Irrigation Effects of Red Beet as Affected by Rainfall in Different Regions of Poland

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Abstract. The purpose of research was to determine the irrigation effects on the root yield of red beet grown on light soil in different regions of Poland, depending on rainfall amounts during the period July-August. Relationship between the increases of root yield and applying of irrigation was estimated using the Grabarczyk's formula. The amounts of rainfall in the average dry year, medium dry and very dry were determined by the Ostromęcki's method. Rainfall deficits in the cultivation of red beet were determined according to the difference between optimum and real precipitation in five meteorological stations. The highest precipitation deficiencies in the red beet crops in July-August were observed in the central Poland, where amounts 51–52, 98 and 118–124 mm, in average dry, medium dry and very dry years, respectively. The highest increases of the root yield obtained using irrigation were estimated also in the central Poland, where amounts 9.26 and 8.96 t ha^{-1}, 17.30 and 17.28 t ha^{-1}, and 20.92 and 22.00 t ha^{-1} in average dry, medium dry and very dry years, respectively. The increases of red beet yield obtained using irrigation showed the large possibilities of raising its productivity in the field cultivation under optimal water conditions.

Keywords: *Beta vulgaris* L. · Irrigation · Water needs · Regions of poland

1 Introduction

The water needs of red beet *Beta vulgaris* L. during the growing period were estimated at around 300 mm [5] or 300–400 mm [1–3]. According to [3] the optimum precipitation for red beet cultivated in the central region of Poland range from 400 to 450 mm

A. Krakowiak-Bal and M. Vaverkova (Eds.): *Infrastructure and Environment*, pp. 53–58, 2019.
https://doi.org/10.1007/978-3-030-16542-0_8

on heavy and medium soils and from 450 to 500 mm on light soils. The highest water needs during the vegetation period occurs in July and August, when the storage roots are growing rapidly [5].

The aim of presented study was to determine the expected effects of irrigation on the yield of the red beet grown on the light soil in different regions of Poland and depending on precipitation amounts during the period July-August (critical period).

2 Materials and Methods

In the present research, a straight line dependency between the red beet (*Beta vulgaris* L.) yield of roots increases obtained after using the irrigation and precipitation amounts during the period July-August was evaluated. The relationship between the increases of root yield and applying of the irrigation was estimated using the Grabarczyk's formula (1) [4]:

$$Q = \left(P_{opt} - P_{rz}\right) \times q \tag{1}$$

where:

Q – yield increases obtained after using the irrigation (kg ha^{-1}),
P_{opt} – optimal precipitation amounts in the period of increased water needs of the plants (mm),
P_{rz} – real precipitation amounts in the period of increased water needs of the plants (mm),
q – yield increases obtained after using the irrigation (kg ha^{-1} per 1 mm of precipitation deficiencies).

The determination of the red beet yield increases obtained after using the irrigation depending on precipitation amounts in the critical period (July-August) was performed according to [12] formula (2):

$$Q = (190 - P_{rz}) \times 177 \tag{2}$$

According to [5], it was assumed that the period of increased water needs of red beet plants lasts from July 1 to August 31.

The increases of the red beet root yield obtained after using irrigation were determined for five agro-climatic regions of Poland [10] with the representative meteorological stations located in Olsztyn, Bydgoszcz, Warszawa, Wrocław and Kraków (Fig. 1).

The amounts of precipitations in the average dry years (P50%), medium dry years (P25%) and very dry years (P10%) were determined by the Ostromęcki's method [14, 15], using Bp% coefficients that determine the variability of precipitation in the particular meteorological stations. The calculations were carried out for precipitations measured in the years 1981–2010. Precipitation deficiencies in the cultivation of red beet were determined based on the difference between optimum precipitation (Popt) and real precipitation (Prz) in the particular meteorological stations.

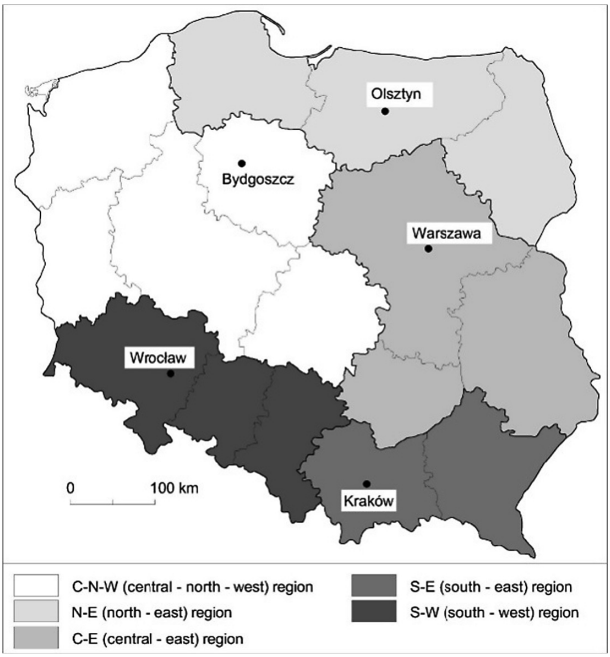

Fig. 1. Agro-climatic regions of Poland with the representative meteorological stations (according to [10]).

3 Results

In the average dry years, the highest precipitation deficiencies (51–52 mm) in the red beet cultivation were calculated in the C-N-W and N-E and C-E regions, and the lowest (25 mm) in the S-E region (Table 1). Subsequently, in the medium dry years, the highest precipitation deficiencies (98 mm) were measured in the C-N-W and C-E regions and the lowest (74 mm) in the S-W region. Finally, in the very dry years, the highest precipitation deficiencies (124 mm) were observed in the C-E region.

The expected increases of the red beet root yield obtained after irrigation applying, in the average dry years, amounted 8.96, 9.04 and 9.26 t ha^{-1} in the C-E, N E and C-N-W regions, respectively, (Table 2). Whereas, the lowest expected increases of the red beet root yield was noted in the S-E region. In the medium dry years, the root yield of red beet obtained after using irrigation was higher, ranging from about 17.3 t ha^{-1} in the C-N-W and C-E regions to 13.15 t ha^{-1} in the S-W region. Eventually, in the very dry years the applying of irrigation could increase the red beet root yield from 18.12 t ha^{-1} in the S-E region to 22.00 t ha^{-1} in the C-E region.

Table 1. Rainfall deficiencies (mm) in the red beet cultivation at the 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
Average dry	50	51	52	51	41	25
Medium dry	25	85	98	98	74	80
Very dry	10	112	118	124	112	102

Table 2. Expected increase of red beet yield (t ha^{-1}) obtained after using irrigation in 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
Average dry	50	9.04	9.26	8.96	7.34	4.38
Medium dry	25	15.09	17.30	17.28	13.15	14.12
Very dry	10	19.87	20.92	22.00	20.04	18.12

4 Discussion

The present studies basing on the relationship between the increases of the red beet root yield obtained after using irrigation treatment and the amounts of precipitation during the critical period (July-August) when, usually, increased the water needs of the plants [12]. The mathematical formula characterizing this dependence, showed the increases of red beet root yield observed as the effect of using irrigation technique, occurred in the period from July 1 to August 31, when the rainfalls were lower than 190 mm. The assessment of precipitation deficiencies in the critical period (July-August) in the cultivation of red beet that based on the comparison of the expected water needs and real precipitation in the particular regions of Poland ($P_{50\%}$, $P_{25\%}$ and $P_{10\%}$), showed the highest precipitation deficiencies in the central Poland (C-N-W and C-E regions). Similarly, [4, 13, 16, 17] also confirm the occurrence of the highest water requirements in the central regions of Poland.

The increase of red beet root yield obtained after irrigation treatment that was estimated in the presented study, indicate the large possibilities of raising the yield of red beet cultivated in the field under optimal water conditions. The prognostic formula, derived from the field experiments allow determining the effects of red beet plants irrigation on the root yield depending on the amounts of precipitations in the different regions of Poland. Similar estimates, including such species as root celery or cucumber, were performed by [17].

According to the reports presented by [6–9, 11], the expected in the near future climate changes, such as the raise of temperature, lead to the increase of water requirements of the plants, including vegetable field cultivation. The direction of climate changes compels the conception of a number of adaptation activities, such as

irrigation treatments, whose role will be appropriately increased along with progressing weather modifying.

Additional factors that stimulate the development of irrigation techniques in the field cultivation of vegetables, regardless of the expected climate changes, are the necessitate to guarantee higher and stable, and good quality crops, as well as ensuring the modernity and competitiveness of agricultural and horticultural farms [16].

5 Conclusions

1. The highest precipitation deficiencies in the red beet crops during the period July-August were observed in the central Poland (C-N-W and C-E regions) where amounts 52 and 51 mm, respectively, in average dry years, 98 mm in medium dry years and 118 and 124 mm, respectively, in very dry years.
2. The highest increases of the red beet root yield obtained after using irrigation was estimated in the central Poland (C-N-W and C-E regions) where amounts 9.26 and 8.96 t ha^{-1}, respectively, in average dry years, 17.30 and 17.28 t ha^{-1}, respectively, in medium dry years, as well 20.92 and 22.00 t ha^{-1}, respectively, in very dry years.

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