EFFICIENCY OF THE ADDITIONAL FERTILIZATION WITH NITROGEN FERTILIZERS GROWING CARROT OF EXCEPTIONAL QUALITY AND ITS INFLUENCE ON PRODUCTION STORAGE

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Abstract

Plant nutrition, among other agro-technical measures most influences yield, quality and production storability. The aim of investigations – instilling new technological elements of the growing of root-crop vegetables of exceptional quality to choose for the additional fertilization the most suitable nitrogen fertilizer and its rate in order the soil, environment was polluted as little as possible and the qualitative production was obtained. There were grown carrot 'Nerac' F_1 and 'Tito'. There was investigated the influence of nitrogen fertilizer used for additional fertilization (ammonium nitrate and calcium nitrate) and their rates (N_{30} and N_{15}) on carrot yield, and its impact on production storage. Additional fertilizations were carried out at 2–4 carrot leaves stage. Carrot were grown on profiled surface, sowing scheme 62+8, there were sown 1 mln. unt. ha^{-1} germinable seeds. Before sowing the field was fertilized with complex fertilizers. Carrots during vegetation period were additionally fertilized through leaves for three times applying soluble complex fertilizers. Experiments were carried out on sandy loam on light loam *Calc(ar)i-Epihypogleyic Luvisol* (*LVg-p-w-cc*). Data of investigations showed that carrot hybrid was more productive than cultivar. Calcium nitre was more effective both to hybrid and cultivar. Vegetables fertilized with it was preserved better than these fertilized with ammonium nitrate.

Keywords: nitrogen fertilizer, exceptional quality.

Introduction

The intensity of agricultural activities determines the level of maintenance of cultural landscapes, biodiversity, and the cultural identity of an area (Li et al., 2013). Success in vegetable culture in a temperate climate has been due to proper mineral nutrition of vegetables, because plant nutrition, among other agro-technical measures most influences yield, quality and production storability (Biesiada et al., 2011; Kant et al., 2011). However, the surplus of supply nutrients, especially nitrogen, may have an adverse effect on the environment as well as quality of the crops. More than 50% of N applied is effectively used by plants, but a large part is lost by leaching and it can lead the contamination of ground and surface water (Fageria et al. 2008; Wang et al., 2008). Optimization of technologies for growing plants is a method to increase plant productivity and to obtain quality yields (Cai, Ge, 2004; McAllister et al., 2012). The data of Cameron (2013) has shown that careful management of temperate systems using best management practices and newly developed technologies can increase the sustainability of agriculture and reduce its impact on the environment. In order to avoid negative consequences on the environment and to grow the production of exceptional quality, the amount of nitrogen scattered during vegetation was limited.

Carrot (*Daucus carota* L.) is the important vegetable crop, grown in temperate climate zone, which includes Lithuania. The objective of the study – instilling new technological elements of the growing of root-crop vegetables of exceptional quality to choose for the additional fertilization the most suitable nitrogen fertilizer and its rate in order the soil, environment was polluted as little as possible and the qualitative production was obtained.

Materials and methods

Experiments were carried out in the Institute of Horticulture in 2010 – 2012, on sandy loam on light loam *Calcari-Epihypogleyic Luvisols (LVg-p-w-cc).* Soil analysis in spring, before N fertilization, was carried out. The soil is characterized by the average content of humus (2.38–2.67), pH neutral to slightly alkaline (7.1-7.7) and by the presence of large amounts of Ca and Mg, which gives more favourable physical-chemical water and soil properties. Mineral nitrogen content in the layer 0–60 cm was low to average (44.2-87.7 mg kg^{-1}), while there was a good stock of soluble phosphorus (P_2O_5 – 166-262 mg kg^{-1}) and potassium (K_2O – 141-184 mg kg^{-1}).

The carrot 'Nerac' F_1 and 'Tito' (factor B) were grown on the profiled surface, 1.0 mln. ha^{-1} viable seed. Both the other cases the sowing scheme were 62 +8 cm.

Scheme of the fertilization (factor A): 1. Basic fertilization (handed before presowing tillage with additionally foliar application (Basic – B); 2. B+calcium nitrate N_{30} (B+CN N_{30}); 3. B+calcium nitrate N_{15} (B+CN N_{15}); 4. B+ammonium nitrate N_{30} (B+AN N_{30}); 5. B+ammonium nitrate N_{15} (B+AN N_{15}).

Soil fertilization was carried out with complex mineral fertilizers using a ratio $N_{84}P_{84}K_{160,4}$. Fertilizers were applied before sowing of carrot. Nitrogen fertilizer for additional fertilization, introduced as ammonium nitrate (34% N, NO_3-N 17%, N-NH_4 17%.) and calcium nitrate (15.5% N, NO_3-N 14.4%, N-NH_4 1.1 % and 26.4 % CaO), was applied once during the growing season when carrot was at 2-4 leaf stage. Carrot during vegetation period were additionally fertilized through leaves for three times applying soluble complex fertilizers: twice with Ferticare 14 11 25 with microelements, 5 kg ha^{-1} by adding Delfan, 2 L ha^{-1}, once Ferticare 6 14 30 with microelements, kg ha^{-1} by adding Final K, 2 L ha^{-1}. Experiments were carried out every year in 4 replications in systematic order. Area of record plot – 6.2 m^2.

Work of plant supervision was carried out according to vegetable growing technologies accepted in LIH, observing requirements of growing of exceptional quality production, where the use of nitrogen and pesticides is limited. Carrot yield was gathered, when vegetables reached technical maturity, classifying into marketable and nonmarketable. When harvesting according to the variants, with three replications, there were taken samples for biochemical investigations and 12–15 kg samples for root-crop storability investigations. Root-crops were stored in freezer, under stabile temperature (-1–+2° C) and relational humidity (85–90%), in the storage houses of Institute of Horticulture, LRCAF. Root-crop storability was inspected after 3 and 7 months, classifying well-preserved and diseased (rotten, partly rotten and wilted, i. e. not suitable for usage) red beet root-crops and establishing the natural loss, i. e., drying.

Table 1

Average monthly air temperature at the experiment site

Month	Air temperature °C			Multi annual
	2010	2011	2012	
May	13.5	15.6	13.2	12.3
Jule	14.6	18.9	14.6	15.9
June	19.9	20.2	18.7	17.3
August	17.8	17.7	16.5	16.7
September	9.9	13.7	13.1	12.1
October	3.8	11.8	6.7	7.1
Average	13.2	16.3	13.8	13.6

Investigations of carrot biochemical composition were carried out at the Laboratory of Biochemistry and Technology, Institute of Horticulture, LRCAF. There was established: dry matter (DM) – gravimetrically, after drying out at the temperature of 105±2 °C up to the unchangeable mass (Food analysis, 1986), dry soluble solids (DSS) – with refractometer (digital refractometer ATAGO) (AOAC, Official..., 1990b), sugars – by AOAC method (AOAC, Official..., 1990a), nitrates – by potentiometrical method with ion selective electrode (Metod. nurod., 1990), carotenes – spectrophotometrically (Davies, 1976).

Analysis of variance was performed using the ANOVA statistical package with two-way factors. Treatment means were compared using Fisher's protected least significant difference (LSD) test at $p \leq 0.05$. Contrasts were used to determine the effect of fertilization rates on yield, yield biochemical composition and quality of storage.

Meteorological conditions during the years of the experiment varied significantly (Tables 1, 2). The year 2010 was the colder, but with the higher temperature and higher amount of precipitation in July and August, as compared to multiannual.

Table 2

Average monthly precipitation at the experiment site

Month	Precipitation, mm			Multi annual
	2010	2011	2012	
May	71.4	15.6	57.8	50.7
Jule	72.6	48.0	99.6	71.2
June	119.2	203.6	135.4	75.3
August	105.4	135.2	81.0	78.4
September	51.0	75.8	59.8	58.7
October	0	4.2	69.8	50.5
Average	70.1	86.8	83.9	64.1

The highest and relatively uniform mean temperature during the whole season was in 2011. The year 2011 had the highest total precipitation, with especially humid July and August, but dry June. In 2012 air temperature was slightly higher than the multiannual average, but June and August were cool and June and August were wet, while July was hot and wet.

Results and Discussion

Using nitrogen in both variants, irrespective cultivars, forms and rates, carrot marketable yield increased averagely by 6.3 t ha % or 13.9%. The output of marketable yield increased correspondingly 9.2% (Fig. 1). Data of investigations carried out in various countries with various plants (Chohura, Kołota, 2009; Biesiada et al., 2011; Toivonen, Hodges, 2011) show that nitrogen determines the growth and productivity of plant most of all. According to the data of Zdravkovic et al. (1997), carrot fertilized with manure produced 48.4 t ha^{-1}, with calcium ammonium nitrate – 41.5 t ha^{-1} and their mixture – 41.5 t ha^{-1} of yield. The output of marketable yield is important parameter, which determines fertilizer suitability and corresponds to one of the main requirements of the optimal yield (Suojala, 2000; Zalatorius, Viškelis, 2005). Additionally fertilizing carrots with nitrogen at 2–4 leaf stage, marketable yield of cultivar 'Nerac' F_1 averagely increased 11.7%, the output of marketable yield – 3.4%. At the same time the yield of carrot cultivar 'Tito' increased 17.4%, output – 9.4%. The vegetable yields were not increased continuously with N rate increase, and oversupply of N reduced the plant growth, leading to a yield decline (Wang, Li, 2003). The data of our investigations showed that applying bigger nitrogen rate for additional fertilization the significant additional yield wasn't obtained – comparing with the case when smaller nitrogen rate for carrot fertilization was used. Both calcium nitrate and ammonium nitrate applied for additional fertilization, irrespective of the rates of nitrogen and cultivars, were equally effective for carrots. The best yields were obtained additionally using 30 kg ha^{-1} of nitrogen.

When the rate of nitrogen was decreased, marketable yield 'Nerac' F_1 decreased by 6.0 t ha^{-1} or 11.7%, but marketable yield of cultivar 'Tito' slightly increased. The output of marketable yield was slightly smaller fertilizing with bigger nitrogen rate, but significant differences between the variants weren't noted. Data of study Kolota et al. (2007) showed that application of ammonium nitrate, calcium nitrate and Entec 26 gave similar to each other and considerable better results than ammonium sulphate.

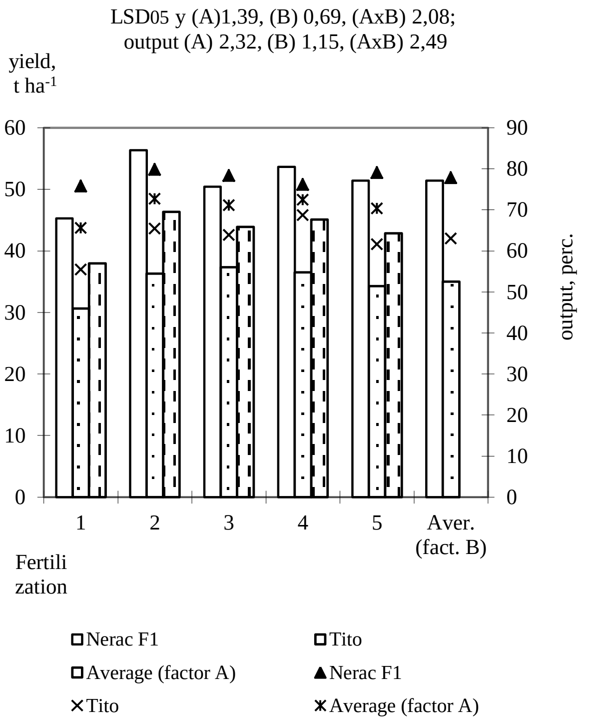

Figure 1. Influence of different nitrogen fertilizers and rates on marketable yield and output of marketable yield of exceptional quality carrot

Fertilization: 1 – Basic fertilization (B), 2 – B + CN N_{30}, 3 – B + CN N_{15}, 4 – B + AN N_{30}, 5 – B + AN N_{15}

Aytko (2004) indicate that in carrot there can be 8–12% of dry matter, 6–8% of sugars, 9–12 mg% of carotene, also potassium and microelements – boron and iodine. Ayaz et al. (2007), affirm that amounts of dry matter fluctuated in wide limits – from 6.40% to 11.43%; nitrates – from 8.1 mg kg^{-1} to 509 mg kg^{-1}. Their concentration in vegetables changes dependently on many factors: vegetable type and cultivar (Seljåsen et al., 2013, Chohura, Kołota, 2009; Rożek et al., 2000), soil, meteorological conditions (Rubatzky et al. 1999). Data of our investigations show that the amounts of dry matter and dry soluble solids fluctuated in very narrow limits and fertilization with nitrogen little influenced their changes (Table 3). Our present studies confirmed Polish (Pokluda, 2006) and Lithuanian (Pekarskas, Bartaševičienė, 2009; Karklelienė et al. 2007) investigators obtain data. They point out that differentiated soil fertilization with nitrogen doesn't significantly influence the amount of dry matter and dry soluble solids, carotenes, nitrates and phenols in carrot root-crops. Paoletti et al. (2012) also indicate that production systems do not affect the nutritional quality of carrot. The amounts of dry soluble so lids, as noted Suojala (2000), can increase when yield gathering is delayed. Slightly bigger amount of dry matter and dry soluble solids as shown in our studies was found in root-crops of cultivar 'Tito'. Big amount of sugars and carotenes, especially β-carotene, and small amount of nitrates are important carrot quality indices (Gajewski et al., 2009, 2010). Arscott and Tanumihardjo (2010) observed that their amounts depend on growth conditions, genotype and fertilization.

Table 3

Influence of different nitrogen fertilizers and rates on biochemical composition of exceptional quality carrot

Fertilization (fact A)	Biochemical composition				
	1	2	3	4	5
Hybrid 'Nerac' (factor B)					
Basic (B)	11.5	9.5	6.1	368.3	13.4
B+CN N_{30}	11.1	9.5	6.4	346.5	13.1
B+CN N_{15}	11.2	9.8	6.3	350.0	13.3
B+AN N_{30}	11.3	9.2	6.4	356.3	13.2
B+AN N_{15}	11.3	9.3	6.4	357.2	13.2
Cultivar 'Tito'(factor B)					
Basic (B)	11.8	9.4	6.3	361.8	13.4
B+CN N_{30}	11.5	9.7	6.3	353.5	13.8
B+CN N_{15}	11.7	9.8	6.2	344.7	14.2
B+AN N_{30}	11.9	9.6	6.4	354.2	12.4
B+AN N_{15}	11.7	9.5	6.2	349.0	12.6
Average fertilization (Factor A)					
Basic (B)	11.6	9.4	6.2	365.1	13.4
B+CN N_{30}	11.3	9.6	6.4	350.0	13.4
B+CN N_{15}	11.4	9.8	6.2	347.3	13.8
B+AN N_{30}	11.6	9.4	6.4	355.3	12.8
B+AN N_{15}	11.5	9.4	6.3	353.1	12.9
Average cultivars (factor B)					
Hybrid	11.3	9.5	13.2	355.7	13.2
Cultivar	11.7	9.6	13.3	352.6	13.3
LSD_{05}(A)	0.3	0.3	0.2	92.9	0.50
LSD_{05}(B)	0.2	0.2	0.1	47.0	0.25
LSD_{05}(AxB)	0.42	0.5	0.3	140.6	0.75

1 – dry matter, %, 2 – dry soluble solids, %, 3- sugars, %, 4 – nitrates, mg kg^{-1}, 5 – carotenes, mg 100 g^{-1}

Our studies have shown that the cultivar did not affect the sugar and carotene content in the roots, and additional nitrogen fertilization slightly increased the sugar content. Carotenes from additional nitrogen fertilizer use declined. Nitrogen fertilizer forms and rates had no significant effect on sugar and carotene content. Too intensive fertilization, especially with nitrogen, according to many researchers (Ayaz et al., 2007; Kona 2006; Santamaria, 2005; Smoleń et al., 2011; Wang et al., 2008; Zeka et al., 2014) can cause unsuitable increases in some plants of nitrates, sugars and decreases of dry soluble solids, ascorbic acid (vitamin C), calcium and magnesium. There were found big differences between nitrates accumulation in different vegetable species (Gajewski et al., 2007). Our research has shown that tested cultivars did not affect the amount of nitrate in the roots. In the grown experiments in carrot root-crops irrespective cultivars there were 365.1 mg kg^{-1} (Table 3). Fertilizing with nitrogen the amount of nitrates increased 13.7 mg kg^{-1}.The least amount of nitrates in root-crops accumulated in carrot fertilized with calcium nitrate.

Table 4

Influence of different nitrogen fertilizers and rates on storability of exceptional quality carrot

Fertilization (fact A)	A			B		
	A1	A2	A3	B1	B2	B3
Hybrid 'Nerac' (factor B)						
Basic (B)	43.5	0.0	4.5	38.8	3.4	7.1
B + CN N_{30}	53.4	0.0	5.5	51.8	2.1	5.4
B + CN N_{15}	48.4	0.0	4.2	45.0	3.5	6.2
B + AN N_{30}	51.2	0.0	4.8	48.3	4.0	5.4
B + AN N_{15}	48.6	0.0	4.9	45.9	3.9	5.2
Cultivar 'Tito' (factor B)						
Basic (B)	28.9	0.0	5.8	26.3	5.3	7.4
B + CN N_{30}	34.3	0.0	5.8	32.0	3.5	8.4
B + CN N_{15}	35.1	0.0	5.9	31.4	8.8	5.9
B + AN N_{30}	34.4	0.0	6.4	31.7	5.9	6.1
B + AN N_{15}	32.5	0.0	5.6	30.8	4.3	5.9
Average fertilization (factor A)						
Basic (B)	36.2	0.0	5.1	32.5	4.4	7.2
B + CN N_{30}	43.8	0.0	5.7	41.9	2.8	6.9
B + CN N_{15}	41.7	0.0	5.1	38.2	6.2	6.0
B + AN N_{30}	42.8	0.0	5.6	40.0	4.9	5.8
B + AN N_{15}	40.6	0.0	5.3	38.3	4.1	5.5
Cultivars (factor B)						
Hybrid	49.0	0.0	4.	49.9	2.2	5.8
Cultivar	33.0	0.0	5.9	30.4	5.6	6.8
LSD_{05}(A)	4.7		0.9	4.7	1.9	1.2
LSD_{05}(B)	2.3		0.4	2.3	1.0	0.8
LSD_{05}(AxB)	7.0		1.3	7.0	2.9	2.4

A – after short-term storage, B – after long-term storage; A1, B1 – marketable production, t ha^{-1}, A2, B2 – sick, %, A3, B3 – natural losses

Vegetable storability is influenced by climatic conditions, soil properties, cultivars, fertilization and forms of fertilizers, as well as the time of harvesting (Rożek et al., 2000, Fikseliová et al., 2010; Wrzodak et al., 2012). To store carrot is more difficult than other root-crop vegetables, because their root-crop, as observed Autko (2004) have a thin epithelium tissue (4–8 layers of periderma, while potato – 9-11 layers), which during yield gathering with mechanical means very often is injured. Therefore water is evaporated more intensively and root-crops of carrot quickly wilt, and wilted are less resistant to diseases, but small mechanical injures root-crop is able to "heal up". According to Suslov et al. (2009), storage of carrots for a pro-longed period of time at temperatures above 2 °C results in heavy sprouting of the tops and lateral roots. When carrot cultivar 'Nerac' F_1 was stored for short time (up till New Year) marketable production comprised averagely 49.0 t ha^{-1}, and after long-time storage (up till May) – 45.9 t ha^{-1}, and cultivar 'Tito' correspondingly 33.0 and 30.4 t ha^{-1} (Table 4). Storage losses correspondingly were 4.8% and 5.9%, and after long-term storage – 9.2 and 12.3%. Losses of cultivar short-term and long-term storage were slightly bigger than these ones of hybrid. Marketable production of carrot fertilized with nitrogen fertilizers after short-time storage, irrespective of cultivars, increased on the average 6.0 t ha^{-1} or 16.7%, after long-time storage – 7.1 t ha^{-1} or 21.8%. This is due to the fact that nitrogen fertilizer increased yields. Nitrogen fertilizer forms and rates used for additional fertilization did not affect the storability quality of carrot. Wrzodiak et al. (2012) observes that there were marked differences in storage life depending on the cultivar, cultivation method and storage period.

Conclusions

The best marketable yield was obtained additionally using 30 kg ha^{-1} of nitrogen in form of calcium nitrate. The marketable yield of carrot 'Nerac' F_1 was 56.4 t ha^{-1}, cultivar 'Tito' – 36.3 t ha^{-1}.

The amounts of dry matter and dry soluble solids fluctuated in very narrow limits and fertilization with nitrogen little influenced their changes. Slightly bigger amount of dry matter and dry soluble solids as shown in our studies was found in root-crops of cultivar 'Tito'. Additional nitrogen fertilization slightly increased sugar content. Carotenes from additional nitrogen fertilizer use declined. Fertilizing with nitrogen the amount of nitrates increased 13.7 mg kg^{-1}.The least amount of nitrates in root-crops accumulated in carrot fertilized with calcium nitrate.

Used for additional fertilization nitrogen fertilizer forms and rates did not affect the storability quality of carrot. Losses of cultivar short-term and long-term storage were slightly bigger than there ones of hybrid. The marketable production after short-time storage irrespective of cultivars increased on the average 6.0 t ha^{-1} or 16.7%, after long-time storage – 7.1 t ha^{-1} or 21.8%.

References

1. AOAC (1990a) Sucrose in fruits and fruit products. In: *Official Methods of Analysis*. 15th edition. Helrich K (ed.), AOAC Inc., Arlington, VA: 922 p.
2. AOAC (1990b) Solids (soluble) in fruits and fruit products. In: *Official Methods of Analysis*. 15th edition, Helrich K. (ed.). AOAC Inc., Arlington, VA: 915 p.
3. Arscott S. A., Tanumihardjo S. A. (2010) Carrots of many colours provide basic nutrition and bioavailable phytochemicals acting as a functional food. *Comprehesive Reviews in Food Science and Food Safety*, Vol. 9, p. 223-239.
4. Ayaz A, Topçy A., Yurttagul M. (2007) Survey of nitrate and nitrite levels of fresh vegetables in Turkey. *Journal of Food Technology*, Vol. 5, Vol. 2, p. 177-179.
5. Biesiada A., Nawirska A., Kucharska A., Anna Sokół-Łętowska A. (2011) The effect of nitrogen fertilization methodson yield and chemical composition of pumpkin (Cucurbita maxima) fruits before and after storage. *Vegetable Crops Research Bulletin*, Vol. 70, p. 203–211.
6. Cai B., Ge J. (2004) He effect of nitrogen level on main nutrient of sugar beet. *Nature and Science*, Vol. 2, No 4, p.79-83.
7. Cameron K.C., Di H. J., Moir J.L. (2013) Nitrogen losses from the soil/plant system: a review. *Annals of Applied Biology*, Vol. 162, p. 145–173.
8. Chohura P., Kołota E. (2009) Effect of nitrogen fertilization on the yield and quality of field-grown leaf lettuce for spring harvest. *Vegetable Crops Research Bulletin*, Vol. 71, p.41-49.
9. Davies B. H. (1976) Carotenoids. In: Chemistry and Biochemistry of Pla, ISBN 10 0122899016, Lon nt Pigments, Vol. 1, ed. Goodwin T. W., Academic Press. p. 35-165. London, New York
10. Fageria N. K., Baligar V. C., Li Y. C. (2008) The Role of Nutrient Efficient Plants in Improving Crop Yields in the Twenty First Century. *Journal of Plant Nutrition*, Vol. 31, p. 1121-1157.
11. Fikselová M., Mareĉek J., Mellen M. (2010). Carotenes content in carrot roots (Daucus carota L.) as affected by cultivation and storage. *Vegetable Crops Research Bulletin*, Vol. 73, p. 47-54.
12. Food analysis: general techniques, additives, contaminants and composition (1986) Rome: FAO, 205 p.
13. Gajewski M., Szymczak P., Elkner K., Dąbrowska A., Kret A., Danilcenko H. (2007) Some aspects of nutritive and biological valueof carrot cultivars with orange, yellowand purple-coloured roots. *Vegetable Crops Research Bulletin*, Vol. 67, p. 149-161.
14. Gajewski M., Węglarz Z., Sereda A., Bajer M., Kuczkowska A., Majewski M. (2010) Carotenoid Accumulation by Carrot Storage Roots in Relation to Nitrogen Fertilization Level. *Notulae Botanicae Horti Agrobotanici Cluj Napoca*, Vol. 38, Vol. 1, p. 71–75.
15. Gajewski M., Węglarz Z., Sereda A., Bajer M., Kuczkowska A., Majewski M. (2009). Quality of carrots grown for processingas affected by nitrogen fertilizationand harvest term. *Vegetable Crops Research Bulletin*, Vol. 70, p. 135-144.
16. Kant S., Bi Y.-M., Rothstein S. J. (2011) Understanding plant response to nitrogen limitation for the improvement of crop nitrogen use efficiency. *Journal of Experimental Botany*, Vol. 62, p. 1499–1509.
17. Karklelienė R., Juškevičienė D., Viškelis P. (2007) Productivity and quality of carrotr (Daucus sativus Röhl.) and onion (Allium cepa L.) cultivars and hybrids. *Sodininkystė ir daržininkystė*, Vol 26, p. 208-216.
18. Kołota E., Adamczewska-Sowińska K., Krężel J. (2007) Suitability of Entec 26 as a source of nitrogen for red beet and celeriac. *Vegetable Crops Research Bulletin*, Vol. 67, p.47-54.
19. Kóňa, J. (2006). Nitrate accumulation in different parts of carrot root during vegetation period. *Acta Horticulturae et Regiotecturae*, Vol. 9, p. 22–24.
20. Li S-H., Wang Z-H., B.A. Stewart B. A. (2013) Responses of Crop Plants to Ammonium and Nitrate N. *Advances in Agronomy*, Vol. 118, p. 205–397.
21. McAllister C. H., Beatty P. H., Good A. G. (2012) Engineering nitrogen use efficient crop plants: the current. *Plant Biotechnology Journal*, Vol. 10, p. 1011–1025.
22. Paoletti F., Raffo A., Kristensen H. L., Thorup-Kristensen K., Seljåsen R., Torp T., Busscher N., Ploeger A., Kahl J. (2012) Multi-method comparison of carrot quality from a conventional and three organic cropping systems with increasing levels of nutrient recycling. *Journal of the Science of Food and Agriculture*, Vol. 92, p. 2855–2869.
23. Pekarskas J., Bartaševičienė D. (2009) Ekologiškai augintų morkų veislių derlingumas ir biocheminė sudėtis. *Sodininkystė ir daržininkystė*, Vol. 28, p. 99-105.
24. Pokluda R. (2006) An assessment of the nutritional value of vegetables using an ascorbate-nitrate index. *Vegetable Crops Research Bulletin*, Vol. 64, p. 28-37.
25. Rożek S., Leja M., Wojciechovska R. (2000) Effect of differentiated nitrogen fertilization on chantes of certain compounds in stored carrot roots. *Folia Horticulturae*, Vol. 12, p. 21-34.
26. Rubatzky V. E., Quiros C. F., Simon P. W. (1999) *Carrots and related vegetable umbelliferae*. USA, University of California, Davis, University of Viskonsin, Madison: C A B Intl, 294 p.
27. Santamaria P. (2006) Nitrate in vegetables: toxicity, content, intake and EC regulation. *Journal of the Science of Food and Agriculture*, Vol 86, p. 10-17.
28. Seljåsen R., Kristensen H. L., Lauridsen Ch., Wyss G. S., Kretzschmar U., Birlouez-Aragone I., Kahl J. (2013) Quality of carrots as affected by pre- and postharvest factors and processing. *Journal of the Science of Food and Agriculture*, Vol. 93, p. 2611-2626
29. Smoleń S., Sady W., Wierzbińska J. (2011) The effect of various nitrogen fertilization regimes on the concentration of thirty three elements in carrot (*Daucus carota* L.) storage roots. *Vegetable Crops Research Bulletin*, Vol. 74, p. 61–76.
30. Suojala T. (2000) Variation in sugar content and composition of carrot storage roots at harvest and during storage. *Scientia Horticulturae*, Vol. 85, p. 1–19.
31. Suslow T.V., Mitchell J., Cantwell M. 2009. Carrot. Recommendation for maintaining postharvest quality.Disponívelem:<http://postharvest.ucdavis.edu/Produce/ProduceFacts/Veg/carrot.
32. Toivonen P. M. A., Hodges D. M (2011) Abiotic Stress in Harvested Fruits and Vegetables, AbioticStress in Plants - Mechanisms and Adaptations, ed. A. Shanker, Available from: http://www. intechopen.com/books/abiotic-stress-in-plants-mechanisms-andadaptations/ abiotic-stress-in-harvested-fruits-and-vegetables

33. Zdravkovic M., Damjanovic M., Corokalo D. (1997) The influence of fertilization on yield of different carrot varietes. *Acta Horticulturae*, vol. 462, p. 93–96.
34. Zalatorius V., Viškelis P. (2005) Papildomo juostinio tręšimo per lapus įtaka morkų produktyvumui ir laikymuisi. *Sodininkystė ir daržininkystė*, Vol. 24, p. 72-79.
35. Zeka N., Mero G., Skenderasi B., Gjançi S. (2014) Effects of nitrogen sources and levels on yield and nutritive values of spinach (*Spinacia Oleracea* L.). *Journal of International Academic Research for Multidisciplinary*, Vol. 1, p. 327-337.
36. Wang Z. H., Li S. X. (2003). Effects of N forms and rates on vegetable growth and nitrate accumulation. *Pedosphere*, Vol. 13, No 4, p. 309-316.
37. Wang Z. H., Li S. H, Malhi S. (2008) Effects of fertilization and other agronomic measures on nutritional quality of crops. *Review. Journal of the Science of Food and Agriculture*, Vol. 88, p. 7-23.
38. Wrzodak A., Szwejda-Grzybowska J., Elkner K., Babik I. (2012) Comparison of the nutritional value and storage life of carrot roots from organic and conventional cultivation. *Vegetable Crops Research Bulletin*, Vol. 76, p. 137–150.
39. Аутко А.А. (2004). *В мире овощей*. Минск, УП «Технопринт», 564 p.