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COST-EFFECTIVENESS OF POSTHARVEST DRIP IRRIGATION OF CHOSEN NORTH-AMERICAN CULTIVARS OF ASPARAGUS GROWN FOR GREEN SPEARS IN OPEN FIELD TECHNOLOGY IN THE CENTRAL POLAND

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Abstract. The aim of the present study was an attempt to calculate the cost-effectiveness of asparagus postharvest drip irrigation in the Central Poland. The results of field experiments on drip irrigation of 13 North-American asparagus cultivars, carried out at Kruszyn Krajenski in the vicinity of Bydgoszcz were investigated in the zone of the largest precipitation deficiency in Poland. The drip irrigation system's economic calculation was conducted following the methodology suggested by Grabarczyk (1987). The effectiveness of drip irrigation (ranging from 0 to 157 %) was the highest for cultivars Jersey Deluxe (157 %) and Jersey Giant (142 %). Lack of significant response to drip irrigation was found in case of cultivars Purple Passion, Jersey King and Atlas. Other cultivars (Jersey Supreme, Jersey Knight, Grande, Apollo, UC 157, NJ 953, UC 115, JWC 1) gave an increase in marketable yield of 35-79 % due to drip irrigation. Economic results of drip irrigation, depending on the increase in produce value and assumed drip irrigation costs were positive in case of 10 cultivars. The drip irrigation of Jersey Deluxe and Jersey Giant turned out most cost-effective. Irrigation was also very cost-effective in the case of cultivars UC115, NJ953, Jersey Knight, Jersey Supreme, UC157, Grande, Apollo and JWC 1. Drip irrigation was unprofitable in case of the following cultivars: Purple Passion, Jersey King and Atlas.

Key words: cost-effectiveness, asparagus, drip irrigation, cultivar, green spears.
JEL code: Q15

Introduction

The growing economic significance of asparagus in Poland is associated with the ability to export to European Union countries (mainly Germany), as well as increased demand for this valuable vegetable among consumers in Poland, where changes of eating habits are observed. Basic species - so-called "heavy" vegetables - are converted into low-calorie, high biological and flavoured value species. Intensive breeding works are underway, as a result of which, apart from old, known and already proven for many years, new cultivars appear, requiring verification in the climatic and soil conditions of Poland. In order to achieve the maximum production effects of a given cultivar, it is necessary to create optimal conditions for growth and development during the growing season - through appropriate fertilization and irrigation. Due to the specific cultivation method (spear harvest in early spring), the height and quality of the yield depends on the amount of ingredients stored in asparagus crown during the growing season of the previous year. Irrigation of asparagus in the current year after the harvest (postharvest irrigation/irrigation of summer stalks) causes the increase of the height, diameter of summer stalks and their number from one crown and positively affects the growth of the yield of spears in the following year (Rolbiecki, 2013).

The aim of the present study was an attempt to calculate the cost-effectiveness of asparagus postharvest drip irrigation in the Central Poland. This region of Poland is recognized as the area of the lowest precipitation and the highest water deficits during the vegetation period (Rolbiecki et al., 2000; Labedzki, 2009; Stachowski and Markiewicz, 2011; Rzekanowski et al., 2007; Zarski et al., 2013).

Material and methods

The results of field experiments on drip irrigation of 13 North-American asparagus cultivars, carried out at Kruszyn Krajenski in the vicinity of Bydgoszcz, were investigated in the zone of the largest precipitation deficiency in Poland (Rolbiecki, 2013). The drip irrigation system's economic

calculation was conducted following the methodology suggested by Grabarczyk (1987). For drip irrigation system, an increase in direct surplus was calculated:

$$\Delta D = \Delta P - (Kd + \Delta Kr)$$

where:

ΔD – increase in direct surplus (PLN ha^{-1}),

ΔP – additional production value received by introducing the drip irrigation (PLN ha^{-1}),

Kd – total drip irrigation costs (PLN ha^{-1}),

ΔKr – direct costs related to receiving additional production (PLN ha^{-1}).

The basic index of economic efficiency of irrigation was the direct surplus obtained as a result of this treatment. It was calculated from the difference in the increase in the value of production and the cost of irrigation and the increase in general agricultural costs related to obtaining additional production. The increase in the value of production was determined by multiplying the average long-term production effects of irrigation obtained in the conducted field experiments by the unit price of green asparagus spear (PLN kg^{-1}). The prices were assumed based on average wholesale prices of asparagus (PLN 8.80 kg^{-1}) on WGRO SA in Poznan in 2017. Five variants of irrigated areas: 1, 2, 5, 10 and 20 ha, corresponding to potential areas of asparagus plantations in Poland, were adopted to analyse the profitability of asparagus irrigation. Calculation of irrigation and irrigation installation costs was based on the data of the 'Lukomet' irrigation company. The analysis of economic efficiency was carried out for the drip irrigation system. The calculation includes index-based depreciation of 6.65 % (Rolbiecki, 2013). The interest rate on the capital was set at 5 %, and the costs of repairs and materials at 2 % of the investment costs. Fuel costs were calculated based on the unit's consumption by a pump generator with a combustion drive (the number of litres of fuel per 1 mm of the seasonal dose of water in drip irrigation) and the average purchase price of diesel. The calculation includes water costs, taking PLN 0.20 m^{-3}. The increase in general agricultural costs related to obtaining additional production was treated index-based, assuming that in conditions of correct economic relations it amounts to 30 % of the value of additional production obtained.

Results and discussion

Production effects of drip irrigated asparagus

Drip irrigation applied in the post-harvest period (from the third decade of June to the end of August) in the growing season of the year preceding the harvest, on average for the tested cultivars and years, significantly increased the yield of green asparagus spears from 4.21 t ha^{-1} to 6.23 t ha^{-1} (Table 1). The increase in the marketable spear yield achieved due to irrigation, on average for the tested cultivars and years of research, was therefore 2.01 t ha^{-1} (48 %).

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Table 1

Effectiveness of drip irrigation of asparagus cultivars in the vicinity of Bydgoszcz

Cultivar	Marketable yield of green spears (t ha^{-1})		Yield increase due to irrigation	
	Control (without irrigation)	Drip irrigation	(t ha^{-1})	%
Jersey Giant	2.75a	6.66b	3.91	+ 142
Jersey Knight	3.47a	5.72b	2.25	+65
Jersey Supreme	4.25a	6.43b	2.18	+51
Jersey Deluxe	2.78a	7.15b	4.37	+157
Jersey King	5.97a	6.27a	0.30	+5
Atlas	4.49a	4.79a	0.30	+7
Grande	5.11a	7.08b	1.97	+38
Apollo	5.58a	7.52b	1.94	+35
Purple Passion	5.38a	5.30a	-0.08	-1
UC 157	4.07a	6.15b	2.08	+51
NJ 953	4.67a	7.22b	2.55	+55
UC 115	3.53a	6.31b	2.78	+79
JWC 1	2.70a	4.41b	1.71	+63
Mean for all the cultivars	4.21a	6.23b	2.02	+48

Explanations: values in a row followed by the same letter do not differ significantly (α = 0.05)
Source: author's calculations based on author's research data

The highest marketable yields in drip irrigation - over 7 t ha^{-1} - were obtained in the following cultivars: Apollo, NJ 953, Jersey Deluxe and Grande. High yields under irrigation conditions - over 6 t ha^{-1} - were obtained in the following cultivars: UC 157, Jersey King, UC 115, Jersey Supreme and Jersey Giant. Yields over 5 t ha^{-1} - collected at Purple Passion and Jersey Knight. The lowest yields in irrigation conditions (over 4 t ha^{-1}) were collected in the JWC 1 and Atlas cultivars.

The best response to drip irrigation was found in Jersey Deluxe and Jersey Giant. Drip irrigation increased marketable yields in these cultivars respectively by 4.37 t ha^{-1} (157 %) and 3.91 t ha^{-1} (142 %). No significant response to drip irrigation was found in Purple Passion, Jersey King and Atlas. The response to drip irrigation in the other tested cultivars was positive, and the yield increases found were in the range 1.71-2.78 t ha^{-1} (35-79 %). A varied reaction of other asparagus cultivars was found in previous experiments carried out in Central Poland (Rolbiecki et al., 2001; Rolbiecki and Rolbiecki, 2008; Rolbiecki, 2013). The results obtained were similar to those reported by Paschold et al. (1996, 1999, 2008) and other foreign authors (Roth and Gardner, 1989; Sterrett et al., 1990; Drost and Wilcox-Lee, 1997; Drost, 1999).

Economic results of drip irrigation of asparagus

According to the adopted assumptions, the minimal investment cost of the drip irrigation system - depending on the assumed area: 1 ha, 2 ha, 5 ha, 10 ha and 20 ha - amounted respectively 13000, 8000, 5000, 4000 and 3250 PLN ha^{-1}. Total annual cost of drip irrigation (Kd) - including depreciation, interest on capital, costs of repairs and materials, water costs, fuel costs - decreased with the increase of irrigated area ranging from 2599 PLN ha^{-1} (1 ha) to 1268 PLN ha^{-1} (20 ha) (Fig. 1). The calculation presented by Kledzik et al. (2015) showed that the cost irrigation per 1 ha decreases as the irrigated area increases.

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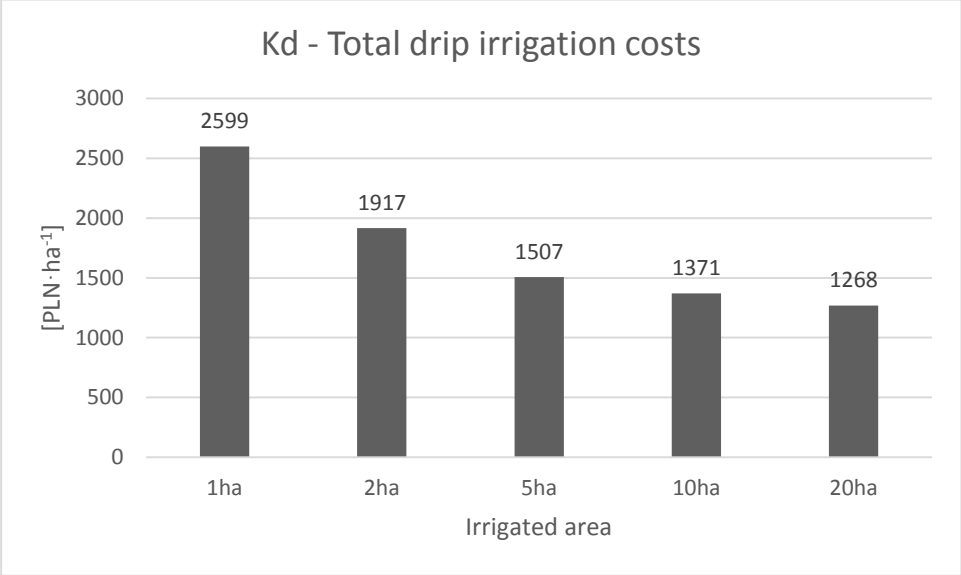

Source: author's calculations based on author's research data

Fig. 1. **Total drip irrigation costs (Kd)**

Asparagus drip irrigation was profitable - the average direct surplus (ΔD) for 13 tested cultivars, depending on the size of the irrigated area, ranged from PLN 9844 ha^{-1} (1 ha) to PLN 11.175 ha^{-1} (20 ha) (Tab. 2). The most profitable was the irrigation of the Jersey Deluxe (ΔD in the range from 34703 to 36034 PLN ha^{-1}) and Jersey Giant (ΔD in the range from 21487 to 22818 PLN ha^{-1}). Irrigation was also highly profitable for the UC115, NJ953, Jersey Knight, Jersey Supreme, UC157, Grande, Apollo and JWC 1 cultivars (ΔD in the range from 15857 to 7935 PLN ha^{-1}). Drip irrigation was unprofitable for the Purple Passion, Jersey King and Atlas cultivars.

The economic analysis proved that the use of postharvest drip irrigation was cost-effective, which confirmed previous opinions and reports concerning also the sprinkler irrigation of other vegetable and field crops and cultivars (Rutkowski and Malecka, 1986; Rutkowski, 1987; Rolbiecki et al., 1999; Zarski et al., 1999; Zarski et al., 2001; Jankowiak and Rzekanowski, 2006; Rolbiecki, 2013; Kledzik et al., 2015). In the study of Kledzik et. al (2017), applying drip irrigation was economically unjustified in moist years and on average in the multi-year period. In the years with dry and average precipitation conditions, the direct surplus was positive (except for irrigation of 1 ha).

Table 2

Cost-effectiveness of drip irrigation of asparagus cultivars

Cultivar	Δ t ha^{-1}	ΔP PLN ha^{-1}	ΔKr PLN ha^{-1}	ΔD PLN ha^{-1}					R
				1ha	2ha	5ha	10ha	20ha	
Jersey Giant	3.91	34408	10322	21487	22169	22579	22715	22818	2
Jersey Knight	2.25	19800	5940	11261	11943	12353	12489	12592	5
Jersey Supreme	2.18	19184	5755	10830	11512	11922	12058	12161	6
Jersey Deluxe	4.37	38456	1154	34703	35385	35795	35931	36034	1
Jersey King	0.30	2640	792	-751	-69	341	477	580	11/12
Atlas	0.30	2640	792	-751	-69	341	477	580	11/12
Grande	1.97	17336	5208	9529	10211	10621	10757	10860	8
Apollo	1.94	17072	5122	9351	10033	10443	10579	10682	9
Purple Passion	-0.08	-	-	-	-	-	-	-	-
UC 157	2.08	18304	5491	10214	10896	11306	11442	11545	7
NJ 953	2.55	22440	6732	13109	13791	14201	14337	14440	4
UC 115	2.78	24464	7339	14526	15208	15618	15754	15857	3
JWC 1	1.71	15048	4514	7935	8617	9027	9163	9266	10
Average	2.02	17776	5333	9844	10526	10936	11072	11175	-

Δ – marketable yield increase influenced by irrigation [t·ha^{-1}]
ΔD – increase of agricultural income [PLN·ha^{-1}]
ΔP – value of additional produce, resulting by irrigation [PLN·ha^{-1}]
ΔKr – an increase in agricultural costs resulting from additional produce [PLN·ha^{-1}]
R – ranking
Source: author's calculations based on author's research data

Conclusions

1) The effectiveness of drip irrigation (ranging from 0 to 157 %) was the highest for cultivars Jersey Deluxe (157 %) and Jersey Giant (142 %). Lack of significant response to drip irrigation was found in case of cultivars Purple Passion, Jersey King and Atlas. Other cultivars (Jersey Supreme, Jersey Knight, Grande, Apollo, UC 157, NJ 953, UC 115, JWC 1) gave an increase in marketable yield of 35-79 % due to drip irrigation.
2) Economic results of drip irrigation, depending on the increase in produce value and assumed drip irrigation costs were positive in case of 10 cultivars. The drip irrigation of Jersey Deluxe and Jersey Giant turned out most cost-effective. Irrigation was also very cost-effective in the case of cultivars UC115, NJ953, Jersey Knight, Jersey Supreme, UC157, Grande, Apollo and JWC 1. Drip irrigation was unprofitable in case of the following cultivars: Purple Passion, Jersey King Atlas.

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