



## THE IMPACT ON GRASS VEGETATION OF MATERIALS REDUCING GRAVEL ROAD DUSTINESS

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**Abstract.** Materials used to reduce dustiness on gravel roads affect both the gravel road surfacing and the neighbouring vegetation. Materials used to reduce dustiness may access vegetation directly (when sprayed on gravel roads) and indirectly (when leached out by precipitation). The investigation examined a new substance, the aqueous solution *Safecote* (of different concentrations) and its mixtures with calcium chloride. 10%, 20% and 30% concentrations of *Safecote* and 36.5% of calcium chloride were used. The mixture ratio was 1:1 by volume. The investigation addressed the impact of the applied solutions on the length and viability of the above-ground part of plants. The timothy grass, white clover and crimson clover species of grass vegetation were selected for the investigation. The choice was determined by the fact that these species frequently grow in pastures by gravel roads. As it was determined during the investigation the viability of the selected plants in non-contaminated soil was 85–89%, in soil contaminated with dust reducing agent was 67–88% using solution *Safecote*, and 0–1% when applying mixtures of solutions. After 6 weeks of growth the length of above-ground part was 6.41–8.57 cm in uncontaminated soil, 4.22–8.18 cm in soil contaminated with *Safecote* solution and 0.00–2.07 cm in soil contaminated with the mixture.

**Keywords:** solution *Safecote*, calcium chloride, timothy-grass, white clover, crimson clover, viability.

### 1. Introduction

In order to ensure traffic safety, measures are taken to help to avoid accidents and reduce the risk of traffic accidents, traffic jams, consumer expenses and environmental pollution (Kochanek, Tynan 2010). Thousands of tonnes of chemicals are applied on Lithuanian roads. They are mainly technical salts (chlorides) reducing dustiness and increasing traffic safety. In Lithuania the most frequently used substances are calcium chlorides ( $\text{CaCl}_2$ ) and bitumen emulsion (Vainalavičiūtė *et al.* 2009). Exchange of best practices, improvement of professional skills, also the scientific research works and studies and dissemination of their results play an important role in the improvement of road infrastructure (Skrinskas 2012).

The emergence of road gravel particles caused by gravel surfacing wear, vehicles and climatic factors are minimised by using asphalt gravel roads or, without changing the type of paving, by treating gravel surfacing with reagents which reduce dustiness: calcium lignosulphonate, calcium chloride or bitumen emulsion.

A stable road paving is the indicator of road durability (Lohnes, Coree 2002; Sanders, Addo 2000).

The impact of substances reducing dustiness on the environment manifests itself in different ways: during

atmospheric transports; with surface run-off; plant absorption; when swallowed by animals; when animal meat containing dust suppressants is eaten by humans; when substances reducing dustiness get infiltrated into the aqueous zone or ground water table during transportation; water evaporation from soil; possible contacts via skin, mouth or respiratory tract during solution spraying; threat to the ecology of soil microbes due to the substances contained therein; movement of dust suppressants' particles towards unforeseen areas due to wind erosion; solution leakage from road sides and during transportation of solvents; use of contaminated ground water; spray that run downwind at the time of application; when the components of substances reducing dustiness are ingested by humans.

Vehicles release large amounts of heavy metals to the environment. There have been done a lot of investigations analysing the distribution of heavy metals in soils near intensive regional roads (Mikalajūnė, Jakučionytė 2011). As other investigations have shown, soil is alkaline because of cement dust emissions (Stravinskienė 2011). The biodegradation of diesel fuel and heavy fuel oil was tested in the soil using chemical additives (oxidizing agents) (Žukauskaitė *et al.* 2012).

With a view to using the smallest possible amounts of chlorides and reducing their negative impact on environment, application of new means aimed at reducing gravel road dustiness is required.

The use of molasses-based products for road de-icing has been launched in foreign countries. Calcium chloride has been used to de-ice roads and reduce dustiness on gravel roads for a long time already. Therefore, the selected molasses-based material is planned to be used for the reduction of dustiness on gravel roads. *Safecote* (the trade name patented in Europe) or *Geomelt* (the trade name patented in the United States) (Baltrėnas, Kazlauskienė 2009), a patented product of the new generation, is an agricultural by-product derived in the sugar production process, otherwise known as molasses. *Safecote* contains minerals, such as calcium, phosphorus, sulphur, chlorine, potassium, sodium. *Safecote* is a brown liquid substance which is mixed with various de-icing salts and their mixtures, and is used rarely alone (Baltrėnas, Kazlauskienė 2009). The distinguishing properties of the *Safecote* solution are: excellent anti-corrosive properties; fast response to snow and ice control; environmentally friendly (Petkuvienė, Paliulis 2009). *Safecote* solution boasts powerful corrosion inhibition properties; it is biodegradable and environmentally friendly (Baltrėnas, Kazlauskienė 2009).

Type of vegetation influences the rate of soil respiration. Soils release around 20% of the total CO<sub>2</sub> content to the atmosphere (Baltrėnas *et al.* 2011).

The toxic effect of de-icing salts was examined on perennial ryegrass, fescue grass and meadow grass (Baltrėnas *et al.* 2006).

Three species of grass vegetation which most frequently grow by roadsides and in pastures by gravel roads were selected for the investigation:

- Timothy grass (variety: tundra) (*Phleum pratense* L.);
- White clover (variety: klondike) (*Trifolium repens* L.);
- Crimson clover (variety: linkarus) (*Trifolium incarnatum* L.).

Timothy grass is an important grass plant from the timothy grass genus (*Phleum*) of the meadow grass family (*Poaceae*). It is growing in meadows, pastures and riverbanks (Oseroff *et al.* 2010; Valenta *et al.* 1992). White clover is a plant of the clover genus (*Trifolium*) of the legume family (*Fabaceae*). It grows in meadows, pastures, fields, forest sites, unbroken soils, between shrubs, by roadsides and in parks. White clover is a very valuable plant, particularly in pastures. It sprouts rapidly and tolerates treading (Huber *et al.* 2009). Crimson clover belongs to the clover genus (*Trifolium*) of the legume family (*Fabaceae*). It grows in meadows, pastures and roadsides. Crimson clover is well adapted to poor soils. It is an annual fodder plant (Kiniry, Evers 2008).

Timothy grass is a quite widely spread species, being one of the most productive in Lithuania. It has been adapted well to the conditions of Northern Europe (Lemežienė

*et al.* 2004). Timothy grass is valued due to its wintering characteristics, good taste and medium nutritional value (Jonavičienė *et al.* 2009). Timothy grass, as a component of gramineous grass mixture, is used to re-seed pastures. Other components of a pasture grass mixture used for pasture re-seeding include white clovers, timothy grass, meadow grass and fescue grass.

A most valuable grass of the legume family is the genus of clovers (Gillett *et al.* 2001). White clover boasts a high resistance to powdery mildew and clover rot as well as unfavourable winter conditions, and starts flowering early (Sturite *et al.* 2010).

Crimson clover which grows in different types of soil is intolerant to drought but tolerates strong winds, it flowers in early spring, is a perfect green fertiliser, grows rapidly, is used for soil regeneration together with other plants, is resistant to root fungus and with some soil bacteria makes symbiosis and evolves nitrogen (Williams, Bartholomew 2009).

The aim of the investigation is to determine the impact of substances used to reduce dustiness on the viability and length of the above-ground part of grass vegetation. Concentrations selected for the mixtures were identical to those used in the experimental investigations of dustiness reduction which determined that *Safecote* solution application on gravel roads reduced dustiness (Zaveckytė, Vasarevičius 2008), and the experiments of the application of *Safecote* solution and CaCl<sub>2</sub> mixture allowed a conclusion that the solution *Safecote* still more efficiently reduced dustiness (Bradulienė, Vasarevičius 2010b) and suppressed chloride ions preventing their migration to the roadside (Bradulienė, Vasarevičius 2010a).

## 2. Investigation methods

*Determination of the seed viability of grass vegetation.* The investigation covered 100 units of each of the selected species of grass vegetation.

Continuous humidity was maintained throughout the investigation as water is the factor which regulates the viability of seeds (Weiterová 2008). Natural lighting was maintained which changed depending on the time of the day. The average prevailing temperature was 22 °C. A bowl was lined with filter paper which was constantly humidified. Seeds were spread on the paper.

Seed viability (%) was determined after 7 days.

*Investigation of the growth of grass vegetation in soil contaminated with Safecote and CaCl<sub>2</sub> solutions.* The investigation employed black peat, a mixture of organic fertiliser and humus with the following parameters of quality: humidity up to 60%, acidity – 7.2, mineral nitrogen amount 156 mg/kg, phosphorus – 105 mg/kg, potassium – 847 mg/kg, calcium – 288 mg/kg, magnesium – 57 mg/kg.

Temperature, air humidity and pressure were measured with a microclimate parameter meter with the measurement limits (0...+40) °C, (0...100)%, (700...800) mm of Hg column, and measurement errors ±1,0 °C, ±5%, ±5 mm of Hg column.

The length of above-ground parts of the plants was measured with callipers with measurement limits ranging from 0 mm to 155 and measurement error was 0.1 mm.

Seed viability was calculated as follows: one germinated plant was equated to 1% (100 seeds were seeded which accounts for 100%).

100 seeds of each selected species of grass vegetation were sown in plastic pots with a soil content of 1 kg in each. Three aqueous *Safecote* concentrations (10%, 20%, 30%) and mixtures with 36.5 % of  $\text{CaCl}_2$  were used during the investigation. Also, control plants were sown in soil untreated with solutions.

The concentration of calcium chloride was selected according to the methodological guidelines laid down in "Reduction of Dustiness on Roads with Gravel Surfacing".

The total volume of each solution was 100 ml. The composition was as follows:

- 10 ml of solution *Safecote* and 90 ml of water;
- 20 ml of solution *Safecote* and 80 ml of water;
- 30 ml of solution *Safecote* and 70 ml of water;
- 5 ml of solution *Safecote*, 45 ml of water, 24.8 g of  $\text{CaCl}_2$  dissolved in 50 ml of water;
- 10 ml of solution *Safecote*, 40 ml of water, 24.8 g of  $\text{CaCl}_2$  dissolved in 50 ml of water;
- 15 ml of solution *Safecote*, 35 ml of water, 24.8 g of  $\text{CaCl}_2$  dissolved in 50 ml of water.

The bottom of each pot had holes to allow a natural water run-off and prevent accumulation of excessive water. The seeds of each species were simultaneously planted in clean and contaminated soils (experimental and control plants). Both the control and the experimental plants were grown under the same conditions – at the same temperature and lighting and were watered with identical water amounts at the same time.

Each experimental and control plant was watered with 40 ml of water every three days.

The investigation determined the seed viability (%) and the length of above-ground part (cm) of grass vegetation.

### 3. Findings

*Results of the seed viability of grass vegetation.* A seed viability experiment was carried out twice in order to achieve reliable results.

100 seeds were placed in each bowl and one seed, therefore, was equated to one percent of viability.

The viability of the selected seeds (timothy grass, white and crimson clovers) was over 90% during both experiments. The obtained results of viability are presented in Fig. 1.

As the viability of the selected grass vegetation exceeded 90% it can be stated that the selected species are suitable for further investigation.

*Results regarding the growth of grass vegetation in soil contaminated with Safecote and  $\text{CaCl}_2$  solutions.* As 100 seeds of each of the selected species of grass vegetation were seeded in each pot, the viability was determined in both control soil and soil contaminated with dust reducing agents. One species of grass vegetation was seeded in 7 pots in the following soils:

- 1) contaminated with solution *Safecote* of 10% concentration;
- 2) contaminated with solution *Safecote* of 20% concentration;
- 3) contaminated with solution *Safecote* of 30% concentration;
- 4) contaminated with a mixture of 10% *Safecote* and 36.5%  $\text{CaCl}_2$  concentration;
- 5) contaminated with a mixture of 20% solution *Safecote* and 36.5%  $\text{CaCl}_2$  concentration;
- 6) contaminated with a mixture of 30% solution *Safecote* and 36.5%  $\text{CaCl}_2$  concentration;
- 7) non-contaminated (control).

The viability of timothy grass, white and crimson clovers in soil is represented in Fig. 2.

As shown in Fig. 2, after 6 weeks of experiments timothy grass and white clover did not germinate in soil contaminated with mixtures, and only one seed of crimson clover germinated in soil contaminated with solution *Safecote* of 10% and  $\text{CaCl}_2$  of 36.5% concentration.

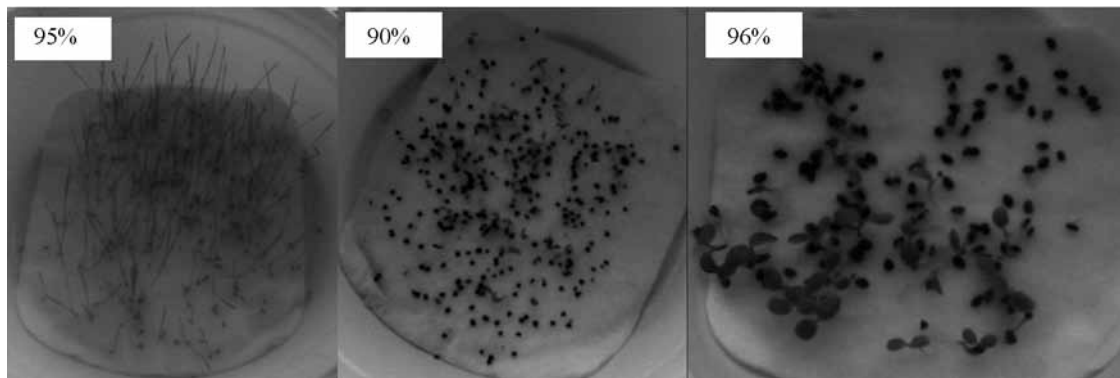


Fig. 1. Viability of seeds: timothy grass, white clover, crimson clover

As mentioned in the methodology, the length of above-ground part was observed during experiments. The obtained results are presented in Figs 3–8. As no plants germinated in soil contaminated with the mixture (except for crimson clover) the results are presented separately.

During the 1<sup>st</sup> week of experiment the clovers of both species germinated in all pots, while timothy grass did not germinate in only two pots containing soil contaminated with the solution *Safecote* of 10% and 20% concentrations. In the 1<sup>st</sup> week of growth room temperature was maintained at 20–21 °C. The diagram (Fig. 3) shows that after the 1<sup>st</sup> week white clover had the biggest length of its above-ground part compared to the length of timothy grass and crimson clover. It is apparent that the biggest difference in the length of above-ground part compared to the control one was in soil contaminated with the solution *Safecote* of 10% concentration: the length of white clover in soil with 10% *Safecote* concentration differed from the control one by 1.6 times, that of crimson clover – 1.7 times and timothy grass did not germinate at all.

Timothy grass started germinating in the experiment's 2<sup>nd</sup> week. Room temperature rose to 22–23 °C and the plants achieved significant growth in the 2<sup>nd</sup> week (Fig. 4). The length of control timothy grass plants reached 4.64 cm that of white clover – 2.47 cm, crimson clover – 2.30 cm. In soil contaminated with 10% concentration of *Safecote* solution compared to control soil the above-ground part's length of timothy grass differed by 2.6 times, that of white clover – 1.1 times and crimson clover – 2.3 times. In the 2<sup>nd</sup> week a lesser variation was recorded: the length of the above-ground part of white clover in control soil was 2.47 cm and in soil contaminated with 10% solution *Safecote* was 2.17 cm. In the 2<sup>nd</sup> week the highest was timothy grass, with the exception of soil contaminated with 10% solution *Safecote* in which white clover was by 1.2 times bigger than the timothy grass.

In the 3<sup>rd</sup> week room temperature fell by 1 °C and was 21–22 °C. A fall in temperature had no big influence on the length of plants (Fig. 5). The length of control timothy grass plants reached 5.17 cm that of white clover – 2.95 cm, crimson clover – 2.94 cm. In soil contaminated with *Safecote* solution of 10% concentration compared to control soil the above-ground part's length of timothy grass differed by 2.2 times, that of white clover – 1.4 times and crimson clover – 1.2 times. Like in the 2<sup>nd</sup> week it was timothy grass that was the highest. In the 3<sup>rd</sup> week crimson clover exceeded white clover in height in contaminated soils by 0.15 cm (30%), 0.03 cm (20%) and 0.22 cm (10%).

In the 4<sup>th</sup> week room temperature rose by 2 °C reaching 23–24 °C. As a result of increased temperature the lengths of above-ground parts increased significantly (Fig. 6). The length of control timothy grass plants reached 5.78 cm, that of white clover – 4.55 cm and crimson clover – 5.09 cm. In soil contaminated with *Safecote* solution of 10% concentration compared to control soil the

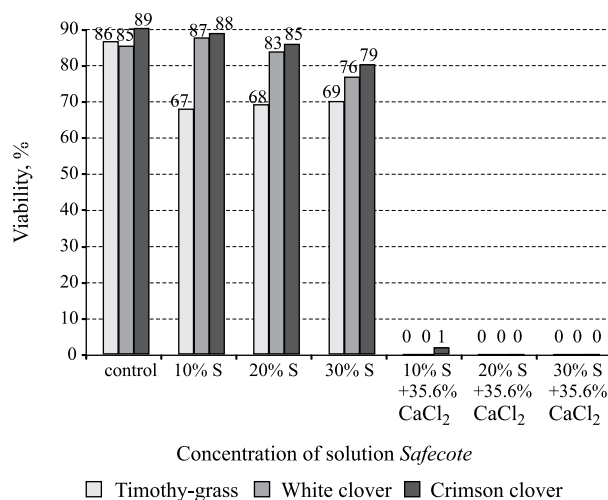


Fig. 2. Viability of timothy grass, white and crimson clovers in soil (during six weeks)

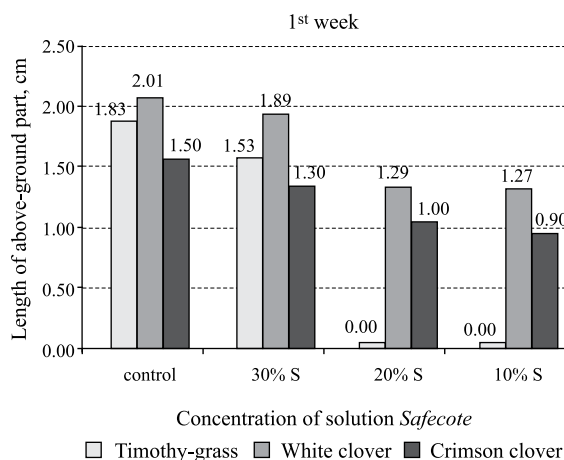


Fig. 3. Length of above-ground part of grass vegetation after 1<sup>st</sup> week of growth

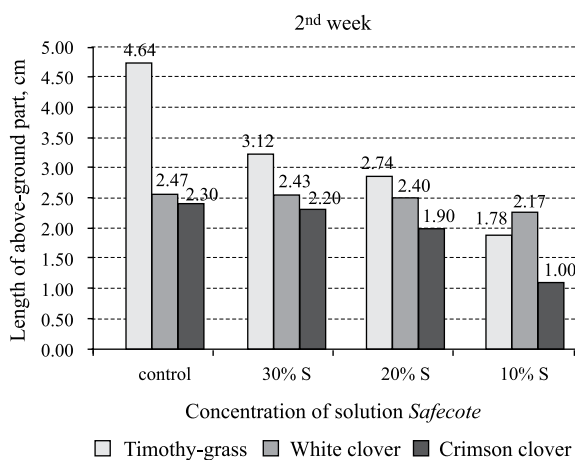


Fig. 4. Length of above-ground part of grass vegetation after 2<sup>nd</sup> week of growth

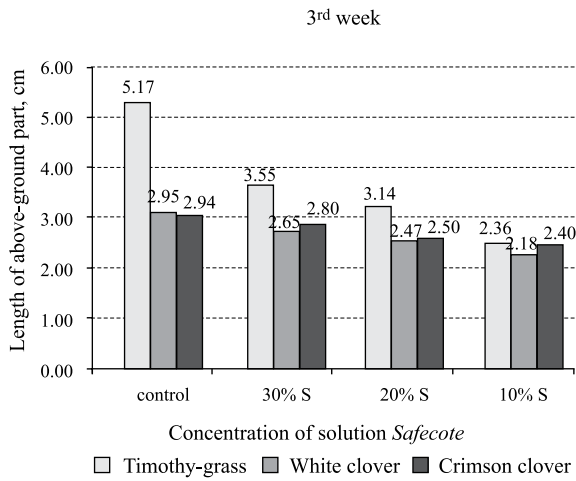


Fig. 5. Length of above-ground part of grass vegetation after 3<sup>rd</sup> week of growth

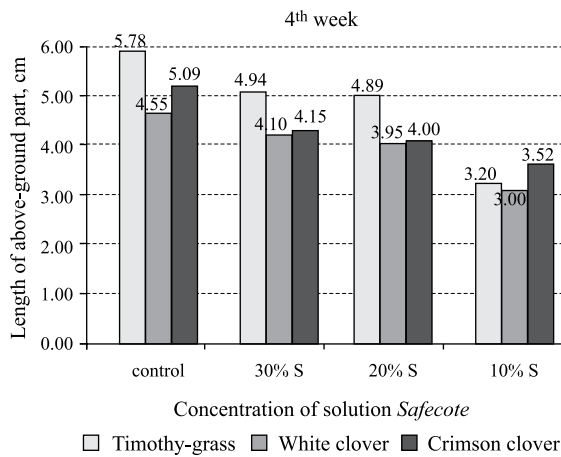


Fig. 6. Length of above-ground part of grass vegetation after 4<sup>th</sup> week of growth

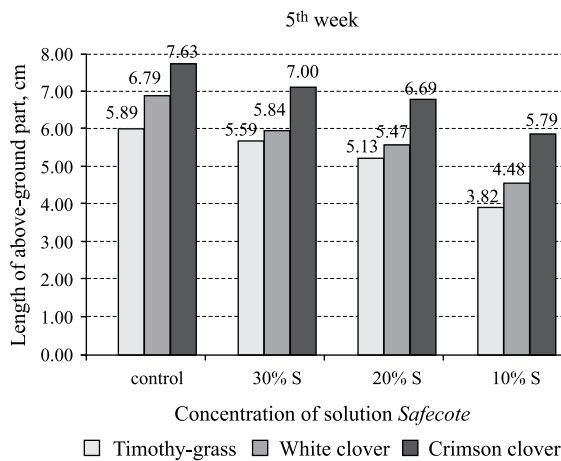


Fig. 7. Length of above-ground part of grass vegetation after 5<sup>th</sup> week of growth

above-ground part's length of timothy grass differed by 1.9 times, that of white clover – 1.5 times and crimson clover – 1.4 times. In the 4<sup>th</sup> week the biggest length of the above-ground part of timothy grass was not achieved only in soil with 10% content of Safecote solution – it was exceeded by 0.40 cm by crimson clover. The difference in length of clovers' above-ground parts in soil with 20% and 30% contents of Safecote solution was a mere 0.05 cm (crimson clover was longer than white clover).

In the 5<sup>th</sup> week room temperature was the same as in the 4<sup>th</sup> week (23–24 °C). This week clovers demonstrated a considerable growth (Fig. 7). The length of control timothy grass plants reached 5.89 cm, that of white clover – 6.79 cm and crimson clover – 7.63 cm. In soil contaminated with 10% Safecote solution concentration compared to control soil, the above-ground parts' lengths of timothy grass and white clover differed by 1.5 times and that of crimson clover – 1.3 times. In the 5<sup>th</sup> week of investigation crimson clover was the highest in both non-contaminated and contaminated soil. This week, as a result of maintenance of higher temperature, white clover exceeded timothy grass in terms of length: by 0.90 cm in control soil, 0.25 cm in soil with 30% Safecote content, 0.34 cm (20%) and 0.66 cm (10%). The above-ground parts' lengths of clovers differed from 0.84 cm (in control soil) to 1.33 cm (in soil with 10% Safecote content).

In the 6<sup>th</sup> week room temperature fell by 2 °C reaching 21–22 °C. The lengths of above-ground parts of the plants increased, though not as much as in the 4<sup>th</sup> and 5<sup>th</sup> weeks (Fig. 8). The length of timothy grass plants reached 6.41 cm, white clover – 7.15 cm and crimson clover – 8.57 cm. In soil contaminated with 10% Safecote solution concentration compared to control soil the above-ground part's length of timothy grass differed by 1.5 times, that of white clover – 1.6 times and crimson clover – 1.1 times. During the last week of investigation the length of crimson clover's above-ground part in non-contaminated and

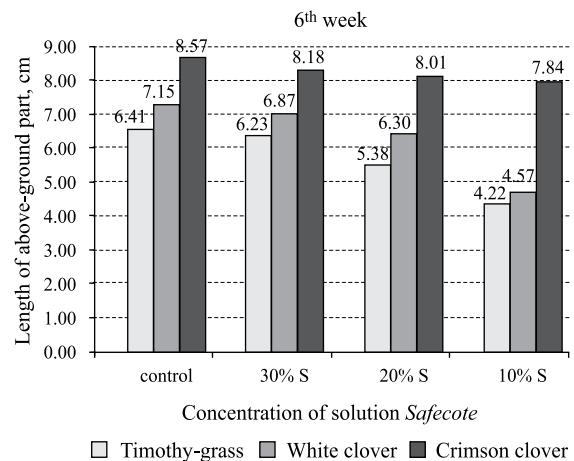


Fig. 8. Length of above-ground part of grass vegetation after 6<sup>th</sup> week of growth

contaminated soil became nearly the same differing by a mere 0.73 cm (it was bigger in control soil than in soil with 10% concentration content).

Variation in length of the above-ground part of each selected species of grass vegetation is presented in Figs 9, 11 and 13 and change of length of above-ground part dependence on change of temperature (in comparison with the previous week's results) is presented in Figs 10, 12 and 14.

The calculations of weekly changes in the lengths of above-ground part show that timothy grass achieved the biggest change in the length of its above-ground part in the 2<sup>nd</sup> week (Fig. 9): by 2.81 cm in control soil, 1.59 cm in soil with 30% Safecote content, 2.74 cm (20%) and 1.78 cm (10%). This increase in the length of above-ground part was influenced by a temperature increase of 1 °C. The 2<sup>nd</sup> increase of temperature in the 4<sup>th</sup> week also resulted in

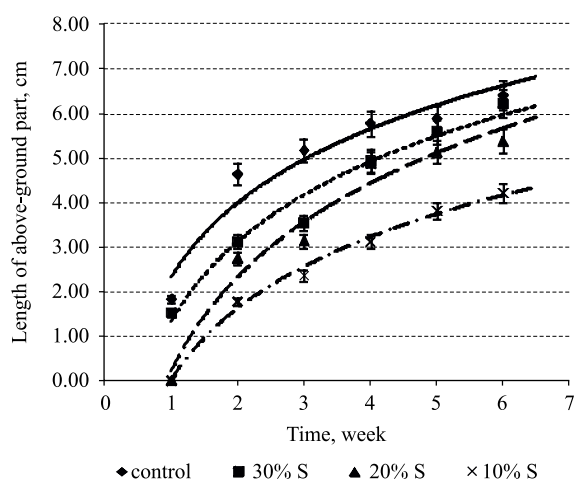


Fig. 9. Length variation of above-ground part of timothy grass

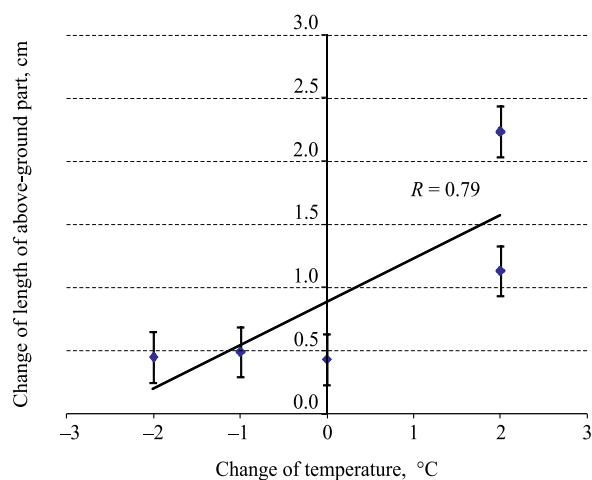


Fig. 10. Change of length of above-ground part of timothy grass dependence on change of temperature

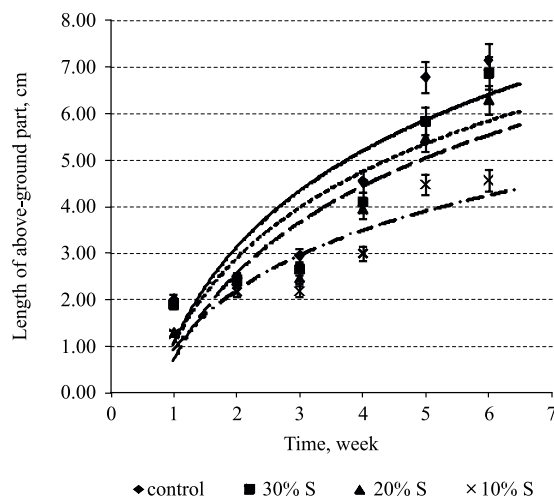


Fig. 11. Length variation of above-ground part of white clover

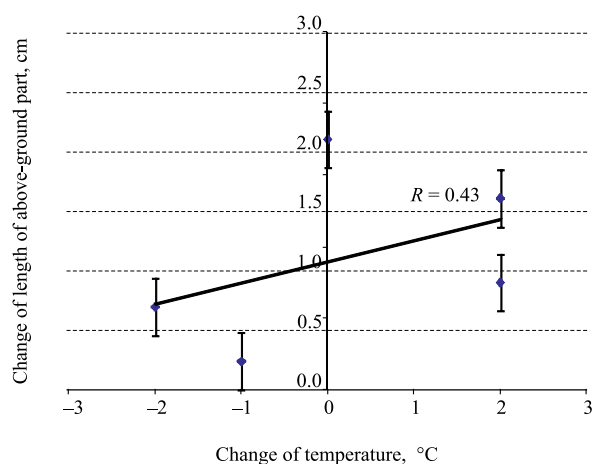


Fig. 12. Change of length of above-ground part of white clover dependence on change of temperature

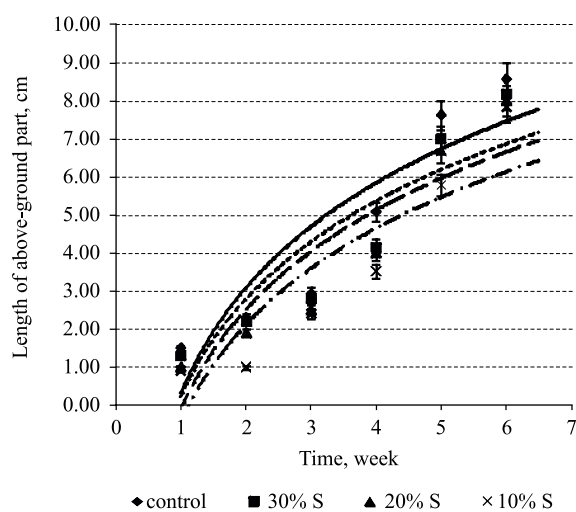


Fig. 13. Length variation of above-ground part of crimson clover

the considerable increase of the length of timothy grass above-ground part: by 0.61 cm in control soil, 1.39 cm in soil with 30% *Safecote* content, 1.75 cm (20%) and 0.76 cm (10%). During other weeks the length of above-ground part, on average, increased by 0.49 cm (3<sup>rd</sup> week), 0.43 cm (5<sup>th</sup> week) and 0.45 cm (6<sup>th</sup> week).

As shown in Fig. 10, the biggest change of length of above-ground part of timothy grass was in week when change of temperature was 2 °C (it was two times). Correlation coefficient of change of above-ground part of timothy grass and temperature was 0.79 (strong statistical relation between the data).

The calculations of variations in the lengths of above-ground parts show that during the 5<sup>th</sup> week white clover achieved the biggest change in the length of its above-ground part (Fig. 11): by 2.24 cm in control soil, 1.74 cm in soil with 30% *Safecote* content, 1.52 cm (20%) and 1.48 cm (10%). This increase in the length of above-ground part was influenced by a temperature

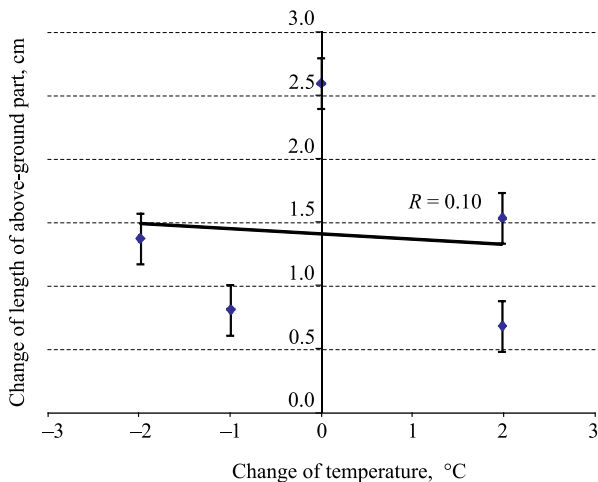


Fig. 14. Change of length of above-ground part of crimson clover dependence on change of temperature

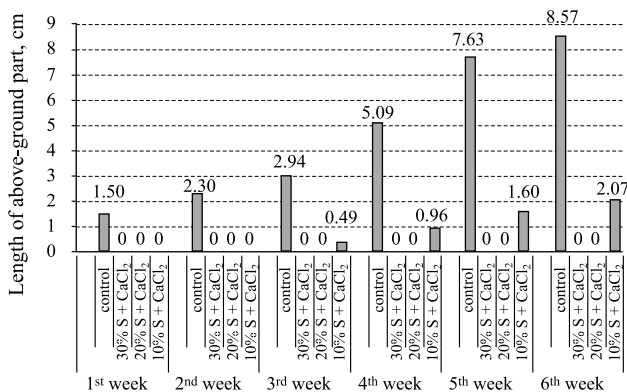


Fig. 15. Length variation of above-ground part of crimson clover in soil, contaminated with mixture

increase of 24 °C. During other weeks the length of above-ground part increased, on average, by 0.75 cm (2<sup>nd</sup> week), 0.20 cm (3<sup>rd</sup> week), 1.34 cm (4<sup>th</sup> week) and 0.58 cm (6<sup>th</sup> week).

As shown in Fig. 12, the biggest change of length of above-ground part of white clover was in a week when the change of temperature was 0 °C. Correlation coefficient of change of above-ground part of white clover and temperature was 0.43 (weak statistical relation between the data).

The calculations of weekly changes in the lengths of above-ground part shows that crimson clover, like white clover, achieved the biggest change in the length of its above-ground part in the 5<sup>th</sup> week (Fig. 13): by 2.54 cm in control soil, 2.85 cm in soil with 30% *Safecote* content, 2.69 cm (20%) and 2.27 cm (10%). This increase in the length of above-ground part was influenced by a temperature increase of 24 °C. During other weeks the length of above-ground part increased by 0.68 cm (2<sup>nd</sup> week), 0.81 cm (3<sup>rd</sup> week), 1.53 cm (4<sup>th</sup> week) and 1.37 cm (6<sup>th</sup> week).

As shown in Fig. 14, the biggest change of length of above-ground part of crimson clover was in week when change of temperature was 0 °C (as in case of white clover). Correlation coefficient of change of above-ground part of crimson clover and temperature was 0.10 (very weak statistical relation between the data).

Crimson clover is the only selected species of grass vegetation which germinated in soil contaminated with a mixture of solution *Safecote* and CaCl<sub>2</sub>. Variation in the length of above-ground part is presented in Fig. 15.

As Fig. 15 shows, crimson clover germinated in contaminated soil only in the 3<sup>rd</sup> week and only in the soil contaminated with a mixture of *Safecote* of 10% concentration and CaCl<sub>2</sub> and the length of its above-ground part reached 0.49 cm (showing a six times decrease against the plants that germinated in control soil). During the 4<sup>th</sup> week the clover grew by 0.47 cm and was smaller by 5.3 times than the clovers which grew in control soil. As in the case of other clovers, the biggest change in the length of above-ground part was recorded in the 5<sup>th</sup> week when the room temperature had risen to 24 °C. The change of this week reached 0.64 cm and was by 4.77 times lesser compared to the crimson clovers which grew in control soil. During the 6<sup>th</sup> week clovers in contaminated soil grew by 0.47 cm and were by 4.14 cm smaller than those in control soil.

#### 4. Conclusions

During the 1<sup>st</sup> week of investigation no plants germinated in soils contaminated with *Safecote* and CaCl<sub>2</sub> mixtures. Timothy grass did not germinate in soils contaminated with *Safecote* mixtures of 10% and 20% concentrations. This shows the negative impacts of these mixtures on the plants.

When temperature rose the plants grew up considerably. The length of above-ground part of timothy grass was more dependent on temperature fluctuations than that of clovers. During investigation temperature rose twice and

the length of the above-ground part of timothy grass also increased more intensely twice. The length of the above-ground parts of white and crimson clovers showed a considerable increase only once when the increased temperature (23–24 °C) has been maintained for two weeks. This means that temperature increase has a major influence on the length of plants' above-ground parts of timothy grass than the length of plants' above-ground parts of white and crimson clover.

During six weeks of investigation the plants achieved the following lengths of their above-ground parts: 6.41–8.57 cm in non-contaminated soil, 6.23–8.18 cm in soil contaminated with solution *Safecote* of 30% concentration, 5.38–8.01 cm in soil contaminated with solution *Safecote* of 20% concentration, 4.22–7.84 cm solution *Safecote* of 10% concentration and 0.00–2.07 cm soil contaminated with a mixture of 10 % *Safecote* concentration and 36.5%  $\text{CaCl}_2$ . This shows the negative influence of  $\text{CaCl}_2$  on the plant's length.

$\text{CaCl}_2$  has a negative effect on grass vegetation as during six weeks of investigation neither timothy-grass nor white clover germinated in soil contaminated with a mixture. We recommend using *Safecote* as more environmental friendly material for the road maintenance in summer.

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