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Influence of Fertilizers with Prolongation Effect on Productivity of Root-Crop Vegetables and Biochemical Composition Before and After Storage

Ona Bundinienė, Danguolė Kavaliauskaitė, Roma Starkutė, Julė Jankauskienė, Vytautas Zalatorius and Česlovas Bobinas
Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry, Lithuania

1. Introduction

Because of the increasing requirements to environment protection and safe food it is necessary to increase the use of non-toxic, environment-friendly substances (Malekian et al., 2011). Vegetable fertilization must correspond to the requirements of ecology, i. e., it is necessary to fertilize environment less and to increase plant productivity and protection. We must look for the suitable and optimal fertilization methods and fertilizer types. Growing foliage needs a lot of nitrogen and root-crops – potassium and phosphorus. Calcium participates in plant growing, nutrient metabolism and many biochemical and physiological processes (White et al., 2003; Saure, 2005). Its deficit in reproductive tissues worsens the quality (Grattan & Grieve, 1998; Porro et al., 2002). The lack of magnesium most often is observed in acid, light soils. Vegetable production storability is better when it is fertilized with potassium and calcium at the end of vegetation. Moreover, calcium stops soil acidification processes (Liet. dirvožemių ..., 1998). It is possible to satisfy the necessity of calcium and to prevent soil acidification by fertilizing with physiologically nonacid fertilizers (Аутко, 2004). This may be ammonium nitre, in the composition of which there are 27 % N (by 13,5 % ammonium – N-NH_4^+ and nitric – N-NO_3^-), 6 % calcium (CaO) and 4 % magnesium (MgO) or nitrogen fertilizer with zeolite, in the composition of which there are 26 % N and a part of dolomite (up to 6 %) is substituted with zeolite. Besides, there are 4.5–5.4 % of calcium (CaO) and 3.1–3.5 % of magnesium (MgO). Calcium and magnesium are extracted from natural dolomite. They decrease ammonium nitre physiological acidity and thus balance soil acidity and improve its biological activity. Insertion of zeolite into calcium ammonium nitre granule improves fertilizer's physical properties, its friability, also decreases the wash out of nutrients, especially ammonium nitrogen, potassium and calcium and improves solubility of non-soluble combinations (Butorac, 2002; Ambruster, 2001; Ramesh et al., 2011; Uher, 2004; Yolcu et al., 2011). According to the data of many various counties (Li et al., 2002; Polat et al., 2004; Gül et al., 2005), sorption properties of zeolite guarantee 15–30 % more economical use of nitrogen ant increase yield, prolong the duration of nutrient effect and decrease the necessity of often fertilization, especially in the soils, which lack nutrients (Lobova, 2000; Beqiraj (Goga) et al., 2008). Moreover, fertilizing with granular fertilizers most nutrient elements remain in 5–10 cm soil layer. Executing EU Council directive 91/676/EEB about water protection from the pollution by nitrates used in agriculture (Nitrates Directive), there are looked for the possibilities to improve nitrogen fertilizers, improving the conditions of plant nutrition. Rines et al. (2006; Rehakova et al., 2004) states that zeolite is the suitable means for creating good conditions for plant growing, being satisfied with less amount of nutrients and water. In 2003 there was started to produce fertilizer with zeolite, which the main compound is klinoptilolite (Ancuta et all., 2011; Mažeika et al., 2008).

The possibilities of different nitrogen fertilizers ((calcium ammonium nitre (CAN 27) N_{90+30}), nitrogen fertilizer with zeolite (N 26 + 6 % zeolite) and zeolite (commercial sign ZeoVit EcoAgro) 2,5 kg m^{-1}) and ammonium nitre (AN N_{90+30})) have been investigated.

2. Materials and methods

2.1 Agrochemical properties of soil

Experiments were carried out in calcaric epihypogleyic luvisol of sandy loam on light loam soil *Calcari – Epihypogleyc Luvisols (LVg-p-w-cc)*. Soil, in which red beet and carrot were grown, was little nitric (in lay of 0–60 cm 45,0 –48,8 kg ha^{-1}), rich in agile phosphorus (364,4–411,8 mg kg^{-1}), calcium (7941–8638 mg kg^{-1}) and magnesium (1952–2357 mg kg^{-1}), averagely rich in agile potassium (154,1 – 165,1 mg kg^{-1}), and there was little amount of humus in it (1,40–1,54 %). Soil pH 7,2 – 7,6.

2.2 Taking and storage of samples

Hybrid red beet 'Pablo' F_1 (500 thousand unt. ha^{-1} of germinable seeds) was grown on flat surface, carrot cultivar 'Samson' (800 thousand unt. ha^{-1} of germinable seeds) – on furrowed surface. Sowing scheme – 62 + 8. Work of plant supervision was carried out according to vegetable growing technologies accepted in LIH. Red beet and edible carrot yield was gathered, when vegetables reached technical maturity. 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, Biochemistry and Technology laboratories. 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.

Soil samples for the investigations of agrochemical properties were taken in autumn, after yield gathering, when the jointed sample according to the variant was created.

2.3 Methods of analysis

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

Investigations of soil agrochemical composition were carried out in the center of Agrochemical investigations LAI (now Center of Agrochemical Investigations of LRCAF).

There were established soil agrochemical indices: pH_{KCl} – ISO 10390:2005 (potenciometrical); agile P_2O_5 and K_2O – GOST 26208-84 (Egner-Riehm-Domingo – A-L), humus – ISO 10694: 1995 (dry burning), calcium and magnesium – SVP D-06 (atomic absorption spectrometrical), mineral nitrogen – 1M KCl extraction, spectrophotometrical MN-1984.

2.4 Growing cultivars, scheme of experiments, applied fertilizers

Hybrid red beet 'Pablo' F_1 (500 thousand unt. ha^{-1} of germinable seeds) was grown on flat surface, carrot cultivar 'Samson' (800 thousand unt. ha^{-1} of germinable seeds) – on furrowed surface. Work of plant supervision was carried out according to vegetable growing technologies accepted in LIH.

Scheme of the experiment:

1. Without N, Ca, Mg, PK before sowing – background (B – $P_{60}K_{120}$)
2. B + calcium ammonium nitre N_{90} before sowing + N_{30} at the stage of 4 – 6 leaves (B + CAN 27 N_{90+30})
3. B + calcium ammonium nitre with zeolite N_{90} before sowing + N_{30} at the stage of 4 – 6 leaves (B + N 26 + 6z N_{90+30})
4. B + ammonium nitre N_{90} before sowing + N_{30} at the stage of 4 – 6 leaves + zeolite (B + AN N_{90+30} + zeolite).
5. B + dusting with zeolite* (i. e., root-crops were sprinkled and mixed with zeolite). Root-crop samples (15 kg each) were taken from the first variant and sprinkled with zeolite 30 kg t^{-1}.

For the background fertilization there was used granular superphosphate and potassium sulphate. Nitrogen fertilizers were applied in the rates and forms indicated in the scheme. In the last variant before vegetable sowing there was inserted 2,5 kg m^{-1} of zeolite. Experiments were carried out every year in 4 replications in randomized fields, storage investigations – in 3 replications (10–12 kg of vegetables per each) storing them in polypropylene bags. Storing vegetables, variant with zeolite was added, vegetable samples were taken from background fertilization (the first variant) and sprinkled (felted up) with zeolite 30 kg t^{-1}. Area of record plot – 6,2 m^2. the analyses of vegetable biochemical composition and soil agrochemical indices were carried out in 3 replications.

2.5 Mathematical procession

Data significance was evaluated by one-factorial dispersion analysis, using program ANOVA; the relation among different indices – by correlation-regression analysis; using program STAT_ENG. Using indicises: r – coreliation coefficient, ** – level of probability 01, * – level of probability 05.

2.6 Meteorological conditions

Meteorological conditions in different years of investigation were different: vegetation period in 2004 was cooler than multiannual and the amount of precipitation bigger than multiannual average, 2005 was warm and dry, 2006 – hot and humid, 2007 – cool and humid (table 1). Especially many precipitations fell in August of 2004, 2005 and 2006. Air temperature was very different. In 2004 and 2006 it was much higher than the multiannual average, but in 2006 it was even in 2 °C cooler. July of 2005 was especially dry and hot. In July 2006 precipitations comprised only 40 % of multiannual rate ant the temperature was in 2 °C higher than the multiannual average.

Month	2004	2005	2006	2007	Multi annual	2004	2005	2006	2007	Multi annual
May	11,1	11,3	12,6	11,2	12,3	46,2	65,4	74,0	104,4	50,7
June	13,7	14,9	16,3	15,1	15,9	77,4	66,6	13,8	72,2	71,2
Jule	16,4	19,1	19,3	15,2	17,3	50,4	3,8	30,2	173,6	75,3
August	17,3	14,7	17,5	16,6	16,7	118,2	109,4	173,4	42,8	78,4
September	10,1	14,2	14,5	10,6	12,1	36,2	46,5	83,0	57,8	58,7
Average	13,7	14,8	16,0	13,7	14,9	65,7	58,3	74,9	90,2	66,9

Table 1. Meteorological conditions during vegetation period. Data of Babtai agrometeorological station, iMETOS prognostication system

3. Results and discussion

3.1 Yield of red beet and carrot

Data of investigations carried out in various countries with various plats show that nitrogen is the factor, which determines the growth and productivity of plant most of all (Scholberg et al., 2000; Babik & Elkner, 2002; Tei et al., 2002; 2001; Rubatzky et al., 1999; Malnou et al., 2008). Nevertheless, nitrogen induced environmental damage such as nitrate pollution and wasting fossil fuel (Fustec et al., 2009). Red-beet productivity, independently of their cultivars and types, also increases applying nitrogen fertilizers (Ugrinovic, 1999; Staugaitis & Tarvydienė, 2004). According to our data of investigations carried out at the Institute of Horticulture, LRCAF, in 2004–2007, red beet yield increased averagely 2,1 times (Fig. 1), using nitrogen fertilizers (N_{90+30}), independently from fertilizer form, in comparison with the yield obtained when red-beet were fertilized only with phosphorus and potassium fertilizers ($P_{90}K_{120}$). The yield of edible carrot increased 14 % (Fig. 2). The output of marketable red-beet yield increased averagely 19,0 %, carrot – 3,5 %. The output of marketable yield is important parameter, which determined fertilizer suitability and corresponds to one of the main requirements of the optimal yield – high output of marketable yield (Suojala, 2000; Zalatorius & Viškelis, 2005). Marketable red-beet yield after fertilizing with ammonium nitre increased by 22,6 t ha^{-1} or in 93,4 % in comparison with this of red-beet grown without nitrogen fertilizer; after fertilizing with ammonium nitre plus zeolite – 28,7 t ha^{-1} or 2,1 times. There was obtained the bigger marketable yield after fertilizing with ammonium nitre and inserting zeolite, because the output of marketable yield was better in 3,3 %. Fertilizing carrots both with ammonium nitre and ammonium nitre with zeolite there was obtained equal yields. Using nitrogen in both variants, marketable carrot yield increased 6,0 t ha^{-1} or 12,3 %; fertilizing with ammonium nitre and zeolite the output of marketable yield increased 2,0 %. The data of foreign scientists show that fertilizing with calcium ammonium nitre the yield increases. When malty barley was fertilized with calcium ammonium nitre, dependently on soil granulometrical composition, the biggest additional yield was obtained after scattering 112.5–137,5 kg ha^{-1} N (Conry, 1997). According to the data of Zdravkovic et al. (1997), carrot fertilized with manure produced 48,4 t ha^{-1}, with calcium ammonium nitre – 41,5 t ha^{-1} and mixture – 41,5 t ha^{-1} of yield. Sorbtional properties of zeolite, according to the data of many investigators (Challinor et al. 1995; Ilsildar, 1999; Li et al., 2002; Polat et al., 2004), guarantee 15–30 % more economical nitrogen usage, prolong the duration of nutrients action and decreases the necessity of often fertilization. Natural zeolites are nature's own slow release fertilizers (Li, 2003; Середина, 2003).

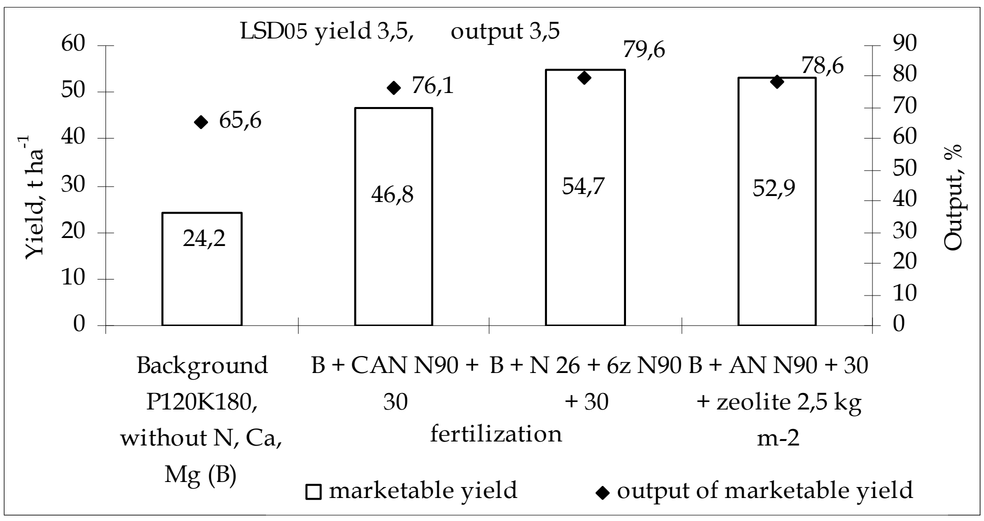

Fig. 1. Influence of fertilizers with prolongation effect on productivity of red beet. Babtai, 2004–2007

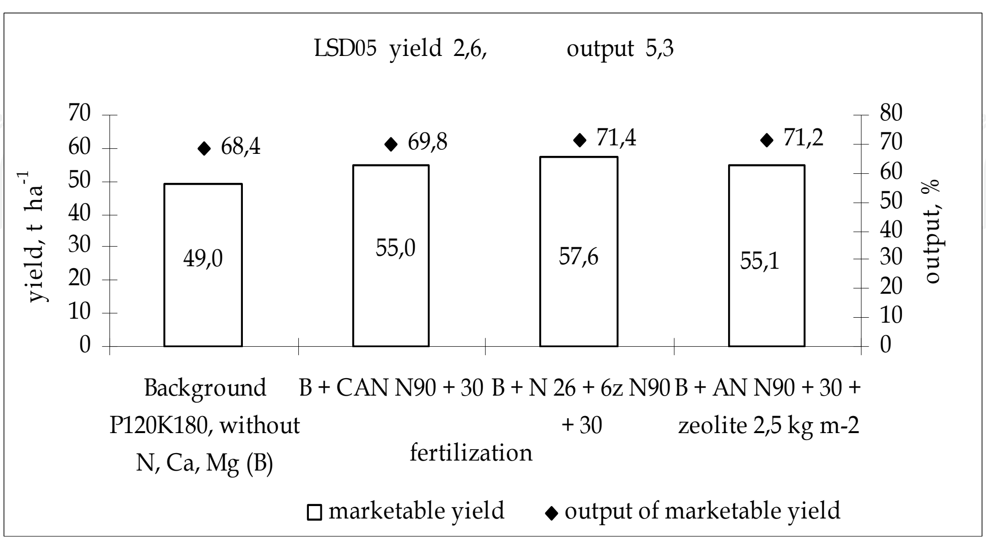

Fig. 2. Influence of fertilizers with prolongation effect on productivity of edible carrot. Babtai, 2004–2007

Grecian scientists (Samartzidis et al., 2005) state that zeolite doesn't have positive influence on rose productivity. Zeolite efficiency is influenced by the size of granules. 3–5 mm zeolite granules are of the biggest sorption susceptibility. According to Russian investigators (Ryakhovskaya & Gainatulina, 2009), the use of zeolites allows reducing the basic fertilizer dose by 25 % and growing annual grasses without fertilizers in the second and thirds years after it application. Introduction of zeolite in our investigations positively influenced the increase of marketable yield output. The data of Siberian peat investigations show that the presence of zeolite in granule, when fertilizing in all directions, didn't produced additional yield, but fertilizing locally increased yield 9–13 %, in comparison with yield, obtained fertilizing only with the granular mixture of peat-mineral fertilizers (Алексеева et al., 1999). The data of Polish investigators showed that nitrogen fertilizer with DMPP nitrification inhibitor is suitable as nitrogen fertilizer, equal to ammonium and calcium nitrates and more effective than ammonium sulphate (Kolota et. al., 2007). The data of the carried out experiments showed that the biggest red beet and carrot yields and the bigger output of the marketable yield, than this obtained fertilizing with other nitrogen fertilizers, was obtained applying nitrogen fertilizer with zeolite (N 26 + 6c N_{90+30}).

3.2 Storage of red beet and carrot crop-root

Vegetable storability is influenced by climatic conditions, soil, cultivars, fertilization, forms of fertilizers and the time of harvesting (Suojala, 2000; Sakalauskas et al, 2004; Rożek et al., 2000). In order to preserve vegetables it is important to keep the suitable temperature, humidity and to create suitable conditions for breathing (Raju et al., 2010; Workneh et al., 2011; Badelek et al., 2002; Kołota et al., 2007). One of the most valuable red beet farm properties is uncomplicated their growing, good biochemical composition and good storability (Petronienė & Viškelis, 2004). Important property of red beet, which improves their storability, is their thicker skin and root-crop ability to pass to the state of tranquility (Аутко, 2004). Round root-crops of red beet is stored better than cylindrical root-crops. The output of marketable production, when growing red beet without nitrogen fertilizers after short-time storing (3 months) comprised 82,6 %, after long-time storing (7 months) – 59,5 %, and losses correspondingly – 17,4 % and 40,5 % (Fig. 3). Additional fertilizing with nitrogen fertilizers the output of marketable red beet production after short-time storing increased averagely 6,3 %, after long-time storing – 21,7 %. The amount of marketable production, suitable for realization increased correspondingly 19,1 t ha^{-1} or 94,6 % and 17,3 t ha^{-1} or 2,2 times. Red beets, fertilized with nitrogen fertilizer with zeolite, were preserved best of all both after 3 and 7 months. The amount of marketable production after 3 months storage, in comparison with this one of red beet fertilized with calcium ammonium nitre, increased 7,3 t ha^{-1} or 17,7 %; in comparison with this one of red beet fertilized with ammonium nitre with zeolite – 2,3 t ha^{-1} or 5,1 %. After long-time storage the amount of marketable production increased correspondingly 8,4 t ha^{-1} or 26,5 % and 3,3 t ha^{-1} or 9,1 %. Red beet root-crops sprinkled with zeolite were stored very well. After short-time storage the output of marketable production, in comparison with this one of red beet grown without nitrogen fertilizers, increased 8,6 %, i. e., storing the same amount of marketable yield as in the background variant there was obtained 1,5 t ha^{-1} more marketable production. After long-time storage the output of marketable production increased 35,5 %, i. e., it was obtained 4,7 t ha^{-1} more of marketable production than storing red beet root-crops fertilized only with phosphorus and potassium fertilizers. It is thought that red beet root-crop storability was improved by zeolite ability to hold up humidity.

To store carrot is more difficult than other root-crop vegetables. It is very important for them temperature and humidity during storage (Suojala, 2000; Fikseliova et al., 2010). Carrot root-crop have thin cover tissue (4–8 layers of periderma, when this one of potatoes – 9–11 layers), which during yield gathering with mechanical means very often is injured. That is why water is evaporated more intensively (Аутко, 2004). Carrots quickly wilt, and wilted are less resistant to diseases, but small mechanical injures root-crop is able to "heal up". Meteorological conditions during the last two weeks before gathering have big influence on carrot storability (Fritz & Weichmann, 1979). Our data showed, that storing carrot for short time (up till New Year) marketable production comprised averagely 46,6 t ha^{-1}, and after long-time storage (up till May) – 38,5 t ha^{-1} (Fig. 3). Storage losses correspondingly were 12,3 % and 27,4 %, i. e., carrots, suitable for realization comprised averagely 87,7 % and 72,6 %.

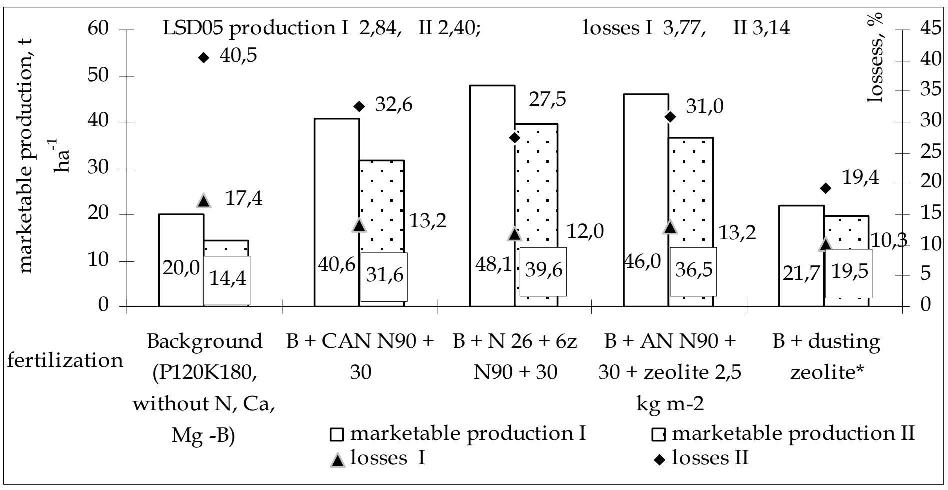

Fig. 3. Influence of fertilizers with prolongation effect on amount marketable production and persistence of red beet crop-root.

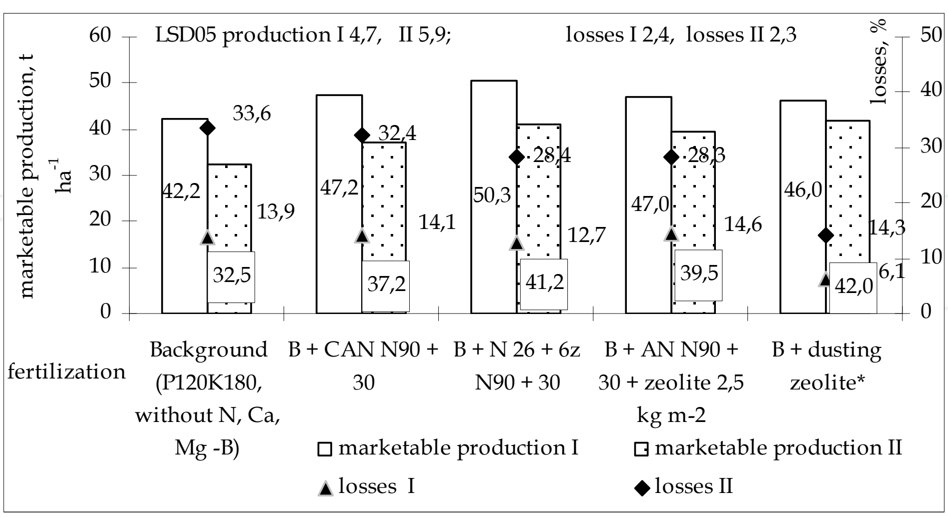

Fig. 4. Influence of fertilizers with prolongation effect on amount marketable production and persistence of carrot crop-root. Babtai, 2004–2008.

The amount of carrot, fertilized with nitrogen fertilizers, marketable production after short-time storage increased on the average 5,4 t ha^{-1} or 12,9 %, after long-time storage– 7,5 t ha^{-1} or

23,0 %. The results of storage investigations showed that carrots, fertilized with nitrogen fertilizer with zeolite, were preserved best of all. The amount of marketable production after short-time storage, in comparison with this one of carrot grown without nitrogen fertilizers, increased 8,1 t ha^{-1} or 19,2 %. Storing carrot till spring (7 months), storage losses decreased from 33,6 % up to 28,4 % and it was obtained additionally 8,7 t ha^{-1} carrot marketable production. Carrot root-crop sprinkling with zeolite very improved their storability (from 86,1 % to 93,9 %, and after long-time storage from 66,4 % to 85,7 %). The amount of marketable production, in comparison with this one of carrot grown without nitrogen fertilizers, increased correspondingly 3,8 t ha^{-1} or 9,0 % and 9,5 t ha^{-1} or 29,2 %.

3.3 Quality of red beet and carrot crop-root

Mineral fertilization is one of the most important and effective factors influencing metabolism and at the same time yield quality. Plants assimilate nutrients, which they receive with mineral and organic fertilizers (Lairon, 2010). Their concentration in vegetables changes dependently on many factors: vegetable type and cultivar (Montemurro et al., 2007; Rożek et al., 2000), soil, meteorological conditions (Rubatzky et al., 1999; Suojala, 2000; Jalali, 2008). Too intensive fertilization, especially with nitrogen, can cause unsuitable increases in some plants of nitrates, sugars and decreases of dry soluble solids, ascorbic acid (vitamin C), calcium and magnesium (Wang et al., 2008; Sorensen, 1999), therefore, it is very important not to delay fertilization and to use suitable fertilizers (Petronienė & Viškelis, 2004). Fresh red beet root-crops accumulate 16–22 % of dry matter, 10–16 % of sugars, 9–32 mg% of vitamin C, small amounts of other vitamins (B_1, B_2, PP), and the color of root-crop depends on the amount of betain (Аутко, 2004). According to the data of investigations carried out in Lithuanian, meteorological conditions, cultivar and soil influence red beet root-crop biochemical composition more than fertilizers (Staugaitis & Dalangauskienė, 2005; Tarvydienė & Petronienė, 2003; Butkuvienė et al., 2006). Lithuanian investigators (Petronienė & Viškelis, 2004a) indicate that the amounts of dry soluble solids in red beet root-crops can be 8,3–16,2 %, these of sugars – 4,98–12,6 %, ascorbic acid – 9,0–31,2 %, betanins – 39,9–96,7 mg 100 g^{-1}, nitrates – 272–2322 mg kg^{-1}. Our investigations showed that after yield gathering the amounts of dry matter and dry soluble solids in red beet root-crop growing them without nitrogen fertilizers were correspondingly 14,4 % and 12,3 % (Fig. 5).

The least amounts of dry matter and correspondingly dry soluble solids were found in root-crops, fertilized with nitrogen fertilizer with zeolite (11,9 and 11,7 %). Precipitation positively influenced the amounts of dry matter (r = 0,73**), dry soluble solids (r = 0,69**) and sugars (r = 0,83**) and decreased the amount of nitrates (r = -0,59*). Temperature effect was opposite (correspondingly r_{dm} = - 0,73**, r_{dss} = -0,64**, r_{sugars} = -0,75**, $r_{nitrates}$ = 0,60*). In the stored vegetable, similarly as during the growth, constant metabolism takes place. Vegetable storage and nutrient losses depend on its intensity. When vegetables are stored in low temperature and suitable humidity, breathing and all the biochemical processes slow down. The most suitable temperature for the storage of root-crop vegetables is from -1 to +2 °C, relational humidity – 85–95 % (Аутко, 2004; Petronienė & Viškelis, 2004). According to the data of Polish investigators (Badelek et al., 2002), the least amount of non marketable red beet root-crop and the best their quality are when in storing houses +2 °C temperature is kept and the size of red beet doesn't have influence on the storage. According to the data of German investigators (Henze & Bauman, 1979), humidity during storage has bigger influence on red beet root-crop preservation than temperature. Red beets are stored better when relational humidity is more than 95 %. Data of our investigations show that during red beet storing the amounts of dry matter in root-crops, in comparison with amounts during yield gathering, decreased fertilizing with nitrogen fertilizer with zeolite and storing red beet, grown without nitrogen fertilizers, sprinkled with zeolite; it increased fertilizing with calcium ammonium nitre and ammonium nitre with zeolite. The amounts of dry soluble solids in all the fertilization variants increased. According to Lithuanian investigators (Karklelienė et al., 2007), the amounts of dry soluble solids after storage depend on genetype. Red beet cultivar 'Kamuoliai 2' was distinguished for the bigger amount of dry soluble solids. Genetype also influence the amount of sugars in red beet root-crops (Karklelienė et al., 2009). The amount of sugars, according to Petronienė & Viškelis (2004a), influences root-crop nutritional properties and procession. Red beets, which have more sugars, are distinguished for better taste properties. Growth conditions influence the amount of sugars too. In the investigations the amounts of sugars didn't fluctuate in wide limits (Fig. 6).

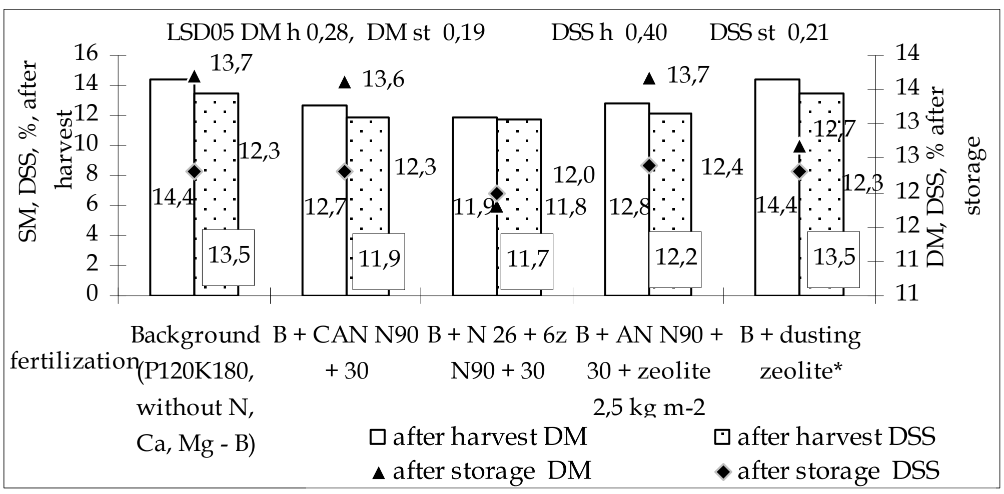

Fig. 5. Influence of fertilizers with prolongation effect on content of dry matter and dry soluble solids in red beet crop-root. Babtai, 2004–2008.

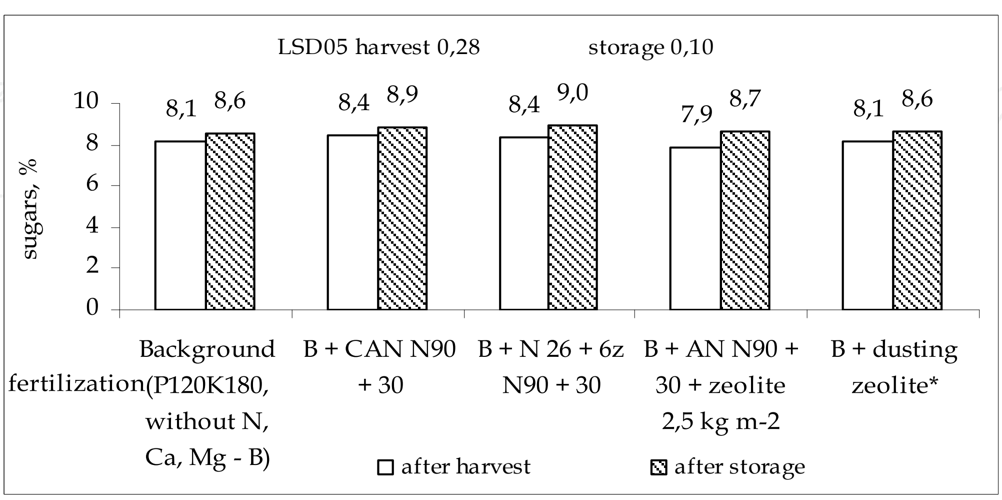

Fig. 6. Influence of fertilizers with prolongation effect on content of sugars in red beet crop-root. Babtai, 2004–2008.

Fertilizing with nitrogen fertilizers the amounts of sugars decreased insignificantly (on the average 0,3 % unt.). They were equal both fertilizing with calcium ammonium nitre and nitrogen fertilizer with zeolite. The amount of sugars depended on the amounts of dry matter (r = 0,50*) and dry soluble solids (r = 0,57**). After storage the amounts of sugars in red beet root-crops slightly increased (from averagely 8,1 % to 8,7 %). The biggest amount of them was in red beet root-crops fertilized with nitrogen fertilizer with zeolite. Polish investigators (Rożek et al., 2000) indicate that during root-crop storage the amounts of soluble sugars and nitrated decrease, but the amounts of phenols increase. Our data showed that sugar amount negatively correlates with nitrate amounts (r = -0,56*) (Fig. 7). Klotz et al. (2004) indicated that sugar beet sucrolytic activities change little during storage, regardless of storage temperature, length of storage. Polish investigators (Szura et al., 2008) indicate that the type of nitrogen fertilizer doesn't influence the amounts of dry matter, sugar, phenols and ammoniac nitrogen (NH_4) and proteins, phosphorus, potassium and magnesium, and that fertilizes with nitrification inhibitor (Entec 26) decreases nitrate amounts. Nitrates, as Lairon (2010) states, are absorbed through roots and naturally accumulate in plants, where later on are used for amino acid synthesis. Even fertilizers rich in nitrogen, especially of organic origin, when there are high soil mineral level, do not accumulate much nitrates and their accumulation also depend on meteorological conditions, plant cultivars and yield gathering time. Some scientist affirm that nitrate amount increases when nitrogen amount increases in the soil, plants suffer stress (shade, drought, etc.) and additionally fertilizing with leaf fertilizer or applying combined fertilization on soil surface and through leaves (Alexandrescu et al., 2000). The data of statistic analysis of our investigations indicate that when the amount of mineral nitrogen in the soil increases, its amount in root-crop increases also (r = 0,51*).

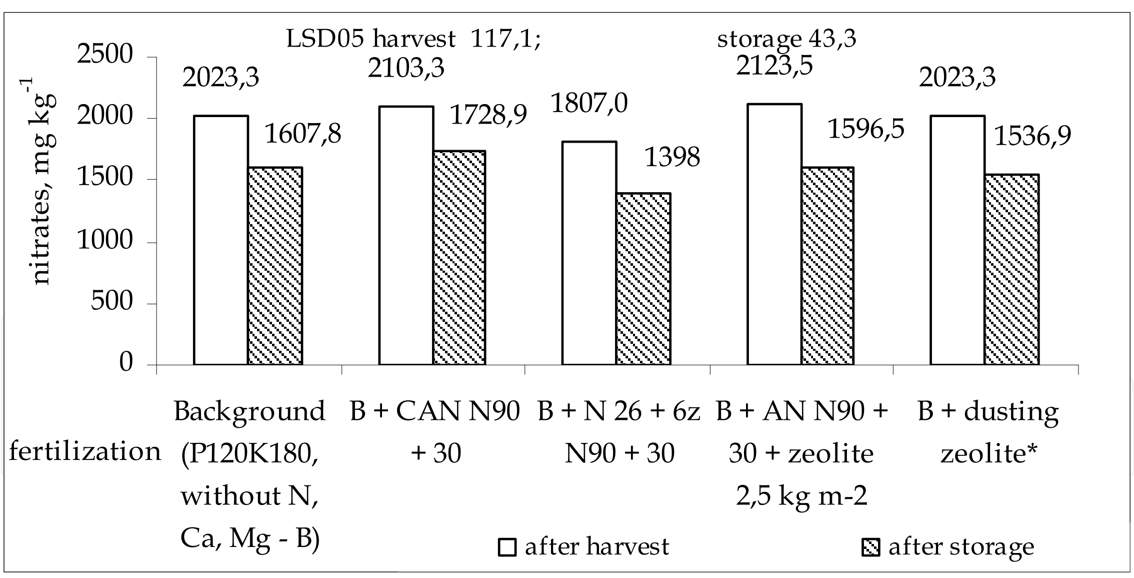

Fig. 7. Influence of fertilizers with prolongation effect on content of nitrates in red beet crop-root. Babtai, 2004–2008.

Field vegetables, gathered later on, as indicate Amr & Hadidi (2001), accumulate fewer nitrates. The influence of nitrogen fertilizers on nitrogen and nitrate amount in root-crops isn't big, but may be important to other properties (Haworth, 1966). Petronienė & Viškelis (2004a) state that the amount of nitrates in red beet increases additionally fertilizing during vegetation, therefore it is important do not delay fertilization. The amount of nitrates can fluctuate from 388–4 880 mg kg^{-1}, fertilizing red beet PK or growing them without fertilizer, and reach even 6 480 mg kg^{-1}, fertilizing them NPK. Influence of fertilizers, in comparison with the influence of meteorological conditions was smaller, and the forms and rates of fertilizers didn't influence nitrate amount (Staugaitis & Dalangauskienė, 2005). In our investigations nitrate amount, when red beet weren't fertilized, was 2023,3 mg kg^{-1} and fertilizing with nitrogen fertilizers didn't influenced the increase of nitrate amount, even though fertilizing with calcium ammonium nitre and ammonium nitre with zeolite their amount was bigger (Fig. 7). The least nitrate amounts both after red beet gathering and after storing were in the root-crops of red beet fertilized with nitrogen fertilizer with zeolite. In red beet root-crops, which were sprinkled with zeolite, nitrate amount was 3,9 % bigger than this in red beet fertilized with nitrogen fertilizer with zeolite, but smaller than after fertilization with nitrogen fertilizer or in red beet grown without nitrogen fertilizer. Polish investigators (Kołota et al., 2007) indicate that fertilizer with nitrification inhibitor (Entec 26) tends to decrease nitrate amounts. According to some investigators (Montemurro et al., 2007), the bigger amount of nitrates in the soil also increases nitrate concentration in plants. Staugaitis (1996) affirms that during storage, because of physiological processes in root-crops, nitrate amount increases, when before storage there are little amount of them (not more than 95 mg kg^{-1}), and decreases when there are more of them. Other investigators indicate that zeolite application in substrate prolongs the time of substrate use and guarantee the bigger and stabile biomass yield and smaller nitrate amount in it (Geodakian, Erofeeva, 1996).

There can be in carrot, as Аутко (2004) indicate, 8–12 % of dry matter, 6–8 % of sugars, 9–12 mg% of carotene, also potassium and microelements – boron and iodine. According to Holden et al. (1999), raw carrot roots contain on average 12 % of dry matter, 4.5 % of sugars, 2.0 % of dietary fiber, 5.7 mg $\cdot$100 g^{-1} of β-carotene, 5.9 mg $\cdot$100 g^{-1} of vitamin C. According to Ayaz et al. (2007), 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}. The data obtained in the investigations correspond to the indicated (Fig. 8, 9, 10).

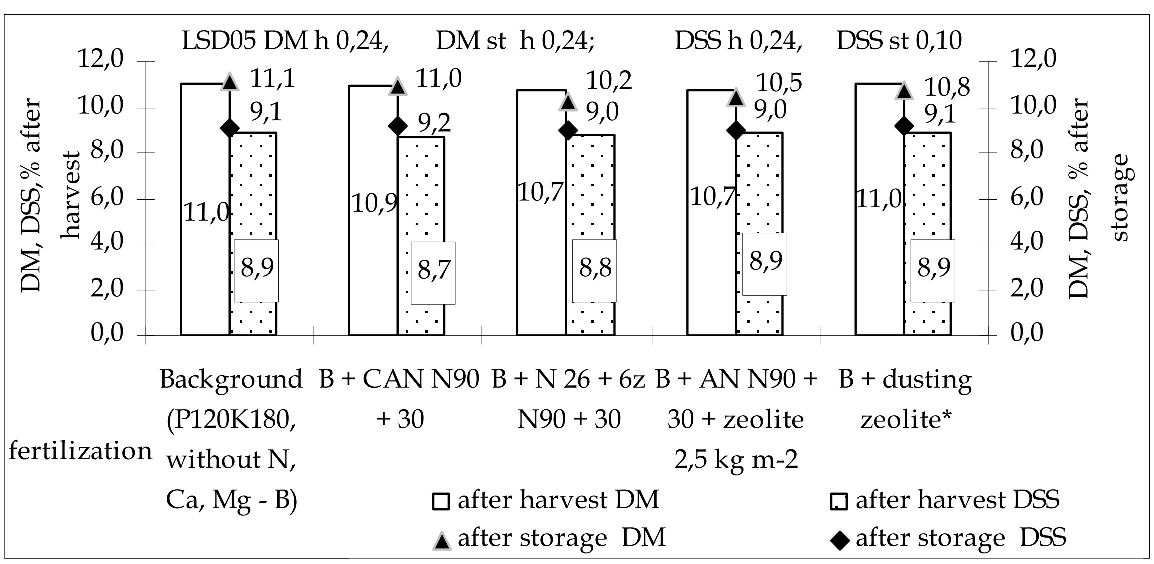

Fig. 8. Influence of fertilizers with prolongation effect on content of dry matter and dry soluble solids in carrot crop-root. Babtai, 2004–2008.

Important carrot quality indices are big amount of sugars and carotenoids, especially β-carotene, and small amount of nitrates (Gajewski et al., 2009). Their amounts depend on growth conditions, genetype and fertilization (Arscott & Tanumihardjo, 2010). During growth period meteorological conditions in our investigations little influenced the changes of biochemical indices in root-crops, with the exception of nitrates. Differentiated soil fertilization with nitrogen doesn't significantly influence the amount of dry matter and dry soluble solids, carotenoids, nitrates and phenols in carrot root-crops (Pokluda, 2006; Pekarskas & Bartaševičienė, 2009; Karklelienė et al., 2007a). The amounts of dry soluble solids can increase when yield gathering is delayed (Suojala, 2000). Data of 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 (Fig. 8). Both after carrot yield gathering and after storage in root-crops of carrots fertilized with nitrogen their amounts were smaller in comparison with the amounts in the root-crops grown without nitrogen fertilizer. After storage dry matter content in carrot changed in general, depending on kind of storage and variety, and β-carotene content was affected as well. Cold storage showed lower loss (13,57–14,28 %) compared to cellar (20–27,3 %) (Fikselová et al., 2010). Investigation data show that in carrot root-crops fertilized with nitrogen fertilizer with zeolite after storage were was slightly bigger amount of dry soluble solids than there was after yield gathering and fertilization with the investigations nitrogen fertilizers didn't have influence.

Growth and storage conditions, genetype influence sugar (Seljasen, et al., 2011) and carotene (Fikseliová et al., 2010; Gajewski et al., 2007, 2010) amounts in carrot root-crops. When growing carrot cultivar 'Samson', as data of our investigations show (Fig. 9), there were 6,2–6,4 % of sugars, 12,8–13,2 mg% of carotenes and fertilization with the investigated nitrogen fertilizers had little influence on sugar and carotene amounts. After carrot storage sugar and carotene amounts, in comparison with the amounts after yield gathering, little changed. According to polish investigators (Rożek et al., 2000), storing root-crops the amounts of dry sugars and nitrates decrease, but the amounts of phenols increase. Fikselová et al. (2010) indicate that storing in cool place the losses of β-carotene were 13,6–14,3 %, and storing in cellars – 20–27,3 %. Some authors (Belitz et al., 2004) indicate that carrot storage, which doesn't correspond to requirements; increase the disintegration of carotenoids 5–40 %. When carrots are stored at 2 °C and 90 % relational humidity, carotenoid amounts slowly increased during the first 100 days, but later on decreased (Lee, 1986).

Fertilizer rates and the time of their sprinkling, growth conditions influence nitrate accumulation in root-crops (Gajewski et al., 2009). Literature data concerning nitrates accumulation in carrots are differentiated and, according to Pokluda (2006), ranged from 50 to 500 mg kg^{-1} plants grown in Middle Europe region, and Koná (2006) indicates narrower limits (302,5–449 mg kg^{-1}). In the grown experiments in carrot root-crops there were 290,0–308,5 mg kg^{-1} (Fig. 10). Fertilizing with calcium ammonium nitre, the amount of nitrates increased 12,7 mg kg^{-1}, and fertilizing with ammonium nitre with zeolite the increase was insignificant. The least amount of nitrates in root-crops both in autumn, after yield gathering, and after storage, accumulated in carrot root-crops fertilized with nitrogen fertilizer with zeolite. After storage nitrate amounts decreased in root-crops fertilized with calcium ammonium nitre, nitrogen fertilizer with zeolite and grown without nitrogen fertilizer; slight increase, in comparison with the amounts after yield gathering were in carrot root-crops fertilized with ammonium nitre with zeolite. The data of statistical analysis showed that under our conditions when temperature increased nitrate amount in root-crop increased also (r = 0,96**), and the increase of precipitation amount during vegetation nitrate amounts decreased (r = -0,98**). Nitrate amount in root-crops increased, when mineral nitrogen amount in the soil increased also (r = 0,56*).

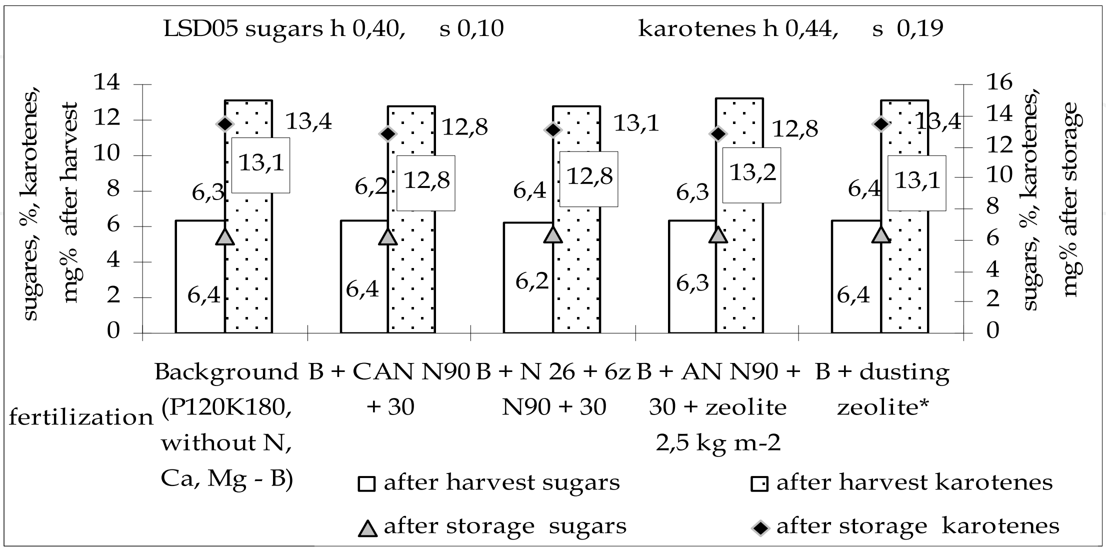

Fig. 9. Influence of fertilizers with prolongation effect on content of sugars and carotenes in carrot crop-root. Babtai, 2004–2008.

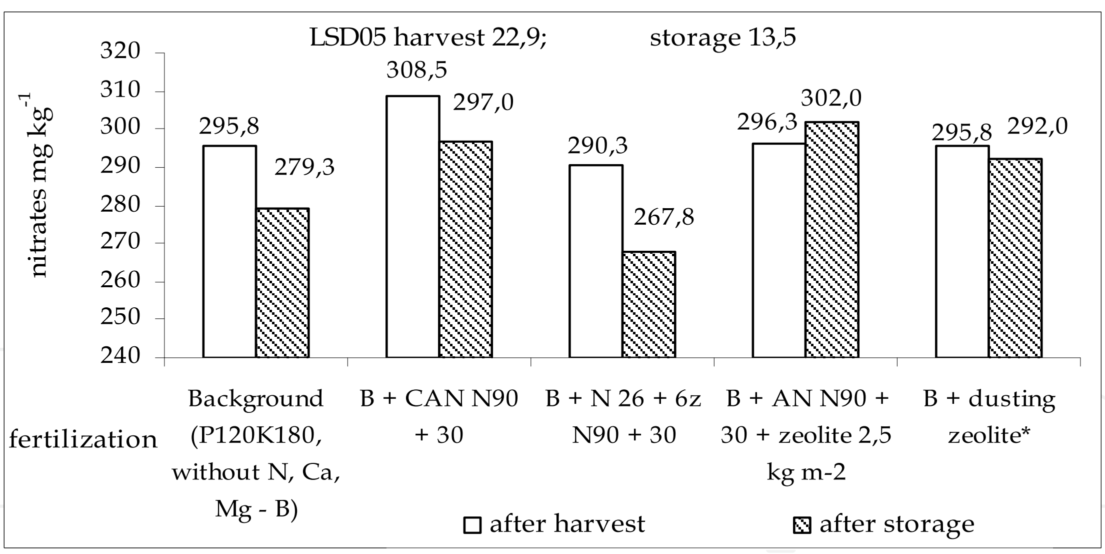

Fig. 10. Influence of fertilizers with prolongation effect on content of nitrates in carrot crop-root. Babtai, 2004–2008.

Red beet, cabbage, cucumber, potatoes, leaf vegetables accumulate more nitrates. Their amount during storage little changes. Carrot accumulate little amount of nitrates (Prasad & Chetty, 2008; Ayaz et al., 2007). Our investigations confirmed this. In red beet root-crops fertilized with nitrogen fertilizer with zeolite after yield gathering there was found 1807 mg kg^{-1}, carrot – 290 mg kg^{-1} of nitrates. After storage nitrates amount of nitrates slightly decreased: in red beet on the average 442,5 mg kg^{-1}, in carrot – 9,6 mg kg^{-1}.

3.4 Agrochemical properties of the soil

The amount of nutrients in the soil depends on the soil itself, fertilization, and time of investigations (Jalali, 2008; Liet. dirvožemių ..., 1998). Application of natural zeolite, that showed Abdi et al. (2006) increased the available nitrogen, potassium, phosphorus, calcium and magnesium of the medium. Beqiraj (Goga) et al. (2008) maintain that the presence of zeolites ameliorates the physical and chemical quality of soil and by thus can reduce nutrient loss due to leaching by increasing the retention of nutrients and slowly releasing them as needed by soil and plants. The influence of nitrogen fertilization is also determined by many other factors (soil type, texture, redox potential and the content of organic matter, cation exchange capacity, and base saturation ratio, soil content of Ca and Mg as well as heavy metals (Sady & Rożek 2002). Zeolite, which the main component is klinoptilolit, according to Russian investigator (Середина, 2003), decrease soil acidity and this effect is seen in many years. Investigations in Croatia showed that fertilizers with zeolite have little effect upon the reduction of soil acidity by comparison to the applied lime materials, but owing to intensive ion exchange it had a good effect on soil fertility and thereby on the plants yield (Butorac et al., 2002). Soil acidity in red beet crop, when it is established after yield gathering, applying fertilizers little changed (Table 2); in carrot crop (Table 3), after fertilization with nitrogen fertilizer with zeolite, it was slightly smaller in comparison with this when fertilizing with calcium ammonium nitre. Smoleń et al., 2011 showed that nitrogen fertilizers only slightly influenced chemical properties of soil, mainly pH, solubility rate of mineral nutrients in soil environment and, thus, mineral uptake (and accumulation) by carrot plants. The amount of mineral nitrogen in the soil in red beet crop fertilizing with nitrogen fertilizer with zeolite, in comparison with red beet fertilized with calcium ammonium nitre, increased 8.2 %, in comparison with ammonium nitre and zeolite – 3,9 % (Table 2); in carrot crop correspondingly 5,1 % and 5,0 % (Table 3). Investigations carried out in *Endocalcari-Endohypogleyc Cambisol (CMg-n-w-can)* showed that fertilizing winter wheat with nitrogen fertilizer with klinoptilolit (N_{120}) at the last leaf stage, in 0–30 cm soil layer there was 37,6 %, and in wax maturity stage – 28,7–32,6 % more mineral nitrogen, in comparison with amount found fertilizing with calcium ammonium nitre. This might because of the reason that plants assimilate less nitrogen, therefore more of it remains in the soil (Mašauskienė & Mašauskas, 2009).

Fertilization/ characteristics	$pH_{(KCl)}$	agile, mg kg^{-1}				Nmin kg ha^{-1}
		P_2O_5	K_2O	Ca	Mg	
Soil agrochemical characteristics before layout of experiments	7,4	371	186	7249	1775	50,4
Background (P120K180, without N, Ca, Mg -B)	7,7	356,5	162,8	7040	1885	42,3
B + CAN N90 + 30	7,8	345,5	168,0	8455	2329	44,1
B + N 26 + 6z N90 + 30	7,8	375	171,8	10260	2834,8	47,7
B + AN N90 + 30 + zeolite 2,5 kg m-2	7,8	380,5	168,0	8795	2379	45,9
LSD05	0,13	49,8	28,8	2337,8	877,8	6,4

Table 2. Influence of fertilizers with prolongation effect on exchange agrochemical properties of soil in red beet crop. Babtai, 2004–2007.

Slightly bigger amount of agile potassium in red beet crop was in the soil fertilized with nitrogen fertilizer with zeolite and in carrot crop – after fertilization with ammonium nitre with zeolite. There was slightly bigger amount of agile phosphorus in both experiments after fertilization with ammonium nitre with zeolite. According to the data of Serbian investigators (Milošević & Milošević, 2010), fertilization with all the rates of investigated fertilizers with zeolite (Agrozel) led to increases in humus, total nitrogen (not significant), potassium and phosphorus (significant to the control – no fertilizer) within all depts. The biggest amount of calcium and magnesium in the soil of red beet crop was fertilizing with nitrogen fertilizer with zeolite, and in carrot crop – fertilizing with ammonium nitre with zeolite. Even though the soil is rich with calcium and magnesium, these elements are antagonists and plats do not assimilate them (Liet. dirvož...., 1998).

Fertilization/ characteristics	$pH_{(KCl)}$	agile, mg kg^{-1}				N min kg ha^{-1}
		P2O5	K2O	Ca	Mg	
Soil agrochemical characteristics before layout of experiments	7,4	371	186	7249	1775	50,4
Background (P120K180, without N, Ca, Mg -B)	7,6	390,3	151,5	7217,5	1822,3	38,8
B + CAN N90 + 30	7,7	407,5	148,2	7960	1912,5	50,6
B + N 26 + 6z N90 + 30	*7,8*	404,5	156,2	7935,1	2020	53,2
B + AN N90 + 30 + zeolite 2,5 kg m-2	7,8	444,8	166,3	8652,5	2053,8	52,7
LSD05	0,16	30,7	40,17	1349	187,2	15,5

Table 3. Influence of fertilizers with prolongation effect on exchange agrochemical properties of soil in carrot crop. Babtai, 2004–2007.

4. Conclusions

The use of nitrogen fertilizers increased red beet marketable yield 2,1 times, carrot – 14,1 %, when growing without fertilizers there was obtained correspondingly 24,2 t ha^{-1} and 49,0 t ha^{-1}. The biggest marketable red beet (54,7 t ha^{-1}) and carrot (57,6 t ha^{-1}) yield and the output of marketable yield (correspondingly 79,6 % and 71,4 %) were applying nitrogen fertilizer with zeolite (N 26 + 6z N_{90+30}). Red beet marketable yield, in comparison with this of the red beet grown without nitrogen fertilizer, increased more than twice, carrot – 17,6 %, output of marketable yield correspondingly 21,3 % and 4,1 %.

The results of storage investigation showed that red beet and carrot fertilized with nitrogen fertilizer with zeolite was preserved best of all. After short-time storage there was 48,1 t ha^{-1} of red beet and 50,3 t ha^{-1} of carrot marketable production; storage losses comprised correspondingly 12,0 % and 12,7 %. After long-time storage there was 39,6 t ha^{-1} of red beet and 41,2 t ha^{-1} of carrot marketable production; storage losses comprised correspondingly 27,5 % and 28,4 %. Red beet and carrot sprinkling with zeolite (30 kg t^{-1}) improved their storability. After short-time storage the output of red beet marketable production in comparison with this of the red beet grown without nitrogen fertilizers increased 8,6 %, carrot – 9,0 %; after long-time storage – correspondingly 35,5 % and 29,2 %; i. e., there was obtained additionally 1,7 and 5,1 t $ha^{-1}$of red beet and 3,8 and 9,5 t $ha^{-1}$of carrot marketable production.

Dry matter amounts after yield gathering in red beet root-crops fluctuated from 11,9 % to 14,4 %, dry soluble solids – from 11,7 % to 13,5 %; nitrates – from 1807 mg kg^{-1} to 2123,5 mg kg^{-1} and the least their amounts were fertilizing the crop with nitrogen fertilizer with zeolite; sugars – from 7,9 % to 8,4 % and fertilization didn't influenced significantly their amount. In carrot root-crops dry matter amounts fluctuated from 10,7 % to 11,0 %; dry soluble solids – from 8,8 % to 8,9 %; nitrates – from 290 mg kg^{-1} to 308.5 mg kg^{1} and the least their amounts were fertilizing the crop with nitrogen fertilizer with zeolite; sugars – from 6,2 % to 6,4 %; carotenes – from 12,8 mg% to 13,2 mg%. After storage in red beet root-crops there was correspondingly 11,8-13,7; 12,0-12,3; 1398-1728,9; 8,6-9,0; in carrot crop – 10,2-11,1; 8,7-8,9; 267,8-302,0; 6,2-6,4 and 12,8-13,4. The least amounts of dry matter, dry soluble solids and nitrates were after fertilization red beet and carrot crop with nitrogen fertilizer with zeolite. Fertilization with the investigated nitrogen fertilizers didn't influence significantly the amounts of sugars and carotenes.

Fertilizing with nitrogen fertilizer with zeolite soil acidity decreased, and the amounts of mineral nitrogen were bigger. The amounts of agile potassium, phosphorus, calcium and magnesium in the soil fertilizing with nitrogen fertilizer with zeolite were bigger than fertilizing with other investigated fertilizers.

Zeolite is the suitable means for soil properties and yield quality improvement.

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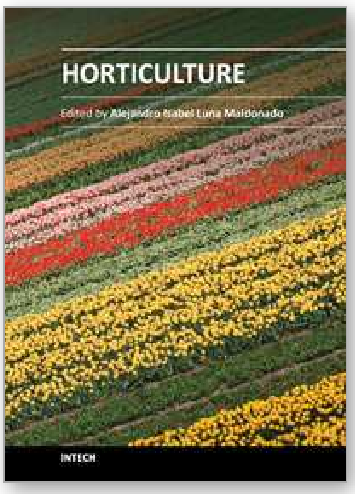

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This book is about the novel aspects and future trends of the horticulture. The topics covered by this book are the effect of the climate and soil characteristics on the nitrogen balance, influence of fertilizers with prolongation effect, diversity in grapevine gene pools, growth and nutrient uptake for tomato plants, post-harvest quality, chemical composition and antioxidant activity, local botanical knowledge and agrobiodiversity, urban horticulture, use of the humectant agents in protected horticulture as well as post-harvest technologies of fresh horticulture produce. This book is a general reference work for students, professional horticulturalists and readers with interest in the subject.