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THE INFLUENCE OF ROAD MAINTENANCE SUBSTANCES ON THE GROWTH OF GRAMINACEOUS PLANTS

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Abstract. The article describes the experimental research on the effect of road maintenance materials on three species of graminaceous plants. The experiment was carried out using technical granular sodium chloride (NaCl) treated with potassium hexacyanoferrate – a road maintenance material most widely applied in wintertime in Lithuania. As an alternative, an organic material obtained on the basis of molasses, patented under the name of *Safecote* in Europe, was selected for the experiment. Three species of graminaceous plants, most frequently used for roadside planting in Lithuania when building new and reconstructing or renovating the existing motor roads, were analysed: perennial rye-grass (*Lolium perenne* L.), meadow fescue (*Festuca pratensis* Huds.), and common meadow-grass (*Poa pratensis* L.). The paper presents experimental findings regarding the effect of road maintenance materials on the parameters of graminaceous plants – the height of the above-ground part and phytomass.

Keywords: graminaceous plant species, perennial rye-grass (*Lolium perenne* L.), meadow fescue (*Festuca pratensis* Huds.), common meadow-grass (*Poa pratensis* L.), molasses, road maintenance salt.

Introduction

During the cold season, approximately 140 000 tons of technical salts are spread on roads to reduce slipperiness in Lithuania. Out of this amount, 70 000 to 80 000 tons are applied on roads of national significance (data of the Lithuanian Road Administration under the Ministry of Transport and Communications) (Baltrėnas, Kazlauskienė 2009a). Technical salts are used to reduce slipperiness in wintertime. They are rather efficient in melting snow and ice but have a negative effect on road components, causing and corrosion of metal parts of motor vehicles as well as r/c structures (bridges, tunnels, etc.); they also have a significant impact on the destruction of cement-concrete structures, and deformation of asphalt-concrete paving, etc. (Kamaitis 2002a, 2002b).

These effects are especially evident in cities as streets are surrounded by numerous buildings and structures, leaving no space for roadside ditches that collect snow and salts cleaned off the roadway. In many such cases, it is impossible to immediately collect and transport snow accumulated on sidewalks. The situation is better with roads of national significance due to many open areas and roadside ditches (Baltrėnas *et al.* 2012).

Significant concentrations of road maintenance salts (up to 3200 mg/*l*) accumulate in snow (Baltrėnas, Kazlauskienė 2009b) and enter the soil together with meltwater carrying heavy metals (Vainalavičiūtė *et al.* 2009; Mikalajūnė, Jakučionytė 2011) and oil products (Žukauskaitė *et al.* 2008; 2012), which negatively affect roadside vegetation (Dobson 1991; Baltrėnas *et al.* 2006; Darginaviciene *et al.* 2008) as well as surface and ground waters (Williams *et al.* 1999) and their fauna (Oškinis, Kaperovičius 2005; Andreikėnaitė *et al.* 2007; Vosylienė *et al.* 2010). As other investigations have shown, soil is alkaline because of cement dust that contains different microelements (Stravinskienė 2011).

By density and quality of its road network, Lithuania equals highly developed states. One of the main aims of road maintenance in winter, aiming to removing snow and ice off road paving and increase the tyre and road paving adhesion coefficient, is to minimise the risk of traffic accidents. Recently, wet salt technology has been applied to protect roads against climatic factors or to de-ice the paving in a very short time. Its effective operation is possible under up to –15 °C (Sakshaug, Vaa 1995; Cornford, Thornes 1996; Žilionienė, Laurinavičius 2007). However,

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once Lithuania joined the European Union, the requirement has been set to use new generation environmentally friendly materials for road maintenance. With the aim to reduce a negative environmental effect of road maintenance salts, it is expedient to gradually reduce the use of technical salts (in particular in cities) replacing them with alternative new generation substances made on the basis of organic materials (Baltrėnas, Kazlauskienė 2009a).

The best practice, improvement of professional skills, scientific research and studies, and dissemination of their results play an important role in the improvement of road infrastructure (Skrinskas 2012).

This research analyses an organic substance molasses – a by-product of sugar manufacturing processes – to minimise road slipperiness and dustiness. In Europe, this product is patented as *Safocote*. Molasses was presented to the market in Great Britain in 2002. Canada and USA have 14 years of experience using this product, followed by Great Britain, which has been using it for 9 years. In Europe, (Austria, Estonia, Germany, Hungary, Ireland, Norway, Poland, Slovenia, Switzerland and Sweden), it has been in use from 3 to 5 years.

In Vilnius (Lithuania), *Safecote* was primarily used to decrease street slipperiness during the wintertime of 2005/2006. The amount of 18 tons of *Safecote* was used during 2006/2007 (Baltrėnas, Kazlauskienė 2009a).

Safecote added to a NaCl solution helps to stay on a road surface 7 times longer and, therefore, no additional treatment is required. It does not cause corrosion of equipment. If technical road maintenance salts were replaced with molasses substance, it would minimise the impact on concrete, bridges, viaducts and asphalt. Furthermore, it would reduce the number of spreader's working hours as well as the number of trips. No additional capital investment in equipment would be required because *Safecote* can be used with the existing equipment while the required volume of technical salts could be reduced from 30% to 50%.

Safecote should not be used on roads with low traffic intensity as it can increase a slippery layer, causing threat to traffic safety. Molasses substance is viscous and dark colour. When applied in big quantities, it requires additional washing of streets as well as vehicle maintenance in springtime.

Safecote costs more than technical salts but it is less harmful to the environment. The use of technical salts can be decreased adding 10% of *Safecote* to the mixture (Vitaliano 1992; Hanbali 1998; Thornes 2000; Petkuvienė, Paliulis 2009). Such a mixture is an effective solution for ice melting and prevention of slipperiness (Burtwell, Wilson 2002; Burtwell 2004).

Solutions of *Safecote* in water have been used during summer on the streets and gravel roads to reduce dustiness (Bradulienė, Vasarevičius 2010, 2011, 2012, 2014).

Safecote is a relatively new product; therefore, it is expedient to analyse it and its effect on road environment components. In this research, attention is given to graminaceous plants particular to Lithuania (Bradulienė, Vasarevičius 2010, 2011, 2012, 2014).

The impact of *Safecote* on herbaceous vegetation has been episodically studied in Lithuania and foreign countries (Bradulienė, Vasarevičius 2012).

The aim of the research: to analyse how road maintenance materials affect the growth process and main parameters (the height of the above-ground part and phytomass) of graminaceous plants.

1. Methods and materials

Three species of graminaceous plants, most often used for roadside planting in Lithuania when building new or reconstructing and renovating the existing roads, have been selected for this research (Baltrėnas *et al.* 2012). The type of vegetation influences the rate of substrate respiration. Substrates release approximately 20% of the total CO_2 content to the atmosphere (Baltrėnas *et al.* 2011).

The following graminaceous plants have been selected for investigation:

- perennial rye-grass (*darimo* cultivar) – *Lolium perenne* L.;
- meadow fescue (*prana* cultivar) – *Festuca pratensis* Huds.;
- common meadow-grass (*balin* cultivar) – *Poa pratensis* L.

Names of these species have also been mentioned in the article by Jankevičienė (1998).

Also known as molasses, *Safecote* is an organic material, which is a by-product of sugar refining. This organic material contains minerals, including Ca, P, S, K, Na, etc. This material is of dark brown colour, liquid and can be mixed with all technical road maintenance salts and their solutions (Baltrėnas, Kazlauskienė 2009a; Bradulienė, Vasarevičius 2011, 2012, 2014).

The research was carried out with crushed technical sodium chloride, including potassium hexacyanoferrate ($K_4[Fe(CN)_6]$), hereinafter referred to as NaCl. In Lithuania, the highest quantities of this admixture are used on rods in winter season (Baltrėnas, Kazlauskienė 2009b; Baltrėnas *et al.* 2012).

The experiment was carried out as follows: 3 g of seeds of perennial ryegrass, fescue grass and meadow-grass were each separately planted into 3 plastic containers fully filled with 1 kg of substrate.

The substrate of the following composition was used for the research: CaO – 300 mg/*l*, $NH_4 + NO_3$ – 100 mg/*l*, P_2O_5 – 50 mg/*l*, MgO – 80 mg/*l*, Fe_2O_3 – 800 mg/*l*, K_2O – 300 mg/*l*.

The research was carried out in two experiments. In experiment I, substrate had been watered with following solutions:

– 5 g/kg of *Safecote*,
– 5 g/kg NaCl,
– Mixture of 5 g/kg of *Safecote* and NaCl salt.

The mixture of *Safecote* and NaCl salt was composed of: 4.5 g/kg of NaCl and 0.5 g/kg of *Safecote.* The mixture proportion (90% NaCl: 10% *Safecote*) was selected following *Safecote* use instructions to reduce slipperiness. Seeking to reduce the required amounts of NaCl, at least 10% of *Safecote* of NaCl amount should be used.

In experiment II, substrate had been watered with following solutions:

– 3 g/kg of *Safecote*,
– 8 g/kg of *Safecote*,
– 10 g/kg of *Safecote*,
– 8 g/kg of mixture (90% NaCl: 10% *Safecote*) composed of 7.2 g/kg of NaCl and 0.8 g/kg of *Safecote*.

Graminaceous plants of the three mentioned species have also been seeded into uncontaminated substrate for control.

During the entire growth period, plats had been growing at the temperature of +20±2 °C and measured humidity of 52 (±3)% and daylighting of 160 (±10) Lx. Certified equipment METREL Poly MI 6401 had been used to measure air temperature and humidity during the experiment.

The experiment lasted for six weeks because this is the exact time, during which, when accessing substrate, road maintenance materials negatively affect the growth process and main parameters of graminaceous plants under both natural and laboratory conditions. During a longer period, road maintenance materials under natural conditions are washed away by precipitation (rain) and their concentrations are diluted. Under laboratory conditions, a similar process takes place when concentration of materials in substrate is reduced during watering of plants. These are the reasons why it is no value in carrying out the experiment for a longer period.

The bottom of each container had holes to allow a natural water run-off and prevent the accumulation of excessive water. Seeds of each species were simultaneously seeded into clean substrate and substrate contaminated with road maintenance materials (control and experimental plants). Both the control and the experimental plants were grown under the same conditions – at the same temperature and lighting. The experimental and control plants were watered once a week with 50 ml of ionised water (Baltrėnas, Kazlauskienė 2007; Kazlauskienė 2010).

The *height of the above-ground part* of graminaceous plants was measured with a calibrated metal ruler *Preisser* No 11 (with height deviation of 0.026 mm). Five samples of each of the graminaceous species were randomly pulled up from containers to measure the average height of the above-ground part (cm). The height of the above-ground part was measured from the start of roots to the end of the longest leaf (Baltrėnas, Kazlauskienė 2007; Kazlauskienė 2010).

Phytomass of graminaceous plants was measured with the calibrated electronic analytical balance KERN 770–60 (weighing 0.01 g ... 60 g, the error is 0.00001 g). Five samples of each of the graminaceous species were randomly pulled up from containers to determine the average phytomass (mg). The phytomass was determined with the help of an electronic balance, weighing plants without roots, i.e. only the green above-ground part (Baltrėnas, Kazlauskienė 2007; Kazlauskienė 2010).

The height of the above-ground part and the phytomass were measured every week of the experiment, i.e. 6 weeks (Baltrėnas *et al.* 2006; Baltrėnas, Kazlauskienė 2009b; Bradulienė, Vasarevičius 2012).

As illustrated in figures, the error of 10% occurred when measuring the parameters of graminaceous plants.

All data obtained from this experiment is presented as the arithmetic mean of five independent analyses (x±SD, n = 5). Significant differences ($p < 0.05$) were deleted from the data evaluation and the measurements were carried out repeatedly. The average characteristics at typical points were:

$$\overline{c} = \frac{1}{n}\sum_{i=1}^{k} c_i m_i, \qquad (1)$$

where: c_i – value of characteristics at typical points; m_i – probability at the obtaining of value; n – number of experimental days; k – number of different values of the characteristics (Kazlauskienė *et al.* 2013).

The above-mentioned average indicators of plants, were also estimated at the typical point. The standard statistical estimation error of the arithmetic average was equal to approx. 10%. The dependencies between different compound characteristics and all indicators in different samples were determined by statistical evaluation using Mathcad 2001 Professional software.

2. Results

Experiment I. At the end of the 1st week of the experiment, graminaceous plants showed a very weak germination. Some of the plants did not come up at all or hardly germinated; consequently, the analytical measurements of graminaceous plants were taken on the 2nd week of the experiment.

After the 2nd week of the experiment, perennial rye-grass had the highest height of its above-ground part compared to plants of other species. Compared to the control, the height of perennial rye-grass in the substrate containing 5 g/kg of NaCl differed by 1.6 times and that of

meadow fescue – by 3.4 times. After the 3rd week of the experiment, the height of control plants of perennial rye-grass reached 11.6 cm. The height of the above-ground part of control and perennial rye-grass in the substrate containing 5 g/kg of NaCl differed by 1.8 times. In one week, the difference of perennial rye-grass increased by 0.2 times. On the 4th week of growth, the height of perennial rye-grass reached 12.7 cm. On the 5th week of the experiment, perennial rye-grass was 14.0 cm. On the 6th week of growth, the height of the above-ground part of perennial rye-grass in the substrate containing *Safecote* was weaker compared to that of control plants (Fig. 1).

During the 3rd week of the experiment, the plants grew significantly; however, since then, common meadow-grass no longer germinated in the substrate with NaCl content. The height of control plants of meadow fescue reached 6.3 cm. Compared to the control, the height of the above-ground part of meadow fescue in the substrate containing 5 g/kg NaCl differed by 2.1 times. In one week, the difference of meadow fescue decreased by 1.3 times. On the 3rd week of growth, the height of plants in the substrate contaminated with *Safecote* considerably increased. In the substrate contaminated with NaCl and *Safecote*, plants were also higher compared to those containing NaCl alone: perennial rye-grass – 1.4 times, meadow fescue – 2.3 times. On the 4th week of growth, the height of meadow fescue reached 7.5 cm. The above-ground part of plants in the substrate contaminated with *Safecote* was the highest on the 4th and 5th weeks of the experiment. On the 5th week of the experiment, meadow fescue was 8.6 cm high. Compared to control plants, meadow fescue continued to grow 1.2 times taller.

Analysis of the weekly plant increment shows that the biggest increment of the above-ground part of plants was recorded on the 3rd week of growth, when perennial rye-grass increased by 1.9 cm in the substrate contaminated with 5 g/kg of NaCl, and 4.1 cm in the substrate containing the mixture of NaCl and *Safecote*. Meadow fescue grew by 1.2 and 2.7 cm, respectively. The increase of graminaceous plants in the substrate contaminated with NaCl was more even compared to the substrate containing *Safecote* (Fig. 2).

The height of the above-ground part of plants in the substrate contaminated with NaCl was the smallest, while common meadow-grass did not germinate at all. On the 3rd week of the experiment, the height of control plants of common meadow-grass reached 2.8 cm. On the 4th week of growth, the height of common meadow-grass reached 3.5 cm. On the 5th week of the experiment, common meadow-grass was 4.8 cm high. In the substrate containing NaCl, common meadow-grass did not germinate while in the substrate contaminated with the mixture of 5 g/kg of *Safecote* and NaCl salt grew evenly and increased by 0.4 cm per week on average (Fig. 3).

During the experiment, phytomass of perennial rye-grass was changing depending on contamination of the substrate. After two weeks of growth, phytomass of perennial rye-grass control plants was 8.9 mg; that of plants in the substrate containing 5 g/kg of NaCl – 7.5 mg; in the substrate containing 5 g/kg of *Safecote* – 8.6 mg; and in the substrate contaminated with the mixture of 5 g/kg NaCl/*Safecote* – 7.1 mg. Other weeks of the experiment showed a clear dependence of phytomass on the specificity on substrate contamination. The weakest phytomass of perennial rye-grass was in the substrate containing 5 g/kg NaCl. The phytomass of plants in the substrate

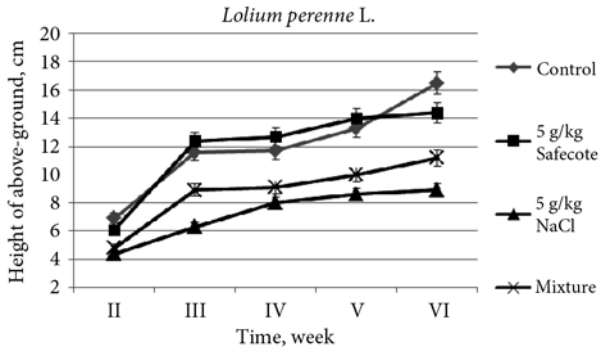

Fig. 1. Change in the height of the above-ground part of perennial rye-grass (*Lolium perenne* L.) (Experiment I)

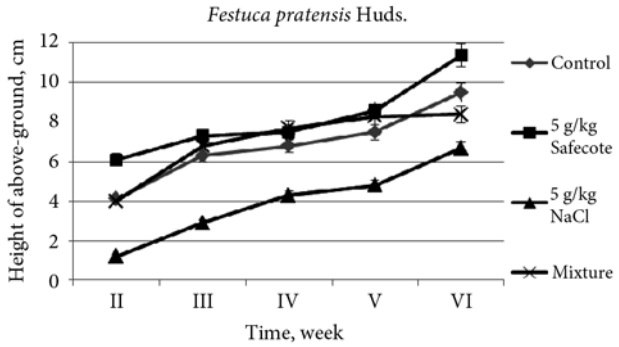

Fig. 2. Change in the height of the above-ground part of meadow fescue (*Festuca pratensis* Huds.) (Experiment I)

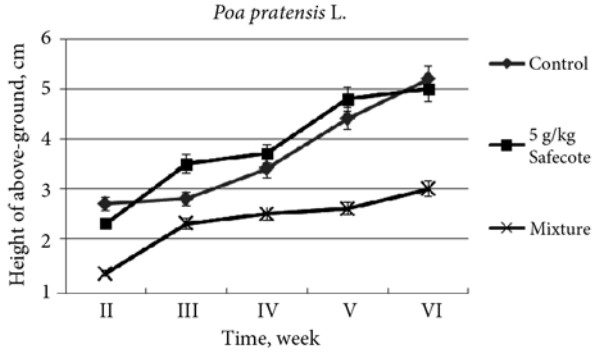

Fig. 3. Change in the height of the above-ground part of common meadow-grass (*Poa pratensis* L.) (Experiment I)

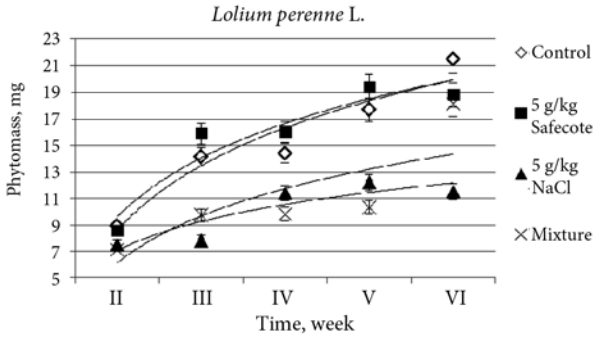

Fig. 4. Change in phytomass of perennial rye-grass (*Lolium perenne* L.) (Experiment I)

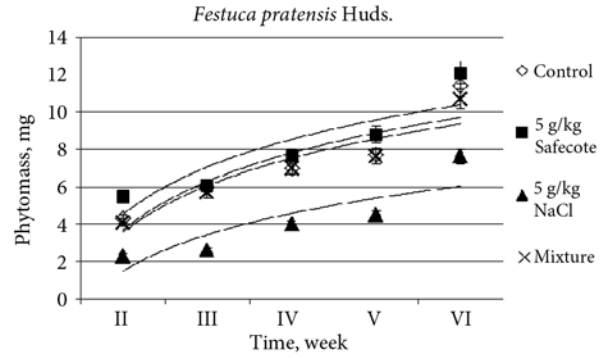

Fig. 5. Change of in phytomass of meadow fescue (*Festuca pratensis* Huds.) (Experiment I)

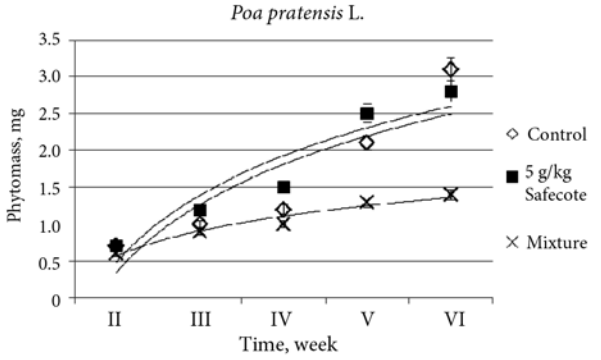

Fig. 6. Change in phytomass of common meadow-grass (*Poa pratensis* L.) (Experiment I)

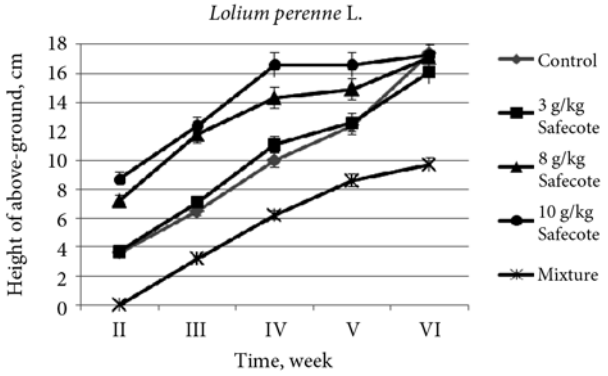

Fig. 7. Change in phytomass of perennial rye-grass (*Lolium perenne* L.) (Experiment II)

contaminated with the mixture of 5 g/kg NaCl and *Safecote*, was bigger compared to the substrate containing only NaCl but by 4 mg smaller than that of control plants. Tor five weeks, in the substrate contaminated only with 5 g/kg *Safecote*, phytomass of perennial rye-grass was on average 1.7 mg bigger than that of control plants but after week 6 it decreased by 2.7 mg (Fig. 4).

Phytomass values of meadow fescue in substrates contaminated only with *Safecote* and the mixture of *Safecote* and NaCl were similar. As Figure 5 shows, phytomass of plants in the substrate contaminated with the mixture of 5 g/kg NaCl and *Safecote* was somewhat smaller than that of control plants, while in the substrate contaminated only with *Safecote*, it was inconsiderably bigger compared to control plants. A significant difference in phytomass of perennial rye-grass in the substrate containing 5 g/kg NaCl and the control substrate, i.e. 3.8 mg, was recorded after growth weeks 3 and 6.

During the first four weeks of the experiment, phytomass of common meadow-grass in differently contaminated substrates was changing evenly. From week 4 to week 6, a significant difference in phytomass change was recorded: in the substrate contaminated with the mixture of 5 g/kg of NaCl and *Safecote*, plants grew by only 0.4 mg, while in the control substrate – 2.1 mg, and in the substrate containing 5 g/kg of *Safecote* – 1.3 mg. Just as in the case of perennial rye-grass, phytomass of common meadow-grass in the substrate contaminated only with *Safecote* was bigger than that of control plants (Fig. 6). During the experiment, common meadow-grass has not germinated in the substrate containing 5 g/kg of NaCl. Within the growth period, phytomass of common meadow-grass grass was the smallest compared to perennial rye-grass and meadow fescue.

Experiment I showed that when added into the substrate, *Safecote* had a positive effect on the growth process of graminaceous vegetation.

Experiment II. As mentioned in the methodology, only two *Safecote* concentrations – 5 g/kg and 0.5 g in the mixture with NaCl – were added to the substrate in the first part of the experiment. To confirm experimental findings, it was decided to continue the experiment by analysing at least several more concentrations of *Safecote* (3 g/kg, 8 g/kg, 10 g/kg) and one more high concentration mixture with NaCl (7.2 g/kg NaCl and 0.8 g/kg *Safecote*).

After the 2nd week, perennial rye-grass had the longest above-ground part compared to plants of the other 2 species, i.e. common meadow-grass and meadow fescue.

After the 2nd week of growth, it has become clear that the higher is *Safecote* concentration, the bigger is the height of the above-ground part of plants. After week 2, all plants growing in the substrate contaminated only with *Safecote* were taller than the control plants. After week 2, none of the plant species germinated in the substrate

contaminated with the mixture of 8 g/kg NaCl and *Safecote*. Compared to the control substrate, the height of the above-ground part of perennial rye-grass in the substrate containing 10 g/kg of *Safecote*, differed by 1.9 times (Fig. 7).

The plants significantly grew on the experiment's 3rd week. The height of control plants of perennial rye-grass reached 6.5 cm, that of fescue-grass – 3.4 cm, common meadow-grass – 2.3 cm. The above-ground part height of meadow fescue differed by 2.4 times in substrate containing 10 g/kg of *Safecote*, when compared to control substrate. Perennial rye-grass reached the height of 3.2 cm In substrate contaminated with the mixture of 8 g/kg NaCl and *Safecote*, fescue-grass – 1.5 cm while common meadow-grass did not germinate even after the 3rd week (Figs 7, 8).

Compared to the control substrate on the 3rd week of growth, the height of the above-ground part of common meadow-grass in the substrate containing 10 g/kg of *Safecote* differed by 2.2 times. On weeks 4 and 5 of the experiment, the height of plants was the greatest in the substrate containing 10 g/kg of *Safecote*: on the 4th week, the height of perennial rye-grass reached 16.6 cm, that of meadow fescue – 10.8 cm, common meadow-grass – 7.2 cm; on the 5th week perennial rye-grass was 16.6, fescue-grass 12.7 cm and common meadow-grass 12.0 cm tall (Figs 7, 8, 9).

On the 6th week of growth, perennial rye-grass in differently contaminated substrates showed nearly the same height of its above-ground part, former differences disappeared. The highest perennial rye-grass plants were in control pots and reached 17.4 cm. However, the difference in heights of fescue-grass and common meadow-grass plants in differently contaminated substrates continued to remain significant. The height of fescue-grass and common meadow-grass in all substrates contaminated with *Safecote* was greater than that of control plants that were watered only with ionised water (Figs 7, 8, 9).

In the substrate contaminated with the mixture of 8 g/kg NaCl and *Safecote*, perennial rye-grass and meadow fescue germinated only on the 3 week of the experiment, while common meadow-grass has not germinated during the entire experiment. Every week germinated plants showed an average increase of: perennial rye-grass – 2.4 cm, meadow fescue – 1.4 cm. After 6 weeks of growth, the height of the above-ground part of perennial rye-grass reached 9.7 cm and that of fescue-grass – 5.5 cm. During the experiment, the height of the above-ground part of plants in the substrate contaminated with the mixture of NaCl and *Safecote* was smaller than that of control plants (Figs 7, 8, 9).

Phytomass of perennial rye-grass was changing diversely depending on contamination of the substrate. Phytomass of control plants was evenly increasing by the average of 4 mg per week. Phytomass of plants in the substrate with 3 g/kg *Safecote* content and the substrate containing the mixture of 8 g/kg NaCl and *Safecote* was changing similarly to that of control plants but plants in the substrate contaminated with the mixture of NaCl and *Safecote* had the weakest phytomass. Compared to control plants, it was 0.1 mg less on the 2nd growth week, 3 mg – 3rd week, 0.7 mg – 4th week, 1.9 mg – 5th week, and 1.5 mg – 6th week. Plants in substrates containing 8 g/kg *Safecote* and 10 g/kg *Safecote* had bigger phytomass compared to control plants (Fig. 10).

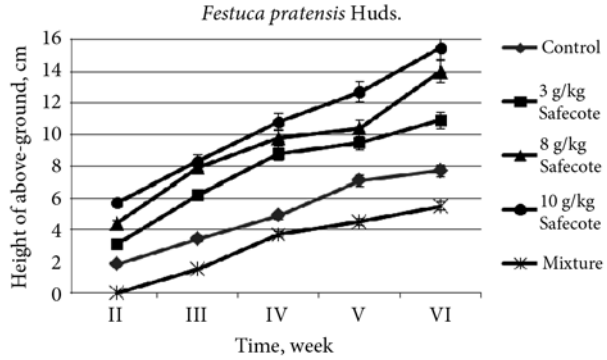

Fig. 8. Change of meadow fescue (*Festuca pratensis* Huds.) height of above-ground (Experiment II)

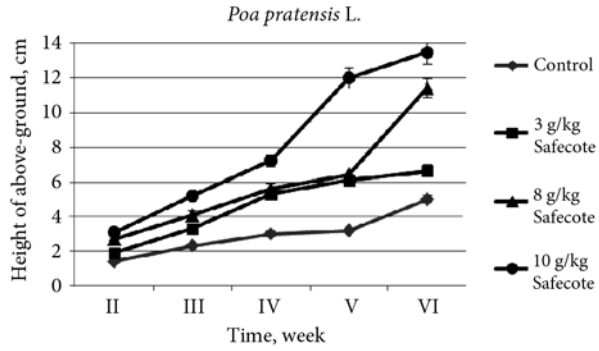

Fig. 9. Change the above-ground height of common meadow-grass (*Poa pratensis* L.) (Experiment II)

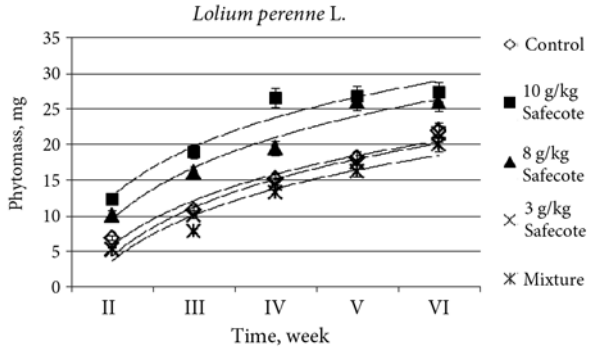

Fig. 10. Change in phytomass of perennial rye-grass (*Lolium perenne* L.) (Experiment II)

As illustrated in Figure 11, the biggest variation in the height of above-ground part of perennial ryegrass was in week when temperature was changed approximately 2 °C. Correlation coefficient of variation of above-ground part of perennial ryegrass and temperature was equal to 0.62.

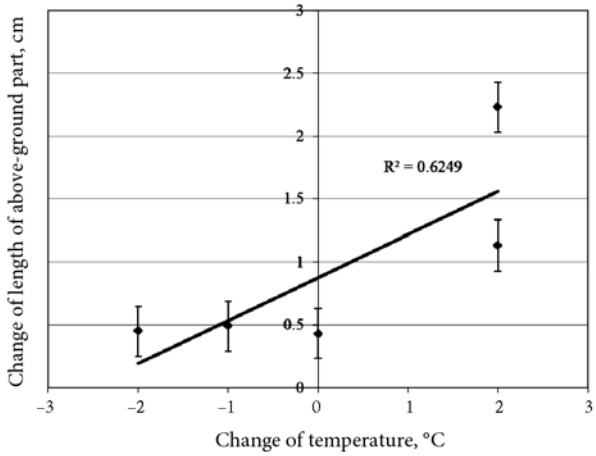

Fig. 11. Variation of the height of the above-ground part of perennial rye-grass (*Lolium perenne* L.) in relation to temperature (Experiment II)

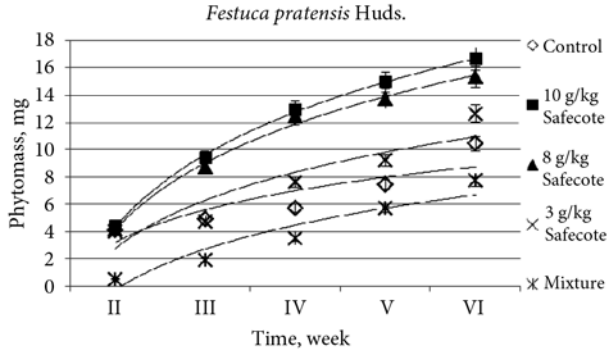

Fig. 12. Change in phytomass of meadow fescue (*Festuca pratensis* Huds.) (Experiment II)

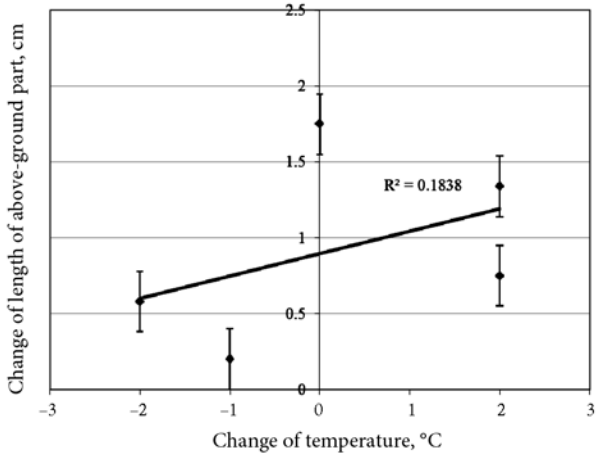

Fig. 13. Variation of the height of the above-ground part of meadow fescue (*Festuca pratensis* Huds.) in relation to temperature (Experiment II)

Obvious differences in phytomass of meadow fescue have been recorded in the substrate with *Safecote* content. The higher was *Safecote* concentration in the substrate, the bigger was phytomass of plants. Phytomass of plants in the substrate contaminated with the mixture of 8 g/kg NaCl and *Safecote*, was weaker than that of control plants: after 2 weeks – 3.5 mg, after 3 weeks – 2.9 mg, after 4 weeks – 2.2 mg, after 5 weeks – 1.7 mg, after 6 weeks – 2.7 mg (Fig. 12).

As illustrated in Figure 13, the biggest variation in the height of the above-ground part of fescue grass was recorded on the week when the temperature was changed to 0 °C. The correlation coefficient of variation of the above-ground part of fescue grass and temperature was equal to 0.18.

During the first weeks of the experiment, phytomass of common meadow-grass was changing gradually and after the 4th week, it amounted to the average of 2.0 mg. Common meadow-grass in the substrate with 10 g/kg *Safecote* content was distinguished by somewhat bigger phytomass. From week 4 to week 6, a big difference in the change of phytomass was recorded: in substrates with 8 g/kg and 10 g/kg of *Safecote* content, plants increased by 7.1 mg and 8.2 mg, respectively. Phytomass of common meadow-grass, just as that of perennial rye-grass, was bigger in pots with higher concentration of *Safecote* (Fig. 14).

As illustrated in Figure 15, the biggest change in the height of the above-ground part of meadow-grass was recorded on the week when the temperature was changed to 0 °C. The correlation coefficient of variation of the above-ground part of meadow-grass and temperature was 0.01.

3. Discussion

J. Bradulienė and S. Vasarevičius (2012) investigated the impact of different concentrations of *Safecote* and *Safecote* mixture with $CaCl_2$ on timothy-grass

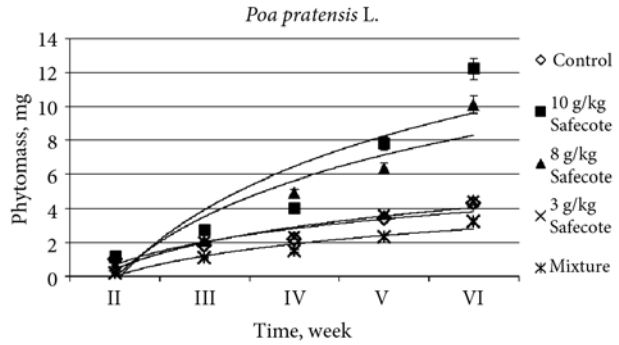

Fig. 14. Change in phytomass of common meadow-grass (*Poa pratensis* L.) (Experiment II)

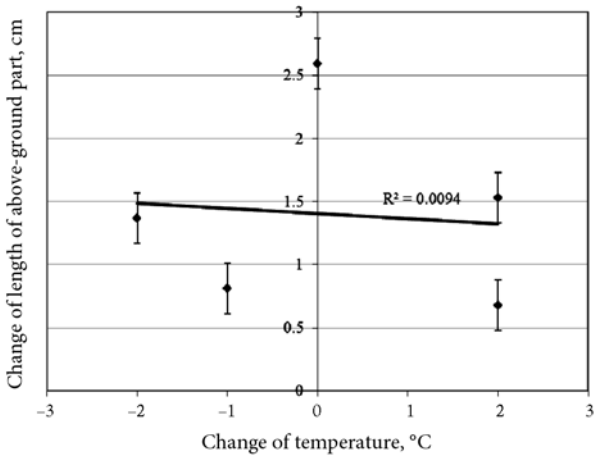

Fig. 15. Variation of the height of the above-ground part of common meadow-grass (*Poa pratensis* L.) in relation to temperature (Experiment II)

(*Phleum pratense* L.), white clover (*Trifolium repens* L.) and crimson clover (*Trifolium incarnatum* L.). These researchers found that the height of herbaceous plants above the ground has a linear dependency on *Safecote* concentrations in the soil, i.e. the greater is the concentration of *Safecote*, the higher part of herbaceous plants was above the ground.

The comparison of results with those of earlier investigations regarding the toxic impact of NaCl on herbaceous vegetation (Baltrėnas *et al.* 2006; Baltrėnas, Kazlauskienė 2007, 2009b; Baltrėnas *et al.* 2012) established that a negative influence of NaCl on vegetation parameters can be reduced by changing some part of NaCl to *Safecote*, e.g. making mixtures. The research results show that technical salts have an adverse effect on the growth of grass plants by slowing down the growth of the above-ground part of plants and limiting their phytomass.

Conclusions

1. Findings of the experiment show that perennial rye-grass had the biggest and meadow grass – the smallest phytomass among the analysed graminaceous plants grown in contaminated substrate.

2. During the experiment, it was determined that perennial rye-grass reached the highest, while meadow grass – the lowest height of the above-ground part of plants.

3. Findings of the experiment also showed that perennial rye-grass had the highest resistance to the toxic effect of salts while common meadow-grass – the lowest as it did not germinate in substrates with big concentrations (5–8 g/kg) of NaCl.

4. *Safecote* infiltrated into the soil had a positive impact on the growth of herbaceous vegetation, e.g. it accelerated the growth of the part of plants above the ground and increased their biomass. The higher was *Safecote* concentration in the soil (in this research, the highest was 10 g/kg), the better it improved the height of herbaceous plants above the ground and added to their phytomass.

5. It has been experimentally proved that the content of NaCl in the substrate has a negative effect on the growth process of graminaceous vegetation, i.e. it retards the increment of the above-ground part and reduces phytomass.

6. Herbaceous vegetation grown in the soil with *Safecote*, sometimes showed higher parameters compared to control plants (even till 50%); consequently, mineral compounds of *Safecote* ingredients can be used as soil fertilisers to improve condition of plants. When inserted into the substrate, *Safecote* had a positive effect on the growth process of graminaceous vegetation, i.e. accelerated the increment of the above-ground part of plants and increases their phytomass. The higher was *Safecote* concentration in the substrate, the greater was the height of the above-ground part and phytomass of graminaceous vegetation. In some cases, graminaceous plants in the substrate with *Safecote* content showed better parameters than those in the control substrate.

7. When NaCl application was reduced by 10%, replacing it with the same amount of *Safecote*, the substrate condition was improved with mineral substances and favourable conditions for plant development were created.

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