Journal of Elementology ISSN 1644-2296

Majkowska-Gadomska J., Arcichowska-Pisarska K., Dobrowolski A., Mikulewicz E. 2016. *Effect of Polimag S on the yield and nutritional value of the Welsh onions (Allium fistolosum* L.*).* J. Elem., 21(3): 757-767. DOI: 10.5601/jelem.2015.20.2.874

EFFECT OF POLIMAG S ON THE YIELD AND NUTRITIONAL VALUE OF THE WELSH ONION (*ALLIUM FISTOLOSUM* L.)

Joanna Majkowska-Gadomska, Katarzyna Arcichowska-Pisarska, Artur Dobrowolski, Emilia Mikulewicz

Department of Horticulture
University of Warmia and Mazury in Olsztyn

Abstract

In Poland, the Welsh onion is still grown on a small scale only, while it is widespread and broadly used in the Far East. Owing to their mild, sweet flavour and delicate consistency, whole Welsh onion plants are used as ingredients in various dishes. Recent years have witnessed the growing popularity of Welsh onions in the Polish cuisine, particularly as a spring seasonal item. A two-factorial field experiment in a randomized block design with replications was performed in 2010 - 2012 in the Experimental Garden of the University of Warmia and Mazury in Olsztyn (NE Poland). Seeds of three Welsh onion cultivars, Long White Ishikura, Parade and Performer, were used. The aim of the study was to determine the effect of Polimag S fertilizer applied at different doses on the yield and the nutritional value of the edible parts of Welsh onion plants. The experimental factors were: (1) Welsh onion cultivars Long White Ishikura, Parade and Performer grown from seedlings, and (2) the application of a mixed fertilizer, Polimag S, at two doses of 0.72 t ha $^{-1}$ and 1.44 t ha $^{-1}$. The Welsh onion cultivars analyzed did not differ significantly with respect to yield. The total yield of Welsh onions did not increase significantly as the dose of Polimag S was increased from 0.72 t ha^{-1} to 1.44 t ha^{-1}, which indicates that increased fertilizer use was economically unjustified. In all the years of the study, the lowest Welsh onion yield was obtained in the control treatments. Welsh onions cv. Performer had the highest dry matter content. Welsh onion cultivars and Polimag S had varied effects on the nitrate accumulation in the plants, but the maximum permissible nitrate levels were not exceeded. According to the current *Regulation of the Minister of Health of 22 December 2004* the content of heavy metals in Welsh onion was lower than the normal range.

Keywords: fertilization, dry matter, nitrates, Cd, Pb, Hg.

dr hab. inż. Joanna Majkowska-Gadomska, Department of Horticulture, University of Warmia and Mazury in Olsztyn, Prawocheńskiego 21, 10-957 Olsztyn, Poland, e-mail: majkowska-gadomska@uwm.edu.pl

INTRODUCTION

In Poland, the Welsh onion (*Allium fistulosum* L.) is still only grown on a small scale, while it is widespread and broadly used in the Far East (Liu et al. 2009). Owing to their mild, sweet flavour and delicate consistency, whole Welsh onion plants are used as ingredients in various dishes. Recent years have witnessed the growing popularity of Welsh onions in the Polish cuisine, particularly on the spring menu (Kołota et al. 2013).

The yield and quality of Welsh onions are determined by the cultivar and an adequate supply of nutrients. Mineral fertilizers are widely used in horticultural farming. Advanced fertilization regimes rely on compound fertilizers that meet the specific nutrient requirements of different crop species. Vegetables of the subfamily Allioideae should be fertilized in spring with Polimag S – a next-generation mixed fertilizer that contains sulfur trioxide, as this chemical compound is recommended for plants that are sensitive to chloride excess. Polimag S contained 10% N, 8% P, 15% K and 35% S. Polimag S can be mixed with urea, ammonium nitrate and nitrochalk immediately before sowing, and with potassium sulfate at any time before application (Filipek-Mazur, Gondek 2005, Majkowska-Gadomska, Arcichowska-Pisarska 2014, Majkowska-Gadomska et al. 2014).

The objective of this study was to determine the effect of Polimag S fertilizer applied at different doses on the yield and nutritional value of the edible parts of three Welsh onion cultivars grown for the harvest of whole plants.

MATERIAL AND METHODS

A two-factorial field experiment in a randomized block design with three replications was performed in 2010 - 2012 in the Experimental Garden of the University of Warmia and Mazury in Olsztyn (NE Poland). Seeds of three Welsh onion cultivars, Long White Ishikura, Parade and Performer, were used.

The effects of the following experimental factors were determined:

- Welsh onion cultivars: Long White Ishikura, Parade and Performer, grown from seedlings;
- The application of mixed fertilizer, Polimag S, at two doses of 0.72 t ha^{-1} and 1.44 t ha^{-1} referred to as 50% and 100% doses. Polimag S was selected because of its sulfur content. The fertilizer was as recommended by the manufacturer.

Seedlings were grown in a greenhouse, where seeds were sown (2 g m^{-2}) in boxes (50 cm x 30 cm) each planting year on 16 March. The seedlings were prepared in accordance with the guidelines for bulbous vegetables. The

substrate used for seedling production was high-moor peat saturated with minerals and nutrients.

In each year of the study, the field was prepared for planting according to the standard recommendations for species of the subfamily Allioideae. Autumn ploughing and spring cultivation were carried out. To determine the basal fertilizer requirements of the plants, the mineral content of soil was analyzed every spring. The soil in which Welsh onion seedlings were planted was found to be of average abundance in phosphorus and potassium. Polimag S, was applied as a supplemental fertilizer at two different doses, and was mixed with soil immediately before the transplanting of the seedlings. Each year, seedlings at the two- or three-leaf stage were individually planted in field on 26 April. In one plot, forty-two seedlings were planted at the 20 cm x 30 cm spacing.

A once-over harvest was carried out manually. Marketable yield consisted of healthy Welsh onion plants, with thickened leaf-bases of more than 1 cm in diameter, free from diseases, pests and mechanical damage. Unmarketable yield comprised Welsh onion plants with thickened leaf-bases of less than 1 cm in diameter, and plants that were infected and damaged. Dry matter and nitrates of the Welsh onion plants were evaluated immediately after harvest. Plant material was collected from the marketable yield of each replication, to obtain an average sample per treatment. At the laboratory of the Department of Horticulture, University of Warmia and Mazury in Olsztyn, the edible parts of Welsh onion plants were assayed for the content of:

– dry matter – by drying to constant weight at 105°C (PN-90/A-75101/03);
– nitrates – by the colorimetric method with the use of salicylic acid.

The prepared material was forwarded to the laboratory at the Chemical and Agricultural Station in Olsztyn, where it was mineralized with concentrated sulfuric acid and analyzed to determine the content of: Cd, Pb and Hg – by atomic absorption spectrometry (AAS). The study was carried out under Accreditation Certificate no. AB 277 issued by the Polish Center for Accreditation in Warsaw.

Data on the yield and nutritional value of Welsh onions obtained in each year of the study were analyzed by ANOVA. The significance of differences between means was estimated using the Tukey's confidence intervals at a 5% significance level.

RESULTS AND DISCUSSION

The Welsh onion (*Allium fistulosum* L.) is well known and broadly grown in China, Japan, Vietnam and other countries of the Far East. According to Tendaj, Mysiak (2007*a*), this perennial develops scapes, forms clumps and possesses thick, fleshy, tubular, hollow and cylindrical leaves. The Welsh

onion does not develop bulbs, but produces a white to light green leek-like stem that has delicate consistency and high nutritional value. New Welsh onion varieties, with elongated tube-like hollow leaves, may be a valuable alternative to common onions grown from small bulbs for early bunch harvest (Kołota et al. 2013).

In a three-year study conducted in north-eastern Poland, the total yield of Welsh onions corresponded to a marketable yield of 5.0-12.0 t ha^{-1} in 2010, 3.0-8.0 t ha^{-1} in 2011, and 8.0 t ha^{-1} -13.0 t ha^{-1} in 2012 (Table 1). The total

Table 1

Total Welsh onion yield subject to cultivar and Polimag S doses in 2010-2012 (t ha^{-1})

Fertilization	Cultivar			
	Long White Ishikura	Parade	Performer	mean
	2010			
Control	5.0	6.0	6.0	6.0
50%	12.0	11.0	12.0	12.0
100%	9.0	8.0	11.0	9.0
Mean	9.0	8.0	9.0	9.0
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 2.2 3.5			
2011				
Control	3.0	4.0	4.0	4.0
50%	7.0	5.0	6.0	6.0
100%	8.0	4.0	5.0	6.0
Mean	6.0	4.0	5.0	5.0
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 1.0 1.2			
2012				
Control	9.0	8.0	9.0	9.0
50%	12.0	11.0	13.0	12.0
100%	12.0	10.0	12.0	12.0
Mean	11.0	10.0	11.0	11.0
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 1.0 2.0			
Mean of 2010-2012				
Control	6.0	6.0	6.0	6.0
50%	10.0	9.0	10.0	10.0
100%	10.0	7.0	9.0	9.0
Mean	8.0	7.0	9.0	8.0
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 2.2 4.0			

Control – treatment that received no fertilizer; 50% – treatment that received 0.72 t ha^{-1} Polimag S; 100% – treatment that received 1.44 t ha^{-1} Polimag S; ns – not statistically significant

yield of Welsh onions in our experiment was comparable with that reported by Tendaj, Mysiak (2007*a*), Kołota et al. (2012). According to Biesiada et al. (2007), and Kołota, Adamczewska-Sowińska (2007*a*), the Welsh onion yield achieved in the Far East is similar to the leek yield attained in Poland. In a study by Jiang et al. (2007), the Welsh onion yield ranged from 60 to 80 t ha^{-1}. The cultivar had no significant effect on the Welsh onion yield, which was significantly affected by fertilization and the interaction between the experimental factors. Polimag S applied at the 50% dose in 2010, and at 50% and 100% doses in 2011 and 2012 significantly increased the Welsh onion yield, in comparison with the control treatment. The total yield of Welsh onions did not increase significantly as the dose of Polimag S was increased from 0.72 t ha^{-1} to 1.44 t ha^{-1}, which indicates that increased fertilizer use was economically unjustified. In all the years of the study, the lowest Welsh onion yield was obtained in the control treatments. Our analysis of the interaction between the experimental factors revealed increased yield in Welsh onions cv. Long White Ishikura and Performer fertilized with Polimag S at the 50% dose in 2010, in Welsh onions cv. Long White Ishikura fertilized with Polimag S at the 100% dose in 2011, and in Welsh onions cv. Performer fertilized with Polimag S at the 50% dose in 2012.

The total yield of Welsh onions (three-year average) varied significantly in response to different fertilization doses and the fertilizer x cultivar interaction. A higher total Welsh onion yield was obtained in treatments with Polimag S than in the control treatment. According to Kołota, Adamczewska-Sowińska (2007*a*,*b*), the yield of vegetable crops is determined by fertilization. Welsh onions require intensive organic and mineral fertilization (Brewster 2008). A yield-forming effect of Polimag S and Polimag 305 in the cultivation of other plant species was observed by Filipek-Mazur, Gondek (2005). Different results were reported by Kołota et al. (2013), who found that an increase in pre-plant nitrogen from 75 to 150 and 225 kg ha^{-1} had no influence on the yield and contributed to nitrate(V) accumulation in plants.

Owing to its mild flavour and high nutritional value, *Allium fistulosum* L. is popular among consumers and grown in all continents, especially in Europe (Tendaj, Mysiak 2007b). Similarly to other bulbous vegetables, the Welsh onion is a rich source of nutrients and biologically active compounds essential for humans (Higashio et al. 2007, Kołota et al. 2013). Welsh onion leaves contain per 100 g fresh weight (FW): 6.5-7.8% dry matter, 2.4-3.0 g total sugars, up to 95 mg L-ascorbic acid, and small amounts of vitamins A, B_1, B_2, PP. Bulbous vegetables contain essential oils that are responsible for their specific taste and aroma as well as their antiseptic and medicinal properties (Kołota et al. 2013).

The dry matter content of whole Welsh onion plants is presented in Table 2. A statistical analysis revealed that the cultivar and the cultivar x fertilizer interaction had a significant effect on the dry matter content of Welsh onions in all years of the study. The highest dry matter content was noted in cv. Long White Ishikura and Performer in 2010, in cv. Performer in 2011, and in cv. Parade in

Table 2

The dry matter content of Welsh onion plants subject to cultivar and Polimag S doses in 2010-2012 (%)

Fertilization	Cultivar			
	Long White Iskihura	Parade	Performer	mean
	2010			
Control	9.76	9.26	11.10	10.04
50%	9.01	8.85	9.53	9.13
100%	12.10	7.44	11.50	10.35
Mean	10.29	8.52	10.71	9.84
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	1.08 n.s. 0.97			
2011				
Control	11.80	10.40	12.10	11.43
50%	10.80	9.10	12.00	10.63
100%	11.30	11.40	13.00	11.90
Mean	11.30	10.30	12.37	11.32
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	0.82 n.s. 0.99			
2012				
Control	10.40	11.30	11.40	11.03
50%	10.80	11.20	10.20	10.73
100%	10.40	11.00	9.87	10.42
Mean	10.53	11.17	10.49	10.73
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	0.56 n.s. 0.80			
Mean of 2010-2012				
Control	10.65	10.32	11.53	10.84
50%	10.20	9.72	10.58	10.17
100%	11.27	9.95	11.46	10.89
Mean	10.71	9.99	11.19	10.63
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	0.40 n.s. 0.40			

Control – treatment that received no fertilizer; 50% – treatment that received 0.72 t ha^{-1} Polimag S; 100% – treatment that received 1.44 t ha^{-1} Polimag S; ns – not statistically significant

2012. As regards the interaction effect, the highest dry matter content was determined in cv. Long White Ishikura fertilized with Polimag S at the 100% dose in 2010, in cv. Performer fertilized with Polimag S at the 100% dose in 2011, and in cv. Performer from the control treatment in 2012.

Each year, the nitrate content of Welsh onion plants was significantly affected by Polimag S doses and the fertilizer *x* cultivar interaction (Table 3).

Table 3

The nitrate content of Welsh onion plants subject to cultivar and Polimag S doses in 2009-2011 (mg NO_3 kg^{-1} FW)

Fertilization	Cultivar			
	Long White Iskihura	Parade	Performer	mean
	2010			
Control	246.8	169.4	65.8	160.7
50%	347.3	209.4	208.6	255.1
100%	99.0	298.6	229.0	208.9
Mean	231.0	225.8	167.8	208.2
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 50.5 80.1			
2011				
Control	262.2	219.5	251.3	244.3
50%	197.4	169.4	189.3	185.4
100%	99.30	190.7	165.1	151.7
Mean	186.3	193.2	201.9	193.8
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 30.0 31.0			
2012				
Control	383.7	100.7	279.5	254.6
50%	179.1	161.6	365.6	235.4
100%	536.0	345.2	424.3	435.2
Mean	366.3	202.5	356.5	308.4
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 80.5 50.2			
Mean of 2010-2012				
Control	297.5	163.2	198.8	219.8
50%	241.2	180.1	254.5	225.3
100%	244.8	278.1	272.8	265.2
Mean	261.2	207.1	242.0	236.8
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. n.s. 55.8			

Control – treatment that received no fertilizer; 50% – treatment that received 0.72 t ha^{-1} Polimag S; 100% – treatment that received 1.44 t ha^{-1} Polimag S; ns - not statistically significant

The maximum permissible nitrate levels, set forth in the *Regulation of the Minister of Health of 22 December 2004* (750 mg NO_3^- FW), were not exceeded. Welsh onion plants of cv. Long White Ishikura from control, Parade and Performer fertilized with Polimag S at the 100 dose contained the highest nitrate concentrations, whereas plants of Parade from control treatments had the lowest nitrate content (three-year averages).

The nitrate content changes as plants grow older. Excessive amounts of nitrates accumulate in plant species characterized by a short growing season, and in early-maturing varieties (Tietze et al. 2007). Nitrate accumulation in vegetables is determined by genetic factors and by various agricultural practices including fertilization (Majkowska-Gadomska et al. 2009, Grzeszczuk et al. 2010, Majkowska-Gadomska 2010). According to the *Regulations …* (2004) on nitrate concentrations in vegetables, nitrate levels in chives should not be higher than 750 mg NO_3 kg^{-1} FW. In a study by Tietze et al. (2007), onions and leeks contained 121.8 mg NO_3 kg^{-1} FW and 229.7 mg NO_3 kg^{-1} FW, respectively. Biesiada et al. (2007) demonstrated that harvest time had a significant effect on a decrease in the nitrate content of leeks. Kołota, Adamczewska-Sowińska (2007*a*) reported that a delayed spring harvest and the overwintering of plants in the field contributed to elevated nitrate levels in leeks. In our study, nitrate(V) content was unaffected by the cultivar, but each year it was influenced by supplemental fertilization with Polimag S, which exerted varied effects on nitrate(V) accumulation in Welsh onions. Polimag S contains sulfur that has been found to prevent the excessive accumulation of nitrates in plants. In a study by Sikorska, Wędzisz (2010), onions had a lower nitrate content than in our experiment. Chohura, Kołota (2011) demonstrated that sulfur fertilizers prevented excessive accumulation of nitrates in plants. Kołota, Adamczewska-Sowińska (2007b) studied early-harvest leeks and found that the edible parts of plants fertilized with Entec 26 applied in two split applications contained nearly 50% less nitrates than plants fertilized with ammonium nitrate. In a study by Wadas et al. (2012), the multi-nutrient complex fertilizer HydroComplex containing magnesium and sulfur contributed to an increase in the nitrate content of potato tubers (by 4.0 mgNO_3 kg^{-1} FW on average).

According to the current *Regulation …* (2004) the content of heavy metals in the Welsh onion was lower than the normal range (Table 4). The cadmium content in leaves of assimilation was in the range of 0.001 mg kg^{-1} FW to 0.006 mg kg^{-1} fresh matter. Most cadmium was contained in chives of the cultivar Long White Iskihura from the treatment with a 100% dose of fertilizer and from the Performer control object, and the least Cd was accumulated by the cultivar Parade from the treatment with a 50% dose Polimag S. These differences, however, were not confirmed statistically. Statistical analysis showed a significant dose-related effect Polimag S and its interaction with the cultivated variety on the lead content in Welsh onions. Seven-year appplication of a 50% dose of fertilizer which contained sulfur contributed to reduced accumulation of this element in foliage leaves. Most lead was found in the cv. Long White Iskihura from the control and from the treatment with a 50% dose of the fertilizer. The least amount of this element was in foliage leaves of the cultivars Parade and Performer with a 50% dose Polimag S. Our statistical analysis showed no significant effects of the factors on the mercury content in the Welsh onion. Most of the element was contained in chives of the cultivar Long White Iskihura from the control, and the least mercury

Tabela 4

Cd. Pb and Hg content of Welsh onion plants subject to cultivar and Polimag S doses in 2010-2012 (mg kg^{-1} F.W.)

Fertilization	Cultivar			
	Long White Iskihura	Parade	Performer	mean
	Cd			
Control	0.004	0.002	0.006	0.004
50%	0.004	0.001	0.003	0.003
100%	0.006	0.002	0.005	0.004
Mean	0.005	0.002	0.005	0.004
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. n.s. n.s.			
Pb				
Control	0.080	0.027	0.065	0.057
50%	0.073	0.015	0.011	0.033
100%	0.050	0.058	0.036	0.048
Mean	0.068	0.033	0.037	0.047
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. 0.005 0.015			
Hg				
Control	0.0024	0.0011	0.0014	0.0016
50%	0.0021	0.0019	0.0017	0.0019
100%	0.0012	0.0014	0.0019	0.0015
Mean	0.0020	0.0014	0.0017	0.0017
$LSD_{0.05}$ Cultivar (*a*) Fertilizer (*b*) Interaction (*a* x *b*)	n.s. n.s. n.s.			

Control – treatment that received no fertilizer; 50% – treatment that received 0.72 t ha^{-1} Polimag S; 100% – treatment that received 1.44 t ha^{-1} Polimag S; ns – not statistically significant

was in cv. Parade from the same plot. The low concentrations of heavy metals in Welsh onion plants can be explained by the low levels of air pollution in the area where they were grown. This is consistent with the observation by ROSADA (2007), who concluded that the degree of contamination by heavy metals of the aerial parts of plants depended on the site of cultivation.

CONCLUSIONS

1. Polimag S applied at 50% and 100% doses significantly increased the total yield of Welsh onions.

2. Three-year averages did not exceed the maximum permissible nitrate levels, set forth in the *Regulation* … (2004). Welsh onion plants of cv. Long

White Ishikura from the control plots, as well as cultiivars Parade and Performer fertilized with Polimag S at the 100% dose contained the highest nitrate concentrations, whereas plants of cv. Parade from control treatments had the lowest nitrate content.

3. The content of heavy metals in the Welsh onion analyzed was lower than the normal range specified in the *Regulation …* (2004).

REFERENCES

Biesiada A., Kołota E., Adamczewska-Sowińska K. 2007. *The effect of maturity stage on nutritional value of leek, zucchini and kohlrabi.* Veg. Crops Res. Bull., 66: 39-45.

Brewster J.L. 2008. *Onions and other vegetable alliums.* 2nd ed., Wallingford, UK, CAB, p. 14-19.

Chohura P., Kołota E. 2011. *The effect of nitrogen fertilization on radish yielding.* Acta Sci. Pol., Hort. Cult., 10(1): 23-30.

Filipek-Mazur B., Gondek K. 2005. *Yielding and sulphur content in white mustard as the effect of application of multi-component fertilizers containing sulphur.* Acta Agrophys., 6(2): 343-351. (in Polish)

Grzeszczuk M., Jadczak D., Kawecka D., Długosz I. 2010. *Effect of sowing date on biological value of garden orache.* Acta Sci. Pol. Hort. Cult.,9(4): 163-169.

Higashio H., Hirokane H., Sato E., Tokuda S., Uragami A. 2007. *Enhancement of functional compounds in Allium vegetables with UV radiation.* Acta Hort., 744: 357-361.

Jiang L.H., Liu Z.H., Chen Q., Lin H.T., Zhang W.J. 2007. *Study of the effect of nitrogen on green Chinese spring onion yield and supplying target value.* Plant Nutrit. Fert. Sci. 13: 890-896.

Kołota E., Adamczewska-Sowińska K. 2007*a*. *The effects of flat covers on overwintering and nutritional value of leeks.* Veget. Crops Res. Bull., 66: 11-16.

Kołota E., Adamczewska-Sowińska K. 2007b. *The usefulness of Entec 26 fertilizer in cultivation of leeek for early harvest.* Rocz. AR Pozn. Ogrodn., 383(41): 529-532. (in Polish)

Kołota E., Adamczewska-Sowińska K., Uklańska-Pusz C. 2012. *Yield and nutritional value of Japanese bunching onion (Allium fistulosum* L.*) depending on the growing season and plant maturation stag.* J. Elementol., 17(4): 587-596. DOI: 10.5601/jelem.2012.17.4.03

Kołota E., Adamczewska-Sowińska, K., Uklańska-Pusz C. 2013. *Response of Japanese bunching onion (Allium fistulosum* L.*) to nitrogen fertilization.* Acta Sci. Pol. Hort. Cult., 12(2): 51-61.

Liu S., He H., Feng G. 2009. *Effects of nitrogen and sulphur interaction on growth and pungency of different pseudostem types of Chinese spring onion* (*Allium fistulosum* L.*),* Sci. Hort. 121: 12-18.

Majkowska-Gadmska J. 2010. *The chemical composition of fruit in selected melon cultivars grown under flat covers with soil mulching.* Acta Sci. Pol., Hort. Cult., 9(2): 39-52.

Majkowska-Gadomska J., Arcichowska-Pisarska K. 2014. *The effect of Polimag S fertilizer on the macronutrient content of the edible parts of three welsh onion (Allium fistulosum* L.*) cultivars.* J. Elementol., 19(3): 709-722. DOI: 10.5601/jelem.2014.19.3.700

Majkowska-Gadomska J., Arcichowska-Pisarska K., Dobrowolski A. 2014. *The yield and winter hardiness of selected welsh onion (Allium fistolosum* L.*) cultivars grown in soils fertilized with Polimag® S.* J. Agric. Sci., 6(5): 91-99. DOI: 10.5539/jas.v6n5p9

Majkowska-Gadomska J., Arcichowska K., Wierzbicka B. 2009. *Nitrate content of the edible parts of vegetables and spice plants.* Acta Sci. Pol., Hort. Cult., 8(3): 25-35.

PN-90/A-75101/03. *Determination of dry matter by weight.*

Rosada J. 2007. *Ecological aspects of utilizing areas influenced by copper foundries for cultivation of agricultural plants.* Post. Ochr. Rośl., 47 (1): 119-127. (in Polish)

Regulation of the Minister of Health of 22 December 2004. On maximum levels of chemical and biological contaminants that may be present in food, food ingredients, allowed additional substances, substances processing aids or on food. OJ. no. 9, 2005. (in Polish)

Sikorska K., Wędzisz A. 2010. *Spinosad residues influence vegetables nutrition value.* Bromat. Chem. Toksykol., 43:101-107. (in Polish)

Tendaj M., Mysiak, B. 2007*a*. *The yield of Japanese bunching onion (Allium fistulosum* L.*) depending on the planting time of transplants and use of flat covers.* Ann. UMCS, Sect. EEE, Horticultura, 17(2): 5-10. (in Polish)

Tendaj M., Mysiak B. 2007*b*. *Usefulness of Japanese bunching onion (Allium fistulosum* L.*) for forcing in greenhouse.* Acta Agrobot., 60(1): 143-146.

Tietze M., Burghardt A., Brągiel P., Mac, J. 2007. *Content of nitrosamines in foodstuff.* Ann. UMCS, Sect. EE, Zootechnica, 25(1): 71-77. (in Polish)

Wadas W., Łęczycka T., Borysiak-Marciniak I. 2012. *Effect of fertilization with multinutrient complex fertilizers on tuber quality of very early potato cultivars.* Acta Sci. Pol. Hort. Cult.,11(3): 27-41.