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THE EFFICIENCY OF DRIP FERTIGATION IN CULTIVATION OF WINTER SQUASH 'GOMEZ' ON THE VERY LIGHT SOIL

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Abstract

The study of drip fertigation of winter squash 'Gomez' was conducted on the very light soil on the experimental field in Kruszyn Krajeński near Bydgoszcz in the years 2007 and 2008. The research was established as one-factorial, using the method of drawn blocks, in four replications. Drip fertigation (D_F) as the liquid fertilization supplied nitrogen, potassium and phosphorus to the plants three times during growing season. As the control (D_p), the drip irrigation combined with broadcast application was used. The potassium and phosphorus fertilization of control plots was applied before seed sawing. The nitrogen fertilization of control plots was provided in three single doses during vegetation. The liquid and powder fertilizations were performed at the same time. The complex fertilizer ‚Universol Blue' (N:P:K = 18:11:18) was used. The dose of fertilizer was 3:2:3 (187.5:125:187.5 kg of NPK per ha). The irrigation was conducted using the drip line ‚T-Tape'. The liquid fertilizer was mixed by the ‚Dosatron' dispenser. The irrigation started when the soil water pressure, measured with the tensiometers, was near – 0.04 MPa. In comparison to the control (powder fertilization), the drip fertigation (liquid fertilization) significantly increased marketable fruit yield, single fruit weight and fruit number. Most of the tested chemical components of 'Gomez' fruits (vitamin C, total sugar, monosaccharides, saccharose, total carotenoids and ß-carotin) were

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not significantly influenced by drip fertigation. However, the level of dry weight of winter squash 'Gomez' fruits was reduced by drip fertigation.

Keywords: carotenoids, *Cucurbita maxima* Duch., dry matter, fruit yield, sugar, vitamin C

INTRODUCTION

Winter squash (*Cucurbita maxima* Duch.) is a plant originating from North America. Recently, this vegetable species has become highly popular in Poland, which is due to its adaptive abilities to climatic conditions, stable yielding, and health benefits. Winter squash fruits are rich in vitamins and minerals. The pumpkin flesh is rich in ß-carotin, lutein and zeaxanthin. Furthermore, it contains vitamins such as B, C, E, PP, folic acid, as well as minerals (calcium, potassium, magnesium, iron, phosphorus, copper), pectin, organic acids and carbohydrates. It is also an excellent source of protein (valuable amino acids) and fiber (Tamer *et al.* 2010, Jacobo-Valenzuela *et al.* 2011).

Under Polish climatic conditions one of the most important factors determining the yield and quality of vegetables is water (Kaniszewski 2005). Beneficial effects of irrigation on the cultivation of cucurbitaceous plants was noted by Rolbiecki (2004, 2007), Rolbiecki and Rolbiecki (2012), Sałata and Stepaniuk (2012) and Coolong (2016). Usually, the irrigation system increased the traits of fruit yield (Ertek *et al.* 2004, Sensoy *et al.* 2007, Peil *et al.* 2012, Yavuz *et al.* 2015). However, much better results in yielding of cucurbitaceous vegetables were noted when plants were fertigated than when traditional techniques of fertilizer application were used (Mohammad 2004 a, b, Zotarelii *et al.* 2008, Fernandes *et al.* 2016).

Cucurbits have some of the highest water requirements, compared to other vegetables. This is because they have comparatively small root system, and yet produce extremely large above-ground mass of leaves as well as fruits. Presently, drip irrigation is widely recommended in open field cultivation of cucurbitaceous plants. The drip fertigation allows delivering both water and fertilizer directly to the root zone, without moistening the surface of leaves. This is an effective and favorable way of water and fertilizer application to the plants. Drip fertigation ensured precision and balanced fertilization. Other advantages resulting from the use of drip fertigation system are: improving the quality of yield, reducing the use of machinery and fuel, labor, kneading the ground with wheels and minimizing the fertilizers rinsing (Jeznach 2007, 2009, Rolbiecki 2007).

The aim of the study was to assess the efficiency of drip fertigation on the winter squash 'Gomez' grown on the very light soil.

MATERIAL AND METHODS

The field researches were conducted on the experimental field in Kruszyn Krajeński near Bydgoszcz in the years 2007 and 2008. The drip irrigation and drip fertigation of winter squash (*Cucurbita maxima* Duch.) 'Gomez' were studied. The experiment was established as one-factorial, using the method of drawn blocks, in four replications. The drip fertigation (D_F) as the liquid fertilization supplying nitrogen, potassium and phosphorus to the plants three times in vegetative season was examined as the experimental factor. The drip irrigation (D_P), combined with powder fertilization, was used as the control. On the control plots, before the seeds sawing, the potassium and phosphorus, as powder fertilization, were applied. The nitrogen fertilization of the control plots was supplied in three single doses. The complex fertilizer ‚Universol Blue' (N:P:K = 18:11:18) for fertigation was used. The doses of fertilizer were applied in relation 3:2:3 (187.5:125:187.5 kg of N:P:K per ha). The drip fertigation was carried out three times at the same time as the powder nitrogen fertilization of control plots. The drip irrigation and drip fertigation were done using the ‚T-Tape' drip line. For irrigation purposes, water from the subsurface well was used. In order to mix the fertilizer with the water, the dispenser ‚Dosatron' was used. Deadlines of irrigations, on the base of soil water potential measured using the tensiometers, were established. The drip irrigation was started when the soil water pressure was near – 0.04 MPa.

In both years of the study the seeds of winter squash 'Gomez' were sown in the third decade of May, spaced 1.0 × 0.8 m. The area of each experimental plot was equal to 13.6 m^2. The field experiment was carried according to the standard crop management practices recommended for cucurbits under Polish conditions (Lisiecka 1993). The fruit of the winter squash 'Gomez' were harvested at technological maturity stage, in the second decade of September in each year of study.

In the experiment marketable yield, single fruit weight and fruit number were measured. Also, the chemical composition of winter squash 'Gomez' fruits, such as dry matter, vitamin C, total sugar, monosaccharides, saccharose, total carotenoids and ß-carotin, were evaluated. Representative samples for chemical analyzes were composed from several fruits. The dry matter content was determined by PN-90/75101-A/03. The sugar content was measured using a spectrophotometer (600 nm) technique according to Talburt and Smith (1987). The vitamin C content was determined by Tillman's method using PN-A-04019:1998. The content of the carotenoids and ß-carotin was evaluated according to PN-90/-75101/12.

The results of the study were statistically analyzed. The calculations were provided using computer package ANALWAR-5.FR, by Fisher-Snedecor test to

determine the significance of tested factors. The significant differences for examined traits were calculated using the Tukey test at the significance level of $P = 0.05$.

The mean air temperature in Kruszyn Krajeński during growing of the winter squash 'Gomez' (V-IX) in the years 2007 and 2008 was 16.0°C, which was 0.3°C higher than the long-term mean (Table 1). In the first year of study (2007), during May (13.8°C) and June (18.2°C), the temperature was higher comparing to the long-term mean. In the second year of research (2008), for three months, May (13.2°C), June (17.6°C) and July (19.2°C), the temperature was higher than the long-term mean.

The precipitation in the period from 1st May until 30th September, as the mean for the years 2007-2008, was 273.9 mm (Table 1). During the first year of study (2007), higher rainfall (358.6 mm) was noted than in the year 2008 (189.6 mm). Particularly high amounts of rainfall (103.4 mm and 111.3 mm) were recorded, respectively, in June and July in the year 2007. The lowest rainfall (3.2 mm) was noted in May 2008 that was less than 8% of the long-term mean. Low rainfall also in June, July and September 2008, was noted, 59, 71 and 59% below the long-term mean, respectively.

Table 1. Air temperature and rainfall during the vegetation of winter squash 'Gomez' cultivated in Kruszyn Krajeński

Study year	Month					Mean
	V	VI	VII	VIII	IX	
Air temperature (°C)						
2007	13.8	18.2	18.0	17.8	12.4	16.0
2008	13.2	17.6	19.2	17.8	12.4	16.0
Mean for 2007-2008	13.5	17.9	18.6	17.8	12.4	16.0
Long-term mean	13.1	16.2	18.2	17.8	13.0	15.7
Rainfall (mm)						
2007	49.1	103.4	111.3	59.2	35.6	358.6
2008	3.2	32.3	46.6	81.5	26.0	189.6
Mean for 2007-2008	26.1	67.8	78.9	70.3	30.8	273.9
Long-term mean	40.7	54.8	65.4	51.4	44.3	256.6

The seasonal irrigation water rates applied during the experiment were closely related to the course of thermal and precipitation conditions for the object of research and amounted to 68.0 and 101.5 mm, in the years 2007 and 2008, respectively.

RESULTS AND DISCUSSION

The mean marketable yield of winter squash 'Gomez' fruits collected from the control plots (drip irrigation combined with powder fertilization) was 30.9 $Mg \cdot ha^{-1}$ (Table 2). Control plots produced 39.5 and 22.2 $Mg \cdot ha^{-1}$ of fruits in the years 2007 and 2008, respectively. These results correlated clearly with the precipitation; so both the yields and rainfalls, noted in the year 2007, were higher than in the year 2008.

The drip fertigation applied during growing of the winter squash 'Gomez' significantly increased the marketable yield of fruits, in relation to the control (Table 2). The higher increase of the fruit yield, compared to the control, was found in the year 2008 (17.6 $Mg \cdot ha^{-1}$) than in the year 2007 (8.7 $Mg \cdot ha^{-1}$). The rise in yielding, as the mean for two years, was 13.1 $Mg \cdot ha^{-1}$ (42%). The beneficial impact of drip fertigation on the yield of cucurbitaceous vegetables was previously observed by Rolbiecki *et al.* (2011) – in this research fertigation using nitrogen resulted in the significant increase of watermelon fruit yield by 27%. The positive influence of the fertigation on the plants yielding was observed also by Glonek and Komosa (2004), Kaniszewski *et al.* (2009) and Trawczyński (2009, 2013).

In the case of fertigated plants, the rise in the single fruits weight, compared to the control, was visible in both years of the study. The weight of a single fruit collected from the control plants, as the mean for two years of study, was 2.2 kg (Table 3). Biesiada *et al.* (2006) reported similar results, regarding the single fruit weight of summer squash 'Danka' (2.05 kg). In the present study, the drip fertigation significantly increased the mean single fruit weight of winter squash 'Gomez' by 1.0 kg. The weight of a single fruit collected from the fertigated plants, as the mean for two years of study, was 3.2 kg, representing a 45% rise in comparison to the control. The higher increase of single fruit weight was found in the year 2007 (1.3 kg) than in the year 2008 (0.7 kg).

Table 2. Influence of drip fertigation on the marketable yield ($Mg \cdot ha^{-1}$) of winter squash 'Gomez' fruits

Treatment	Study years		Mean
	2007	2008	
Drip irrigation – control (D_P)	39.5	22.2	30.9
Drip fertigation (D_F)	48.2	39.8	44.0
Mean	43.9	30.1	37.0
$D_F - D_P$	8.7	17.6	13.1
$LSD_{0.05}$	5.166	2.663	3.226

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

Table 3. Influence of drip fertigation on the single fruit weight (kg) of winter squash 'Gomez'

Treatment	Study years		Mean
	2007	2008	
Drip irrigation – control (D_P)	2.6	1.8	2.2
Drip fertigation (D_F)	3.9	2.5	3.2
Mean	3.3	2.2	2.7
$D_F - D_P$	1.3	0.7	1.0
$LSD_{0.05}$	0.974	0.343	0.524

Explanations: see Table 3

Table 4. Influence of drip fertigation on the number of fruits of winter squash 'Gomez' (pcs·plant^{-1})

Treatment	Study years		Mean
	2007	2008	
Drip irrigation – control (D_P)	1.4	0.98	1.24
Drip fertigation (D_F)	1.7	1.2	1.45
Mean	1.6	1.1	1.35
$D_F - D_P$	0.3	0.22	0.21
$LSD_{0.05}$	0.122	0.114	0.102

Explanations: see Table 3

The drip fertigation significantly influenced the increase of the number of fruits per plant (Table 4). In the case of fertigated plants, the mean number of fruits per plant was 1.45 pcs·plant^{-1}. Application of drip fertigation resulted in the rise of the number of fruits per plant by 17%, compared to the control. A similar increase, of 20%, in the number of watermelon fruits that were harvested from the plants drip-fertigated with nitrogen, was reported by Rolbiecki *et al.* (2011).

The chemical composition of the fruits of cucurbitaceous plants is diversified and depends on the climatic and soil conditions, as well as the species and cultivars (Danilčenko *et al.* 2004, Korzeniowska *et al.* 2004, Rolbiecki *et al.* 2006, Wojdyła *et al.* 2007, Wichrowska and Wojdyła 2011). In the present study, the content of dry matter in the winter squash 'Gomez' fruits collected from the control plants was higher compared to the fruits harvested from the drip-fertigated plots (Table 5). In the case of other studied features of chemical composition of fruits, such as vitamin C, total sugar, monosaccharides, saccharose, total carotenoids and ß-carotin, non significant impact of drip fertigation was noted. The

main ingredient of the dry weight of *Cucurbita* sp. fruits is sugar, its content was not significantly influenced in the present study, however. The drip fertigation caused only a slight increase in the content of antioxidants (vitamin C, total carotenoids and ß-carotin). Carotenoids are also used as a natural food dye, which colors the product yellow, orange or red. Pumpkins, like carrots, are the valuable sources of dietary antioxidants, carotenoids and particularly ß-carotin. In contrast to the carrot, a pumpkin does not bind heavy metals and nitrates, which makes it a common component of baby food (Wichrowska and Wojdyła 2011).

Table 5. Influence of drip irrigation on the chemical composition of winter squash 'Gomez' fruits (mean values for the years 2007 and 2008)

Treatment	Study years	Dry matter [%]	Vitamin C [mg 100g^{-1}]	Total sugar [g 100g^{-1}]	Monosaccharides [g 100g^{-1}]	Saccharose [g 100g^{-1}]	Carotenoids and ß-carotin [mg 100 g^{-1}]
Drip irrigation (control)	2007	8.57	6.15	3.93	2.24	1.69	4.35
	2008	8.01	5.76	3.24	1.89	1.34	3.78
	Mean	8.29	5.96	3.48	2.10	1.38	4.07
Drip fertigation	2007	6.94	6.53	3.50	2.24	1.26	4.73
	2008	6.21	5.57	3.33	2.01	1.32	4.36
	Mean	6.57	6.05	3.42	2.12	1.29	4.55
Mean		7.43	6.00	3.48	2.10	1.38	4.31
$LSD_{0.05}$		1.080	ns	Ns	ns	ns	ns

Explanations: see Table 3

CONCLUSIONS

As compared to the control (drip irrigation combined with powder fertilization), the drip fertigation (liquid fertilization), supplying nitrogen, potassium and phosphorus to the plants, used during the cultivation of winter squash 'Gomez' on a very light soil, significantly increased the fruit yield from 30.9 to 44.0 Mg·ha^{-1} (by 42%). Fertilization applied in liquid form (drip fertigation) increased also the single fruit weight and the number of fruits per plant of tested winter squash 'Gomez' in relation to the control. Most of studied chemical components, such as vitamin C, total sugar, monosaccharides, saccharose, total carotenoids and ß-carotin, was not significantly influenced by drip fertigation. The content of dry weight of winter squash 'Gomez' fruits was even reduced in the case of drip-fertigated plants, though.

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