Pol. J. Environ. Stud. Vol. 21, No. 4 (2012), 937-942

Original Research

The Effects of Genetic and Agronomic Factors on Quantity and Quality of Leafy Parsley Yield

Eugeniusz Kołota, Sylwia Winiarska, Katarzyna Adamczewska-Sowińska*

Department of Horticulture, Wrocław University of Environmental and Life Sciences,
Pl. Grunwaldzki 24a, 50-363 Wrocław, Poland

Received: 14 June 2011
Accepted: 28 February 2012

Abstract

Four field experiments were conducted to determine the effects of the use of plane (Titan, Karnaval, Festival, and Natalka) and curled-leaf cultivars (Paramount, Petra), the quality of transplants raised in different cell volumes (95, 69.3, 32.0, 25.6, 10.0 cm^3), Jiffy pots – (112.5 cm^3) and the number of plants per cell (1, 2, and 3), as well as plant cover in the field with perforated foil fleece, and plastic tunnel on yield and nutritional value of parsley leaves. Harvest of leaves was conducted three times: in early July, at the end of August, and mid October. The samples of leaves were collected for evaluation of the content of vitamin C and nitrates.

All plain leaf cultivars significantly overyielded those of curled-leaf and the highest total leaf biomass was produced by 'Karnaval', appreciated also for its high value of vitamin C, but showing a tendency to nitrate accumulation. Jiffy pots and multicell trays with the cell volumes 95.0 and 69.3 cm^3 were preferable for the quality of seedlings and total yield of leaves obtained during three subsequent harvests. The enhanced number of seedlings produced in the cell had disadvantageous effects on the yield and nutritional value of parsley, expressed by a decreased amount of vitamin C and higher value of nitrates in the first two harvests. The most suitable for covering plants of leafy parsley proved to be fleece, followed by perforated foil and plastic tunnel. All these covers caused an increment of vitamin C and a decrease in nitrate accumulation in leaves.

Keywords: leafy parsley, cultivars, transplant quality, plant covers, yield, chemical composition

Introduction

Leafy type parsley (*Petroselinum sativum* L. var. *crispum*) is recognized as a rich source of vitamin C, carotenoids, mineral salts, flavonoids, and volatile oils [1-4]. An important advantage of this vegetable is the possibility of its consumption in fresh or preserved forms – frozen or dried [5]. Until now it has been a minor crop in Poland, like in the other Central European countries, where the Hamburg type of parsley (*Petroselinum hortense* Hoffm.) is widely cultivated for harvest of roots, while in its early growth stages the whole plants or abundant leaf rosettes may be supplied fresh, in bunches, to the market [6, 7].

*e-mail: katarzyna.a-sowinska@up.wroc.pl

Leafy type parsley is classified on the basis of morphological differences of leaf blade features [8]. Curled leaf parsley (var. *crispum*) is commonly cultivated in Western Europe and used for garnishing dishes or as a dried component of herb mixtures. Plain leaf varieties (var. *neapolitanum* Danert) – are used as flavorings to fresh dishes, soups and sauces.

Leafy parsley may be grown from direct seed sowing into the field [9, 10] or from transplants, which provide acceleration of its harvest and enhancement of leaf yield. Generally, the use of multicell trays are recommended for transplant raising, which cell volume and compression of the medium can highly modify the quality of seedlings and plant shape by altering plant density, competition for light and water, nutrient retention, and root volume [11-13].

Studies with different vegetable species have proven that differences in transplant quality resulting from differences in tray cell size affected the stand, earliness, yield, and quality [14-16]. Generally, greater cell volume appeared to be beneficial for earliness of tomato, pepper, head lettuce, and broccoli [11, 16-19], while total yield of the crop was unaffected. In the other experiments with watermelon, endive, and leek, the greater cell volume was associated with higher total and marketable yield [20-23]. No relation was observed between cell shape and yield, as well as time of harvest of broccoli [12]. So far, there have not been reported any data regarding optimum pot volume, nor the number of seedlings per pot for plant growth and yield of leafy parsley.

The important factor, which improves the growing conditions and enables acceleration of yielding, is the use of plant covers, such as plastic row covers, perforated foil, or nonwoven polypropylene. There are many data in the literature proving favorable effects of the mentioned covers on advanced maturation of different vegetable species and obtaining higher yield of the crop [24-30]. Similar effects can probably be expected in cultivation of leafy parsley.

Material and Methods

Four field experiments were conducted in Piastów Horticultural Experimental Station, on a heavy clay soil of pH 6.8-7.0 and organic matter content averaging 1.8%.

Experiment 1
Cultivars Evaluation

Four plain-leaf cultivars (Titan, Karnaval, Festival, and Natalka) and two curled-leaf cultivars (Paramount, Petra) were subjected to investigation in order to estimate the yield of leaves, as well as vitamin C and nitrate contents in the subsequent terms of harvest in 2004-05.

The seeds of all tested cultivars were sown in the greenhouse on 25 February into multiseeded trays with cell volume 69.3 cm^3, filled with peat substrate. One week before planting, well developed transplants were hardened in a plastic tunnel and then planted in the field on 21st April, in spacing 30×20 cm. Harvest of leaves was conducted three times each year: on 5 July, 25 August, and 15 October. There were estimated marketable yield of leaves and participation of leaf blades in total biomass of yield.

Experiment 2
Pot Volume for Transplant Raising

Seeds of leafy parsley cv. 'Paramount' were sown on 15 February into the Jiffy pots (112.5 cm^3 pot volume) and to multiseeded trays with different cell volumes: 95.0, 69.3, 32.0, 25.6, and 10.0 cm^3, filled with peat substrate. Directly before planting, which took place on 17 April, the samples of 40 seedlings from each treatment were collected for the assessment of transplant quality on the basis of mean values of plant height and weight. Subsequent harvests of leaves were conducted on 10 July, 28 August, and 16 October in the years 2004-06.

Experiment 3
The Number of Seedlings Per Pot

Seeds of 'Paramount' cv. were sown in the greenhouse into plastic boxes filled with peat substrate on 15 Febuary. One month later the seedlings in the stage of one true leaf were pricked out into the multicell trays with cell volume 69.3 cm^3 in the number of 1, 2, or 3 plants per pot. Transplants were planted into the field on 16 April, in spacing 30×20 cm. Harvest of leaves was conducted on 12 July, 29 August, and 16 October each year, of 2001-03.

Experiment 4
The Type of Plastic Cover

Seeds of 'Paramount' cv. were sown into multicell trays with cell volume 69.3 cm^3. Well hardened seedlings were planted on 17 April, in spacing 30×20 cm and covered with perforated foil 0.08 mm thick with 100 holes per 1 m^2, fleece (17 $g \cdot m^{-2}$) or low plastic tunnel (120 cm wide and 60 cm high) covered with a sheet of 0.06 mm thick polyethylene foil. All tested covers were removed from plants after four weeks from the date of transplanting. The harvest of leaves took place on 2nd July, 21st August, and 14th October in 2001-03.

The soil was fertilized with nitrogen in the amount of 50 $kg \cdot ha^{-1}$ as a preplant dose and 30 $kg \cdot ha^{-1}$ after each harvest as top dressing. The contents of available forms of phosphorus and potassium were supplemented by early spring fertilization to the level of 60 mg P and 200 mg K, respectively. Ammonium nitrate, triple superphosphate, and potassium chloride were used as the source of nutrients. Cultural practices and plant protection followed the standard recommendations for parsley. During harvest, each time the samples of leaves were collected for chemical analysis of vitamin C (Tillmans method) and nitrates content (ion-selective electrode, Orions method).

All field experiments were established in one-factorial design, in four replications and plot area amounted 2.16 m^2 (1.8×1.2 m). The results of the experiments were analyzed by standard statistical procedure and the least significant differences between means were calculated by Tukey test at α=0.05.

Results and Discussion

The data of experiment I (Table 1) indicate that, generally, plain-leaf cultivars produced substantially higher yield of leaves than curled-leaf ones. Belonging to this group 'Karnaval' cv. formed biggest rosettes, consisting of well shaped, long green leaves, and provided the highest total yield of three subsequent harvests, averaging 45.41 $t \cdot ha^{-1}$. The disadvantage of this cultivar was a strong tendency for nitrate accumulation, especially in poor light conditions during the harvest conducted in the half of October .'Titan'

Table 1. Marketable yield, participation of leaf blades in total yield, vitamin C, and nitrate contents depending on the cultivar of leafy type of parsley (mean for 2004-05).

Cultivar	Marketable yield of leaves ($t \cdot ha^{-1}$)				Participation of leaf blades in total yield (%)			Vitamin C ($mg \cdot 100\ g^{-1}$ f.w.)			Nitrates ($mg\ NO_3\text{-}N \cdot kg^{-1}$ f.w.)		
	Subsequent harvest terms												
	I[y]	II	III	Total from 3 harvest	I	II	III	I	II	III	I	II	III
Titan	15.49a	9.53b	10.49b	35.51b	61.6	67.6	65.3	362.8a	287.2c	245.0d	221c	266e	778d
Karnaval	15.94a	16.10a	13.37a	45.41a	56.4	64.8	63.3	370.9a	240.3e	336.1a	533a	656a	1159a
Natalka	14.12a	3.67de	7.02c	24.81c	56.2	65.8	51.3	354.6a	276.3d	324.2ab	535a	750a	1051b
Festival	15.08a	5.73c	7.23c	28.04c	60.3	68.0	57.6	370.7a	305.9b	334.7ab	406b	530b	560e
Paramount	9.70b	4.64cd	5.04d	19.38d	70.8	66.7	69.0	357.6a	316.3a	267.0c	433b	507c	959c
Petra	10.04b	2.14e	2.00e	14.08e	71.7	75.1	78.3	212.8b	291.9c	268.3c	230c	288d	520e
Mean	13.40	6.97	7.53	27.90	62.8	68.0	64.1	338.2	286.3	295.9	393	500	838

[y]Term of harvest: I – 5 July, II – 25 August, III – 15 October
Means followed by the same letter are not significantly different from each other using the LSD test ($\alpha \leq 0.05$)

was another valuable cultivar with dark green long leaves, excellent flavor, and pleasant smell that, irrespective of the term of harvest, contained low amounts of nitrates. It was also a rich source of vitamin C during the first two harvests, but in October the content of this component was significantly lower in comparison with other tested cultivars.

Similar to each other, but significantly lower total yields than 'Karnaval' and 'Titan', were produced by 'Festival' and 'Natalka' cvs. The reason was low biomass of leaves obtained in August and October due to their limited regrowth after first cutting in July. Both these cultivars contained high amounts of vitamin C, but the nutritional value of 'Natalka' was considerably diminished by high nitrate accumulation, at the level similar to 'Karnaval' cv.

Curled-leaf parsley provided markedly lower yield as a result of smaller leaf blades in comparison to plain-leaf cultivars. Widely currently grown 'Paramount' cv., which is appreciated for its aromatic and tasty leaves, rich in vitamin C, and suitable for drying or freezing, significantly overyielded 'Petra', another curled-leaf cultivar. At the first cutting 'Petra' produced similar of yield biomass size, but in the following two harvests that parameter showed considerably lower values due to poor regrowth of leaves. Its leaves, which apart from 'Titan' cv., accumulated lower amounts of nitrates than other cultivars, can be used not only for eating but also for garnishing dishes due to its decorative features:dark green leaves and strongly curled surface. Leaf-blades, plant parts used for processing, providing for nearly 4/5 of the whole leaf weight in 'Petra' and over 2/3 in 'Paramount' cultivar, which constituted significantly higher share than in plane-leaf cultivars. According to Kmiecik and Lisiewska [7] such properties make these cultivars more suitable for drying, as well as freezing purposes. Generally, results of our study remain in agreement with

Table 2. The effect of pot volume on quality of transplants and yield of leafy type of parsley (mean for 2004-06).

Pot volume (cm^3)	Quality of transplants		Marketable yield of leaves in subsequent harvest terms ($t \cdot ha^{-1}$)			
	Height of plant (cm)	Weight of above-ground part of plant (g)	I[y]	II	III	Total from 3 harvests
112.5 (Jiffy pot)	10.2b	9.67ab	12.22a	16.65a	9.57a	38.94a
95.0	11.7a	10.50a	11.19b	16.22a	9.34a	37.37b
69.3	11.5a	10.33a	10.95b	15.37b	8.84b	35.66c
32.0	9.3c	8.67c	7.17d	12.96c	7.77c	29.12e
25.6	9.5c	9.33bc	7.82c	13.03c	8.58b	30.41d
10.0	8.7d	8.50c	6.50e	11.02d	7.00d	25.65f
Mean	10.1	9.50	9.31	14.21	7.64	32.86

[y]Term of harvest: I – 10 July, II – 28 August, III – 16 October
Means followed by the same letter are not significantly different from each other using the LSD test ($\alpha \leq 0.05$)

Table 3. Yield, vitamin C, and nitrates content in the leaves at harvest depending on the method of transplant production (mean for 2001-03).

Number of plants per pot	Marketable yield of leaves (t·ha^{-1})				Vitamin C (mg·100 g^{-1} f.w.)			Nitrates (mg NO_3-N·kg^{-1} f.w.)		
	Subsequent harvest terms									
	I[y]	II	III	Total yield of leaves	I	II	III	I	II	III
1	17.66a	14.95a	8.09a	40.70a	357a	285a	276a	377b	352b	450a
2	15.79b	12.64b	7.23b	35.66b	339b	266b	271a	387a	364a	453a
3	15.97b	11.62b	5.98c	33.57c	338b	256c	269a	393a	370a	453a
Mean	16.47	13.07	7.10	36.64	345	269	272	386	362	452

[y]Term of harvest: I – 12 July, II – 29 August, III – 16 October
Means followed by the same letter are not significantly different from each other using the LSD test (α≤0.05)

the data presented by Dyduch and Janowska [10], and Pasikowska et al. [31], who reported that plain-leaf parsley overyielded its curled-leaf cultivar and 'Karnaval' can be recognized as one of the most valuable because of high initial and satisfactory yield of leaves in subsequent harvests.

The results of experiment II (Table 2) showed that pot volume used for seedling raising significantly affected the height and weight of transplants of leafy parsley. Among all used pots the most preferable appeared to be multiseeded trays with cell volume of 95.0 and 69.3 cm^3, followed by Jiffy pots with a volume 112.5 cm^3. Seedlings produced in these pots were substantially better developed at planting time in comparison to those grown in smaller cells of multiseeded trays with cell volume ranging within 10.0-32.0 cm^3.

The yield of parsley leaves was significantly influenced by the quality of seedlings used for planting. Plants from Jiffy pots ensured the highest total yield of three subsequent harvests (38.94 t·ha^{-1}), followed by those produced in multiseeded trays with cell volumes 95.0 cm^3 (37.37 t·ha^{-1}) and 69.3 cm^3 (35.66 t·ha^{-1}). Plants from smaller cell volumes produced significantly lower yield of leaves, especially in the case of cell volume of 10.0 cm^3. Similar relations between the quality of transplants produced in different sized cells used for raising the seedlings and final yield could be also observed in our previous study with leeks [23] and, by Reghin et al. [21], with endive. In many other vegetable crops the using of larger cell volume trays was not beneficial because of the higher cost of medium and production space requirement for transplants raising, with a similar level of marketable yield. However, in the case of leafy parsley, a crop sensitive to transplanting, the substantial yield increment may justify the use of trays with cell volume 69.3 cm^3.

Experiment III. The use of multi-seeded transplants comprising 2 or 3 seedlings per pot (Table 3) adversely affected the yield of leafy parsley in all terms of harvest as compared to that of single ones. Total yield of subsequent harvests was diminished by 12.4% and 17.5%, respectively. High population of plants per unit area in treatments with 2 or 3 seedlings per pot also caused a significant decrease in vitamin C content and elevated values regarding nitrate accumulation. The only exceptions were the results of the last term of harvest, when differences in the amounts of both mentioned constituents were negligible.

Experiment IV. All covers used in the study appeared to be preferable for growth of plants after their transplanting into the field, as the examined plants were higher and produced more leaves than those of control treatment (Table 4). However, the yield of leaves and their nutritional value

Table 4. The influence of the kind of plant cover on yielding of parsley and vitamin C and nitrate content in the leaves (mean for 2001-03).

Type of plant cover	Marketable yield of leaves (t·ha^{-1})				Vitamin C (mg·100 g^{-1} f.w.)			Nitrates (mg NO_3-N·kg^{-1} f.w.)		
	Subsequent harvest terms									
	I[y]	II	III	Total from 3 harvest	I	II	III	I	II	III
Foil	15.9b	13.7a	11.1a	40.7a	260ab	275a	280a	522ab	510a	605a
Fleece	17.6a	13.3a	10.9a	41.8a	268a	273a	281a	518ab	522a	603a
Plastic tunnel	15.0b	13.4a	9.8a	38.2b	262a	274a	280a	508b	502a	602a
Control	13.7c	13.2a	10.0a	36.8b	250b	272a	281a	533a	509a	602a
Mean	15.6	13.4	10.4	39.4	260	274	280	520	511	603

[y]Term of harvest: I – 2 July, II – 21 August, III – 14 October
Means followed by the same letter are not significantly different from each other using the LSD test (α≤0.05)

were significantly affected by the covers only during the first term of harvest conducted at the beginning of July. Flat covering of plants with fleece was the most preferable for plant growth and yield of leaves. Similar to each other, but significantly lower yields than in treatment with fleece, were obtained by using perforated foil and a plastic tunnel. Another advantage of the use of all covers was the enhancement of vitamin C level and lower nitrates accumulation in parsley leaves.

As could be expected, the covers removed from over the plants after four weeks from the date of transplanting did not influence the yield, as well as vitamin C and nitrate content in the second and third term of harvest conducted in late August and half of October.

Summarizing the effects of evaluated factors on biological value of parsley leaves, it can be stated that content of vitamin C was highly affected not only by the cultivar but also such agronomic factors as date of harvest, plant population and type of plant cover. The decrease of this compound in the second and third harvest terms and in treatments with 2 or 3 seedlings produced in the pot may be explained by the less favorable light growing conditions. Lester [32] indicated that both light intensity and light quality are extremely influential in regulation fruit and vegetable vitamin content. The declined concentration of ascorbic acid in low light intensity may be the effects of the reduction of glucose synthesis rate, which is the starting molecule in ascorbic acid biosynthesis. Such a relationship is found to be in agreement with earlier Makus and Lester [33], who observed a high reduction of vitamin C content in mustard greens grown in 50% shade in comparison to full sunlight, as well as in some other vegetable species like parsley, lamb's lettuce, spinach, butter head lettuce, and chicory grown in autumn [34-37]. The adverse effect of higher temperature on vitamin C biosynthesis proved by Sayre et al. [38] in tomato fruits was not confirmed in our study. Higher temperature assured by plastic tunnel flat covers appeared to be favorable for the content of this compound in early spring harvest.

The quality of autumn harvested leafy vegetables may also be substantially diminished by high nitrate accumulation. Foliage crops, including parsley, invariably contain a lot of nitrates, even when grown at reasonable nitrogen fertilization [39], and their amounts may be considerably enhanced by growing in poor light conditions [35, 40-42]. In our study with leafy parsley the highest nitrate accumulation was noticed when the harvest was conducted in October at short-day duration and low-light intensity, which caused the reduction of photosynthesis rate and sugar content in plants. Low nitrate reductase activity in such conditions slows down the reduction of nitrates to ammonia and finally provides high nitrate accumulation in plants [41].

Based on the data from the literature it can be concluded that in the case of growing for leaf harvest, leafy type of parsley gave better effects that the rooted one [7, 10]. Results of our studies indicate that the increased yield of leafy parsley can be attributed to the use of plain-leaf cultivars, the high quality of transplants, and covering the seedlings directly after planting, especially with the fleece. The ultimate selection for particular cell size will be determined by transplant production costs and the price for a marketable product.

Conclusions

1. Karnaval, a plane leaf cultivar, produced the highest yield of leaves rich in vitamin C, but with high tendency for nitrate accumulation, especially when harvested in October in poor light conditions. Titan was the other valuable cultivar, with low nitrates content irrespective of the harvest date.
2. Jiffy pots and multicell trays with cell volume 95.0 and 69.3 cm^3 were preferable for quality of transplants and final yield of leaves.
3. Enhanced number of seedlings from 1 to 3 produced in one cell of multicell trays bad disadvantageous effects on yield of and vitamin C content in leafy parsley.
4. The most suitable for plant covering proved to be fleece, followed by perforated foil and plastic tunnel.

References

1. BUCHTER-WISBRODT H. Vegetables – utilization and health: parsley. Gemüse **5**, 10, **2005**.
2. DIAZ-MAROTO M., PEREZ-COELLO M. S., CABEZUDO M. D. Effect of different methods on the volatile components of parsley (*Petroselinum crispum* L.). Eur. Food Res. Technol. **215**, 227, **2002**.
3. MAŁOLEPSZA U., URBANEK H. Plant flavonoids as biochemical active compounds. Wiadom. Bot. **44**, 27, **2000** [In Polish].
4. MIKOŁAJCZYK K., WIERZBICKI A. Herbs as a source of health. Oficyna Wydawniczo-Poligraficzna "Adam," Warszawa, pp. 236-237, **1999** [In Polish].
5. BĄKOWSKI J., MICHALIK H.. Suitability of several vegetable species for drying. Biul. Warz. **XXIX**, 191, **1986**.
6. GRZESZCZUK M., JADCZAK D., ORŁOWSKI M. The estimation of biological value of leafy type parsley and its suitability for freezing. Scientific Works of the Lithuanian Institute of Hort. and Lithuanian Univ. of Agric. Hort. and Veg. Growing. **24**, (3), 387, **2005**.
7. KMIECIK W., LISIEWSKA Z. Comparison of leaf yields and chemical composition of the Hamburg and leafy types of parsley. Part I. Leaf yields and their structure. Folia Hort. **11**, (1), 53, **1999**.
8. SIMON J.E., QUINN J. Characterization of essential oil of parsley. J. Agric. Food Chem. **36**, 467, **1988**.
9. BŁAŻEWICZ-WOŹNIAK M. The dynamics of growth of parsley leaves depending on depth of sowing and plant density. Mat. VIII Ogólnopol. Zjazdu Nauk. "Hodowla Roślin Ogrodniczych u progu XXI wieku", Lublin, pp. 51-54, **1999**.
10. DYDUCH J., JANOWSKA K. Yielding of some parsley (*Petrosolinum sativum* L. ssp. *crispum*) cultivars. Acta Sci Pol. Hortorum Cultus **3**, (1), 145, **2004** [In Polish].
11. BABIK I. 2000. The influence of transplant age and method of plant raising on yield and harvest time of autumn broccoli (*Brasica oleracea* L. var. *italica* Plenck). Acta Hort. **533**, 145, **2000**.
12. DAMATO G., TROTTA L. Cell shape, transplant age, cultivars and yield in broccoli. Acta Hort. **533**, 153, **2000**.

13. AGUILA-SANCHO J.F. The present status of the substrate as an ecosystem component and its function and importance in crop productivity. Acta Hort. **221**, 53, **1988**.
14. KNAVEL D.E. Influence of container, container size, and spacing on growth of transplants and yield in tomato. Proc. Amer. Soc. Hort. Sci. **86**, 582, **1965**.
15. KRETCHMAN D.W., SHORT T.H. A further evaluation of transplants for processing tomatoes in Ohio. Ohio Agr. Res. And Development Ctr., Wooster, Hort. Ser. **443**, **1977**.
16. NICOLA S., CANTLIFFE D.J. Increasing cell size and reducing medium compression enhance lettuce transplant quality and field production. HortSci. **31**, (2), 184, **1996**.
17. BASOCCU L., NICOLA S. Influence of different growing techniques on seedlings and fruit production of pepper (*Capsicum annuum* L.), p. 4056. In: Proc. 23rd Intl. Hort. Congr., Intl. Soc. Hort. Sci. Florence, Italy, 27 Aug.-1 Sept. **1990**.
18. WESTON L.A., ZANDRA B. Effect of root container size and location of production on growth and yield of tomato transplants. J. Amer. Soc. Hort. Sci. **111**, 498, **1986**.
19. GIANQUINTO G. Ricerche sulla modalita di allevamento in vivaio di piantine di lattuga cappuccia (*Lactuca sativa* L. var. *capitata* (L.) Janchen): Riflessi sulla produzione in coltura protetta. Colture Protette **1**, 83, **1991**.
20. HALL M.R. Cell size of seedling containers influences early vine growth and yield of transplanted watermelon. HortSci. **24**, 771, **1989**.
21. REGHIN M.Y., OTTO R.F., OLINIK J.R., JACOBY C.F.S. Endive (*Cichorium endivia* L.) yield in function of tray types and seedlings age at transplanting. Cienc. Agrotec. **31**, (3), 739, **2007**.
22. KOŁOTA E., ADAMCZEWSKA-SOWIŃSKA K. The effects of seed sowing date and size of multicell trays on quality of transplants and yield of early leeks. Part I. Quality of Transplants. Allium Improvement Nwsl. Dep. Hort. Univ. of Wisconsin. Madison USA **9**, 14, **1999**.
23. KOŁOTA E., ADAMCZEWSKA- SOWIŃSKA K. The effects of seed sowing date and size of multicell trays on quality of transplants and yield of early leeks. Part II. Crop yield. Allium Improvement Nwsl. Dep. Hort. Univ. of Wisconsin. Madison USA **9**, 18, **1999**.
24. BENOIT F., CEUSTERMANS N. Horticultural applications of plastics in the Benelux. Research Report European Vegetable R&D Centre, Sint Katelijne Waver, Belgium, **1985**.
25. DOBROMILSKA R. Forecrop fennel cultivation in a cold greenhouse and in the field under covers. Veg. Crops Res. Bul. **54**, 99, **2001**.
26. MAYNC A. Verfrühung von Gemüse. Gewusst wie? Landes- Lehr- und Forschungsanstalt. Neustadt. Neustadter Hefte 17, **1983**.
27. RUMPEL J. Plastic and agrotextile covers in pickling cucumber production. Acta Hort. **371**, 253, **1994**.
28. SIWEK P., LIBIK A. The influence of plastic film and non-woven covers in the early celery cultivation on the quantity and quality of yield. Zesz. Nauk AR we Wrocławiu **515**, 483, **2005** [In Polish].
29. SŁODKOWSKI P., REKOWSKA E. Butterhead lettuce yielding in dependence on the way of covering and the growing method. Veg. Crops Res. Bul. **54**, 25, **2001**.
30. WADAS, W., JABŁOŃSKA–CEGLAREK R. The effect of nonwoven polypropylene covering on the yield of very early potato cultivars. Veg. Crops Res. Bul. **54**, 31, **2001**.
31. PASIKOWSKA, R., DĄBROWSKA B., CAPECKA E. 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. Folia Hort. **14**, (1), 177, **2002**.
32. LESTER G.E. Environmental regulation of human health nutrients (ascorbic acid, β-carotene, and folic acid) in fruits and vegetables. HortSci. **41**, (1), 59, **2006**.
33. MAKUS D.J., LESTER G.E. Effect of soil type, Light intensity and cultivar on leaf nutrients in mustard greens. Subtrop. Plant Sci. **54**, 23, **2002**.
34. BOHRER M.E. The effect of the harvest term and postharvest treatment on yield and quality of leafy parsley cultivars. Gemüse **1**, 38, **1990**.
35. DREWS M., SCHONHOF I., KRUMBEIN A. Nitrates, Vitamin C, β-carotene and sugar contents in letuce throughout the year in greenhouse cultivation (*Lactuca sativa* L.). Gartenbauwiss. **60**, (4), 180, **1995**.
36. ADAMCZEWSKA-SOWIŃSKA K., KOŁOTA E. Estimation of yielding and nutritional value of some lamb lettuce cultivars grown for early spring and autumn harvest. Rocz. AR w Poznaniu, Ogrodn. **3**, 205, **2000** [In Polish].
37. MAJKOWSKA-GADOMSKA J., WIERZBICKA B. Effect of cultivation season and sorbent applied on the yield and content of some nutritional components in lettuce leaves. Zesz. Nauk. AR we Wrocławiu, Rol., **515**, 339, **2005** [In Polish].
38. SAYRE C.B., ROBINSON W.B., WISHNETSKY T. Effect of temperature on the color, lycopene and carotene content of detached and of vine ripened tomatoes. Proc. Amer. Soc. Hort. Sci. **61**, 381, **1953**.
39. GREENWOD D.J., HUNT J. Effect of nitrogen fertilizer on the nitrate contents of field vegetables grown in Britain. J. Sci. Food Agric. **37**, 373, **1985**.
40. JAWORSKA G., KMIECIK W. Content of selected mineral compounds, nitrates III and V, and oxalates in spinach (*Spinacia oleracea* L.) and New Zealand spinach (*Tetragonia expansa* Murr.) from spring and autumn growing seasons. Electronic Journal of Polish Agricultural Universities. Food Science and Technology, **2**, **1999**.
41. KOZIK E. Effect of harvest term and nitrogen and potassium fertilization on content of nitrates in greenhouse lettuce. Acta Agrophysica **7**, (3), 633, **2006** [In Polish].
42. FRANCKE A., MAJKOWSKA-GADOMSKA J. Effect of planting date and method on the chemical composition of radicchio heads. J. Elementol. **13**, (2), 199, **2008**.