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RESPONSE OF SWISS CHARD (*Beta vulgaris* L. var. *cicla* L.) TO NITROGEN FERTILIZATION

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ABSTRACT

Swiss chard may be cultivated for a single or in small scale of production for multiple harvest. The objective of the field experiment conducted in 2012–2014 was to determine the response of this vegetable crop to nitrogen fertilization. Lukullus and Green Silver cultivars were grown from direct seed sowing into the field and supplied with 100 or 200 kg $N \cdot ha^{-1}$ by using ammonium nitrate and Entec 26. Harvest of leaves started at the end of June was made weekly till half of September, each time the yield of leaf blades and petioles were evaluated. At the end of July the samples were collected for chemical analysis. Results of the study proved that both tested N fertilizers were equally valuable sources of this nutrient for Swiss chard and the increase of its dose from 100 to 200 $kg \cdot ha^{-1}$ was ineffective for crop yield, while caused the significant enhancement of nitrates accumulation. Leaf blades appeared to be a rich source of vitamin C and contained lower level of sugars and Ca while higher amounts of P and Mg if compared to petioles. Nitrates accumulation in leaf petioles was generally twice as high as in the blades. Green Silver cultivar produced higher yield of leaf petioles and higher amounts of chlorophyll showing smaller tendency for nitrates accumulation than Lukullus.

Key words: cultivars, yield, blades, petioles, nutritional value

INTRODUCTION

Swiss chard (*Beta vulgaris* L. var. *cicla* L.) is a foliage beet cultivated for its large, fleshy leaf petioles and broad crisp leaf blades. Petiole colors may be white, red or green, while leaf colors range from light to dark green, with curled or plain surface. The leaf blades are prepared for the consumption like spinach, while petioles are cooked and served like asparagus. Both edible parts of plant are recognized as a rich source of protein, vitamins C, carotenoides and minerals especially iron and calcium [Dzida and Jarosz 2011]. According to [Singhal and Kulkarni 1998] the average content of protein is equal to 1.8%, carbohydrates 2.90%, potassium 380 mg, calcium 51 mg, magnesium 81 mg, phosphorus 46 mg, iron 1.8 mg, carotene 4.6%, thiamine 0.004 mg, riboflavin 0.09 mg, niacyn 0.4 mg, vitamin C 20 mg and only 19 kcal per 100 g of row material. Similar composition of Swiss chard is reported by Lorenz and Maynard [1987], who indicate however that the content of vitamin C may reach the level over 30 mg per 100 g FW and this is in agreement with our own findings [Kołota et al. 2010].

The plant is cool season biennial, which can be planted from early spring until midsummer, mostly started from seed, but transplants can be used too. Normally, the crop is ready to harvest in about

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60 days after planting, but its delay to around 3 month cause a substantial yield increment [Czerniak and Kołota 2008].

Commercial growers very often cut off all leaves above the growing point, and they are frequently used for canning or freezing. In home gardens for the domestic use there is usually conducted a multiple Swiss chard harvest. In this case the outer leaves are pulled away from the base of the rosette growth. Inner leaves are left to enlarge for the subsequent harvests, which often are made weekly over the period of several weeks to 2 months. The harvested leaves are bunched and tied for a market.

Little information is available in the literature with respect to the response of Swiss chard to nitrogen fertilization, especially in prolonged cultivation for multiple harvest. In our study conducted with this vegetable species grown for a single harvest the best results were obtained in treatment supplied with 100 kg $N \cdot ha^{-1}$. Higher rates of N appeared to be ineffective in yield production, and adversely affected the quality of the crop due to high nitrates accumulation [Kołota and Czerniak 2010]. High tendency for nitrates accumulation by edible parts of Swiss chard in the case of heavy N fertilization can be supported by research data obtained by Santamaria et al. [1999] as well as Dzida and Pitura [2008]. It was proved that not only the dose but also the form of this nutrient play an important role in nitrates accumulation. Some of the experimental data with different vegetable crop species indicate that a considerable drop of nitrates amounts may be obtained by application a new concept nitrogen fertilizer containing DMPP nitrification inhibitor [Hähndel and Strohm 2001, Hähndel and Zerulla 2001, Pasda et al. 2001, Hähndel and Wissemeier 2008, Paschold et al. 2008].

The aim of the present study was to evaluate the response of Swiss chard cultivated for prolonged multiple harvest to nitrogen fertilization with respect to its form and dose. From the nutritional point of view there is important to look for such N source, which applied in reasonable rate do not cause high nitrates accumulation in leaf blades and petioles.

MATERIAL AND METHODS

Field experiment was conducted in 2012–2014 in Vegetable and Ornamental Plants Research Station located in Wroclaw (long. 17.00 E; lat. 51.05 N) on a sandy clay soil with pH 6.9 and organic matter content 1.8%. Available forms of phosphorus and potassium per 1 dm^3 of the soil were raised up to the standard level for field vegetable crops equal to 80 mg P and 200 mg K by early spring fertilization with triple superphosphate and potassium chloride. Nitrogen at the rate of 100 or 200 kg $N \cdot ha^{-1}$ was applied in a single dose prior to planting and incorporated with a surface layer of the soil by harrowing. Ammonium nitrate (NH_4NO_3 – 34% N) or Entec 26 – a mixture of ammonium sulphate and ammonium nitrate with total amount of 26% N, 13% S and DMPP nitrification inhibitor (3.4 dimethylpyrazole phosphate) were used as the sources of nitrogen.

Seeds of Lukullus (curled leaf surface) and Green Silver (plain leaf surface) cultivars were sown a plots on 17–18 of April in spacing 45 × 25 cm. At the stage of 2–4 true leaves the seedlings were thinned to one per spot. The experiment was established in three factorial design in four replications and plot area 5.4 m^2 (3.0 × 1.8 m), with the source of N as the I^{st}, rate of N as the II^{nd} and kind of cultivar as the III^{rd} factor. Crop management included hand weeding of plots and supplementary water supply by sprinkler irrigation system in rainfall deficiency periods. Generally, weather conditions during all trial periods were favorable for the growth and development of Swiss chard.

Multiple harvest of leaves started at the end of June each year and made weekly till half of September. Each time the outside most developed leaves were pulled away from the base of plant rosette and their petioles and blades were weighted separately. At the period of maximum yielding (end of July) the samples of 15 leaves from each plot were collected for chemical analysis. In both leaf parts there was evaluated the contents of dry matter (by drying at 105°C to the constant weight), total sugars (Loof – Schoorl method), nitrates expressed by the amount of NO_3^--N (ion. selective electrode, Orions method). Vitamin C (Tillmaǹs method) and total chlorophyll (spectrophotometric method) were determined only in leaf blades. Macroelements were determined in dry matter of plants by P and Mg colorimetric method, K and Ca by photometric method [Nowosielski 1988].

The results of the field study and chemical analysis were elaborated statistically using analysis of variance for three factorial design and the least significant differences calculated by Tukey test at α = 0.05.

RESULTS AND DISCUSSION

Data of the field experiment shown as means for three years of the study (tab. 1) indicate that ammonium nitrate and Entec 26 – nitrogen fertilizer containing DMPP nitrification inhibitor appeared to be equally valuable sources of nitrogen for Swiss chard grown for prolonged multiple harvest, irrespective of its rate applied prior to planting. Many field studies have demonstrated higher efficiency of N fertilizer with DMPP addition expressed by either increased yield level or lower demand for N application. Such successful impact was obtained in trials with cauliflower, cabbage, Chinese cabbage, radish, lamb lettuce and spinach [Hähndel and Zerulla 2001, Krężel and Kołota 2014]. Contrary to this statement no advantage of the use of Entec 26 was found in red beet, celeriac, white cabbage and leek cultivation [Hähndel and Zerulla 2001, Kołota et al. 2007, Kołota and Adamczewska-Sowińska 2007, Chohura and Kołota 2014]. Such variable effects of Entec 26 on crop yield may be explained by differences in soil and climatic conditions. According to Pasda et al. [2001] positive effects of fertilizers containing a DMPP nitrification inhibitor on crop yield can be especially pronounced at sites with a high precipitation rate or intensive irrigation, and light sandy soils. Such conditions did not occur in our study, conducted on a clay soil with no need supplemental watering.

Table 1. Yield of Swiss chard leaves in relation to nitrogen fertilization as the mean for 2012–2014 ($t \cdot ha^{-1}$)

Kind of fertlizer	N rate ($kg \cdot ha^{-1}$)	Leaf petioles			Leaf blades			Total yield		
		Green Silver	Lukullus	mean	Green Silver	Lukullus	mean	Green Silver	Lukullus	mean
Entec 26	100	25.07	17.59	21.33	18.18	17.98	18.08	43.25	35.57	39.41
	200	25.48	20.06	22.77	19.43	20.37	19.90	44.91	40.43	42.67
	mean	25.28	18.78	22.05	18.81	19.18	18.99	44.08	38.00	41.04
Ammonium nitrate	100	25.30	18.62	21.96	19.99	18.22	19.10	45.29	36.84	41.07
	200	25.05	19.97	22.51	19.68	19.89	19.78	44.73	39.86	42.30
	mean	25.18	19.30	22.24	19.84	19.06	19.44	45.01	38.35	41.69
Mean for N rate	100	25.19	18.11	21.65	19.09	18.10	18.59	44.27	36.21	40.24
	200	25.27	20.02	22.64	19.56	20.13	19.84	44.82	40.15	42.49
Mean		25.23	19.07	22.15	19.33	19.12	19.22	44.55	38.18	41.36
LSD at α = 0.05 for: N form				n.s.			n.s			n.s
N rate				n.s.			n.s			n.s.
cultivar				1.63			n.s			2.43
interaction: N form × N rate				n.s.			n.s.			n.s

Table 2. Dry matter and total sugar content in petioles and leaf blades in relation to nitrogen fertilization (mean for 2012–2014)

	Kind of fertlizer	N rate ($kg \cdot ha^{-1}$)	Petioles			Blades		
			Green Silver	Lukullus	mean	Green Silver	Lukullus	mean
Dry matter (%)	Entec 26	100	6.85	9.96	8.41	10.71	11.89	11.30
		200	7.07	8.99	8.03	10.95	12.12	11.54
		mean	6.96	9.48	8.22	10.83	12.01	11.42
	ammonium nitrate	100	9.20	10.52	9.86	10.85	11,92	11.39
		200	10.02	8.85	9.44	10.98	11.75	11.37
		mean	9.61	9.69	9.65	10.92	11.84	11.38
	mean for N rate	100	8.03	10.24	9.13	10.78	11.91	11.35
		200	8.55	8.88	8.73	10.97	11.94	11.46
	mean		8.29	9.58	8.93	10.88	11.93	11.41
	LSD at α = 0.05 for: N form				0.62			n.s.
	N rate				n.s.			n.s.
	cultivar				0.38			0.24
	interaction: N form × N rate				n.s.			n.s.
Total sugar (% FW)	Entec 26	100	2.40	2.52	2.46	0.79	0.93	0.86
		200	2.61	2.50	2.56	1.01	1.04	1.03
		mean	2.51	2.51	2.51	0.90	0.99	0.94
	ammonium nitrate	100	2.46	2.71	2.59	0.90	1.09	0.99
		200	2.60	2.61	2.61	0.98	0.94	0.96
		mean	2.53	2.66	2.60	0.94	1.02	0.98
	mean for N rate	100	2.43	2.62	2.52	0.85	1.01	0.93
		200	2.61	2.56	2.58	1.00	0.99	0.99
	mean		2.52	2.59	2.55	0.92	1.00	0.96
	LSD at α = 0.05 for: N form				n.s.			n.s.
	N rate				n.s.			0.05
	cultivar				n.s.			0.05
	interaction: N form × N rate				n.s.			0.11

Table 3. Nitrates content in petioles and leaf blades in relation to nitrogen fertilization (mean for 2012–2014) (mg NO_3^- $\cdot kg^{-1}$ FW)

Kind of fertlizer	N rate ($kg \cdot ha^{-1}$)	Petioles			Blades		
		Green Silver	Lukullus	mean	Green Silver	Lukullus	mean
Entec 26	100	670.0	856.0	763.0	353.0	536.0	444.5
	200	814.0	946.0	880.0	407.0	550.0	478.5
	mean	742.0	901.0	821.5	556.5	543.0	549.8
Ammonium nitrate	100	812.0	1018.0	915.0	469.0	551.0	510.0
	200	1023.0	1022.0	1022.5	570.0	662.0	616.0
	mean	917.5	1020.0	968.8	519.5	606.5	563.0
Mean for N rate	100	741.0	937.0	839.0	411.0	543.5	477.3
	200	918.5	984.0	951.3	488.5	606.0	547.3
Mean		829.8	960.5	895.2	449.8	574.8	512.3
LSD at α = 0.05 for: N form				83.7			n.s.
N rate				28.3			26.1
cultivar				24.5			31.8
interaction: N form × N rate				n.s.			n.s.

Table 4. Vitamin C and total chlorophyll content in leaf blades in relation to nitrogen fertilization (mean for 2012–2014)

Kind of fertlizer	N rate ($kg \cdot ha^{-1}$)	Vitamin C ($mg \cdot 100\ g^{-1}$ FW)			Chlorophyll ($mg \cdot 100\ g^{-1}$ FW)		
		Green Silver	Lukullus	mean	Green Silver	Lukullus	mean
Entec 26	100	53.76	48.10	50.93	0.820	0.670	0.745
	200	42.89	47.82	45.36	0.720	0.820	0.770
	mean	48.33	47.96	48.15	0.770	0.745	0.757
Ammonium nitrate	100	55.01	47.55	51.28	0.880	0.770	0.825
	200	56.23	54.31	55.27	0.740	0.770	0.755
	mean	55.62	50.93	53.28	0.810	0.770	0.790
Mean for N rate	100	54.39	47.83	51.11	0.850	0.720	0.785
	200	49.56	51.07	50.32	0.730	0.805	0.762
Mean		51.98	49.45	50.72	0.790	0.757	0.773
LSD at α = 0.05 for: N form				1.18			0.004
N rate				n.s.			0.006
cultivar				n.s.			0.011
interaction: N form × N rate				1.77			0.009

Table 5. Phosphorus and potassium content in petioles and leaf blades in relation to nitrogen fertilization (mean for 2012–2014)

	Kind of fertlizer	N rate ($kg \cdot ha^{-1}$)	Petioles			Blades		
			Green Silver	Lukullus	Mean	Green Silver	Lukullus	Mean
Phosphorus (% DM)	Entec 26	100	0.27	0.30	0.29	0.35	0.35	0.35
		200	0.28	0.28	0.28	0.36	0.29	0.33
		mean	0.28	0.29	0.28	0.36	0.32	0.34
	ammonium nitrate	100	0.35	0.30	0.33	0.35	0.42	0.39
		200	0.28	0.24	0.26	0.28	0.32	0.30
		mean	0.32	0.27	0.29	0.32	0.37	0.34
	mean for N rate	100	0.31	0.30	0.31	0.35	0.39	0.37
		200	0.28	0.26	0.27	0.32	0.31	0.31
	mean		0.30	0.28	0.29	0.34	0.35	0.34
	LSD at α =0.05 for: N form				n.s.			n.s.
	N rate				0.03			0.02
	cultivar				n.s.			n.s.
	interaction: N form × N rate				0.04			0.02
Potassium (% DM)	Entec 26	100	7.22	6.10	6.66	6.00	6.00	6.00
		200	6.50	5.92	6.21	5.06	5.92	5.49
		mean	6.66	6.01	6.44	5.53	5.96	5.75
	ammonium nitrate	100	6.17	5.25	5.71	5.89	6.32	6.11
		200	5.75	6.06	5.91	5.91	6.12	6.02
		mean	5.96	5.66	5.81	5.90	6.22	6.06
	mean for N rate	100	6.70	5.68	6.19	5.95	6.16	6.05
		200	6.13	5.99	6.06	5.49	6.02	5.75
	mean		6.41	5.83	6.12	5.72	6.09	6.90
	LSD at α =0.05 for: N form				0.05			0.23
	N rate				n.s.			0.12
	cultivar				0.09			0.18
	interaction: N form × N rate				0.27			0.25

Table 6. Magnesium and calcium content in leaf petioles and blades in relation to nitrogen fertilization (mean for 2012–2014)

	Kind of fertlizer	N rate (kg·ha^{-1})	Petioles			Blades		
			Green Silver	Lukullus	mean	Green Silver	Lukullus	mean
Magnesium (% DM)	Entec 26	100	0.32	0.26	0.29	0.47	0.43	0.45
		200	0.28	0.27	0.28	0.48	0.43	0.46
		mean	0.30	0.27	0.28	0.48	0.43	0.45
	ammonium nitrate	100	0.28	0.23	0.26	0.50	0.47	0.49
		200	0.28	0.25	0.27	0.43	0.42	0.43
		mean	0.28	0.24	0.26	0.47	0.45	0.46
	mean for N rate	100	0.30	0.25	0.28	0.49	0.45	0.47
		200	0.28	0.26	0.27	0.46	0.43	0.44
	mean		0.29	0.25	0.27	0.47	0.44	
	LSD at α = 0.05 for: N form				n.s.			n.s.
	N rate				n.s.			0.02
	cultivar				0.02			0.02
	interaction: N form × N rate				n.s.			0.06
Calcium (% DM)	Entec 26	100	0.45	0.31	0.38	0.21	0.22	0.22
		200	0.42	0.37	0.40	0.23	0.21	0.22
		mean	0.44	0.34	0.39	0.22	0.22	0.22
	ammonium nitrate	100	0.45	0.31	0.38	0.23	0.21	0.22
		200	0.40	0.35	0.38	0.23	0.23	0.23
		mean	0.43	0.33	0.38	0.23	0.22	0.23
	mean for N rate	100	0.45	0.31	0.38	0.22	0.22	0.22
		200	0.41	0.36	0.39	0.23	0.22	0.23
	mean		0.43	0.34	0.38	0.23	0.22	0.22
	LSD at α = 0.05 for: N form				n.s.			n.s.
	N rate				n.s.			n.s.
	cultivar				0.02			n.s.
	interaction: N form × N rate				0.04			n.s.

The increment of N dose from 100 to 200 kg·ha^{-1} did not cause any substantial yield enhancement. Similar response of Swiss chard yield to nitrogen was also observed in the previous study, where the dose of 100 kg N·ha^{-1} was the most favorable for plants grown for a single spring harvest [Kołota and Czerniak 2010]. Lower dose amounted 50 kg N·ha^{-1} caused the reduction of plant growth, while its enhancement to 150–200 kg N·ha^{-1} appeared to be ineffective for crop yield production.

Among tested cultivars, Green Silver forming broad stem and midribs provided significantly higher yield of petioles, while similar level of leaf blades as Lukullus, the cultivar commonly grown in different European countries, and appreciated by the consumers for its attractive, curled pale green color leaves. Similar results were obtained in the other trial in which Green Silver over yielded some other Swiss chard cultivars, including Lukullus and Vulcan [Kołota et al. 2010].

Dry mater content in Swiss chard was highly influenced by the kind of edible part, and irrespective of investigated factors maintained at the level of 8.93 and 11.40% in leaf petioles and blades, respectively (tab. 2). Similar relations were also observed in celery and dill [Dyduch and Najda 2005, Kmiecik et al. 2005] in which both plant parts are used for the consumption. Leaf petioles of plants fertilized with Entec 26 contained lower amounts of dry matter if compared to ammonium nitrate. Both sources of this nutrient applied at the dose of 200 kg N·ha^{-1} adversely affected its content in petioles, however the differences were not proved statistically In leaf blades the content of dry matter was not differentiated by the N form and rate. The only significant difference likewise to petioles was its higher level in Lukullus cv. if compared to Green Silver cv.

Total sugar contents was approximately 2.5 times higher in leaf petioles than in blades, but the differences between treatments with different nitrogen fertilization and tested cultivars were rather small and not significant (tab. 2). However, it could be observed some tendency for, mostly their higher amounts in the foliage of Lukullus cv. and petioles of Green Siolver cv. after application 200 kg N·ha^{-1}.

Nitrates accumulation in edible parts of Swiss chard maintained far below the accepted limit of 1500 mg per 1 kg of fresh weight (tab. 3). It is worth to notice however, that the amount of this compound in petioles was almost double as high as in the leaf blades and in both plant parts significantly influenced by nitrogen fertilization. This finding is in agreement with Wang and Li [2003] statement that addition of N fertilizer is being considered as the major cause for increase of nitrates concentration in vegetables, and normally in their roots, stems or petioles the amount of NO_3^--N is higher than in blades at any N rate. In our study the increment of N dose from 100 to 200 kg·ha^{-1} caused a considerable enhancement of nitrates accumulation, irrespective of the form of fertilizer. The use of Entec 26 can be considered as an efficient way of the reduction of nitrates accumulation in both edible parts of Swiss chard. However this effect was especially evident and statistically proved in leaaf petioles at heavy N application. This advantageous effect of the application of nitrogen fertilizer containing DMPP nitrification inhibitor was observed in growing of different field vegetable crops such as celeriac, red beet, lettuce, spinach, cauliflower, leek and carrot [Hähndel and Zerulla 2001, Pasda et al. 2001, Kołota et al. 2007, Kołota and Adamczewska-Sowińska 2007] In the study conducted by Dzida and Pitura [2008] it was also proved that not only the dose but also N form play an important role in nitrates accumulation. With respect to the reduced NO_3^--N accumulation the better source of nitrogen can be considered urea and potassium nitrate than commonly used ammonium nitrate. Higher tendency for nitrate accumulation in curled leaf cultivars observed in leafy parsley, [Pasikowska et al. 2002] was also confirmed in this trial. It was found that irrespective of nitrogen rate and form, Lukullus cv. contained considerably higher amounts of this nutrient than Green Silver, both in leaf blades and petioles.

Vitamin C content in Swiss chard leaf blades varied within 42.89 and 56.23 mg·100 g^{-1} FW (tab. 4) and was considerable higher than reported in the literature [Lorenz and Maynard 1987], but similar to that obtained in our previous study [Kołota and Czerniak 2010], in which the similar parts of foliage was collected for chemical analysis. Nitrogen form and cultivar significantly affected the content of this compound in the leaves at harvest. However the use of 200 kg N·ha^{-1} had advantageous effect in the case of ammonium nitrogen application, while negative impact if Entec 26 was the source of N.

As it could be expected, a plain leaf Lukullus cv. contained lower amounts of total chlorophyll, but its significant increment was found under influence of heavy Entec 26 application at the rate of 200 kg N·ha^{-1}. Such effects of nitrogen nutrition were not observed in Green Silver cv. or in the use of ammonium nitrate. More intensive green color leaves due to enhanced chlorophyll content in different species of vegetable crops supplied with fertilizers containing DMPP nitrification inhibitor was observed by Hähndel and Zerulla [2000], Hähndel and Strohm [2001] and Pasda et al. [2001].

Not significant impact of nitrogen fertilization was found in reference to the accumulation of phosphorus, magnesium and calcium in edible parts of Swiss chard at harvest. (tabs 5, 6). The only exception was potassium, which amounts in leaf blades was increased while in petioles significantly decreased in treatment with ammonium nitrate. Similar relations were also observed by Smoleń et al. [2012] who in the field trial with carrot supplied Entec 26 and ammonium nitrate at different N rates. The increment of N dose from 100 to 200 kg·ha^{-1} caused a reduction in the accumulation of phosphorus in edible parts of Swiss chard as well as of potassium and magnesium in leaf blades. Among two compared cultivars Green Silver accumulated higher amounts of magnesium in both tested edible plant parts, while potassium and calcium only in leaf petioles. Phosphorus concentration was not differentiated under influence of cultivar. Great differences were observed in mineral composition of particular plant parts. Irrespective of nitrogen form and level as well as cultivar of Swiss chard the leaf blades contained nearly twofold higher amounts of magnesium, significantly more phosphorus but much lower concentration of calcium if compared to the leaf petioles. Similar variability of mineral concentration in leaf blades and petioles were also observed in our previous study with different cultivars of this vegetable species grown for a single harvest in the spring seasons [Kołota and Czerniak 2010].

CONCLUSIONS

Results of the field study proved that Swiss chard grown for multiple leaf harvest can assure the continues supply of this valuable vegetable crop to the fresh market since early summer to autumn months. Both sources of nitrogen: ammonium nitrate and Entec 26 being equally valuable sources of this nutrient supplied at a single preplant rate of 100 kg N·ha^{-1} assured satisfactory of a good quality yield with significantly lower content of nitrates if compared to plants fertilized with 200 kg N·ha^{-1}. Total marketable crop yield of Lukullus cv. consisted of similar, while Green Silver cv. lower percentage of leaf blades than petioles.

REFERENCES

Chohura, P., Kołota, E. (2014). Suitability of some nitrogen fertilizers for the cultivation of early cabbage. J. Elem., 19(3), 661–672.

Czerniak, K., Kołota, E. (2008). Effect of the term of harvest on yield and nutritional value of spinach beet. J. Elem., 13(2), 181–188.

Dyduch, J. Najda, A. (2005). Changes of dry matter and L-ascorbic acid contents in the leaves of two cultivars of celery (*Apium graveolens* L. var. *dulce* Mill/Pers.) relative to the length of vegetation and soil mulching. Zesz. Nauk. Akad. Rol. Wroc., Rolnictwo, 515, 111–119 (in Polish).

Dzida, K., Jarosz, Z. (2011). The effect of diversified potassium fertilization on the yield and chemical composition of *Beta vulgaris* L. Konf. Nauk. „Nauka i praktyka ogrodnicza dla zdrowia i środowiska". Lublin, 14–16 września, 37–38.

Dzida, K., Pitura, K. (2008). The influence of varied nitrogen fertilization on yield and chemical composition of Swiss chard (*Beta vulgaris* var. *cicla* L.). Acta Sci. Pol. Hortorum Cultus, 7(3), 15–24.

Hähndel, R., Strohm, M. (2001). New stabilized N fertilizer: further studies. Gemüse, 6, 13–16 (in German).

Hähndel, R., Wissemeier, A.H. (2008). Yield and quality of field – grown vegetables at different sites in Europe as affected by fertilizer application together with the nitrification inhibitor DMPP and its environmental implications. First Symposium on Horticulture in Europe 17–20 February, Vienna, Austria. Book of Abstracts, 139.

Hähndel, R., Zerulla, W. (2000). Effect of Entec application on yield and yield quality of vegetables. Gemüse, 3, 14–16 (in German).

Hähndel, R., Zerulla, W. (2001). Effects of ammonium-stabilized N-fertilizer on yield and quality of vegetables. Acta Hort., 563, 81–86.

Kołota, E., Adamczewska-Sowińska, K. (2007). The effect of Entec 26 stabilized nitrogen fertilizer on yielding of early leeks. Rocz. Akad. Rol. Pozn., Ogrodnictwo, 41, 529–532 (in Polish).

Kołota, E., Adamczewska-Sowińska, K., Krężel, J. (2007). Suitability of Entec 26 as a source of nitrogen for red beet and celeriac. Veg. Crops Res. Bull., 67, 47–54.

Kołota, E., Adamczewska-Sowińska, K., Czerniak, K. (2010). Yield and nutritional value of Swiss chard grown for summer and autumn harvest. J. Agric. Sci., 2(4), 120–124.

Kołota, E., Czerniak, K. (2010). The effects of nitrogen fertilization on yield and nutritional value of Swiss chard. Acta Sci. Pol. Hortorum Cultus, 9(2), 31–37.

Kmiecik, W., Lisiewska, Z., Gebczyński, P. (2005). The level of nitrates and oxalates in different usable parts of dill (*Anethum graveolens* L.) depending on plant height. Acta Sci. Pol. Technologia Alimentaria, 4(1), 93–102.

Krężel, J., Kołota, E. (2014). Source of nitrogen affects the yield and quality of spinach cultivars grown for autumn harvest. Acta Agric. Scand., Soil Plant Sci., 64(7), 583–589.

Lorenz, O.A., Maynard, D.N. (1987). Knott's Handbook for Vegetable Growers. 3rd Edition. John Wiley and Sons, New York.

Nowosielski, O. (1988). Zasady opracowywania zaleceń nawozowych w ogrodnictwie. PWRiL, Warszawa (in Polish).

Paschold, P., Artelt, B., Hermann, G. (2008). Effect of the stabilized nitrogen fertilizer Entec 26 on the yield of asparagus (*Asparagus officinalis* L.). Acta Hort., 776, 111–116.

Pasda, G., Hähndel, R., Zerulla, W. (2001). Effect of fertilizer with the new nitrification inhibitor DMPP (3,4-dimethylpyrazole phosphate) on yield and quality of agricultural and horticultural crops. Biol. Fert. Soils, 34(2), 85–97.

Pasikowska, R., Dąbrowska, B., Cepecka, E. (2002). The effect of nitrogen fertilization rate on the yield and quality of two cultivars of parsley (*Petroselinum sativum* L. ssp. *crispum*) grown on different soil types. Fol. Hortic., 14(1), 177–185.

Santamaria, P., Elia, A., Serio, F., Gonnela, M. (1999). Comparison between nitrate and ammonium nutrition in fennel, celery and Swiss chard. J. Plant Nutr., 22(7), 1091–1106.

Singhal, R.S., Kulkarni, P.R. (1998). Leafy vegetables. In: Handbook of vegetable science and technology. Production, composition, storage, and processing, Salunkhe, D.K., Kadam, S.S. (eds). Marcel Dekker Inc., New York.

Smoleń, S., Sady, W., Wierzbińska, J. (2012). The influence of nitrogen fertilization with Entec-26 and ammonium nitrate on the concentration of thirty-one elements in carrot (*Daucus carota* L.) storage roots. J. Elem., 17(1), 115–137. doi: 10.5601/jelem.2012.17.1.1

Wang, Z.H., Li, S.X. (2003). Effects of N forms and rates on vegetable growth and nitrate acumulation. Pedosphere, 13(4), 309–316.