Poland) and in the Isparta region (Turkey). The paper refers to the 1984-2014 temperature and precipitation values in the Bydgoszcz and Isparta regions. To determine the reference evapotranspiration (ET_0), the calculation model by Hargreaves modified by Droogers and Allen was applied. Potential evapotranspiration, identified with apple tree water requirements, was determined using the method of plant coefficients proposed by Doorenbos and Pruitt. In each of the seven months considered (April-October) higher apple tree water requirements occurred in the Isparta region. The highest apple tree water requirements were noted in July and for that month during the thirty-year period they were 167.3 mm and 286 mm, on average, in the Bydgoszcz and Isparta regions, respectively. Daily water requirements of apple trees in July were more than 9.2 mm in the Isparta region and 5.4 mm in the Bydgoszcz region. Apple tree water requirements throughout the vegetation period (April-October) were much higher (by 120 %) in the Isparta region than in the Bydgoszcz region. The highest precipitation deficits occurred in July and amounted to 95.5 mm and 269.1 mm for the Bydgoszcz and Isparta regions, respectively. The differences in the irrigation requirements for apple tree, next to water requirements differences, were affected by a different precipitation distribution in time in the regions com-

pared. In the Isparta region higher precipitation occurred at the beginning (April, May) and at the end (October) of the vegetation period, while in the Bydgoszcz region – just opposite – in summer months (June, July, August).

Keywords: apple tree, water requirements, Bydgoszcz region, Isparta region

INTRODUCTION

Of all the species grown in Poland, apple tree is considered the most important species in terms of the economy (Treder and Pacholak 2006, Makosz 2013). It is estimated that for optimal growth and yielding, the apple tree requires about 650-750 mm of precipitation annually. However, for apple tree it is not only the total precipitation but also precipitation distribution in time, especially during the vegetation period, which is extremely important. In Poland's important orchard-growing regions, in the central, western and south-western part of Poland, precipitation deficits for apple tree range from 120 to 180 mm annually. Rzekanowski (2009) reports on the highest water deficits for apple tree occurring in the central belt of Poland (the Great Valleys Region) and accounting for, on average, 140 to 170 mm in the vegetation period. It is mostly due to the fact that in central Poland the mean annual precipitation most often falls within the range from 500 to 550 mm, and the precipitation of the vegetation period (April-September) – around 320 mm. High supplementary irrigation requirements in the Bydgoszcz region are also confirmed by other publications (Rzekanowski and Rolbiecki 2000; Rzekanowski *et al*. 2001, 2011).

Turkey – after China and USA – is the third largest apple producing country – 2.6 million Mg (FAO, 2012). Isparta region – which provides almost 20% of total apple production of Turkey – has important role in apple production for Turkey (TSI, 2009).

The aim of the present research was an attempt to compare apple tree water requirements in the vegetation period in the Bydgoszcz region (Poland) and in the Isparta region (Turkey).

MATERIAL AND METHODS

The paper uses the 1984-2014 temperature and precipitation values for the Bydgoszcz and Isparta regions. To determine reference evapotranspiration (ET_0), the calculation model by Hargreaves modified by Droogers and Allen (Treder *et al*. 2010) was applied:

$$ET_o = HC\ Ra(Tmax - Tmin)^{HE}(\frac{Tmax + Tmin}{2} + HT)$$

HC – empirical coefficients provided by the authors = 0.0025,
Ra – radiation over the atmosphere (mm day^{-1}),
Tmax − maximum temperature (°C),
Tmin − minimum temperature (°C),
HE − empirical coefficient provided by the authors = 0.5,
HT − empirical coefficient provided by the authors = 16.8.

Potential evapotranspiration, identified using apple tree water requirements, was determined by means of the plant coefficients method (Łabędzki 1996). Coefficient "***k***" values for apple tree orchards at full development were used, as proposed by Doorenbos and Pruitt (1977).

RESULTS AND DISCUSSION

Apple tree water requirements showed a lower variation in the Isparta region than in the Bydgoszcz region (Table 1). The coefficient of apple tree water requirements variation in the Isparta region, in respective months of the vegetation period, ranged from 5 % (September) to 9 % (April). In the Bydgoszcz region, however, it varied from 9 % (August) to 12 % (July). Throughout the vegetation period, in the thirty-year period under study, the coefficient of variation in apple tree water requirements accounted for 7 % and 4 % for Bydgoszcz and Isparta, respectively.

In each of the seven months, higher apple tree water requirements occurred in the Isparta region (Table 1, Figure 1).

Table 1. Statistical characteristics of the apple tree water requirements during the vegetation season (mm)

Month	Minimum		Maximum		Median		Mean		SD		VC (%)	
	B	I	B	I	B	I	B	I	B	I	B	I
April	11.5	47.5	19.0	68.3	14.8	58.3	15.0	58.9	1.65	5.53	11	9
May	39.5	139.8	61.8	176.4	53.3	158.5	52.9	156.9	5.49	10.87	10	7
June	85.4	199.8	134.4	241.0	104.4	222.2	105.3	222.4	10.94	12.71	10	6
July	136.3	246.7	212.1	348.0	164.9	281.1	167.3	286.0	19.95	18.92	12	7
August	111.2	221.0	162.6	302.4	138.3	255.5	137.7	255.6	13.00	15.91	9	6
September	48.7	138.2	78.8	170.8	61.5	154.5	61.8	153.6	8.87	7.59	14	5
October	10.2	75.4	16.3	100.4	12.9	90.2	13.2	89.1	1.48	7.15	11	8
April – October	475.5	1052.4	617.1	1305.7	557.8	1217.3	553.1	1215.5	37.74	43.27	7	4

Explanations: B – Bydgoszcz region, I – Isparta region, SD – standard deviation, VC – variation coefficient

The highest apple tree water requirements were reported in July – for the thirty-year period they amounted to an average of 167.3 mm and 286 mm (Figure 1) for the Bydgoszcz and Isparta regions, respectively. Slightly lower apple tree water requirements occurred in the successive summer months: August and June, respectively for the regions and months, amounting to 137.7 mm and 255.6 mm as well as 105.3 mm and 222.4 mm.

For comparison, Treder (2012) provides estimated apple tree water requirements for the Toruń region (Toruń is southeast of Bydgoszcz, and the straight line distance is 41 km), which amount to 459 mm in the April-September period, while in June, July and August they are 103 mm, 108 mm and 93 mm, respectively.

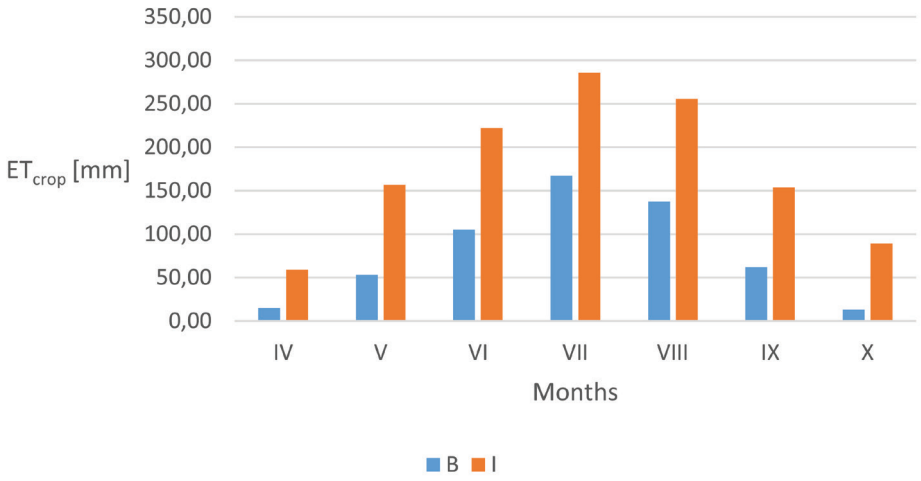

Figure 1. Comparison of water requirements for apple trees in consecutive months of the growing season. Explanations: B – Bydgoszcz region; I – Isparta region

Daily water requirements of apple trees were highest also in July, reaching more than 9.2 mm in the Isparta region and 5.4 mm in the Bydgoszcz region (Figure 2). Slightly lower values of daily water requirements of apple tree were found in August, 8.2 mm and 4.4 mm in the Isparta region and in the Bydgoszcz region, respectively, and even lower – in June (7.4 mm and 3.5 mm, respectively). Apple trees required least water in April (1.9 mm and 0.5 mm, respectively) and in October (2.9 mm and 0.4 mm), and slightly more – in May (5.1 mm and 1.7 mm) and September (4.9 mm and 2.1 mm).

For comparison, in the apple tree irrigation experiment carried out in the Isparta region, daily evapotranspiration in 'Jersey Mac' and 'Wiliams Pride' apple tree in August 2006 was on average 10.0 mm and 10.4 mm, respectively for the cultivars, while on average in July 2007 – it was even higher, falling

within the range of 11.0-11.4 mm and 10.9-13.0 mm, respectively (Senyigit and Kadayifci 2007).

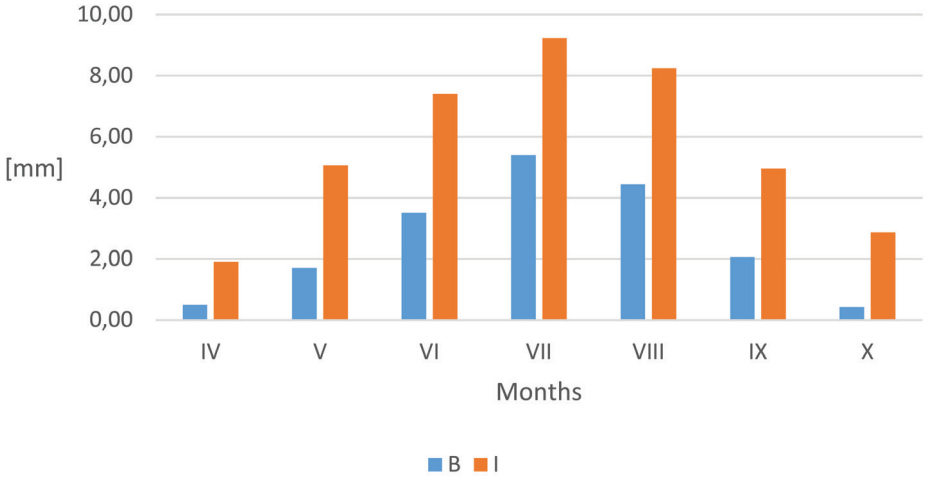

Figure 2. Comparison of daily water requirements for apple trees in consecutive months of the growing season. Explanations: see Figure1

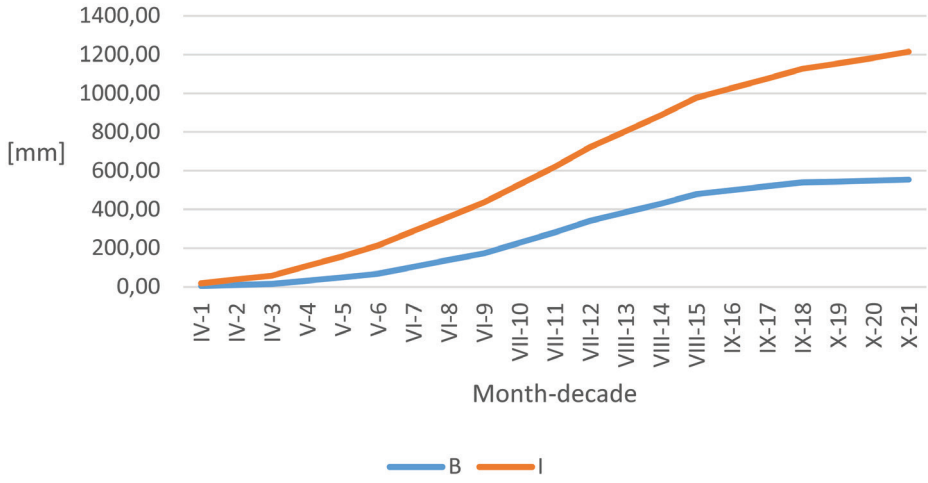

Figure 3. Cumulative apple tree water requirements in consecutive decades of the growing season. Explanations: see Figure 1

Apple tree water requirements throughout the vegetation period (April-October) were much higher in the Isparta region than in the Bydgoszcz region and amounted to, on average in the thirty-year period, 553 mm and 1215 mm, respectively (Table 1, Figure 3). It means that the seasonal apple tree water requirements in the Isparta region were as much as 120% higher than the water requirements of apple tree grown in the Bydgoszcz region.

A comparison of the apple tree water balance developed for respective months of the vegetation period shows that a positive water balance occurred in April and October, exclusively in the Bydgoszcz region (Figure 4). In the Isparta region the apple tree water requirements in each month exceeded the total natural precipitation, thus the balance was negative in each of the seven months. The highest precipitation deficits occurred in July and amounted to – 95.5 mm and – 269.1 mm for the Bydgoszcz and Isparta regions, respectively. Slightly lower precipitation deficits were recorded in August (-73.2 mm and – 242.7 mm) and June (-47.1 mm and – 196.2 mm).

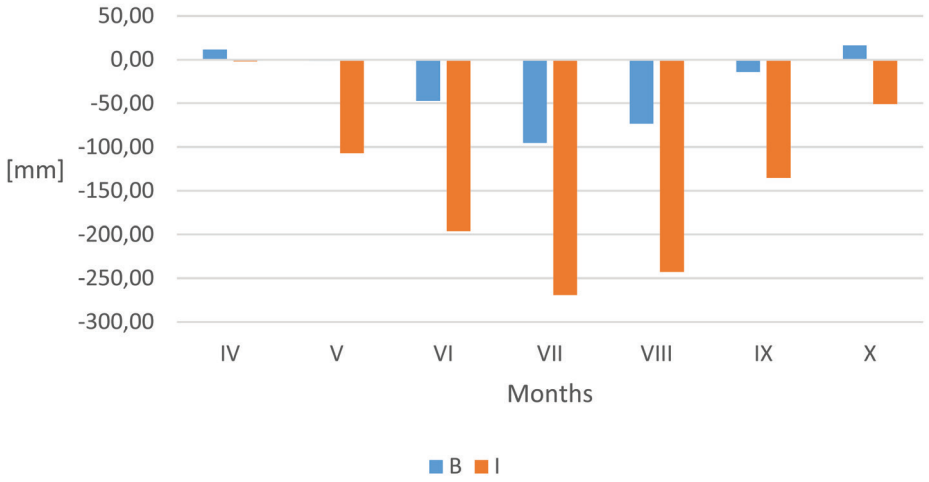

Figure 4. Comparison of water balance for apple trees in consecutive months of the growing season. Explanations: see Figure 1

Those natural precipitation deficits can be considered as apple tree orchard irrigation requirements in the regions compared. The precipitation deficits must be covered in respective months with water provided with supplementary irrigation. The curves plotted for the sum of the indicators under study point to seasonal irrigation requirements (Figure 5). In the Bydgoszcz region they amount to 231 mm for the period between 1 May and 30 September. However, in the

Isparta region, the seasonal irrigation requirements for apple tree (from 1 April through 31 October) was as much as 1003 mm.

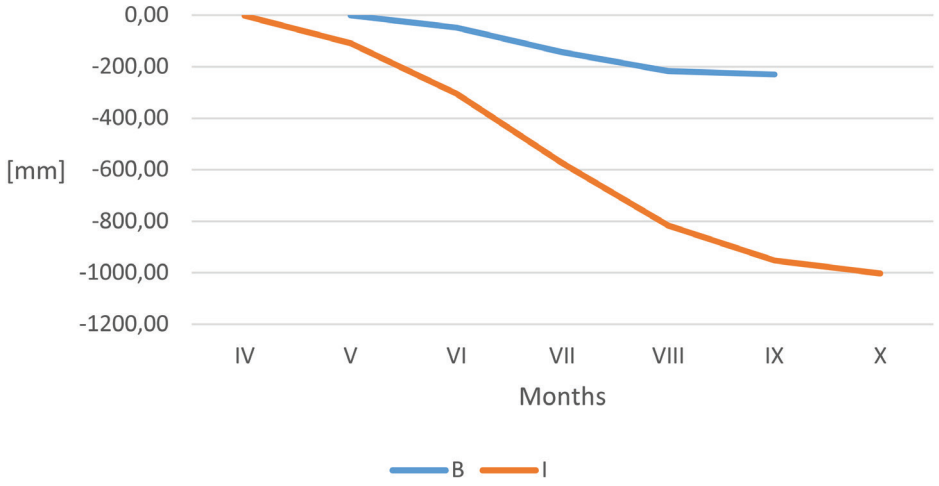

Figure 5. Cumulative apple tree irrigation requirements in consecutive months of the growing season. Explanations: see Figure 1

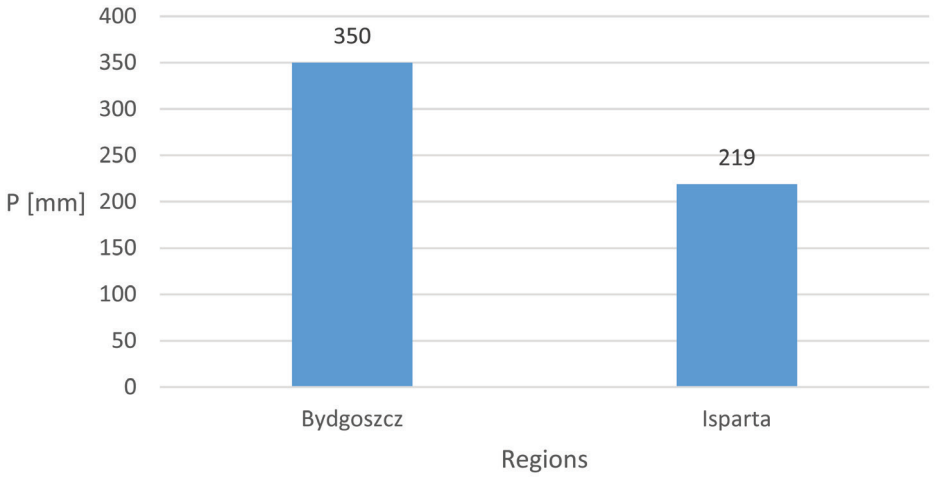

Figure 6. Seasonal (IV-X) rainfall amounts in the compared regions

The findings regarding high apple tree irrigation requirements in the Isparta region were confirmed by the results of the experiment with 'Wiliams Pride'

and 'Jersey Mac' apple tree irrigation performed in the Isparta region in 2006 and 2007, in which the total amount of water used for irrigation in the vegetation period, depending on the experiment year and the variant, ranged from 349.5 mm to 724 mm and from 391.2 mm to 1186 mm (Senyigit and Kadayifci 2007).

Such high irrigation requirements in the Isparta region are primarily due to the amount of precipitation which from 1 April to 31 October was only 219 mm, on average for 1984-2014 (Figure 6). In the Bydgoszcz region it was much higher – 350 mm.

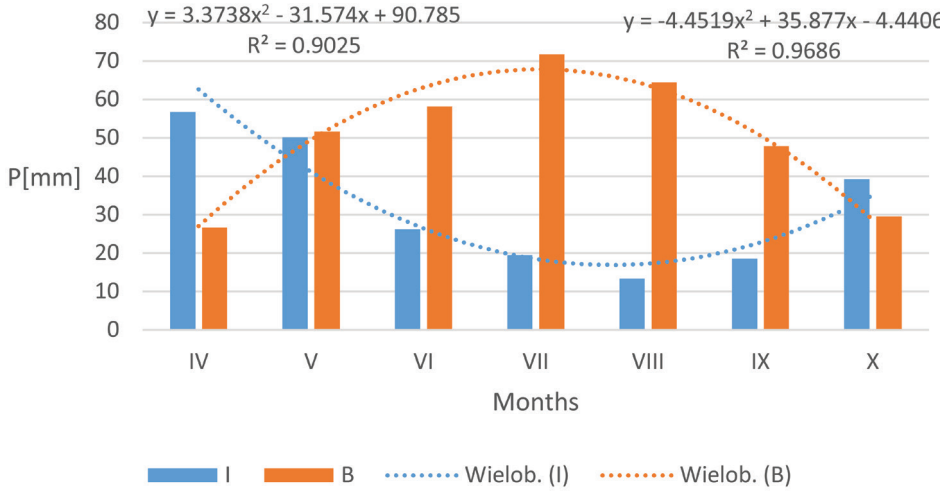

Figure 7. Rainfall amounts in consecutive months of the growing season. Explanations: see Figure 1

The differences in the amount of apple tree irrigation requirements were also affected by a different precipitation distribution in time in the regions compared (Figure 7). In the Isparta region higher precipitation occurred at the beginning (April, May) and at the end (October) of the vegetation period, while in the Bydgoszcz region – just opposite, in summer (June, July, August).

The variation in the amount and distribution of natural precipitation in the regions compared, together with high water requirements of apple tree in summer months (June, July, August) showed a definite effect on such high precipitation deficits and, as a result, high irrigation requirements in the Isparta region.

Kadayifci *et al*. (2015) reported that the annual average rainfall of Isparta is 520 mm and only 162 mm (31%) of this amount falls during the months of May and October. Accordingly, this region has a semi-arid climate and irrigation is vital for an effective plant cultivation in the region.

In the present research ETo and coefficient *k* were calculated using the Hargreaves model and the Penman-Monteith formula, respectively. According to our analysis, the Hargreaves model modified by Droogers and Allen generates higher ETo values for the period from May to July than the Penman-Monteith formula (Treder *et al*. 2010), which can result in estimating 10-20% higher water requirements. However, one should note that, in the research cited, in August ETo calculated with both formulas was almost identical and in September – higher values were provided with the Penman-Monteith formula. Thus, as a result, the differences between models for the entire vegetation period are not too high.

RECAPITULATION AND CONCLUSIONS

In each of the seven months of the vegetation period (April-October) higher water requirements in apple tree were reported in the Isparta region. The highest apple tree water requirements occurred in July and for that month during the thirty-year period they were 167.3 mm and 286 mm, on average, in the Bydgoszcz and Isparta regions, respectively

Daily water requirements of apple tree in July were more than 9.2 mm in the Isparta region and 5.4 mm in the Bydgoszcz region.

Water requirements of apple tree throughout the vegetation period (April-October) were much higher (by 120 %) in the Isparta region than in the Bydgoszcz region. The highest precipitation deficits occurred in July and were 95.5 mm and 269.1 mm for the Bydgoszcz and Isparta regions, respectively.

Such high precipitation deficits in the Isparta region, and related supplementary irrigation requirements, are connected to the amount of precipitation, which from 1 April to 31 October was 219 mm, on average for the years 1984-2014, while in the Bydgoszcz region it was much higher – 350 mm.

The differences in apple tree irrigation requirements, next to huge (120%) differences in water requirements, were also affected by a different precipitation distribution in time in the regions. In the Isparta region higher precipitation occurred at the beginning (April, May) and the end (October) of the vegetation period, while in the Bydgoszcz region – just opposite, in summer months (June, July, August).

REFERENCES

Doorenbos J., Pruitt W.O. (1977). *Guidelines for predicting crop water requirements*. Irrigation and Drainage Paper, 31, FAO, Rome. p. 144.

FAO (2012). *Faostat Database Search Results*, http://www.fao.org (accessed December, 2012).

Kadayifci A., Senyigit U., Kepenek K. (2015). *Water consumption of oil rose (Rosa damascene Mill.) in Isparta conditions*. Infrastruktura i Ekologia Terenów Wiejskich, III/2/2015: 745-757.

Łabędzki L. (1996). *Ewapotranspiracja upraw rolniczych – terminologia, definicje, metody obliczania*. Materiały Informacyjne IMUZ, 33: 1-15.

Makosz E. (2013). *Polskie jabłka*. Międzynarodowa Konferencja Sadownicza „Przyszłość Polskiego Jabłka" Lublin 4 XII: 111-116.

Rzekanowski Cz. (2009). *Kształtowanie się potrzeb nawodnieniowych roślin sadowniczych w Polsce*. Infrastruktura i Ekologia Terenów Wiejskich, 3: 19-27.

Rzekanowski Cz., Rolbiecki St. (2000). *The influence of drip irrigation on yields of some cultivars of apple trees in central Poland under different rainfall conditions during the vegetation season*. Acta Horticulturae 537, Vol. 2: 929-936.

Rzekanowski Cz., Rolbiecki St., Żarski J. (2001). *Potrzeby wodne i efekty produkcyjne stosowania mikronawodnień w uprawie roślin sadowniczych w rejonie Bydgoszczy*. Zeszyty Problemowe Postępów Nauk Rolniczych, 478: 313-325.

Rzekanowski C., Żarski J., Rolbiecki St. (2011). *Potrzeby, efekty i perspektywy nawadniania roślin na obszarach szczególnie deficytowych w wodę*. Postępy Nauk Rolniczych, 1: 51-63.

Senyigit U., Kadayifci A. (2007). *Evapotranpiration of "Williams Pride"and "Jersey Mac" apple cultivars*
budded on M9 for different irrigation methods. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi, 2(2): 43-52.

Treder W. (2012). *Potrzeby wodne roślin sadowniczych*. Informator Sadowniczy, 3: 1-4.

Treder W., Wójcik K., Żarski J. (2010). *Wstępna ocena możliwości szacowania potrzeb wodnych roślin na podstawie prostych pomiarów meteorologicznych*. Zesz. Nauk. Int. Sad. i Kwiac., 18: 143-153.

Treder W., Pacholak E. (2006). *Nawadnianie roślin sadowniczych*. In: Nawadnianie roślin (ed. S. Karczmarczyk i L. Nowak), 333-365.

TSI (2009). *Turkish Statistical Institute. Population Statistics*. http://www.tuik.gov.tr (accessed January 2, 2011).

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