J. Elem. s. 351–360

DOI: 10.5601/jelem.2014.19.1.638

EFFECT OF FLAT COVERS ON MACRONUTRIENT CONCENTRATIONS IN ARUGULA LEAVES

Anna Francke

Chair of Horticulture
University of Warmia and Mazury in Olsztyn

Abstract

Arugula is a common name for several leafy vegetable species of the family Brassicaceae, characterized by a strong aroma and pungent peppery flavor. The perennial wall rocket *Diplotaxis tenuifolia* (L.) D.C. and the annual salad rocket *Eruca sativa* Mill. are grown commercially for human consumption. The objective of this study was to determine the effect of two types of flat covers, perforated PE film and non-woven PP fabric, on macroelement concentrations in arugula leaves. A two-factorial experiment was conducted in 2006 - 2008 in the Experimental Garden of the University of Warmia and Mazury in Olsztyn. The experimental factors were: (1) plant species *Diplotaxis tenuifolia* (L.) D.C. and *Eruca sativa* Mill., (2) the type of plant cover perforated PE film with 100 openings per m^2 and non-woven PP fabric with surface density of 17 g m^{-2}; plants grown without protective covers served as control. Arugula was grown on proper black earth soil of quality class IIIb and cereal-fodder strong complex. Each year, seeds were sown in the middle of April. After planting out in the field, the seedlings were covered with PE film or non-woven PP fabric. The covers were removed after approximately five weeks. Leaves were harvested gradually over the growing season, one to three times from each treatment. The concentrations of mineral compounds were determined in dried plant material from the first harvest, as follows: total nitrogen – by the Kjeldahl method, phosphorus – by the vanadium molybdate method, potassium and calcium – by emission flame photometry (EFP), magnesium – by atomic absorption spectrometry (AAS). The concentrations of all analyzed macroelements in arugula leaves were significantly affected by both plant species and the type of cover. Leaves of *Diplotaxis tenuifolia* (L.) D.C. had a higher content of phosphorus, potassium and calcium, whereas leaves of *Eruca sativa* Mill. accumulated more total nitrogen and magnesium. Leaves of arugula plants covered with non-woven PP fabric contained the highest concentrations of phosphorus, potassium, calcium and magnesium, while plants covered with PE film had the highest total nitrogen content. The Ca:P, Ca:Mg and K:Mg ratios were wide in all treatments. The K:(Ca+Mg) and K:Ca ratios were relatively narrow, but they remained within the normal range.

Keywords: *Diplotaxis tenuifolia* (L.) D.C.*,* *Eruca sativa* Mill.*,* perforated PE film, non-woven PP fabric.

---

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

ZAWARTOŚĆ MAKROELEMENTÓW W LIŚCIACH RUKOLI W ZALEŻNOŚCI OD RODZAJU ZASTOSOWANYCH OSŁON PŁASKICH

Abstrakt

Rukola to wspólna handlowa nazwa kilku gatunków warzyw należących do rodziny Brassicaceae o jadalnych liściach. Charakteryzują się one wyrazistym aromatem i ostrym gorzkawym smakiem. Największe znaczenie gospodarcze mają dwa z nich – bylina *Diplotaxis tenuifolia* (L.) D.C. (dwurząd wąskolistny) oraz gatunek jednoroczny *Eruca sativa* Mill. (rokietta siewna). Celem badań była ocena wpływu płaskiego osłaniania folią perforowaną i włókniną polipropylenową na zawartość makroelementów w liściach rukoli. Dwuczynnikowe doświadczenie przeprowadzono w latach 2006-2008 na polu Ogrodu Doświadczalnego Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. Badanymi czynnikami były: gatunek rośliny – *Diplotaxis tenuifolia* (L.) D.C. i *Eruca sativa* Mill. oraz rodzaj stosowanych osłon – folia perforowana o 100 otworach na 1 m^2, włóknina polipropylenowa o masie 17 g m^{-2}; rośliny uprawiane bez osłon stanowiły obiekt kontrolny. Rukolę uprawiano na glebie typu czarna ziemia właściwa, zaliczonej do klasy bonitacyjnej IIIb, należącej do kompleksu zbożowo-pastewnego mocnego. Nasiona każdego roku wysiewano w połowie kwietnia. Bezpośrednio po siewie poletka przykrywano osłonami, które zdejmowano po ok. 5 tygodniach. Liście zbierano w miarę ich dorastania, od 1 do 3 razy z każdego wariantu doświadczenia. Analizy na zawartość składników mineralnych wykonywano w materiale suchym z pierwszych zbiorów. Oznaczenia zawartości azotu ogółem dokonano metodą Kjeldahla, fosforu – metodą wanadowo-molibdenową, potasu i wapnia – metodą emisyjnej spektrometrii fotometrii płomieniowej (ESA), natomiast magnezu – metodą absorpcyjnej spektrometrii atomowej (ASA). Na zawartość wszystkich makroelementów w liściach rukoli istotny wpływ wywarły zarówno cechy gatunku, jak i rodzaj osłony. Liście *Diplotaxis tenuifolia* (L.) D.C. zawierały więcej fosforu, potasu i wapnia, natomiast liście *Eruca sativa* Mill. więcej azotu ogółem i magnezu. Najwięcej fosforu, potasu, wapnia i magnezu oznaczono w liściach roślin osłanianych włókniną, natomiast azotu ogółem – folią perforowaną. Proporcje Ca:P, Ca:Mg oraz K:Mg we wszystkich wariantach doświadczenia były szerokie, natomiast K:(Ca+Mg) oraz K:Ca były zawężone, niemniej jednak mieściły się w przedziale wartości, które są uznawane za prawidłowe.

Słowa kluczowe: *Diplotaxis tenuifolia* (L.) D.C., *Eruca sativa* Mill., folia perforowana, włóknina polipropylenowa.

INTRODUCTION

The structure of vegetable consumption in Poland shows that only a few vegetable species are consumed in larger amounts. Despite their high nutritional value, leafy vegetables are not fully appreciated in our country. In modern culture, leafy vegetables are a vital component of a healthy and balanced diet. The total area under vegetable cultivation and the consumption levels of vegetable species, including less popular ones, have been steadily increasing (Adamczyk 2002, Kawashima, Valente-Soares 2003, Dyduch, Najda 2005).

Arugula is a common name for several leafy vegetable species of the family *Brassicaceae*, characterized by a peppery taste and pungent flavor. The perennial *Diplotaxis tenuifolia* (L.) D.C., known by the common name of wall rocket, and the annual *Eruca sativa*, commonly known as salad rocket, are grown commercially for human consumption. The above species differ with respect to biological characteristics and structure, yet their properties and uses as well as cultivation methods are identical. Arugula has been grown since the Roman times. Once forgotten, it has only recently been rediscovered. Today, arugula is grown as a leafy vegetable and a spice plant mainly in the Mediterranean region, Central Asia and the USA. Arugula leaves can be eaten raw in a salad, added to sandwiches or mixed with cottage cheese. Because of its exceptionally strong flavor, arugula is often used in mixed salads, including the Mesclun salad mix, pizzas and spaghetti. Arugula can be served stewed, cooked and fried (MORALES, JANICK 2002, MORALES et al. 2006, HALL et al. 2012). Apart from its culinary uses, arugula is highly valued for its medicinal and therapeutic properties (stimulating, anti-scurvy, diuretic, promoting the passage of foods through the digestive tract) (PIGNONE 1997). Arugula leaves contain healthy compounds, which play an important role in the prevention of neoplastic diseases, in particular the colorectal cancer (NITZ, SCHNITZLER 2002, BARILLARI et al. 2005, MELCHINI et al. 2009, D'ANTUONO et al. 2008).

In both animals and plants, macroelements have an important body building function. Compared with other edible plants, vegetables are a rich source of calcium and potassium, but their magnesium content is relatively low. Macronutrient deficiencies can have serious health consequences in humans and animals. Magnesium and calcium shortages are among the most common mineral deficiencies, since their dietary intake levels are often inadequate and insufficient to meet the requirements of healthy individuals (JĘDRZEJCZAK et al. 1999).

According to SIWEK and LIBIK (2005), as well as MAJKOWSKA-GADOMSKA (2010), plastic covers improve thermal conditions in the formative region of a plant. Higher temperatures stimulate the plant growth, development of roots and mineral uptake (SZULC, KRUCZEK 2008).

The aim of this study was to determine the effect of two types of flat covers, perforated PE film and non-woven PP fabric, on macronutrient concentrations in arugula leaves.

MATERIAL AND METHODS

A field experiment in a split-plot design with three replications was conducted in the Garden of the Agricultural Research and Experimental Station of the University of Warmia and Mazury in Olsztyn (20°29´E, 53°45´N; 125 m a.s.l.) in 2006-2008. The experimental factors were as follows:

- plant species: *Diplotaxis tenuifolia* (L.) D.C. (wall rocket) supplied by Enza Zaden, and *Eruca sativa* Mill. (salad rocket) from Hortag Seed;
- type of plant cover: perforated PE film with 100 openings per m^2 and

non-woven PP fabric with the surface density of 17 g m^{-2}; plants grown without protective covers served as the control.

All plants were grown on typical black earth soil of quality class IIIb and cereal-fodder strong complex (*Classification* ... 1989). Our analysis of the chemical composition of soil prior to the experiment revealed the following levels of mineral nutrients: N-NO_3 – 32, P – 121, K – 97, Ca – 2340, Mg – 166 and Cl – 11 (mg dm^{-3}). Based on the soil nutrient analysis, 90 kg N ha^{-1} (ammonium nitrate) and 50 kg K ha^{-1} (60% KCl, because of a relatively high potassium content) were applied before sowing the seeds. Phosphates were not used. The recommended tillage treatments were applied.

Each year, seeds were sown in mid-April. The plot surface area was 1.0 m^2 and the row spacing was 20 cm. Immediately after sowing the seeds, the plots were covered with PE film or non-woven PP fabric. The covers were removed after approximately five weeks. The plots were weeded by hand whenever needed. Leaves were harvested progressively over the growing season, one to three times from each treatment. The mineral content was determined in dry plant material collected during the first harvest season, in three replications. Averaged leaf samples from each treatment were dried to constant mass at 65°C and then ground. The plant material was wet mineralized in H_2SO_4+H_2O_2, and analyzed to determine the content of total nitrogen by the Kjeldahl method, phosphorus by the vanadium-molybdate method, potassium and calcium by atomic emission spectroscopy (AES), and magnesium by atomic absorption spectrometry (AAS). The following mineral ratios were also calculated: Ca:P, Ca:Mg, K:Mg, K:(Ca+Mg), and K:Ca.

The results were processed statistically by Anova, using the Statistica 10 software. The significance of differences between means was evaluated by constructing the Tukey's confidence intervals at α = 0.05.

RESULTS AND DISCUSSION

Both experimental factors had a significant effect on the macronutrient content of arugula leaves (Table 1). The macronutrient levels in the analyzed plant material were similar to those determined in leaves of *Eruca sativa* Mill. and *Diplotaxis tenuifolia* (L.) D.C. by CAVARIANNI et al. (2008) and BOZOKALFA et al. (2009), and in leaves of *Eruca sativa* Mill. reported by ACIKGOZ (2011), ESIYOK et al. (1999), NURZYŃSKA-WIERDAK (2009), BARLAS et al. (2011), KAWASHIMA AND VALENTE-SOARES (2003). The total nitrogen content of arugula leaves ranged from 25.71 (plots without covers) to 36.52 g kg^{-1} d.m. (*Eruca sativa* Mill. covered with perforated PE film). Average total nitrogen concentrations were higher in *Eruca sativa* Mill. than in *Diplotaxis tenuifolia* (L.) D.C. A slightly higher nitrogen content was determined in *D. tenuifolia* (L.) D.C. by SANTAMARIA et al. (2002), but the difference was sta-

Table 1

Concentrations of selected macronutrients in arugula leaves depending on the species and type of plant cover

Species	Type of plant cover	(g kg^{-1} d.m.)				
		N_{total}	P	K	Mg	Ca
Diplotaxis tenuifolia (L.) D.C.	PE film non-woven PP fabric without cover	35.08 32.20 25.71	7.45 8.28 6.91	29.33 30.38 26.01	3.03 3.53 2.29	32.52 39.41 28.34
Mean		31.00	7.55	28.57	2.95	33.43
Eruca sativa Mill.	PE film non-woven PP fabric without cover	36.53 31.48 29.32	6.82 7.37 7.91	28.03 27.77 27.78	3.45 3.79 4.17	28.59 31.79 34.74
Mean		32.44	7.37	27.86	3.80	31.70
Mean for type plant cover	PE film non-woven PP fabric without cover	35.81 31.84 27.51	7.13 7.83 7.44	28.68 29.08 26.89	3.24 3.66 3.23	30.56 35.60 31.54
$LSD_{0.05}$ species type of cover interaction		 0.74 0.91 1.28	 0.11 0.13 0.18	 0.26 0.32 0.45	 0.05 0.06 0.08	 0.45 0.55 0.78

tistically insignificant. The leaves of arugula plants grown in covered plots had a higher total nitrogen content, irrespective of the cover type. The same trend was observed by ORŁOWSKI et al. (2005) in bunch harvested shallots. In a study by BŁAŻEWICZ-WOŹNIAK (2010), leaves of fennel plants grown in plots covered with black PF film had a lower total nitrogen content, whereas leaves of plants covered with black PP non-woven fabric had a higher nitrogen content than leaves of fennel plants grown without covers. Contrary results were reported by JADCZAK et al. (2006), who found that basil plants in control plots accumulated the largest amounts of total nitrogen.

The phosphorus concentrations in arugula leaves were determined in the range of 6.82 to 8.28 g kg^{-1} d.m., in the following order: *D. tenuifolia* (L.) D.C. covered with non-woven PP fabric > *E. sativa* Mill. without covers > *D. tenuifolia* (L.) D.C. covered with PE film > *E. sativa* Mill. covered with non-woven PP fabric > *D. tenuifolia* (L.) D.C. without covers > *E. sativa* Mill. covered with PE film. Unlike in a study by CAVARIANNI et al. (2008), *Diplotaxis tenuifolia* (L.) D.C. accumulated larger amounts of phosphorus. BOZOKALFA et al. (2009) reported no differences in the phosphorus content between the analyzed species. PE film contributed to a decrease, and non-woven PP fabric to an increase in phosphorus concentrations in arugula leaves, as compared with plants grown in plots without covers. BŁAŻEWICZ-WOŹNIAK (2010) demonstrated that the use of covers decreased the phosphorus content of the edible parts of fennel. ORŁOWSKI et al. (2005), and BIESIADA and KĘDRA (2012) reported that flat covers contributed to an increase in phosphorus levels in shallots and dill, respectively. Protective covers had no effect on the phosphorus content of basil leaves (JADCZAK et al. 2006).

The potassium content of arugula leaves ranged from 26.01 to 30.38 g kg^{-1} d.m. In the current study, unlike in experiments carried out by CAVARIANNI et al. (2008) and BOZOKALFA et al. (2009), the leaves of *Diplotaxis tenuifolia* (L.) D.C had a higher potassium content. The highest potassium concentrations were found in plant samples collected from plots covered with non-woven PP fabric, which is consistent with the findings of BŁAŻEWICZ-WOŹNIAK (2010) who studied fennel bulbs, and of BIESIADA and KĘDRA (2012) who analyzed dill leaves. Different results were reported by JADCZAK et al. (2006) and ORŁOWSKI et al. (2005), who noted the lowest potassium levels in the edible parts of basil and shallot plants covered with non-woven PP fabric, respectively.

Magnesium concentrations in arugula leaves were determined in a relatively wide range of 2.29 to 4.17 g kg^{-1} d.m., and *Eruca sativa* Mill. grown in control plots had the highest magnesium content. Magnesium levels were considerably affected by the plant species. In the present study, the magnesium content was on average nearly 29% higher in the leaves of *Eruca sativa* Mill., which corroborates the findings of CAVARIANNI et al. (2008). Non-woven PP fabric had a positive effect on magnesium accumulation in arugula leaves. ORŁOWSKI et al. (2005), JADCZAK et al. (2006), and BIESIADA and KĘDRA (2012) demonstrated that flat covers had no influence on magnesium levels in the edible parts of the analyzed vegetable species.

The calcium concentrations in arugula leaves ranged from 28.34 to 39.41 g kg^{-1} d.m. The highest calcium content was determined in plant samples collected from plots covered with non-woven PP fabric, where it was by 16% and nearly 9% higher than in plots covered with PE film and in plots without covers, respectively; the noted differences were significant. BŁAŻEWICZ-WOŹNIAK (2010) in a study of fennel bulbs and ORŁOWSKI et al. (2005) in a study of shallots reported that plants covered with PE film had the lowest calcium content. However, JADCZAK et al. (2006) demonstrated that basil plants grown under PE film contained the highest calcium concentrations. In the current experiment, the leaves of *D. tenuifolia* (L.) D.C. were higher in calcium, which is in agreement with the findings of CAVARIANNI et al. (2008). According to BOZOKALFA et al. (2009), calcium levels are similar in both species.

The use of perforated PE film and non-woven PP fabric caused an increase in soil temperature. The highest temperature rise was observed in plots covered with PE film, compared with the control treatment. Soil temperature increased from 1.7 to 3.6°C at a depth of 5 cm, and from 1.2 to 2.8°C at a depth of 10 cm (FRANCKE 2011). Based on long-term observations, SZULC and KRUCZEK (2008) concluded that temperature is one of the key factors that determined the mineral uptake. In the present study, arugula plants grown under flat covers contained more total nitrogen, potassium and magnesium than plants harvested from control plots without covers, regardless of a cover type. The edible parts of arugula plants covered with non-woven PP fabric had the highest phosphorus and magnesium levels. Phosphorus and magnesium concentrations in the leaves of plants grown under PE film were lower, compared with plots covered with non-woven PP fabric and control plots.

The nutritional value of edible plant parts is determined by their mineral content and nutrient ratios (Kotowska, Wybieralski 1999). According to Czapla and Nowak (1995) and Radkowski et al. (2005), the optimal macronutrient ratios in edible plants are as follows: Ca:P – 2, Ca:Mg – 3, K:(Ca+Mg) – 1.6 – 2.2, K:Mg – 6, and K:Ca – 2. The above ratios may vary widely depending on various factors such as a plant species, the part(s) sampled, degree of ripeness, planting and harvesting times and fertilization levels (Wróbel, Marska 1998, Kotowska, Wybieralski 1999, Matraszek et al. 2002, Michałojć, Buczkowska 2009, Francke 2010*a*,*b*). Wider than optimal Ca:Mg and Ca:P ratios are indicative of nutritional magnesium and/or phosphorus deficiency. Irrespective of the species and cover type, the Ca:P ratios in arugula leaves remained on a similar level, ranging between 4.2 and 4.8, thus being wider than optimal. The Ca:Mg ratios in the analyzed plant material were also broadened in all the treatments (8.3-12.4). More desirable values of the above ratios were noted in *Eruca sativa* Mill. The use of flat covers, regardless of their type, improved the proportions between the analyzed macronutrients (Table 2). Widely varying Ca: Mg ratios were also noted in tree onions by Jadczak (2005). Quantitative K:Mg ratios in arugula leaves were wider than optimal, ranging from 6.7 to 11.4, and the most desirable values were observed in *E. sativa* Mill. grown

Table 2

Ratios between macronutrients in arugula leaves depending on the species and type of plant cover

Species	Type of plant cover	K:Ca	K:Mg	Ca:P	Ca:Mg	K:(Ca+Mg)
Diplotaxis tenuifolia (L.) D.C.	PE film	0.9	9.7	4.4	10.7	0.8
	non-woven PP fabric	0.8	8.6	4.8	11.2	0.7
	without cover	0.9	11.4	4.1	12.4	0.8
Mean		0.9	9.9	4.4	11.4	0.8
Eruca sativa Mill.	PE film	1.0	8.1	4.2	8.3	0.9
	non-woven PP fabric	0.9	7.3	4.3	8.4	0.8
	without cover	0.8	6.7	4.4	8.3	0.7
Mean		0.9	7.4	4.3	8.3	0.8
Mean for type plant cover	PE film	1.0	8.9	4.3	9.5	0.9
	non-woven PP fabric	0.9	8.0	4.6	9.8	0.8
	without cover	0.9	9.1	4.3	10.4	0.8
Mean		0.9	8.7	4.4	9.9	0.8

without covers. The K:Mg ratio was more favorable in *Eruca sativa* Mill. (7.4 on average). The use of non-woven PP fabric improved the values of the above ratio. The K:Ca ratios in arugula leaves were comparable in all treatments, at 0.8-1.0, and never exceeded the optimal level. The edible parts of *D. tenuifolia* (L.) D.C. and *E. sativa* Mill. were characterized by identical K:Ca ratios. The use of PE film had a positive albeit small effect on the proportions between the above macronutrients. Analogous relationships were observed for the K:(Ca + Mg) ratios, which were similar in the studied species. The use of PE film insignificantly improved their values. In a study by Jadczak (2005), the K:(Ca + Mg) ratio varied depending on the age and organ(s) of tree onions. The most desirable values of the above ratio were noted in onion leaves, where they remained within the normal limits, similarly to arugula leaves in the present experiment. The K:(Ca + Mg) ratios in other edible parts of tree onions were substantially wider.

CONCLUSIONS

1. Macronutrient concentrations in arugula leaves were significantly affected by both experimental factors, i.e. the plant species and cover type.

2. The leaves of *Diplotaxis tenuifolia* (L.) D.C. had higher concentrations of phosphorus, potassium and calcium, whereas the leaves of *Eruca sativa* Mill. had a higher content of total nitrogen and magnesium.

3. The use of flat covers increased the accumulation of macronutrients in the edible parts of arugula plants. The leaves of plants covered with non-woven PP fabric had the highest concentrations of phosphorus, potassium, calcium and magnesium, and plants protected with PE film had the highest total nitrogen content.

4. The Ca:P, Ca:Mg and K:Mg ratios were broader in all the treatments. The K:(Ca+Mg) and K:Ca ratios remained within the normal ranges.

REFERENCES

Acikgoz F. E. 2011. *The effects of different sowing time practices on Vitamin C and mineral material content for rocket (Eruca vesicaria subsp. sativa (*Mill*)).* Sci. Res. Essays, 6(15): 3127-3131.

Adamczyk G. 2002. *Selected aspects of consumer behaviour and dietary patterns in Polish households in the 1990s*. Rocz. AR Poznań CCCXLIII, Ekon., 1: 31-41. (in Polish)

Barillari J., Canistro D., Paolini M., Ferroni F., Pedulli G.F., Iori R., Valgimigli L. 2005. *Direct antioxidant activity of purified glucoerucin, the dietary secondary metabolite contained in rocket (Eruca sativa* Mill.*) seeds and sprouts.* J. Agric. Food Chem., 53: 2475-2482.

Barlas N. T., Irget M. E., Tepecik M. 2011. *Mineral content of the rocket plant (Eruca sativa).* Afr. J. Biotechnol., 10(64): 14080-14082.

Biesiada A., Kędra K. 2012. *The effect of emergence-improving treatments on the growth, yield* *and content of macroelements in leaves of garden dill (Anethum graveolens* L.*) cultivated for early crop*. Acta Sci. Pol., Hort. Cult., 11(4): 89-100.

BŁAŻEWICZ-WOŹNIAK M. 2010. *Effect of soil and plant covering as well as sowing term upon fennel bulb nutritional value.* Acta Sci. Pol., Hort. Cult., 9(1): 3-12.

BOZOKALFA M. K., YAGMUR B., ILBI H., ESIYOK D. KAVAK S. 2009. *Genetic variability for mineral concentration of Eruca sativa L. and Diplotaxis tenuifolia L. accessions.* Crop Breed. Appl. Biotechnol., 9: 372-381.

CAVARIANNI R.L., FILHO A.B.C., CAZETTA J.O., MAY A., CORRADI M.M. 2008. *Nutrient contents and production of rocket as affected by nitrogen concentrations in the nutritive solution.* Sci. Agric., 65(6): 652-658.

CZAPLA J., NOWAK G. 1995. *Yields and yield quality at differentiated potassium, sodium, calcium and magnesium nutrition.* Part II. *Oat*. Acta Acad. Tech. Olst. Agric., 61: 101-107. (in Polish)

D'ANTUONO L.F., ELEMENTI S., NERI R. 2008. *Glucosinolates in Diplotaxis and Eruca leaves: Diversity, taxonomic relations and applied aspects.* Phytochemistry, 69: 187-199.

DYDUCH J., NAJDA A. 2005: *Changes in the content of dry matter and L-ascorbic in leaves of two cultivars of stalk celery (Apium graveolens* L. *var. dulce* Mill/Pers.*) depending on the age of harvested plants and soil litter cover.* Zesz. Nauk AR Wrocław, Rol., 86(515): 111-119. (in Polish)

EŞIYOK D., OKUR B., DELIBACAK S., DUMAN I. 1999. *Effect of manure doses and growth media on the productivity and mineral composition of rocket leaves (Eruca sativa).* Develop. Plant Soil Sci., 86: 237-240.

FRANCKE A. 2010*a*. *The effect of magnesium fertilization on the macronutrient content of pepino dulce (Solanum muricatum Ait.) fruit*. J. Elem., 15(3): 467-475.

FRANCKE A. 2010*b*. *The effect of potassium fertilization on the macronutrient content of pepino dulce (Solanum muricatum Ait.) fruit.* Acta Sci. Pol., Hort. Cult., 9(3): 51-57.

FRANCKE A. 2011. *The effect of flat covers on the quantity and quality of arugula yield.* Acta Sci. Pol., Hort. Cult., 10(4): 3-14.

HALL M. K.D., JOBLING J. J., ROGERS G. S. 2012. *Some perspectives on rocket as a vegetable crop: A review.* Veg. Crops Res. Bull., 76: 21-41.

JADCZAK D. 2005. *Effect of some agronomic factors on yields and nutritional value of tree onion.* Wyd. AR w Szczecinie, Rozprawy, 228. (in Polish)

JADCZAK D., BŁASZCZUK A., REKOWSKA E. 2006. *Effect of covering on the content of macroelements in yield of basil (Ocimum basilicum* L.*) cultivated for a bunch harvest*. J. Elementol., 11(2): 135-141.

JĘDRZEJCZAK R., RĘCZAJSKA W., SZTEKE B. 1999. *Magnesium and other macronutrients in edible plant produce.* Biul. Magnezol., 4(1): 72-76. (in Polish)

KAWASHIMA L.M., VALENTE-SOARES L.M. 2003. *Mineral profile of raw and cooked leafy vegetables consumed in Southern Brazil.* J. Food Comp. Anal., 16(5): 605-611.

KOTOWSKA J., WYBIERALSKI J. 1999. *The shaping of quantitative ratios between K, Ca and Mg in soil and in plants.* Biul. Magnezol., 4(1): 104-110. (in Polish)

MAJKOWSKA-GADOMSKA J. 2010. *Studies on the direct effect of plant covers and soil liter cover on the growth, developent and yields of melonds (Cucumis melo* L.*).* Wyd. UWM Olsztyn, Rozpr. i Monogr., 159. (in Polish)

MATRASZEK R., SZYMAŃSKA M., WRÓBLEWSKA M. 2002. *Effect of nickel on yielding and mineral composition of the selected vegetables*. Acta Sci. Pol., Hort. Cult., 1(1): 13-22.

MELCHINI A., COSTA C., TRAKA M., MICELI N., MITHEN R., DE PASQUALE R., TROVATO A. 2009. *Erucin, a new promising cancer chemopreventive agent from rocket salads, shows antiproliferative activity on human lung carcinoma A549 cells.* Food Chem. Toxicol., 47: 1430-1436.

MICHAŁOJĆ Z., BUCZKOWSKA H. 2009. *Content of macroelements in eggplant fruits depending on varied potassium fertilization*. J. Elem., 14(1): 111-118.

MORALES M., JANICK J. 2002. *Arugula: A promising specialty leaf vegetable*. In: *Trends in new crops and new uses*. JANICK J., WHIPKEY A. (eds.) ASHS Press, Alexandria, VA, 418-423.

MORALES M., MAYNARD E., JANICK J. 2006. *'Adagio': A slow-bolting arugula.* Hort. Sci., 41(6): 1506-1507.

NITZ G.M., SCHNITZLER W.H. 2002. *Variation der glucosinolat gehalte bei den rucola arten Eruca sativa und Diplotaxis tenuifolia in abhängigkeit des erntesschnittes*. J. Appl. Bot., 76(3/4): 82-86.

NURZYŃSKA-WIERDAK R. 2009. *Growth and yield of garden rocket (Eruca sativa* Mill.*) affected by nitrogen and potassium fertilization*. Acta Sci. Pol., Hort. Cult., 8(4): 23-33.

ORŁOWSKI M., JADCZAK D., ŻURAWIK A. 2005. *Effect of covers and diameter of planted bulbs on the volume and quality of bunch harvested shallots*. Zesz. Nauk. AR we Wrocławiu, Rol., 515(86): 387-393. (in Polish)

PIGNONE D. 1997. *Present status of rocket genetic resources and conservation activities.* In: *Rocket: A Mediterranean crop for the world*. Conf. IPGRI Legnaro (Italy), 13-14 December 1996, 2-12 pp.

RADKOWSKI A., GRYGIERZEC B., SOŁEK-PODWIKA K. 2005. *Content of mineral nutrienst in some grass species and varieties*. J. Elem., 10(1): 121-128. (in Polish)

SANTAMARIA P., ELIA A., SERIO F. 2002. *Effect of solution nitrogen concentration on yield, leaf element content, and water and nitrogen use efficiency of three hydroponically-grown rocket salad genotypes*. J. Plant Nutr., 25(2): 245-258.

SIWEK P., LIBIK A. 2005. *Effect of film and fibre covers used in growing early stalk celery on the volume and quality of yield.* Zesz. Nauk. AR we Wrocławiu, Rol. LXXXVI, 515: 483-490. (in Polish)

Classification of Polish Soils. 1989. Rocz. Gleb., 40(3/4): 7-103. (in Polish)

SZULC P., KRUCZEK A. 2008. *Effect of precipitation and temperaturę on accumulation of dry matter and mineral uptake by maize in the early development phase, depending on fertilization.* Acta Agroph., 11(3): 753-766. (in Polish)

WRÓBEL J., MARSKA E. 1998. *Effect of dolomite fertilizer on concentration of calcium, magnesium and potassium in leaves and pods of two cultivares of runner bean as indicators of its biological value*. Biul. Magnezol., 3(4): 199-205. (in Polish)