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# GROWTH, YIELD AND QUALITY OF ZUCCHINI 'SORAYA' VARIETY FRUITS UNDER DRIP IRRIGATION

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**Abstract.** The improvement in zucchini growth in climatic conditions of Poland can be achieved by drip irrigation of plants. The effect of drip irrigation on zucchini plants of 'Soraya' variety during different growth phases on size of fruits and content of L-ascorbic acid, nitrates (V) and carotenoids was estimated. In the research plants were irrigated according to different variants: irrigated during a whole cultivation, irrigated during vegetative growth till fruit sets forming and not irrigated during yielding, not irrigated during vegetative growth till fruit sets forming and irrigated during yielding, not irrigated at all (water in soil came only from precipitation). Irrigation during whole cultivation period and during intensive vegetative growth phase increased yield. Regardless the irrigation method significant values of correlation coefficient for these features were noted. The chemical analysis of zucchini fruits composition showed differentiation of marked elements depending on irrigation method used. The highest content of L-ascorbic acid was in fruits harvested from plants that were not irrigated. Establishment of optimal aquatic-air conditions through improvement in soil humidity during a whole cultivation period of zucchini plants increased content of nitrates in zucchini fruits and decreased carotenes content.

**Key words:** *Cucurbita pepo* var. *giromontina* Alef., L-ascorbic acid, nitrate, carotenoids

## INTRODUCTION

A zucchini (*Cucurbita pepo* var. *giromontina* Alef.) is an annual plant of a big commercial importance. It is characterized by large yield and it is a valuable raw material for a processing industry.

In Poland a considerable increase in zucchini cultivation could have been observed in recent years. Widespread of zucchini cultivation results from big progress in breeding

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and obtaining a vast assortment of valuable varieties, but most of all thanks to cognition of biology of flowering [Mancini and Calabrese 1999]. The optimal period to form zucchini female flowers is a short day and low temperatures at the optimal conditions of soil humidity [NeSmith et al. 1994]. Most varieties respond to increase of temperature up to 30°C with male flowers initiation [Suleiman and Suwwan 1990]. Differentiation of zucchini flowers usually takes place before plants form two proper leaves [Hume and Novell 1983].

A significant inhibition of growth of plants at insufficient water supply was observed [Dweikat and Kostewicz 1989]. Requirement and use of water during growth is differentiated. Depending on the period of water deficiency different reactions of plants can be observed. The first symptom is wilting due to reduced turgor pressure, what causes decrease in photosynthesis intensity. This phenomenon often appears in summer, when due to intense sunlight and hot wind blasts in the afternoon, transpiration is superior to water absorption [Khalil et al. 1996]. Zucchini has higher water requirement during fruit formation and development – humidity of soil should not be lower than 80–85% of field water capacity [Kaniszewski 2005]. In research relating to irrigation of Cucurbitaceae plants the increase in yield and high effectiveness of both drip irrigation and micro-jet sprinkling was proven [Kaniszewski 2005, Kaniszewski and Elkner 2002]. Yield of zucchini increased under irrigation on average by 85%, while for *Cucurbita maxima* on average by 61% with drip irrigation system and by 73% with micro-jet sprinkling [Rolbiecki et al. 2005, Rolbiecki and Rolbiecki 2005].

The aim of the work was to estimate the effect of drip irrigation on size and quality of fruits of zucchini plants applied during different stages of growth.

## MATERIAL AND METHODS

Agrotechnical research was conducted in the years 2009–2011 in a zucchini plantation covering the area of 1 ha. The field was located at 51°11' North longitude and 22°35' East latitude. The research material were plants of zucchini (*Cucurbita pepo* var. *giromontina* Alef.) of 'Soraya' variety. A single factor and completely randomised design was established in four replications with 80 plants per each replication, with 20 plants per each combination. The spacing between plants was 1.0 × 0.8 (used in horticulture practice) and the plot area was 16 $m^2$. Different variants of irrigation of zucchini plants were used in the experiment. Plants were cultivated in layouts as following: objects irrigated during a whole cultivation period, objects irrigated during vegetative growth till fruits formation and without irrigation during yielding, objects not irrigated during vegetative growth and irrigated during yielding from the moment of fruits forming and objects not irrigated at all (shortage of water was supplemented only by rainfalls).

In order to produce transplants for 20th of April, the seeds were sown in a heated tunnel into multi-pots filled with peat Hartmann substrate (capacity of a single pot was 56 $cm^3$). Seedlings were planted in the field in the second decade of May.

Drip irrigation with drip line (system TIV) of emitters efficiency of 4.0 $l \cdot h^{-1}$ was used during cultivation. The date of irrigation was established according to tensiometer and the irrigation was started when the soil water potential was not lower than -40 kPa. Irrigation was done every 3–4 days and single doses of water were 3–4 mm. Total water doses were 25–55 mm, depending on the year.

The cultivation was carried out on the loess soil of mechanical composition of loamy sand containing 1.6% of organic matter. Soil was classified a good wheat complex, valuation IIa (Polish classification). Carrot was a forecrop for zucchini in the years of the research. In October, when carrot was harvested, the soil was fertilized with manure in the amount of 15 $t \cdot ha^{-1}$. On the basis of soil analysis, the contents of macro nutrients were supplemented to the level of: 120 mg $N \cdot dm^{-3}$ ($N\text{-}NO_3$), 80 mg $P \cdot dm^{-3}$, 180 mg $K \cdot dm^{-3}$, 50 mg $Mg \cdot dm^{-3}$. The soil pH was 7.2. Mineral fertilization was done before planting seedlings into the field and the following fertilizers were used: triple superphosphate, potassium sulfate, ammonium nitrate and magnesium. Plants were fertilized twice with calcium nitrate during vegetation: in fourth and eighth week after seedlings planting.

In the years of research, fruits were harvested successively every 5 days, from the $25^{th}$ of June till the $25^{th}$ of September. Zucchini fruits 8 to 35 cm long constituted the yield. The unit weight and length of fruits were estimated directly after harvest.

On the $20^{th}$ of August, samples for chemical analysis were taken randomly, 10 fruits of different sizes from each of 4 replicates. In fresh zucchini fruits the content of L-ascorbic acid was marked with Roe method modified according to Evelyn [Roe 1961] and the content of nitrates (V) was marked with colorimetric method [PN-82/C--04576/08]. The content of carotenoids was marked in dry plant material with colorimetric method [PN-90/A-75101/12].

The basis for evaluation was numeric description of function correlations of the mean values of weight and length of zucchini fruits defined statistically. The function correlations were expressed as relations of these values with the use of multiple analysis. The correlations were evaluated with SAS software (9.1 version) that counts equations of linear regression ($y = a + bx$), correlation coefficient (r) and values of test of statistical significance F parallelly for each relation. As the definitive form of correlations, a logarithmic equation was accepted, which parameters, such as values of correlation coefficient and the test of significance F, the most precisely described function correlations between values of weight and length of fruits in relation to plant irrigation combinations used in the experiment. A statistical analysis of the obtained results regarding chemical content of fruits was done according to a nonparametric Kruskal test ($p \leq 0.05$).

## RESULTS AND DISCUSSION

The effect of zucchini plants irrigation during different growth phases on yield is shown in table 1. Significantly higher mean yield of fruits was obtained when plants irrigated during a whole cultivation (mean 40.17 $t \cdot ha^{-1}$) and irrigated till setting fruits on plants (mean 38.40 $t \cdot ha^{-1}$). significantly smaller yield was obtained from plants not irrigated (22.87 $t \cdot ha^{-1}$) and when irrigation was preceded by drought stress (31.47 $t \cdot ha^{-1}$).

Table 1. The effect of plants irrigation on yield of zucchini fruits

| Treatments | Yield ($t \cdot ha^{-1}$) | | | |
|---|---|---|---|---|
| | 2009 | 2010 | 2011 | mean |
| Irrigated | 41.50 ±5.4*a | 33.50 ±3.3b | 45.50 ±3.5a | 40.17a |
| Irrigated and non irrigated | 35.50 ±4.5b | 42.20 ±2.3a | 37.50 ±3.3b | 38.40a |
| Non irrigated and irrigated | 29.80 ±3.5b | 32.00 ±4.5b | 32.60 ±2.6c | 31.47b |
| Non irrigated | 21.80 ±2.0c | 24.40 ±2.4c | 22.40 ±1.8d | 22.87c |

* mean values with standard deviations
a, b, c, d statistically homogenous groups in column at $p \leq 0.05$

The attempt to determine relations between the weight of a fruit and it's length at different variants of plants irrigation was made (fig. 2–5). Regardless of the irrigation method significant values of correlation coefficient for relation between weight of a fruit and its length was noted. Higher value of correlation coefficient was observed when plants were irrigated during a whole cultivation (r = 0.97) and irrigated during vegetative growth till fruits formation (r = 0.95). Lower value for correlation between fruit weight and length was noted when plants were cultivated without irrigation (shortage of water was supplemented only by rainfalls) and in combination when irrigation was proceeded by drought stress (r = 0.81).

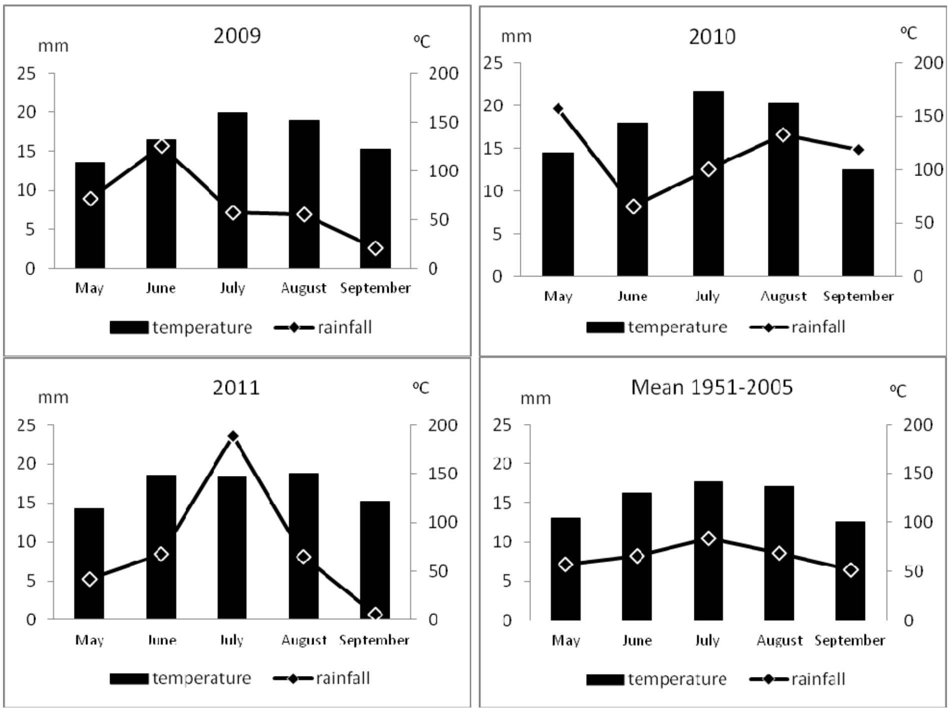


Fig. 1. The total decade and monthly rainfall and average air temperature during research, according to Felin Meteorological Station of the University of Life Sciences in Lublin

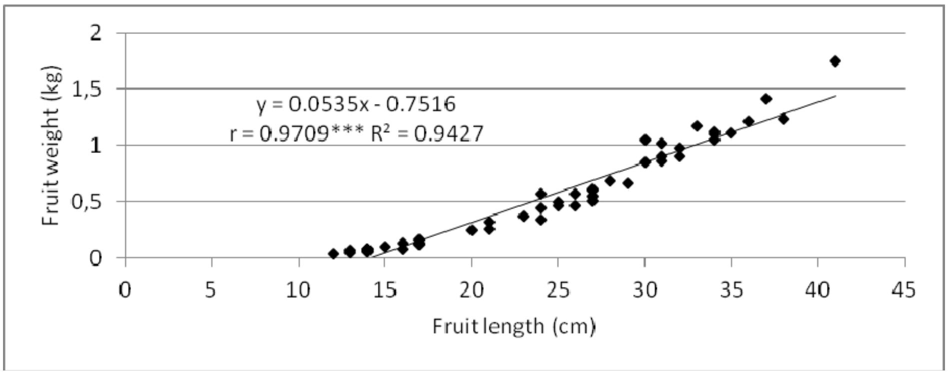


Fig. 2. The effect of plants irrigation during a whole cultivation period on zucchini fruits size (mean from 2009–2011)

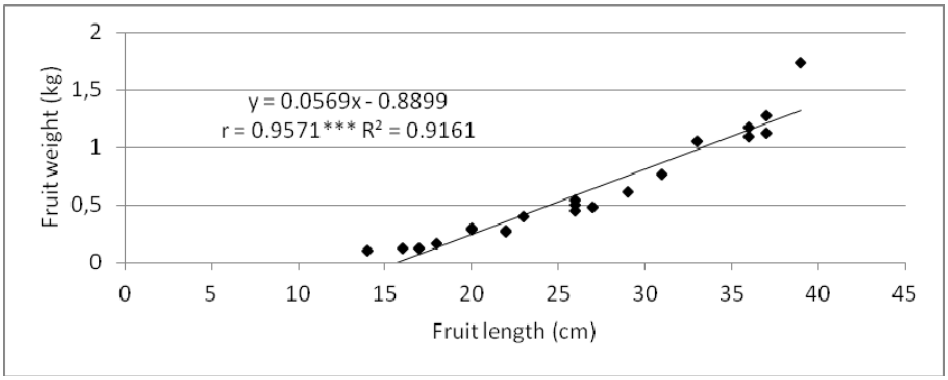


Fig. 3. The effect of plants irrigation during vegetative growth and non irrigation during yielding on zucchini fruits size (mean from 2009–2011)

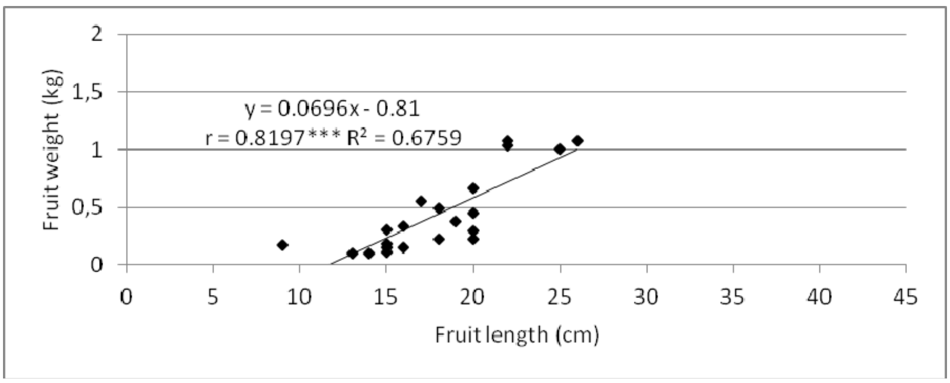


Fig. 4. The effect of plants non irrigation during vegetative growth and irrigation during yielding on zucchini fruits size (mean from 2009–2011)

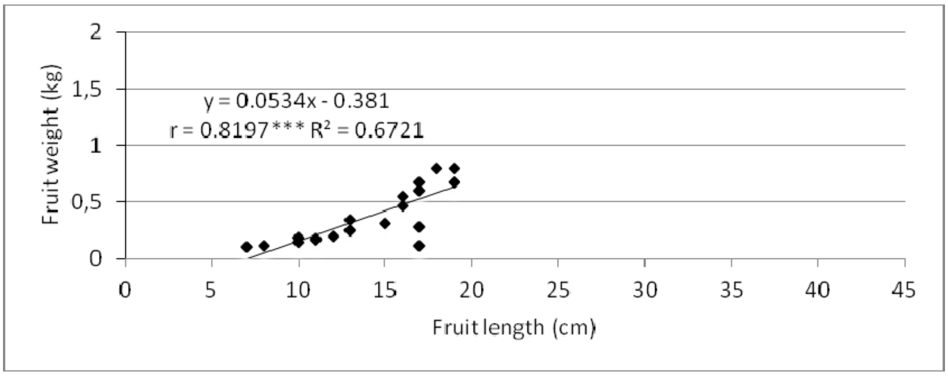


Fig. 5. The effect of plants non irrigation during a whole cultivation period on zucchini fruits size (mean from 2009–2011)

It is commonly thought that relatively low soil humidity during Cucurbitaceae flower buds initiation favours their formation. Further growth of fruit (from the moment of setting), depends mainly on continuous water supply from soil [Sałata and Stepaniuk 2012]. Reaction on water shortage in soil during this time depends on transpiration, which depends on environmental conditions [Brown and Channel-Butcher 2001, Galindo et al. 2004]. Articles relating to irrigation of Cucurbitaceae plants proved that the more intensive plants growth was observed the higher yield was obtained [Loy 2004, Nimah 2007, Robiecki and Rolbiecki 2005, Rolbiecki et al. 2005].

In the presented research, shortage of water during intensive vegetative growth of plants resulted in development of fruits of significantly lower mean weight below 1.0 kg and length not exceeding 20 cm, in comparison to fruits harvested from plants irrigated during this time. Fruits obtained from plants cultivated in optimal conditions of soil humidity were bigger and they reached 1.5 kg of weight and 35 cm of length. Big size of fruits was probably caused by favourable weather conditions during flowering, setting and development of fruits (fig. 1).

The chemical composition analysis of zucchini fruits showed differentiation of marked components depending on irrigation used in the experiment. A mean content of L-ascorbic acid was 19.58 mg·100 $g^{-1}$ of fresh weight (tab. 2). The most L-ascorbic acid contained fruits harvested from plants not irrigated (mean 22.34 mg·100 $g^{-1}$ fresh weight). Definitely less L-ascorbic acid contained fruits obtained from plants that were cultivated in the best conditions of soil humidity (mean 17.54 mg·100 $g^{-1}$ fresh weight), and those irrigated or not irrigated during vegetative growth, 19.01 and 19.46 mg·100 $g^{-1}$ fresh weight respectively.

Results of previous research regarding the effect of irrigation on chemical composition of vegetables are not unambiguous. It is essential to estimate which criteria decide about necessity of irrigation, and these are unspecified or inaccurate [Treder et al. 2010]. Research of Sorensen et al. [1995] showed that lower dose of irrigation increased content of raw fibre and vitamin C in onion. Authors, at the same time, emphasize that degree of tissue hydratation decided about chemical composition of onion. Kosterna et al. [2011] showed that irrigation of kohlrabi during a whole cultivation decreased content of vitamin C in comparison to plants not irrigated.

In the presented research fruits harvested from irrigated plants contained over twice less carotenoids (1.51 mg·100 $g^{-1}$ dry weight) in comparison to not irrigated ones (3.16 mg·100 $g^{-1}$ dry weight) (tab. 3). Maintenance of stable, optimal humidity of soil during fruitage decreased the content of carotenoids in fruits in comparison to those not irrigated during this phase. According to Galindo et al. [2004], lower content of carotenoids during irrigation is caused mainly by higher flow of these elements with water and higher diffusion.

Table 2. The effect of plants irrigation of L-ascorbic acid content in zucchini fruits

| Treatments | Ascorbic acid (mg·100 $g^{-1}$ f.w.) | | | |
|---|---|---|---|---|
| | 2009 | 2010 | 2011 | mean |
| Irrigated | 20.07 ±1.8b* | 15.89 ±0.9c | 16.67 ±1.0c | 17.54c |
| Irrigated and non irrigated | 21.67 ±1.2c | 17.54 ±1.1b | 17.81 ±1.1b | 19.01b |
| Non irrigated and irrigated | 21.38 ±1.1c | 18.34 ±2.0b | 18.66 ±1.8b | 19.46b |
| Non irrigated | 22.23 ±2.1a | 22.51 ±2.2a | 22.29 ±2.3a | 22.34a |

* see table 1

Table 3. The effect of plants irrigation on carotenoids content in zucchini fruits

| Treatments | Carotenes (mg·100 $g^{-1}$ d.w.) | | | |
|---|---|---|---|---|
| | 2009 | 2010 | 2011 | mean |
| Irrigated | 0.84 ±0.24c* | 1.67 ±0.35d | 2.03 ±0.42d | 1.51d |
| Irrigated and non irrigated | 1.86 ±0.21b | 2.39 ±0.33b | 2.98 ±0.21b | 2.41b |
| Non irrigated and irrigated | 1.78 ±0.22b | 1.93 ±0.24c | 2.53 ±0.31c | 2.08c |
| Non irrigated | 2.17 ±0.52a | 4.00 ±0.35a | 3.32 ±0.23a | 3.16a |

* see table 1

Table 4. The effect of plants irrigation on nitrates (V) content in zucchini fruits

| Treatments | Nitrates (V) (mg·$kg^{-1}$ f.w.) | | | |
|---|---|---|---|---|
| | 2009 | 2010 | 2011 | mean |
| Irrigated | 131 ±3.5a* | 194 ±3.8a | 207 ±4.5a | 177a |
| Irrigated and non irrigated | 119 ±2.1c | 170 ±3.7b | 168 ±3.2b | 152b |
| Non irrigated and irrigated | 125 ±2.2b | 108 ±3.2d | 157 ±3.0c | 130c |
| Non irrigated | 121 ±3.1b | 124 ±2.1c | 162 ±2.7c | 136c |

* see table 1

Establishment of optimal aquatic-air conditions through improvement in soil humidity during a whole cultivation of zucchini increased content of nitrates in fruits (tab. 3). In conditions of worse soil humidity from planting seedlings into the ground till fruit sets forming, plants accumulated less nitrates (V). Fruits contained 130 mg·100 $g^{-1}$ fresh weight of nitrates when plants were irrigated only during yielding, and in variant without irrigation it was 136 mg·100 $g^{-1}$ fresh weight. Few experiments relating to the effect of irrigation on yield quality show, that in cultivation of broccoli, irrigation increases effectiveness of mineral fertilization and accumulation of nitrates (V) in florets [Toivonen et al. 1994]. Kołota and Adamczewska-Sowińska [2011] noted, that quality of zucchini fruits depends on their size: plants 8–15 cm long accumulated more vitamin C, phosphorus and potassium, while fruits longer than 22 cm contained more nitrates (V) and carotenoids.

Regardless of the period of water shortage in the years of cultivation similar reactions of plants were observed, as weather conditions were alike (fig. 1). During intensive vegetative growth of zucchini plants in the years 2009–2011, temperatures significantly exceeded many years means (especially in June, July and August). In the year 2010, during growth of plants, the precipitation was lower than average as heavy rainfall exceeding by 64.2 mm monthly mean occured in August, while in the year 2011 heavy precipitation exceeded monthly mean by 105.5 mm in July and in the year 2009 in June, by 40.1 mm.

## CONCLUSIONS

Irrigation during whole cultivation period and during intensive vegetative growth phase increased yield. Cultivation in conditions of optimal water amount during growth guaranteed that plants contained less L-ascorbic acid and accumulated more nitrates in comparison to those cultivated without irrigation. Effectiveness of irrigation depended on the growth phase of plants. Plants used water more efficiently in the period from planting seedlings till appearing first fruit sets. Irrigation during a whole cultivation of zucchini and during vegetative growth caused increase in number of fruits per plant and exceeded yielding. Stimulation of generative processes through water limitation resulted from stopping growth of plants.

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## WZROST, PLON I JAKOŚĆ OWOCÓW CUKINII ODMIANY 'SORAYA' W WARUNKACH NAWADNIANIA KROPLOWEGO

**Streszczenie.** Poprawę warunków wzrostu cukinii w klimacie Polski można uzyskać przez nawadnianie kroplowe roślin. W pracy oceniono wpływ nawadniania kroplowego roślin cukinii odmiany 'Soraya' w różnym okresie ich wzrostu na wielkość owoców oraz zawartość kwasu askorbinowego, azotanów(V) i karotenów. W doświadczeniu zastosowano różne warianty nawadniania roślin: nawadnianie w całym okresie uprawy, nawadnianie w okresie wzrostu wegetatywnego do wykształcania zawiązków owoców i nienawadniane w okresie plonowania, nienawadniane w okresie wzrostu wegetatywnego do fazy wykształcania przez rośliny zawiązków owoców i nawadniane w okresie plonowania oraz nienawadniane w okresie uprawy (woda w glebie pochodziła tylko z opadu naturalnego). Znacząco większy średni plon owoców uzyskano w wariancie z nawadnianiem roślin w całym okresie uprawy (średnio 40,17 $t \cdot ha^{-1}$) oraz z nawadnianiem prowadzonym w okresie intensywnego wzrostu wegetatywnego (38,40 $t \cdot ha^{-1}$). Niezależnie od sposobu nawadniania roślin stwierdzono istotne wartości współczynnika korelacji dla zależności masy owocu od jego długości. Analiza składu chemicznego owoców cukinii wykazała zróżnicowanie badanych składników w zależności od zastosowanych kombinacji z nawadnianiem roślin. Największą ilość kwasu L-askorbinowego zawierały owoce zebrane z roślin, które nie były nawadniane. Stworzenie optymalnych warunków wodno-powietrznych przez poprawę uwilgotnienia gleby w całym okresie wzrostu roślin cukinii spowodowała zwiększenie zawartości azotanów w owocach cukinii oraz mniejszą zawartość karotenów.

**Key words:** *Cucurbita pepo* var. *giromontina* Alef., kwas L-ascorbinowy, azotany, karotenoidy

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