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THE EFFECT OF MAGNESIUM FERTILIZATION ON THE MACRONUTRIENT CONTENT OF PEPINO DULCE (*SOLANUM MURICATUM* AIT.) FRUIT

Anna Francke

Chair of Horticulture
University of Warmia and Mazury in Olsztyn

Abstract

Pepino dulce (*Solanum muricatum* Ait.) of the family *Solanaceae* is native to the tropical and subtropical regions of the Andes. Pepino dulce fruit can be harvested at different stages of ripeness. As the majority of vegetables of the family *Solanaceae,* the fruit is abundant in potassium. Since there are no fertilizer recommendations for pepino dulce grown under cover, a study was launched to determine the fertilizer requirements of this vegetable. The aim of this study was to evaluate the effect of increasing magnesium rates and fruit ripeness stages on macronutrient content and ratios in the fruit of pepino dulce cv. Konsuelo. A two-factorial experiment in a completely randomized design 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 was propagated by cuttings taken from stock plants grown from seeds in 2004. The rooted cuttings were transferred to Kick-Brauchman pots filled with 9 dm^3 mineral soil with pH 6.8. Experimental factors were as follows: I – Mg rates: 0.5, 1.0, 1.5 g Mg $plant^{-1}$, II – 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 was performed in four replications, and each replication comprised a pot with a single plant. Every pot was fertilized with 2 g N applied as $CO(NH_2)_2$, 3 g K applied as K_2SO_4 and increasing rates of Mg applied as $MgSO_4 \cdot 7\ H_2O$. 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). The concentrations of organic N, P, K, Ca and Mg in pepino fruit were determined, and the following weight ratios were 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. The highest total nitrogen and

dr inż. Anna Francke, Chair of Horticulture, University of Warmia and Mazury, 10-952 Olsztyn, ul. Prawocheńskiego 21, phone (89) 523 43 44, e-mail: afrancke@uwm.edu.pl

potassium levels were noted in the fruit of plants fertilized with the lowest magnesium rate (0.5 g Mg per plant), while the fruit of plants fertilized with the highest magnesium rate (1.5 g Mg per plant) accumulated the highest amounts of calcium and magnesium. The highest phosphorus content was reported in the fruit of non-fertilized plants. Fully ripe fruit contained significantly more nitrogen an magnesium, while unripe fruit had a higher content of phosphorus, potassium and calcium. An adequate Ca:Mg ratio, a narrow Ca:P ratio and wide K:Mg, K:(Ca + Mg) and K:Ca ratios were observed in all treatments.

Key words: *Solanum muricatum*, magnesium fertilization, macronutrients.

WPŁYW NAWOŻENIA MAGNEZEM NA ZAWARTOŚĆ MAKROELEMENTÓW W OWOCACH PEPINO (*SOLANUM MURICATUM* AIT.)

Abstrakt

Pepino (*Solanum muricatum* Ait.) należy do rodziny psiankowatych (*Solanaceae*), pochodzi z tropikalnych i subtropikalnych rejonów Andów. Owoce pepino można zbierać w różnych fazach dojrzałości. Jak w przypadku większości warzyw z rodziny *Solanaceae*, są one zasobne przede wszystkim w potas. Z powodu braku informacji o zaleceniach nawozowych do uprawy pepino pod osłonami, podjęto badania nad określeniem potrzeb nawozowych tego warzywa. Celem badań była ocena wpływu wzrastających dawek magnezu oraz stopnia dojrzałości owoców pepino na zawartość makroskładników, a także ich wzajemnych proporcji. Owoce pepino odmiany Konsuelo badano w latach 2005-2007 w wysokim nieogrzewanym tunelu foliowym, zlokalizowanym w Ogrodzie Doświadczalnym Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. Pepino uprawiano z sadzonek pędowych, które pobierano z egzemplarzy uzyskanych z wysiewu nasion w 2004 r. Po ukorzenieniu sadzonki przesadzano do wazonów typu Kick-Brauchmana napełnionych 9 dm^3 gleby mineralnej o pH 6,8. Doświadczenie przeprowadzono jako dwuczynnikowe w układzie kompletnej randomizacji. Badano wpływ czynników: I – dawka Mg: 0,5; 1; 1,5 g Mg roślinę$^{-1}$; II – stopień dojrzałości owoców: dojrzałe – wybarwione (żółtofioletowe, żółte, kremowe), niedojrzałe – wyrośnięte, ale zielone. Eksperyment prowadzono w 4 powtórzeniach, powtórzenie stanowił wazon z pojedynczą rośliną. Do każdego wazonu wprowadzono: 2 g N w postaci $CO(NH_2)_2$, 3 g K w formie K_2SO_4 oraz wzrastające dawki Mg w formie $MgSO_4 \cdot 7H_2O$. Kontrolę stanowiły rośliny bez nawożenia. Rośliny prowadzono na 2 pędy. Owoce do analiz chemicznych zbierano w pełni owocowania roślin (ok. połowy sierpnia). W owocach oznaczano zawartość Nog., P, K, Ca oraz Mg. Obliczono również wagowe proporcje – Ca:P, Ca:Mg, K:Mg, K:(Ca+Mg) oraz K:Ca. Wyniki analiz chemicznych opracowano statystycznie, stosując program Statistica 8,0 i analizę wariancji ANOVA. Najwięcej azotu ogółem i potasu stwierdzono w owocach roślin nawożonych najmniejszą (0,5 g Mg na roślinę) dawką magnezu, najwięcej wapnia i magnezu – dawką maksymalną (1,5 g Mg na roślinę), natomiast najwięcej fosforu było w owocach roślin nienawożonych magnezem. Istotnie więcej azotu i magnezu zawierały owoce dojrzałe, natomiast fosforu, potasu i wapnia – owoce niedojrzałe. W każdym z wariantów doświadczenia zanotowano prawidłowe proporcje Ca : Mg, zawężone Ca : P oraz szerokie K : Mg, K : (Ca + Mg) oraz K : Ca.

Słowa kluczowe: *Solanum muricatum*, nawożenie magnezem, makroelementy.

INTRODUCTION

Pepino dulce (*Solanum muricatum* Ait.) belongs to the family *Solanaceae* and it is closely related to the tomato, pepper and potato. It is native to South America, to the tropical and subtropical regions of the Andes, where it grows at high altitudes of up to 3 000 m a.s.l. 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, 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.

Macronutrients are building blocks for the human body whose healthy development is dependent upon their bioavailability. Magnesium is part of chlorophyll in green plants, and it helps activate many plant enzymes needed for growth. According to JĘDRZEJCZAK et al. (1999), vegetables are not a rich source of magnesium, compared with other edible plants. The deficiency of macroelements, in particular magnesium and calcium whose intake does not always meet the nutritional needs of humans and animals, may have serious health implications. Since there are no fertilizer recommendations for pepino dulce grown under cover, a study was launched to determine the fertilizer requirements of this vegetable.

The aim of this study was to evaluate the effect of increasing magnesium rates and fruit ripeness stages on macronutrient content and ratios in pepino dulce fruit.

MATERIALS AND METHODS

Pepino dulce cv. Konsuelo (Gavrish) was used in the study. A two-factorial experiment in a completely randomized design 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 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^3 mineral soil with pH 6.8. 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. Experimental factors were as follows:

I – Mg rates: 0.5, 1.0, 1.5 g Mg $plant^{-1}$;
II – 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 magnesium rates and two fruit ripeness stages). It was performed in four replications, and each replication comprised a pot with a single plant. Every pot was fertilized with 2 g N applied as $CO(NH_2)_2$, 3 g K applied as K_2SO_4 and increasing rates of Mg applied as $MgSO_4 \cdot 7H_2O$. 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 weight of an individual samples of fresh plant material was 2 000 g.

The concentrations of organic nitrogen, phosphorus, potassium, calcium and magnesium in pepino fruit were determined. The content of organic 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_2SO_4+H_2O_2. 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.

RESULTS AND DISCUSSION

A statistical analysis showed that both experimental factors, i.e. magnesium rates and fruit ripeness stages, had a significant effect on the content of all analyzed macronutrients in pepino dulce fruit (Table 1). The total nitrogen content of the fruit varied widely, from 5.11 to 17.78 g kg^{-1} d.m. The

Table 1

The effect of magnesium rates and fruit ripeness stages on the macronutrient content of pepino dulce fruit

Mg rates in g per plant	Ripeness stage	(g kg^{-1} d.m.)				
		N_{total}	P	K	Mg	Ca
0	fully ripe	6.24	2.92	17.06	0.89	1.63
	unripe	5.11	3.03	18.22	0.85	2.00
Average		5.67	2.97	17.64	0.87	1.82
0.5	fully ripe	17.78	2.66	22.15	1.17	1.63
	unripe	12.50	3.03	21.55	0.76	2.37
Average		15.14	2.84	21.85	0.97	2.00
1.0	fully ripe	7.69	1.86	14.81	0.75	0.69
	unripe	5.90	1.96	16.00	0.71	2.48
Average		6.80	1.91	15.41	0.73	1.59
1.5	fully ripe	9.85	2.34	17.90	1.12	1.13
	unripe	9.00	2.81	25.00	1.00	3.06
Average		9.43	2.58	21.45	1.06	2.09
Average for ripeness stage	fully ripe	10.39	2.44	17.98	0.98	1.27
	unripe	8.13	2.71	20.19	0.83	2.47
Average		9.26	2.58	19.09	0.91	1.87
$LSD_{0.01}$ for						
I – fertilization		0.43	0.15	0.44	0.02	0.15
II – ripeness stage		0.30	0.11	0.31	0.01	0.11
I × II – interaction		0.60	0.16	0.63	0.03	0.22

lowest nitrogen amount was recorded in the fruit of non-fertilized plants, while the highest – in the fruit of plants fertilized with the lowest magnesium rate. Ripe fruit contained significantly more nitrogen than unripe, green-colored fruit. The phosphorus content of the analyzed plant material ranged between 1.86 and 3.03 g kg^{-1} d.m. The fruit of non-fertilized plants accumulated the largest quantity of phosphorus. Similarly as in a study by Kowalczyk, Kobryń (2002), unripe fruit was richer in phosphorus.

The potassium content of the edible parts of pepino plants was within the 14.81-25.00 g kg^{-1} d.m. range, and it was influenced by both experimental factors. The highest potassium concentrations were noted in the fruit of plants fertilized with the lowest magnesium rate (21.85 g kg^{-1} d.m.) and in unripe fruit (20.19 g kg^{-1} d.m.). Kowalczyk, Kobryń (2002) demonstrated that ripe pepino fruit had a higher potassium content, and Rubio et al. (2002) 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 0.71 to 1.17 g kg^{-1} d.m. Magnesium fertilization levels had a significant effect on the amount of this macronutrient accumulated in fruit. The highest magnesium concentrations were determined in the fruit of plants fertilized with the highest magnesium rate. Ripe fruit had a higher magnesium content (by 18% on average) than unripe fruit. The above results are consistent with the findings of KOWALCZYK, KOBRYŃ (2000a, 2002), REDGEWELL, TURNER (1986). KOWALCZYK, 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) and RUBIO et al. (2002) reported that red pepper fruit contained more magnesium.

The calcium content of pepino dulce fruit was within a wide range of 0.69 to 3.06 g kg^{-1} d.m. The quantity of this element was clearly affected by both magnesium fertilization levels and fruit ripeness stages. A significantly higher calcium content was noted in pepino plants fertilized with the highest magnesium rate (2.09 g kg^{-1} d.m.) and, similarly as in an experiment by KOWALCZYK, KOBRYŃ (2002), in unripe fruit (2.47 g kg^{-1} d.m.).

The concentrations of the analyzed macronutrients in pepino dulce fruit were comparable with those reported by KOWALCZYK, KOBRYŃ (2000a,b, 2002), KOWALCZYK et al. (2004) and REDGEWELL, TURNER (1986) for the same species.

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, WYBIERALSKI 1999). According to CZAPLA, 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 indicative of magnesium and phosphorus deficiency.

The Ca : P ratio was narrow in all collected pepino fruit samples, ranging from 0.4 to 1.3, regardless of magnesium rates and fruit ripeness. The Ca : Mg ratio in pepino fruit was adequate. In the majority of cases, the ratios of macronutrients in unripe fruit were highly satisfactory (3.0 on average). In ripe fruit the investigated ratios were narrower, within the 0.9-1.8 range. Increasing magnesium rates contributed to the widening of the above ratios in unripe fruit, and to their narrowing in ripe fruit. The K : Mg ratio in pepino fruit was very wide, ranging from 16.0 to 28.4. As regards the nutritional quality of pepino dulce, a more favorable K : Mg ratio was noted in unripe fruit. Increasing magnesium rates contributed to the narrowing of this ratio. The K : (Ca + Mg) ratio in pepino fruit ranged from 5.0 (1.0 g Mg, unripe fruit) to 10.3 (1.0 g Mg, ripe fruit). In all cases the above ratio was much wider than the optimal value. A more desirable K: (Ca + Mg)

ratio was recorded in unripe fruit. Magnesium fertilization had no significant effect on the proportions between the above macronutrients. The K : Ca varied within the widest range of 6.5 (1 g Mg, unripe fruit) to 21.5 (1 g Mg, ripe fruit). This ratio was determined primarily by the degree of fruit ripeness, while magnesium rates were of lesser importance (Table 2).

Table 2

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

Mg rates in g per plant	Ripeness stage	K : Ca	K : Mg	Ca : P	Ca : Mg	K : (Ca+Mg)
0	fully ripe	10.5	19.2	0.6	1.8	6.8
	unripe	9.1	21.4	0.7	2.4	6.4
Average		9.7	20.3	0.6	2.1	6.6
0.5	fully ripe	13.6	18.9	0.6	1.4	7.9
	unripe	9.1	28.4	0.8	3.1	6.9
Average		10.9	22.5	0.7	2.1	7.4
1.0	fully ripe	21.5	19.7	0.4	0.9	10.3
	unripe	6.5	22.5	1.3	3.5	5.0
Average		9.7	21.1	0.8	2.2	6.6
1.5	fully ripe	15.8	16.0	0.5	1.0	8.0
	unripe	8.2	25.0	1.1	3.1	6.2
Average		10.3	20.2	0.8	2.0	6.8
Average for ripeness stage	fully ripe	14.2	18.3	0.5	1.3	8.0
	unripe	8.2	24.3	0.9	3.0	6.1
Average		10.2	21.0	0.7	2.1	6.9

CONCLUSIONS

1. Magnesium rates and fruit ripeness stages had a significant effect on the macronutrient content of pepino dulce fruit.

2. The highest total nitrogen and potassium levels were noted in the fruit of plants fertilized with the lowest magnesium rate (0.5 g Mg per plant), while the fruit of plants fertilized with the highest magnesium rate (1.5 g Mg per plant) accumulated the highest amounts of calcium and magnesium. The highest phosphorus content was reported in the fruit of non-fertilized plants.

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

4. An adequate Ca : Mg ratio, a narrow Ca : P ratio and wide K : Mg, K : (Ca + Mg) and K : Ca ratios were observed in all treatments.

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