

## THE EFFECT OF POTASSIUM FERTILIZATION ON THE MACRONUTRIENT CONTENT OF PEPINO DULCE (*Solanum muricatum* Ait.) FRUIT

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**Abstract.** Pepino dulce is a new crop in Poland. Its fruit can be harvested at different stages of ripeness. As the majority of vegetables of the family *Solanaceae*, pepino fruit is abundant in potassium. The objective of this study was to investigate the effect of increasing potassium rates and fruit ripeness stages on macronutrient content and ratios in the fruit of pepino dulce cv. Konsuelo. Both experimental factors, i.e. potassium fertilization levels and the degree of fruit ripeness, had a significant effect on the macronutrient content of pepino dulce. The highest total nitrogen, potassium and magnesium levels were noted in the fruit of plants fertilized with potassium at a rate of 2 g per plant, while the fruit of plants fertilized with the lowest potassium rate (1 g per plant) accumulated the highest amounts of calcium. The highest phosphorus content was reported in the fruit of non-fertilized plants. Fully ripe fruit contained significantly more nitrogen and magnesium, while unripe fruit had a higher content of phosphorus, potassium and calcium. A close to optimal Ca:Mg ratio (2.4 on average), a narrow Ca:P ratio (from 0.6 to 1.7) and wide K:Mg (from 16.1 to 28.4), K:(Ca + Mg) (from 3.7 to 7.9) and K:Ca (from 4.5 to 13.6) ratios were observed in all treatments.

**Key words:** *Solanaceae*, fruit, K rate, chemical composition

### INTRODUCTION

Pepino dulce (*Solanum muricatum* Ait.) is native to South America, to the tropical and subtropical regions of the Andes, where it has been grown since prehistoric times. Today pepino dulce is cultivated mostly in the mountains of Latin America, in New Zealand, East Africa, East Asia, Australia, in the Canary Islands and in the Mediterranean region. It enjoys increasing popularity and continues to gain interest among gardeners throughout Europe, including in Poland. This is highly important as the typical Polish diet includes a few vegetable species only, and because eating a low variety of

foods with a low nutritional value is one of the main reasons for lifestyle diseases [Prohens et al. 1996, Heiser and Anderson 1999, Lost Crops of the Incas 1989, Nalborczyk 1999, Adamczyk 2002].

Pepino dulce fruit can be harvested at different stages of ripeness. Unripe (green-colored) fruit resembles the cucumber in taste, flavor and aroma. It can be consumed raw or cooked. Ripe fruit can be served as a dessert. Their taste is similar to that of melons and mangos. As the majority of vegetables of the family *Solanaceae*, pepino fruit is abundant in potassium.

The objective of this study was to investigate the effect of increasing potassium rates and fruit ripeness stages on macronutrient content and ratios in pepino dulce fruit.

## MATERIALS AND METHODS

The study was conducted in 2005–2007, in a tall, unheated, plastic tunnel at the Experimental Garden of the University of Warmia and Mazury in Olsztyn. Pepino dulce cv. Konsuelo (Gavrish) was used in the study. Pepino dulce was propagated by cuttings (10 cm in length) taken from stock plants grown from seeds in 2004. The rooted cuttings were transferred to Kick-Brauchman pots filled with 9 dm<sup>3</sup> mineral soil. Proper brown soil developed from slightly loamy sand, with pH in 1 mol KCl of 6.8 and EC of 1.1, was used in the experiment. The concentrations of available nutrients were as follows: phosphorus – 88 mg P · kg<sup>-1</sup> soil, potassium – 110 mg K · kg<sup>-1</sup> soil, magnesium – 62 mg Mg · kg<sup>-1</sup> soil. Each year the cuttings were planted in a plastic tunnel between 10 and 15 May. The growing season, from taking cuttings from stock plants until the end of harvest, lasted approximately seven months. The two-factorial experiment was performed in a completely randomized design. Experimental factors were as follows:

factor 1 – potassium rates: 1; 2; 3 g K · plant<sup>-1</sup>

factor 2 - fruit ripeness stages: ripe fruit showing a typical fully ripe color (yellowish-purple, yellow, cream), unripe green-colored fruit that has reached a typical form and size.

The experiment consisted of six treatment combinations: three potassium rates (K<sub>1</sub>, K<sub>2</sub> (1+1), K<sub>3</sub> (1+1+1) and two fruit ripeness stages. Every pot was fertilized with 2 g N (1+1) applied as CO(NH<sub>2</sub>)<sub>2</sub>, 0.5 g Mg applied as MgSO<sub>4</sub> · 7 H<sub>2</sub>O and increasing rates of K applied as K<sub>2</sub>SO<sub>4</sub>. Phosphorus fertilizers were not applied as soil was found to be rich in this element. Nitrogen, potassium and magnesium were applied as solutions. The first rate was administered three days after transferring the cuttings to pots, and the next two rates were applied at one-week intervals. Non-fertilized plants served as a control treatment.

The plants were pruned for two stems. Fruit samples for chemical analyses were collected at full ripening (in mid-August). Averaged samples from each treatment were comminuted, dried to constant weight at 65°C and ground.

The concentrations of nitrogen, phosphorus, potassium, calcium and magnesium in pepino fruit were determined. The content of total N (by the Kjeldahl method), P (by the vanadium-molybdenum method), K and Ca (by flame photometry – AES) and Mg (by atomic absorption spectrometry – AAS) was estimated following wet mineralization in

H<sub>2</sub>SO<sub>4</sub>+H<sub>2</sub>O<sub>2</sub>. The concentrations of total nitrogen, phosphorus, potassium, calcium and magnesium in pepino fruit were comparable in 2005, 2006 and 2007, which is why they are presented as mean values for the years of the study. The following weight ratios were also calculated: Ca:P, Ca:Mg, K:Mg, K:(Ca+Mg), K:Ca.

The results of chemical analyses were processed statistically by an analysis of variance (ANOVA), using Statistica 8.0 software. Mean values were compared by Duncan's test.

## RESULTS AND DISCUSSION

A statistical analysis showed that both experimental factors, i.e. potassium rates and fruit ripeness stages, had a significant effect on the content of all analyzed macronutrients in pepino dulce fruit (tab. 1). The total nitrogen content of the fruit varied widely, from 5.11 to 18.50 g · kg<sup>-1</sup> d.m. The lowest nitrogen amount was recorded in the fruit of non-fertilized plants, while the highest – in the fruit of plants fertilized with a potassium

Table 1. The effect of potassium rates and fruit ripeness stages on the macronutrient content of pepino dulce fruit

Tabela 1. Zawartość makroelementów w owocach pepino w zależności od dawki potasu oraz stopnia dojrzałości owoców

| K rates (g per plant)<br>Dawka K (g · roślin <sup>-1</sup> )  | Ripeness stage<br>Stopień dojrzałości | (g · kg <sup>-1</sup> d.m.) – (g · kg <sup>-1</sup> s.m.) |                |              |                |              |              |
|---|---------------------------------------|---|----------------|--------------|----------------|--------------|--------------|
|   |                                       | N <sub>total</sub> – N <sub>og.</sub>                     | P              | K            | Mg             | Ca           |              |
| 0   | fully ripe – dojrzałe                 | 6.24  | 2.92           | 17.06        | 0.89           | 1.63         |              |
|   | unripe – niedojrzałe                  | 5.11  | 3.03           | 18.22        | 0.85           | 2.00         |              |
| Average – Średnio   |                                       | 5.67  | 2.97           | 17.64        | 0.87           | 1.82         |              |
| 1   | fully ripe – dojrzałe                 | 9.85  | 2.23           | 17.48        | 1.01           | 1.44         |              |
|   | unripe – niedojrzałe                  | 10.70   | 2.58           | 19.60        | 0.94           | 4.40         |              |
| Average – Średnio   |                                       | 10.28   | 2.40           | 18.54        | 0.98           | 2.92         |              |
| 2   | fully ripe – dojrzałe                 | 18.50   | 2.75           | 22.38        | 1.39           | 2.26         |              |
|   | unripe – niedojrzałe                  | 13.47   | 2.90           | 26.40        | 0.98           | 3.51         |              |
| Average – Średnio   |                                       | 15.98   | 2.83           | 24.39        | 1.19           | 2.89         |              |
| 3   | fully ripe – dojrzałe                 | 17.78   | 2.66           | 22.15        | 1.17           | 1.63         |              |
|   | unripe – niedojrzałe                  | 12.50   | 3.03           | 21.55        | 0.76           | 2.37         |              |
| Average – Średnio   |                                       | 15.14   | 2.84           | 21.85        | 0.97           | 2.00         |              |
| Average for ripeness stage<br>Średnio dla stopnia dojrzałości |                                       | fully ripe – dojrzałe<br>unripe – niedojrzałe             | 13.09<br>10.44 | 2.64<br>2.88 | 19.77<br>21.44 | 1.11<br>0.88 | 1.74<br>3.07 |
| Average – Średnio   |                                       |   | 11.77          | 2.76         | 20.19          | 1.00         | 2.41         |
| LSD <sub>0.01</sub> – NIR <sub>0.01</sub>                     |                                       |   |                |              |                |              |              |
| I – fertilization – nawożenie                                 |                                       |   | 0.60           | 0.15         | 0.44           | 0.02         | 0.15         |
| II – ripeness stage – stopień dojrzałości                     |                                       |   | 0.43           | 0.11         | 0.30           | 0.01         | 0.11         |
| I × II – interaction – współdziałanie                         |                                       |   | 0.85           | 0.21         | 0.60           | 0.02         | 0.21         |

rate of  $2 \text{ g} \cdot \text{plant}^{-1}$ . Ripe fruit contained significantly more nitrogen than unripe, green-colored fruit. The phosphorus content of the analyzed plant material ranged between 2.23 and  $3.03 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$  The fruit of non-fertilized plants accumulated the largest quantity of phosphorus. Similarly as in a study by Kowalczyk and Kobryń [2002], unripe fruit was richer in phosphorus.

The potassium content of pepino fruit was within the  $17.06\text{--}26.40 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$  range, and it was influenced by both experimental factors. The highest potassium concentrations were noted in the fruit of plants fertilized with a potassium rate of  $2 \text{ g} \cdot \text{plant}^{-1}$  ( $24.39 \cdot \text{kg}^{-1} \text{ d.m.}$ ) and in unripe fruit ( $21.44 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$ ). Similar results were reported by Golcz [2001] who found that increasing potassium rates had a direct effect on an increase in the quantity of potassium in peppers. However, a drop in the content of this macronutrient was noted as a certain level of fertilization was exceeded. Kowalczyk and Kobryń [2002] demonstrated that ripe pepino fruit had a higher potassium content, and Rubio et al. [2002] as well as Kunachowicz et al. [2006] reported higher potassium concentrations in red peppers, in comparison with green. The results obtained by Bernardo et al. [2008], Flores et al. [2009] and Grembecka et al. [2008] show that green peppers contain more potassium.

In the present study, the magnesium content of pepino dulce fruit ranged from 0.76 to  $1.39 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$  The highest magnesium concentrations were determined in the fruit of plants fertilized with a potassium rate of  $2 \text{ g} \cdot \text{plant}^{-1}$ . Ripe fruit had a higher magnesium content (by 26% on average) than unripe fruit. The above results are consistent with the findings of other authors [Kowalczyk and Kobryń 2000a, 2002, Redgewell and Turner 1986]. Kowalczyk and Kobryń [2002] found that unripe pepino fruit contained more magnesium than ripe fruit. In a study by Flores et al. [2009] green peppers had a higher magnesium content than red peppers, whereas Bernardo et al. [2008], Rubio et al. [2002] and Kunachowicz et al. [2006] reported that red pepper fruit contained more magnesium.

The calcium content of pepino dulce fruit was within a wide range of 1.44 to  $4.40 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$  The quantity of this element was clearly affected by both potassium fertilization levels and fruit ripeness stages. A significantly higher calcium content was noted in pepino plants fertilized with the lowest potassium rate ( $2.92 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$ ) and, similarly as in an experiment by Kowalczyk and Kobryń [2002], in unripe fruit ( $3.07 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$ ).

The concentrations of the analyzed macronutrients in pepino dulce fruit were comparable with those reported by Kowalczyk and Kobryń [2000a, 2000b, 2002], Kowalczyk et al. [2004], and Redgewell and Turner [1986] for the same species. According to Kunachowicz et al. [2006], they were within the ranges set for other vegetables of the family *Solanaceae*.

In addition to the concentrations of mineral nutrients in the edible parts of plants, also their ratios are an important indicator of nutritive value [Kotowska and Wybieralski 1999]. According to Czapla and Nowak [1995], and Radkowski et al. [2005], the optimum ratios between macroelements in the diet of mammals should not be higher than: Ca:P – 2, Ca:Mg – 3, K:(Ca + Mg) – 1.6 – 2.2, K:Mg – 6, K:Ca – 2. Kotowska and Wybieralski [1999], and Matraszek et al. [2002] demonstrated that the above ratios may vary widely depending, among others, on the species, edible part of a plant, cultivation time and fertilization regime. Wider than optimal Ca:Mg and Ca:P ratios could be in-

dicative of magnesium and phosphorus deficiency. According to Skibniewska et al. [2007], excess phosphorus intake can lead to reduced calcium absorption, and an inadequate Ca:P ratio in the diet constitutes a risk factor for osteoporosis.

Table 2. The effect of magnesium rates and fruit ripeness stages on weight ratios between macronutrients in pepino dulce fruit

Tabela 2. Proporcje wagowe między makroelementami w owocach pepino w zależności od nawożenia potasem oraz stopnia dojrzałości

| K rates in g per plant<br>Dawka K w g · roślin <sup>-1</sup> | Ripeness stage<br>Stopień dojrzałości | K:Ca | K:Mg | Ca:P | Ca:Mg | K:(Ca+Mg) |
|--|---------------------------------------|------|------|------|-------|-----------|
| 0  | fully ripe – dojrzałe                 | 10.5 | 19.2 | 0.6  | 1.8   | 6.8       |
|  | unripe – niedojrzałe                  | 9.1  | 21.4 | 0.7  | 2.4   | 6.4       |
|  | Average – Średnio                     | 9.7  | 20.3 | 0.6  | 2.1   | 6.6       |
| 1  | fully ripe – dojrzałe                 | 12.1 | 17.3 | 0.6  | 1.4   | 7.1       |
|  | unripe – niedojrzałe                  | 4.5  | 20.9 | 1.7  | 4.7   | 3.7       |
|  | Average – Średnio                     | 6.3  | 18.9 | 1.2  | 3.0   | 4.8       |
| 2  | fully ripe – dojrzałe                 | 9.9  | 16.1 | 0.8  | 1.6   | 6.1       |
|  | unripe – niedojrzałe                  | 7.5  | 26.9 | 1.2  | 3.6   | 5.9       |
|  | Average – Średnio                     | 8.4  | 20.5 | 1.0  | 2.4   | 6.0       |
| 3  | fully ripe – dojrzałe                 | 13.6 | 18.9 | 0.6  | 1.4   | 7.9       |
|  | unripe – niedojrzałe                  | 9.1  | 28.4 | 0.8  | 3.1   | 6.9       |
|  | Average – Średnio                     | 10.9 | 22.5 | 0.7  | 2.1   | 7.4       |
| Average for ripeness stage                                   | fully ripe – dojrzałe                 | 11.4 | 17.8 | 0.7  | 1.6   | 6.9       |
| Średnio dla stopnia dojrzałości                              | unripe – niedojrzałe                  | 7.0  | 24.4 | 1.1  | 3.5   | 5.4       |
| Average – Średnio  |                                       | 8.4  | 20.2 | 0.9  | 2.4   | 5.9       |

In the present experiment (tab. 2) the Ca:P ratio was narrow in all collected pepino fruit samples, ranging from 0.6 to 1.7, regardless of potassium rates and fruit ripeness. The Ca:Mg ratio in pepino fruit was in the 1.4–4.7 range. In the majority of cases, the above ratio was satisfactory (2.4 on average). Increasing potassium rates contributed to the narrowing of the Ca:Mg ratio in unripe fruit. Such a trend was not observed in ripe fruit. The K:Mg ratio in pepino fruit was very wide, ranging from 16.1 to 28.4. As regards the nutritional quality of pepino dulce, a more favorable K:Mg ratio was noted in ripe fruit. Increasing potassium rates contributed to the widening of this ratio. The K:(Ca + Mg) ratio in pepino fruit ranged from 3.7 (1 g K, unripe fruit) to 7.9 (3 g K, ripe fruit). In all treatments the above ratio was wider than the optimal value. A more desirable K:(Ca + Mg) ratio was recorded in unripe fruit and in the fruit of plants fertilized with the lowest potassium rate. The K:Ca ratio varied within a wide range of 4.5 (1 g K, unripe fruit) to 13.6 (3 g K, ripe fruit). Similarly as in a study by Michałojć and Buczkowska [2009], increasing potassium rates contributed to the widening of the above ratio, which was closer to the optimum value in unripe fruit.

## CONCLUSIONS

1. Potassium fertilization levels and the degree of fruit ripeness, had a significant effect on the macronutrient content of pepino dulce.

2. The highest total N, K and Mg levels were noted in the fruit of pepino plants fertilized with 2 g K · plant<sup>-1</sup>. The fruit of plants fertilized with 1 g K per plant accumulated the highest amounts of Ca. The fruit of non-fertilized plants had the highest P content.

3. Fully ripe fruit contained significantly more nitrogen and magnesium, while unripe fruit had a higher content of phosphorus, potassium and calcium.

4. A close to optimal Ca:Mg ratio (2.4 on average), a narrow Ca:P ratio (from 0.6 to 1.7) and wide K:Mg (from 16.1 to 28.4), K:(Ca + Mg) (from 3.7 to 7.9) and K:Ca (from 4.5 to 13.6) ratios were observed in all treatments.

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## WPLYW NAWOŻENIA POTASEM NA ZAWARTOŚĆ MAKROELEMEN- TÓW W OWOCACH PEPINO (*Solanum muricatum* Ait.)

**Streszczenie.** Pepino jest w Polsce warzywem mało znanym. Owoce pepino można spożywać w różnych fazach dojrzałości. Jak większość warzyw z rodziny *Solanaceae* ich owoce są bogatym źródłem potasu. W doświadczeniu badano wpływ wzrastających dawek potasu oraz stopnia dojrzałości owoców pepino odmiany Konsuelo na zawartość w nich makroskładników, a także ich wzajemnych proporcji. Istotny wpływ na poziom makroelementów w owocach pepino wywarły obydwa czynniki doświadczenia – poziom nawożenia potasem oraz stopień dojrzałości owoców. Najwięcej azotu ogólnego, potasu i magnezu stwierdzono w owocach roślin nawożonych potasem w dawce 2 g na roślinę, wapnia dawką najmniejszą (1 g K na roślinę), natomiast fosforu w owocach roślin, które nie były nawożone potasem. Istotnie więcej azotu i magnezu zgromadziły owoce dojrzałe, natomiast fosforu, potasu i wapnia owoce zielone. W owocach pepino z każdego z wariantów doświadczenia zanotowano bliskie optymalnym proporcje Ca : Mg (przeciętnie 2,4), zawężone między Ca : P (od 0,6 do 1,7) oraz szerokie K : Mg (od 16,1 do 28,4), K : (Ca + Mg) (od 3,7 do 7,9) oraz K : Ca (od 4,5 do 13,6).

**Słowa kluczowe:** *Solanaceae*, owoc, dawka K, skład chemiczny

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