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INFLUENCE OF DRIP IRRIGATION ON THE YIELDING OF SUMMER SQUASH 'WHITE BUSH' UNDER RAINFALL-THERMAL CONDITIONS OF BYDGOSZCZ AND STARGARD

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Abstract

The aim of the study was to determine the effect of drip irrigation on yielding of summer squash 'White Bush' grown under conditions of two localities: Lipnik near Stargard Szczeciński (soil of quality class IVb, and of good-rye-soil-complex) and Kruszyn Krajeński near Bydgoszcz (soil of quality class V, and of weak-rye-soil-complex). The study was designed as one-factorial trial: drip irrigation as the experimental factor was considered. Drip irrigation was conducted according to soil tensiometer indications (-0.04 MPa). Both, in Lipnik as well as in Kruszyn Krajeński, drip irrigation significantly increased marketable yield of summer squash 'White Bush'. A higher rise in yields due to irrigation was obtained in Kruszyn Krajeński than in Lipnik. Mean marketable yield of summer squash fruits in Lipnik was higher than that obtained in Kruszyn Krajeński. Drip irrigation significantly increased the single fruit weight in relation to the control, in both crop localities. The system of drip irrigation significantly affected the number of fruits per plant. Summer squash plants grown in Lipnik produced higher number of fruits, than in Kruszyn Krajeński. In addition, essential influence of drip irrigation was affirmed on

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chemical composition of fruits, i.e. dry matter, vitamin C, monosaccharides, saccharose, content of total sugars and sum of carotenoids and ß-carotin.

Keywords: chemical composition, *Cucurbita pepo* L., cultivar, fruit weight, fruit yield, light soil

INTRODUCTION

In the climatic conditions of Poland, due to the insufficient rainfall during the growing season, there are frequent water shortages. This results in significant fluctuations in the amount of harvesting and quality of crops in a particular year. It is estimated that in the middle belt of Poland, called Land of the Great Valleys, water shortage may reach 200 or even 300 mm (Kaniszewski 2005). The production of cucurbitaceous vegetables in the field depends largely on the thermal and precipitation conditions during the growing season. An important element of receiving the high and good quality yield is to ensure optimum humidity of the soil during plant growth. In our country, water needs of cucurbitaceous plants during a growing season are estimated to be about 400 mm. The main reason of such high water demand is high fertility and the production of the aboveground mass of leaves with the high coefficient of transpiration.

Many studies have demonstrated that the field cultivation of cucurbits should be provided using irrigation system (Rolbiecki 2004, 2007, Rolbiecki and Rolbiecki 2012, Sałata and Stepaniuk 2012, Coolong 2016). Nowadays, drip irrigation system, delivering water directly to the root zone of plants, is one of the most economically efficient solution to supply water to the plants. Furthermore, by using drip irrigation, overground parts of plants remain dry, so they are less susceptible to bacterial or fungal infections. Therefore, drip irrigation method is considered to be beneficial for the agricultural productivity effects (Jeznach 2007, 2009, Rolbiecki 2007).

Generally, irrigation of cucurbitaceous vegetables, clearly affects both yield and fruit quality. In the studies of Ertek *et al.* (2004), Sensoy *et al.* (2007), Peil *et al.* (2012), Yavuz *et al.* (2015), with the rise of irrigation quantity, the yield characteristics increased significantly. On the other hand, although the irrigation usually improves the yield, it often causes the decrease in the fruit chemical composition. In the study reported by Sałata and Stepaniuk (2013) the contents of L-ascorbic acid and carotenoids in zucchini fruits, collected from irrigated plants, were significantly lower and the level of nitrates was higher than in the case of non irrigated plants. In the research provided by Rouphael and Colla (2005) drip irrigation of zucchini plants reduced the content of carbohydrates and did not affect the mineral concentrations of N, P, K, Ca, Mg and Na. Kuslu *et al.* (2014) found the connection between the irrigation quantities and quality of

the summer squash fruits. They indicated the level of irrigation that was the most suitable due to the high mineral contents (Na, N, K, Mg, S, Fe, Mn, Zn and B), total phenolic content and yield traits. At the same time, the antioxidant activity of summer squash fruits was not affected by the irrigation.

The aim of this study was to determine the effect of drip irrigation on the yielding of summer squash 'White Bush' grown under conditions of the Pyrzycko-Stargard Plains (Lipnik near Stargard Szczeciński) and the eastern end of Krajeńskie Lake (Kruszyn Krajeński near Bydgoszcz).

MATERIAL AND METHODS

Experiments were carried out in the conditions of the Pyrzycko-Stargardska Plain (Lipnik near Stargard Szczeciński) and the eastern end of Krajeńskie Lake (Kruszyn Krajeński near Bydgoszcz). Facility in Lipnik is situated about 5 km north-west of Stargard Szczeciński, on the border of river basins of the rivers Płonia and Ina. Facility in Kruszyn Krajeński is situated about 12 km from the city center of Bydgoszcz, near the Górnonotecki Canal. The field experiment of drip irrigation of summer squash 'White Bush' plants was carried out in 2005-2006 in Lipnik (soil of quality class IVb, and of good-rye-soil-complex) and Kruszyn Krajeński (soil of quality class V, and of weak-rye-soil-complex). One-factorial experiment in four replications was performed. Two treatments of drip irrigation were studied: D – drip irrigation and O – control (without irrigation).

The drip irrigation was started when the soil water pressure was below –0.04 MPa. Irrigation was done with the drip line "T-Tape" (Jeznach 2009), for which the distance between the dripers was 20 cm and an expense of water was about 5 $dm^3 \cdot m^{-1}$. Tensiometers of soil were used to determine the timing and dose of irrigation.

The plant material was summer squash (*Cucurbita pepo* L.) 'White Bush'. In both growing seasons (2005 and 2006) the seeds were sown in the third decade of May, spaced 1.0 × 0.7 m. The area of single experimental plot was 9.1 m^2. Doses of potassium (potash salt) and phosphorus (superphosphate) fertilization were used before sowing in dosages suitable for the contents of these components in soil. The nitrogen fertilization (ammonium nitrate) was supplied at 115 $kg \cdot ha^{-1}$ in three rates.

The field experiments were carried out based on the standards used across the country (Lisiecka 1993). The agrotechnical practices were carried out mechanically according to the needs. The fruits of summer squash 'White Bush" were harvested in the phase of technological maturity in the second decade of September, in both growing seasons.

In the experiment marketable yield, single fruit weight and fruit number were measured. Additionally, selected chemical constituents of fruit squash, i.e. dry matter, vitamin C, total and simple sugars, as well as the total carotenoids and ß-carotin, were determined.

The material for chemical analyses was part of a technologically fresh fruit squash cultivar ‚White Bush'. During the study, the dry matter content was determined by weighing according to PN-A-75101/03:1990. The sugar content was determined in the lyophilized material using a spectrophotometer at a wavelength of 600 nm in accordance with the procedure described by Taburt and Smith (1987). The vitamin C content was determined by Tillmans according to PN-A-04019:1998. The content of the sum of carotenoids and ß-carotin was determined according to PN-A-75101/12:1990

The results were statistically analysed using computer package ANALWAR-5.FR. The calculations were made by Fisher-Snedecor test to determine the significance of factors. The differences between the means were estimated using Tukey test at a significance level $P = 0.05$.

The average air temperature during the growing of summer squash 'White Bush' (V-IX) in 2005 and 2006 was 15.8°C in Kruszyn Krajeński, while in Lipnik it was higher and stood at 17.0°C (Table 1). Both, in Kryszyn Krajeński as well in Lipnik, the higher temperature was recorded in the second year of study (2006), 16.6 and 18.0°C, respectively. The average monthly temperature during two years of experiment was higher in Lipnik than in Kruszyn Krajeński. The highest air temperature was marked in July, so it was the period of the highest water needs of the summer squash.

Table 1. Air temperature (°C) during the vegetation period of summer squash 'White Bush'

Crop localities / Study year	Month					Mean
	V	VI	VII	VIII	IX	
Kruszyn Krajeński						
2005	12.2	14.9	19.4	16.3	12.7	15.1
2006	12.5	16.8	22.4	16.6	14.8	16.6
Mean for 2005-2006	12.3	15.8	20.9	16.4	13.7	15.8
Long-termmean 1981-2010	13.1	16.0	18.5	17.9	13.2	15.7
Lipnik						
2005	13.1	15.8	19.4	16.6	15.5	16.1
2006	13.7	18.2	23.5	17.7	17.1	18.0
Mean for 2005-2006	13.4	17.0	21.4	17.1	16.3	17.0
Long-term mean 1981-2010	12.5	15.9	17.4	17.0	13.2	15.2

Table 2. Rainfall (mm) during the vegetation period of summer squash 'White Bush'

Crop localities / Study year	Month					Mean
	V	VI	VII	VIII	IX	
Kruszyn Krajeński						
2005	69	31	40	21	25	186
2006	63	22	30	114	18	247
Mean for 2005-2006	66	26	35	67	21	215
Long-term mean 1981-2010	40	52	63	51	45	251
Lipnik						
2005	67	26	76	53	26	248
2006	43	23	7	105	38	216
Mean for 2005-2006	55	24	41	78	32	232
Long-term mean 1981-2010	51	61	63	56	47	278

Table 3. Seasonal irrigation water rates (mm)

Crop localities	Year		Mean
	2005	2006	
Kruszyn Krajeński	99.5	111.5	105.5
Lipnik	116.5	165.5	141.0
Mean	108.0	138.5	123.3

The mean sum of rainfall in the period of V-IX in the years 2005-2006 was similar in both crop localities and reached 215 mm in Kruszyn Krajeński and 232 mm in Lipnik (Table 2). In the first year of study the rainfall was lower in Kruszyn Krajeński (186 mm) than in Lipnik (248 mm). During the second year of experiment, higher precipitation in Kruszyn Krajeński (247 mm) than in Lipnik (216 mm) was noted. The lowest rainfall was in June – only 26 mm in Kruszyn Krajeński and 24 mm in Lipnik. These values reached 50% and 39%, respectively, of the long-term mean (1981-2010) for this month. Rainfall below the long-term mean was noticed also in July and September.

The seasonal irrigation doses, used during the research period, were closely related to the course of thermal and precipitation conditions for studied species (Table 3). In 2005 and 2006, water rates amounted in Kruszyn Krajeński to 99.5 and 111.5 mm, respectively, and in Lipnik to 116.5 and 165.5 mm, respectively. Average applied irrigation water rates were higher in Lipnik (141.0 mm), than in Kruszyn Krajeński (105.5 mm).

RESULTS AND DISCUSSION

The mean yield of summer squash 'White Bush' marketable fruits harvested in the years 2005 and 2006 from the control plots (without irrigation) amounted 49.3 Mg·ha^{-1} in Kruszyn Krajeński and 60.0 Mg·ha^{-1} in Lipnik (Table 4). These results correlated directly with the level of rainfall, which in the period of study was higher in Lipnik than in Kruszyn Krajeński. Similar trends in the yielding obtained at the same experimental plots were also noted in the irrigation study of summer squash 'Danka', in which the yield of fruits collected from the control plots was 30.3 Mg·ha^{-1} in Kruszyn Krajeński and 42.5 Mg·ha^{-1} in Lipnik (Rolbiecki *et al.* 2011b). Drip irrigation, applied in the present study, proved a significant increase of the marketable yield of summer squash 'White Bush' fruits in relation to the control, in both experimental localities. The increase in yield of irrigated plants, compared to the control, as the mean of two years, was 61.55 Mg·ha^{-1} (125%) in Kruszyn Krajeński and 46.20 Mg·ha^{-1} (77%) in Lipnik. In both study years, the higher marketable fruit yield increase was noted in Kruszyn Krajeński than in Lipnik. In Kruszyn Krajeński better effect of drip irrigation on the yield was found in the second year of the study (63.9 Mg·ha^{-1}) than in the first (59.2 Mg·ha^{-1}). In the case of Lipnik, the higher rise in the marketable yield, compared to the control, was recorded in 2005 (58.20 Mg·ha^{-1}), than in 2006 (34.2 Mg·ha^{-1}). Rolbiecki (2004, 2007), Rolbiecki and Rolbiecki (2003, 2005), Rolbiecki *et al.* (2006) have already discussed the beneficial effects of drip irrigation of cucurbitaceous vegetables grown in the same soil conditions.

Table 4. Influence of drip irrigation on the marketable yield (Mg·ha^{-1}) of summer squash 'White Bush'

Treatment	Crop localities / Study year				Mean
	Kruszyn Krajeński		Lipnik		
	2005	2006	2005	2006	
Control (O)	64.1	34.5	62.6	57.4	54.65
Drip irrigation (D)	123.3	98.4	120.8	91.6	108.52
Mean	93.7	66.5	91.7	74.5	81.60
D – O	59.2	63.9	58.2	34.2	53.87
$LSD_{0.05}$	1.915	1.308	2.458	2.651	2.159

LSD – lowest significant difference (Tukey's confidence half-interval) at $P < 0.05$; ns – not significant at $P < 0.05$

The mean weight of a single summer squash 'White Bush' fruit harvested from the control plots was 1.35 kg in Kruszyn Krajeński and 1.20 kg in Lipnik (Table 5). The drip irrigation significantly increased the mean fruit weight by 0.60 kg in Kruszyn Krajeński and 0.75 kg in Lipnik. The highest increase in the single fruit weight under irrigation was found in 2005 in Lipnik (0.9 kg). Both, in Lipnik as well in Kruszyn Krajeński, the mean weight of a single fruit collected from the irrigated plots was 1.95 kg. Rolbiecki *et al.* (2011b) also reported the significant influence of drip irrigation on the increase of squash 'Danka' fruits weight by 0.56 kg in Kruszyn Krajeński (mean fruit weight equaling to 1.86 kg) and by 0.84 kg in Lipnik (mean fruit weight equaling to 2.24 kg).

Table 5. Influence of drip irrigation on the single fruit weight (kg) of summer squash 'White Bush'

Treatment	Crop localities / Study year				Mean
	Kruszyn Krajeński		Lipnik		
	2005	2006	2005	2006	
Control (O)	1.6	1.1	1.4	1.0	1.27
Drip irrigation (D)	2.2	1.7	2.3	1.6	1.95
Mean	1.9	1.4	1.9	1.3	1.62
D – O	0.6	0.6	0.9	0.6	0.68
$LSD_{0.05}$	0.280	0.121	0.332	0.254	0.235

Explanations: see Table 4

Table 6. Influence of drip irrigation on the number of fruits per plant (pcs·plant^{-1}) of summer squash 'White Bush'

Treatment	Crop localities / Study year				Mean
	Kruszyn Krajeński		Lipnik		
	2005	2006	2005	2006	
Control (O)	2.9	2.3	3.1	3.3	2.9
Drip irrigation (D)	4.1	3.9	4.0	4.5	4.1
Mean	3.5	3.1	3.6	3.9	3.5
D – O	1.2	1.6	0.9	1.2	1.2
$LSD_{0.05}$	0.370	0.367	0.389	0.411	0.395

Explanations: see Table 4

Drip irrigation significantly influenced the increase also in the number of fruits per plant (Table 6). The mean number of fruits harvested from irrigated plots amounted to 4.25 pcs plant^{-1} in Lipnik and 4.00 pcs plant^{-1} in Kruszyn Krajeński. Biesiada *et al.* (2006) reported a similar number of summer squash fruits per plant (4.19 pcs plant^{-1}). Beneficial influence of drip irrigation on the number of fruits as well as on the single fruit weight, in the case of cucurbitaceous vegetables grown in the region of Bydgoszcz, were presented previously by, among others, Rolbiecki (2004, 2007), Rolbiecki and Rolbiecki (2003, 2005), Rolbiecki *et al.* (2006, 2009, 2011a, b) and Rolbiecki *et al.* (2014).

Drip irrigation applied in the experiment in Kruszyn Krajeński significantly differentiated the content of dry matter, vitamin C, monosaccharides, saccharose in fruit squash, affecting their increases (Table 7). No significant differences were found in the content of total sugars and sum of carotenoids and ß-carotin, despite the visible tendency for growth. On the other hand, in the fruit squash from plots cultivated in Lipnik irrigation significantly increased the level of all the tested components (Table 8). The results confirm the findings of previous studies (Wichrowska and Wojdyła 2011) concerning the impact of irrigation on cucurbits, in which this factor significantly modified the chemical composition of plants. In the studies of the authors, the application of drip irrigation of pumpkin during the growing season resulted in an increase in the sum of carotenoids in fruits by 131.0% and in vitamin C by 44%.

Table 7. Influence of drip irrigation on the chemical composition of summer squash 'White Bush' in Kruszyn Krajeński

Treatment	Years of study	Dry matter [%]	Vitamin C [mg · 100g^{-1}]	Total sugars [g · 100g^{-1}]	Mono-saccharides [g · 100g^{-1}]	Saccharose [g · 100g^{-1}]	Sum of carotenoids and ß-carotin [mg · 100g^{-1}]
Control (O)	2005	3.21	14.31	2.88	1.88	1.00	0.45
	2006	4.05	12.07	2.18	1.58	0.61	0.50
	Mean	3.78	13.19	2.53	1.73	0.81	0.48
Drip irrigation (D)	2005	4.02	19.31	3.00	1.25	1.75	0.60
	2006	4.50	16.73	2.81	1.10	1.71	0.55
	Mean	4.26	18.02	2.91	1.73	1.18	0.58
Mean		4.02	15.61	2.72	1.73	0.99	0.53
$LSD_{0.05}$		0.383	0.367	n.s.	0.237	0.293	n.s.

Explanations: see Table 4

Table 8. Influence of drip irrigation on the chemical composition of summer squash 'White Bush' in Lipnik

Treatment	Years of study	Dry matter [%]	Vitamin C [mg · 100g^{-1}]	Total sugars [g · 100g^{-1}]	Mono-saccharides [g · 100g^{-1}]	Saccharose [g · 100g^{-1}]	Sum of carotenoids and ß-carotin [mg · 100g^{-1}]
Control (O)	2005	3.39	12.48	1.75	1.25	0.50	0.93
	2006	3.86	10.56	1.50	1.13	0.38	0.88
	Mean	3.63	11.52	1.63	1.19	0.44	0.91
Drip irrigation (D)	2005	4.10	13.44	2.50	1.50	1.00	1.24
	2006	4.21	11.52	2.25	1.63	0.63	1.07
	Mean	4.16	12.48	2.38	1.57	0.82	1.16
Mean		3.89	12.00	2.00	1.38	0.63	1.03
$LSD_{0.05}$		0.384	0.193	0.192	0.300	0.301	0.222

Explanations: see Table 4

CONCLUSIONS

The use of drip irrigation in the cultivation of summer squash 'White Bush' proved to be a significant factor of increasing the fruits marketable yield, both in Kruszyn Krajeński as well in Lipnik. A higher yield increase of irrigated plants, compared to the control, was obtained in Kruszyn Krajeński than in Lipnik. Generally, the mean marketable yield of summer squash fruits was higher in Lipnik than in Kruszyn Krajeński. Drip irrigation considerably raised the single fruits weight in relation to the control, in both crop localities. The system of drip irrigation significantly affected also the number of fruits per plant. Summer squash 'White Bush' plants grown in Lipnik produced higher number of fruits than plants in Kruszyn Krajeński. Also, essential influence of drip irrigation on chemical composition of summer squash fruits both in Kruszyn Krajeński and in Lipnik was proven.

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