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Water Needs of Asparagus Plants in the Different Regions of Poland

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1. Introduction

The researchers involved in the study of water requirements of the plants in Poland believe that asparagus (*Asparagus officinalis* L.), due to their deep and well-developed root system, are relatively resistant to the water deficits in the soil (Kaniszewski 2005, Kaniszewski 2006). On the other hand, asparagus plants grown on the light soil positively respond to irrigation treatments (Rolbiecki 2013). In the experiment published by Rolbiecki (2013), the micro-irrigation applied during the post-harvest period (June-August) significantly increased the marketable yield of asparagus spears collected in the next growing season (April-June). The studies on the water needs of asparagus in Poland are very rare. The exceptions are the results published by Rolbiecki (2013) that presented observations of many-years field experiments, in which irrigated asparagus plants were investigated. In these studies, using the Grabarczyk's formula (1976) that determines the reference evapotranspiration, the plant coefficients (kc) were evaluated for this vegetable species. Finally, as the result of the research the crop evapotranspiration i.e. the water needs of asparagus plants was determined. Generally, the crop evapotranspiration is used as the measure of plant water requirements of particular species (Doorenbos & Pruitt 1977, Doorenbos & Kassam 1979, Allen et al. 1998).

The purpose of this investigation was to determine the water requirements of asparagus plants cultivated in the five different regions of Poland.

2. Material and methods

The calculations of asparagus (*Asparagus officinalis* L.) water requirements, based on the precipitation measurements, were performed for the thirty-year period from 1981 to 2010. To estimate the needs of asparagus plants, considered as the crop evapotranspiration (Etp), the plant coefficients (kc) were applied (1):

$$Etp = kc \times Eto \quad (1)$$

The plant coefficients were determined for the Polish field conditions by Rolbiecki (2013) that based on the long-term field experiments, which included observations of the irrigated asparagus plants. The reference evapotranspiration (Eto) was calculated in accordance with the Grabarczyk et al. (1994) method (2):

$$Eto = K + P\,(1 - k) \quad (2)$$

where:
K – constant value characteristic for individual months and different regions of Poland
k – coefficient indicating the reduction value of water deficiencies as a result of precipitation equal to 1 mm, designated for individual months and different regions of Poland
P – monthly sum of atmospheric precipitation (mm).

The Grabarczyk's formula was chosen because it allowed estimating the reference evapotranspiration in a simplified way, i.e. based only on the rainfall measurements.

The precipitation deficiencies (N) were considered according to the Ostromęcki's method (Żakowicz et al. 2009). The rainfall deficit in the period, including months July and August that are critical in terms of the amount of water available to the plants, was calculated as the difference between the water needs of asparagus, expressed as the crop evapotranspiration for a considered month, and the total precipitation in this month (3):

$$N = Etp - P \quad (3)$$

The water needs of asparagus were determined for five agro-climatic regions of Poland (Łabędzki et al. 2013) with the representative meteorological stations located in Olsztyn, Bydgoszcz, Warszawa, Wroclaw and Krakow (Fig. 1).

Fig. 1. Agro-climatic regions of Poland with the representative meteorological stations (according to Łabędzki et al. 2013)

The results were statistically calculated by determining the values, such as maximum, minimum and median, as well as standard deviation and variation coefficient. The calculations were performed using Excel software.

3. Results

The highest variability of asparagus water needs was calculated in in July in the C-E region (Table 1). The variation coefficient was 8.4%. High value of the variability of asparagus water needs was calculated also in the C-N-W region of the Poland. The variation coefficient in July and August was 7.7% and 7.6%, respectively. Whereas the lowest variability of asparagus water requirements were observed in the S-W and S-E region of Poland.

Figure 2 presents the water needs of asparagus (expressed as the crop evapotranspiration) in the period from July 1 to August 31 in the different regions of Poland. The highest water requirements of asparagus plants were noted in C-N-W and C-E region (100 and 129 mm in July, and 100 and 128 mm in August, respectively). Finally, during both considered months, in total, the level of water needs of this vegetable species was by 228 mm. The lowest water requirements of asparagus were calculated in the N-E region of Poland (206 mm).

Table 1. Crop evapotranspiration of asparagus plants in the different regions of Poland

Specification	Region of Poland					Poland
	N-E	C-N-W	C-E	S-W	S-E	
July						
Minimum (mm)	70	79	66	77	71	75
Maximum (mm)	100	110	109	106	105	105
Median (mm)	89	100	101	98	97	96
SD (mm)	6.478	7.670	8.430	5.968	6.667	6.097
VC (%)	7.3	7.7	8.4	6.2	6.9	6.3
August						
Minimum (mm)	97	92	96	100	107	106
Maximum (mm)	130	141	141	135	134	134
Median (mm)	119	130	129	128	126	126
SD (mm)	8.350	9.725	8.899	7.732	6.362	6.311
VC (%)	7.1	7.6	7.0	6.1	5.1	5.1

SD – standard deviation; VC – variation coefficient

During the considered period from July 1 to August 31, the highest precipitation deficiencies were observed in the C-N-W and C-E region Poland, where the values of $N_{50\%}$, $N_{25\%}$ and $N_{10\%}$ were 91, 157 and 209 mm, respectively in the C-N-W region, and 89, 166 and 245 mm, respectively, in the C-E region (Table 2). In the S-E region, were noted the lowest rainfall deficiencies of 55, 125 and 160 mm, in average dry years, medium dry years and very dry years, respectively.

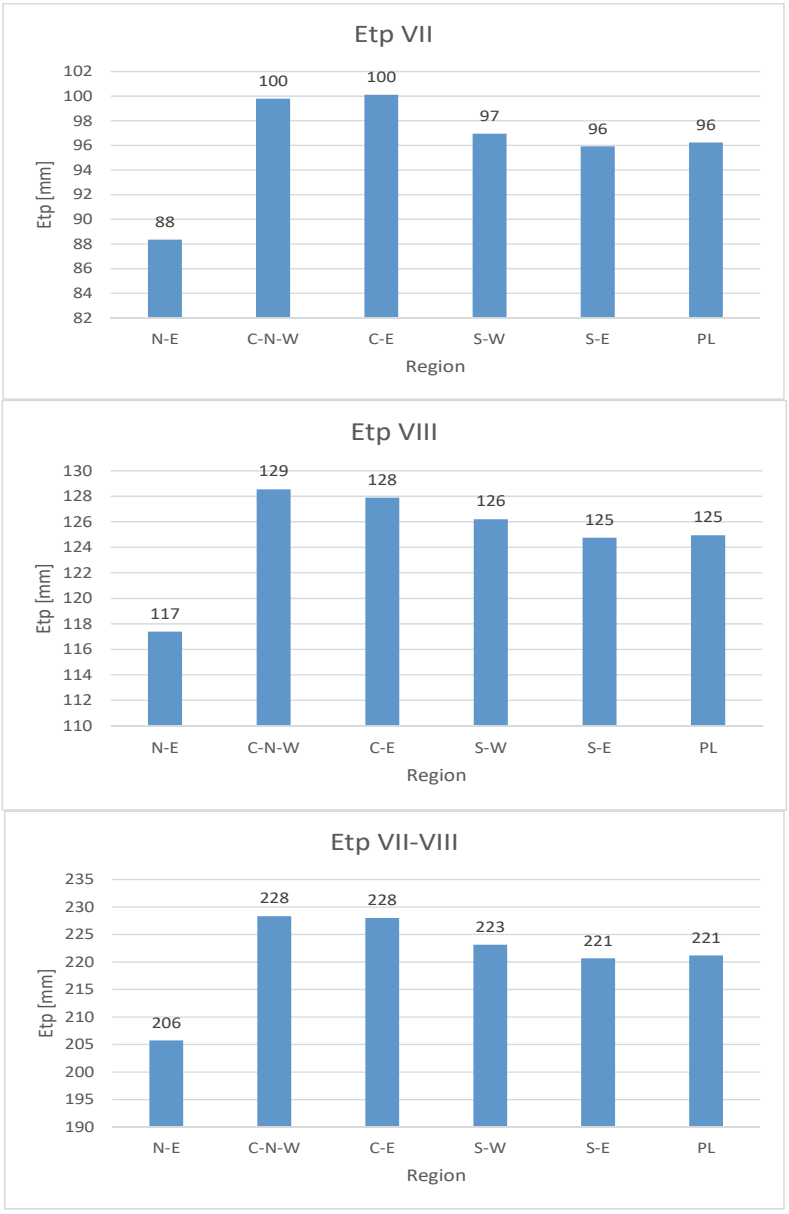

Fig. 2. Water needs (Etp) of asparagus, expressed as crop evapotranspiration, in the period from July 1 to August 31 in the different regions of Poland

Table 2. Rainfall deficit (mm) in the asparagus cultivation at the critical period (July-August) in the different regions of Poland

Year in terms of the amount of rainfall	Probability (p) of occurrence % of years	Region of Poland				
		N-E	C-N-W	C-E	S-W	S-E
July						
Average dry	50	14	22	23	17	8
Medium dry	25	56	76	72	53	57
Very dry	10	76	107	103	95	82
August						
Average dry	50	52	69	66	58	47
Medium dry	25	86	81	94	75	68
Very dry	10	131	102	142	92	78
July-August						
Average dry	50	67	91	89	75	55
Medium dry	25	142	157	166	128	125
Very dry	10	207	209	245	187	160

4. Discussion

In the present study, the reference evapotranspiration was calculated according to the formula reported by Grabarczyk et al. (1994) that based on the results of precipitation measurements. Usually, rainfall occurring during the summer is connected to the changes in other weather factors that affect the growth and development of plants. During precipitation, there is an increase in cloud cover and reduction in insolation, as well as a drop in air humidity deficits and, generally, fall of the temperature. The weather factors, mentioned above, determine the amount of reference evapotranspiration and thus establish the water needs and deficits in the period of intensive biomass growth (Doorenbos & Pruitt 1977, Doorenbos & Kassam 1979, Grabarczyk et al. 1994, Allen et al. 1998).

The largest water requirements of asparagus plants were estimated in the C-N-W and C-E region of Poland. Previously, similar observations were published by Rolbiecki et al. (2000 a, b), Rolbiecki & Rolbiecki (2008), Stachowski & Markiewicz (2011) and Żarski et al. (2013), which the greatest necessity to use

irrigation treatments complementing rainfall shortages noted in the central Poland, i.e. in areas with high water deficits.

In the study reported by Paschold et al. (2004), the water consumption of asparagus plants evaluated in the lysimeter conditions ranged from 266 to 292 mm. In turn, according to Pardo et al. (1997) the seasonal water consumption of asparagus plants under lysimeter conditions was between 274 and 294 mm. In the present research, the total water needs of asparagus in the C-N-W and C-E region of Poland during the period from July 1 to August 31 was nearly 230 mm, while the precipitation deficits were 91 and 89 mm, 157 and 166 mm, and 209 and 245 mm, respectively, in average dry years, medium dry years and very dry years, respectively. The value of rainfall deficit in very dry years ($N_{10\%}$) that securing the plant water needs at p = 90%, is especially useful during planning and designing of the irrigation system (Żakowicz et al. 2009). According to Kaufmann (1977), the total water deficits (i.e. irrigation needs) in the cultivation of asparagus in the central Europe climatic conditions ranged from 20 to 160 mm, depending on the location of the crop. In turn, Paschold et al. (2001), based on the many-years experiment conducted at the Horticultural Institute in Geisenheim (Germany), noted that the irrigation needs of asparagus cultivated on sandy soil depend on the level and distribution of precipitation in the range from 48 to 153 mm.

In the study published by Rolbiecki et al. (2017), the comparison of water needs of the asparagus plants grown in the regions of Bydgoszcz and Wroclaw during the period from 1996 to 2015, demonstrate a tendency to raise the asparagus water needs observed in July in both considered regions. In July, the monthly amount of the asparagus crop evapotranspiration increased in every ten years by 12.3 mm in the region of Bydgoszcz and by 21.2 mm in the region of Wroclaw. The results presented by Rolbiecki et al. (2017) confirm the opinion published by Łabędzki (2009), who believes that the expected in the near future climate changes will increase the water needs most of the plants species. In order to get ready for the forecasted climate changes, it would be necessary to undertake the adaptation activities, such as the development of an irrigation program, the importance of which will grow with the increasing of the weather changes (Łabędzki 2009, Kuchar & Iwanski 2011, 2013, Żarski et al. 2013, Kuchar et al. 2015, 2017).

According to Rolbiecki et al. (2017), in the period from June 1 to August 31 observed during the twenty-year study, the average precipitation deficit in the asparagus cultivation was 128 mm in the region of Wroclaw and 87 mm in the region of Bydgoszcz. However, in August, the highest monthly rainfall deficiencies – 100 and 70 mm – in the Wroclaw and Bydgoszcz regions, respectively, were noted. In the present study, the highest precipitation deficits also in August were measured, although the values were much higher (126 and 129 mm in the Wroclaw and Bydgoszcz regions, respectively). On the one hand, these

differences can be explained by a different period of research (1996-2015 in the study reported by Rolbiecki et al. (2017) and 1981-2010 in the present study). On the other hand, different methods of the reference evapotranspiration estimation were applied in both experiments; in the study published by Rolbiecki et al. (2017) the calculations based on the temperature and deficits of air humidity (Grabarczyk 1976), however in the present study the determination of reference evapotranspiration based only on the precipitations measurements (Grabarczyk et al. 1994).

5. Conclusions

1. The highest variability of asparagus water needs was calculated in July in the C-E region of Poland (variation coefficient 8.4%). High variability of the asparagus water requirements (7.7 and 7.6% in July and August, respectively) was also estimated in the central-north-west region of the country. While the lowest variability of asparagus water needs were find in the south-west and south-east region of Poland.
2. The highest water requirements of asparagus plants in the period from July 1 to August 31, on average 228 mm, were noted in the central-north-west and central-east region of Poland.
3. The highest rainfall deficit calculated for medium dry years, average dry years and very dry years were 91 and 89 mm, 157 and 166 mm, and 209 and 245 mm, respectively, in the central-north-west and central-east region of Poland, respectively.
4. In August, generally, were noted higher precipitation deficiencies than in July.

Reference

Allen, R.G., Pereira, L.S., Raes, D., Smith, M. (1998). Crop evapotranspiration. Guidelines for computing crop water requirements. *FAO Irrigation and Drainage* Paper, 56, 300.

Doorenbos, J., & Kassam, A.H. (1979). Yield response to water. *FAO Irrigation and Drainage Paper, 33,* 176.

Doorenbos, J., & Pruitt, W.O. (1977). Guidelines for computing crop water requirements. *FAO Irrigation and Drainage Paper, 24,* 156.

Grabarczyk, S. (1976). Polowe zużycie wody a czynniki meteorologiczne. *Zeszyty Problemowe Postępów Nauk Rolniczych, 181,* 495-511.

Grabarczyk, S., Żarski, J., Dudek, S. (1994). Zależność klimatycznych wskaźników niedoborów wodnych od opadów atmosferycznych. *Roczniki AR Poznań, CCLVII,* 15-19.

Kaniszewski, S. (2005). *Nawadnianie warzyw gruntowych.* Kraków: Plantpress.

Kaniszewski, S. (2006). *Nawadnianie warzyw.* In: S. Karczmarczyk & L. Nowak (Editors) *Nawadnianie roślin.* Warszawa: PWRiL, 295-332.

Kaufmann, F. (1977). Intensivierung der Spargelproduktion durch Bewasserrung. *Gartenbau, 24(3),* 73-74.

Kuchar, L., & Iwański, S. (2011). Rainfall simulation for the prediction of crop irrigation in future climate. *Infrastructure and Ecology of Rural Areas, 5,* 7-18.

Kuchar, L., & Iwański, S. (2013). Rainfall evaluation for crop production until 2050-2060 and selected climate change scenarios for North Central Poland. *Infrastructure and Ecology of Rural Areas, 2(I),* 187-200.

Kuchar, L., Iwański, S., Diakowska, E., Gąsiorek, E. (2015). Simulation of hydrothermal conditions for crop production purpose until 2050-2060 and selected climate change scenarios for North Central Poland. *Infrastructure and Ecology of Rural Areas, II(1),* 319-334.

Kuchar, L., Iwański, S., Diakowska, E., Gąsiorek, E. (2017). Assessment of meteorological drought in 2015 for North Central part of Poland using hydrothermal coefficient (HTC) in the context of climate change. *Infrastructure and Ecology of Rural Areas, I(2),* 257-273.

Łabędzki, L. (2009). Foreseen climate changes and irrigation development in Poland. *Infrastructure and Ecology of Rural Areas, 3,* 7-18.

Łabędzki, L., Bąk, B., Liszewska, M. (2013). Wpływ przewidywanej zmiany klimatu na zapotrzebowanie ziemniaka późnego na wodę. *Infrastructure and Ecology of Rural Areas, 2(I),* 155-165.

Pardo, A., Arbizou, J., Suso, M.L. (1997). Evapotranspiration and crop coefficients in white asparagus. *Acta Horticulturae, 449(1),* 187-192.

Paschold, P.J., Eckes, U., Löbmeier, F.J., Hoppmann, D. (2001). *Untersuchungen zur Ermittlung des langjährigen Wasser und Beregnungsbedarfs bei ausgewählten Gemüsearten, unveröff.* Arbeitsbericht, Forschungsanstalt Geisenheim.

Paschold, P.J., Artelt, B., Hermann, G. (2004). The water need of asparagus (*Asparagus officinalis* L.) determined in a lysimeter station. *Acta Horticulturae, 664,* 529-536.

Rolbiecki, R. (2013). *Ocena potrzeb i efektów mikronawodnień szparaga (Asparagus officinalis L.) na obszarze szczególnie deficytowym w wodę.* Bydgoszcz: Wydawnictwo UTP, Scientific dissertations, 162, 1-103.

Rolbiecki, S., Żarski, J., Grabarczyk, S. (2000 a). Yield-irrigation relationships for field vegetable crops grown in Central Poland. *Acta Horticulturae, 537(2),* 867-870.

Rolbiecki, S., Rolbiecki, R., Rzekanowski, Cz., Żarski, J. (2000 b). The influence of sprinkler irrigation on yields of some vegetable crops in the region of Bydgoszcz, Poland. *Acta Horticulturae, 537(2),* 871-877.

Rolbiecki, R., & Rolbiecki, S. (2008). Effect of surface drip irrigation on asparagus cultivars in central Poland. *Acta Horticulturae, 776,* 45-50.

Rolbiecki, S., Rolbiecki, R., Jagosz, B., Biniak-Pieróg, M., Żyromski, A. (2017). Comparison of water needs and precipitation deficiency during the growing season of asparagus in the region of Bydgoszcz and Wrocław. *Infrastructure and Ecology of Rural Areas, IV/3,* 1843-1854.

Stachowski, P., & Markiewicz, J. (2011). The need of irrigation in central Poland on the example of Kutno county. *Rocznik Ochrona Środowiska, 13,* 1453-1472.

Żakowicz, S., Hewelke, P., Gnatowski, T. (2009). *Podstawy infrastruktury technicznej w przestrzeni produkcyjnej.* Warszawa: Wydawnictwo SGGW, 192.
Żarski, J., Dudek, S., Kuśmierek-Tomaszewska, R., Rolbiecki, R., Rolbiecki, S. (2013). Forecasting effects of plants irrigation based on selected meteorological and agricultural drought indices. *Rocznik Ochrona Środowiska, 15,* 2185-2203.

Abstract

Asparagus (*Asparagus officinalis* L.), due to their deep and well-developed root system, are relatively resistant to the water deficits in the soil. On the other hand, asparagus plants grown on the light soil positively respond to the irrigation treatments. The aim of the present study was the determination of water needs of asparagus plants in the different agro-climatic regions of Poland. The calculations of asparagus water requirements, considered as the crop evapotranspiration, based on the precipitation measurements collected during the thirty-year period from 1981 to 2010. The estimations were achieved for the months, including July and August, critical in terms of the amount of water available to the plants. The calculation of asparagus water needs using the plant coefficients was performed. The plant coefficients for asparagus cultivated in the Polish field conditions were determined by Rolbiecki. Published by him calculations based on the long-term observations of the irrigated asparagus crop. The reference evapotranspiration was calculated according to Grabarczyk's method. The Grabarczyk's formula was chosen because it allowed estimating the reference evapotranspiration in a simplified way, i.e. based only on the precipitation measurements. The rainfall deficit was considered using the Ostromęcki's method. The precipitation deficit in the period from July 1 to August 31 was calculated as the difference between the water needs of asparagus, expressed as the crop evapotranspiration for a considered month and the total precipitation in this month. The water needs of asparagus plants were determined for five agro-climatic regions of Poland with the representative meteorological stations located in Olsztyn, Bydgoszcz, Warszawa, Wroclaw and Krakow. The highest variability of asparagus water requirements was calculated in the central-north-west (C-N-W) region of the Poland. The variation coefficient in July and August was 7.7% and 7.6%, respectively. In contrast, the lowest variability of asparagus water needs were find in the south-west (S-W) and south-east (S-E) region of Poland. The highest water needs of asparagus plants, on average 228 mm, in the period from July to August were noted in the C-N-W and central-east (C-E) region of Poland. The highest rainfall deficit, calculated for medium dry years, average dry years and very dry years, was 91 mm and 89 mm, 157 mm and 166 mm, and 209 mm and 245 mm, respectively, in the C-N-W and C-E region, respectively. Generally, higher precipitation deficiencies were noted in August than in July.

Keywords:
Asparagus officinalis L., crop evapotranspiration, rainfall deficiencies, reference evapotranspiration, water requirements

Potrzeby wodne szparaga w różnych regionach Polski

Streszczenie

Szparagi (*Asparagus officinalis* L.), ze względu na swój głęboki oraz dobrze rozwinięty system korzeniowy, są roślinami uważanymi za stosunkowo odporne na niedobory wody w glebie. Z drugiej strony, rośliny szparagów uprawiane na glebie lekkiej bardzo pozytywnie reagują na przeprowadzone zabiegi nawadniające. Podstawowym celem niniejszej pracy było określenie potrzeb wodnych roślin szparagów w różnych regionach agro-klimatycznych Polski. Obliczenie zapotrzebowania roślin tego gatunku warzywnego na wodę, wyrażonego jako ewapotranspiracja potencjalna, wykonano na podstawie pomiarów opadów atmosferycznych przeprowadzonych w okresie trzydziestu lat licząc od 1981 do 2010 roku. Obliczenia wykonano dla dwóch miesięcy, dla lipca oraz dla sierpnia. Miesiące te stanowią okres krytyczny pod względem ilości wody dostępnej dla roślin. Potrzeby wodne roślin szparaga oszacowano przy użyciu współczynników roślinnych. Współczynniki roślinne dla roślin szparaga uprawianych w Polsce w warunkach polowych zostały ustalone przez Rolbieckiego w oparciu o długoterminowe obserwacje nawadnianych nasadzeń szparaga. Ewapotranspirację wskaźnikową obliczono zgodnie z metodą zaproponowaną przez Grabarczyka. Metoda Grabarczyka została wybrana do niniejszych badań, ponieważ pozwoliła ona na określenie ewapotranspiracji wskaźnikowej w uproszczony sposób, to znaczy tylko na podstawie pomiarów opadów atmosferycznych. Niedobory opadów zostały obliczone przy użyciu metody Ostromęckiego. Deficyt opadów w okresie od 1 lipca do 31 sierpnia obliczono, jako różnicę między potrzebami wodnymi roślin szparagów, wyrażonymi jako ewapotranspiracja potencjalna dla danego miesiąca, a sumą opadów atmosferycznych w tym miesiącu. Potrzeby wodne roślin szparaga określono dla pięciu różnych regionów agro-klimatycznych Polski wraz z reprezentatywnymi stacjami meteorologicznymi zlokalizowanymi na terenie Olsztyna, Bydgoszczy, Warszawy, Wrocławia i Krakowa. Największą zmienność potrzeb wodnych roślin szparaga obliczono w środkowo-północno-zachodnim (C-N-W) regionie Polski. Współczynnik zmienności w lipcu oraz w sierpniu wyniósł odpowiednio 7,7% i 7,6%. Natomiast najmniejszą zmienność potrzeb wodnych roślin szparaga stwierdzono w południowo-zachodnim (S-W), a także południowo-wschodnim (S-E) regionie Polski. Największe potrzeby wodne roślin szparagów, średnio 228 mm, w okresie od 1 lipca do 31 sierpnia, odnotowano w C-N-W, a także środkowo-wschodnim (C-E) regionie Polski. Największy deficyt opadów atmosferycznych, obliczony dla przeciętnie suchych lat, średnio suchych lat oraz bardzo suchych lat, wynosił odpowiednio 91 mm i 89 mm, 157 mm i 166 mm oraz 209 mm i 245 mm, odpowiednio w C-N-W i C-E regionie Polski. Podsumowując, większe niedobory opadów atmosferycznych odnotowano w sierpniu niż w lipcu.

Słowa kluczowe:
Asparagus officinalis L., niedobory opadów, potencjalna ewapotranspiracja, potrzeby wodne, wskaźnikowa ewapotranspiracja