

APPLICATION OF DIFFERENT UREA CONCENTRATIONS IN PROTECTION OF GREENHOUSES AND POLYTUNNELS FROM SNOW

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Summary

In Bosnia and Herzegovina, greenhouses and polytunnels are often exposed to excessive snowfall during the winter period. In order to prevent the side-effect of retaining large amounts of snow (greenhouses, polytunnels), it is necessary to implement preventive measures. The objective of this study is aimed at determining the rate of snow melting through the application of different concentrations of urea (5%, 10%, 15%, 20% and 30%), at different temperatures.

The results of the study show that the highest rate of snow melting, within one hour and at temperature ranging from 0 to 5⁰ C, is recorded in the application of 10% and 30% urea concentrations, and the lowest at a concentration of 20%. Urea concentrations of 15% and 30% show the best effect on snow melting rate within day, at the stated positive air temperatures, while the concentration of 20% had the least effect. At temperatures ranging from 0 to -5⁰ C, the highest snow melting rate was recorded in the urea concentration of 10% within both one hour and one day, and the lowest at a 15% concentration. In the conducted studies, all urea concentrations showed statistically significantly better results at positive temperatures compared to negative ones, by 2 to 3 times on average.

Key words: *greenhouses, polytunnels, snow, urea, melting.*

INTRODUCTION

The energy crisis of the 1970s can be considered a major reason for the development of production in sheltered spaces (Castilla and Hernández, 2004). As energy prices rose, the area of the greenhouses remained stable or decreased in countries with low winter temperatures, whereas in the areas with lower heating requirements it significantly increased. Today, production in sheltered conditions is a normal occurrence worldwide, with about 405,000 hectares of greenhouses distributed across all continents (FAO, 2013). The experience of production in sheltered space that first emerged in northern Europe encouraged development in other areas. The mere transfer

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of the method of cultivation in sheltered space from northern Europe has not proved to be an ideal solution for other areas. Each environment requires the application of further studies, development, training, and new standards, in order to meet local requirements. In recent years, there has been a revolution in the technology of production of sheltered spaces in terms of their design, type and quality of material, fertilization, maintenance, irrigation, use of pesticides, etc. When selecting the location for building a sheltered space, it is important to take into account the distance from pollutants, terrain configuration, slope, position, groundwater level, wind protection, and accessibility (Parađiković and Kraljićak, 2008).

When installing a polytunnel, it is important to take account of the roof arches' inclination in order to prevent uncontrolled accumulation of snow on the roof foil. The shape of the polytunnel should be tailored to the area where it is being installed (Parađiković and Kraljićak, 2008). The intensification of crop production in greenhouses has created favorable conditions for numerous pests and diseases. This has significantly increased the need for insecticide application. At the same time, legislative measures and requirements relating to food quality and safety, are becoming increasingly demanding. Many producers opt for this production, because this is labor, but also the most economically viable production for small farms (most in BiH are like that) (Karić *et al.*, 2014). The size of the greenhouse is from 100 to 1000 m². Consumers are becoming increasingly aware and concerned that the food they buy and eat is healthy, free of hormones and pesticides. In our country, during the winter, we often have large amounts of snowfall, which often results in damaged and collapsed sheltered spaces (greenhouses and polytunnels). Therefore, many producers take preventive measures to prevent damages caused by snow and ice. If producers don't have a spraying system installed on the greenhouses roof, a knapsack sprayer can be used. It is recommended to use position 3 of the flow-rate dosing element on the knapsack sprayer, for the best fluid distribution on the snow (Omerović *et al.*, 2019). Given the above issues, the objective of this paper is to examine the possibility of protecting sheltered spaces (greenhouses and polytunnels) from snow, through the application of appropriate solutions. The obtained results will point out the importance of preventive actions, and provide recommendations to producers concerning the optimal way of melting snow on their sheltered spaces.

MATERIAL AND METHOD

The research was conducted at the faculty's experimental site Butmir, during the winter period (2020 and 2021). Agricultural plastic containers (120 pcs) of standard dimension, filled with natural snow were used for the experiment. Urea solutions in various concentrations (A1-5%, A2-10%, A3-15%, A4-20% and A5-30%) were prepared in special containers. During the experiment, all solutions were at the same temperature and the containers with snow were treated simultaneously. The dynamics of snow melting was monitored at time intervals where the containers were weighed, from the moment they were filled with snow to the moment of melting. The measurement of the

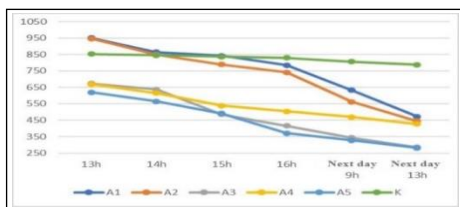
mass of melted snow was performed by using a digital scale, and the accuracy of the measurement was to two decimal places.

The examination was performed at two different outdoor temperature intervals, one ranging from 0° to 5°C , and the other from 0° to -5°C . The mathematical method, mass measurement method, and statistical method were used in the study. Mathematical method included addition and subtraction, and the percentage calculation was used for a better presentation of the obtained data. The mass method of weighing treated snow containers every hour within a 24-hour period was used to determine the amount of snow melted over a period of time for all used solvents.

Containers of 17 cm in diameter and equal in other dimensions were used. The containers were first filled with equal amount of snow and treated with the prepared solvents. All containers were weighed at that time and their initial masses were recorded. The containers were subsequently weighed every hour for a day. For the purpose of statistical processing of the obtained data, the IBM SPSS Statistics v20 statistical software was used. To obtain general parameters on the mass of melted snow, descriptive statistics were used, mainly the arithmetic mean. To examine the statistically significant impact of the solvent used on the snow melting dynamics, a one-way analysis of variance (ANOVA) was applied, and a post-hoc Tukey test was used to subsequently compare the solvents with each other. A parametric t-test for independent samples was used to compare the dynamics of melting snow mass of the same solutions at different temperatures. A significance level of 0.05 was used for all tests performed. Conclusions were made based on p values from all tests.

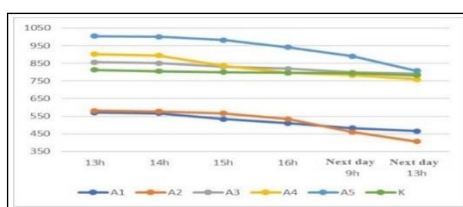
RESULTS AND DISCUSSION

In accordance with the set objectives and working methods, it is necessary to show how the action of various concentration of solutions affects the dynamics of snow melting. The action of urea solutions A1, A2, A3, A4 and A5 are shown here. All solutions were compared with the control (K) that was not treated. The results of snow melting (in grams) are shown through time dynamics, as shown in Graph 1., which can visually show the trend of snow melting at temperatures ranging from 0° to 5°C .



Graph 1. Dynamics of melting of snow at temperatures from 0° to 5°C (g)

Graf. 1. Dinamika topljenja mase snijega na temperaturama od 0° do 5°C (g)



Graph 2. Dynamics of melting of snow at temperatures from 0° to -5°C (g)

Graf. 2. Dinamika topljenja mase snijega na temperaturama 0° do -5°C (g)

Graph 1 shows that the slowest trend in snow melting was recorded in the control group of snow that was not treated with solutions, which is the expected result. Observing urea as a solvent, at temperatures above zero, the slowest melting dynamics was recorded in solution A4, while solutions A1 and A2 were the most effective with the largest drop in snow mass. Solutions A3 and A5 showed similar effectiveness in melting snow, however, they proved to be less effective than the above-mentioned solutions A1 and A2, but more effective than the A4 and control solutions. In addition to temperatures above zero, temperatures below zero are even more significant as they are much more represented in the wintertime in the climatic conditions of Bosnia and Herzegovina. Graph 2 shows the results of the dynamics of melting snow mass at temperatures ranging from 0⁰ to -5⁰C.

Graph 2 shows that the slowest melting trend was recorded in the control group of containers with no solvents used. Looking at urea as a solvent, at sub-zero temperatures, solutions A3 and A5 showed the slowest melting dynamics, while solutions A1 and A2 were the most effective. Solution A4 showed moderately good results in melting snow at sub-zero temperatures.

Table 1 shows the average percentage change in mass of snow melted by different solvent concentrations and comparison with the control group. Melting of the mass expressed as a percentage was monitored through one hour of action and through one day.

Table 1. Average change in snow mass (in percent) at temperatures from 0⁰ to 5⁰ C
Tabela 1. Prosječne promjene u masi snijega (u procentima) na temperaturama od 0⁰ do 5⁰ C

Solution	Average per hour (%)	Average per day (%)
A1	5.79	50.38
A2	7.26	53.11
A3	5.27	57.71
A4	4.47	36.07
A5	7.41	54.75
K	0.89	7.68
ANOVA	F=294.4 P=0.000***	F=1527.8 P=0.000***

A1- 5% urea solution, A2- 10% urea solution, A3- 15% urea solution, A4- 20% urea solution, A5- 30% urea solution, K- control

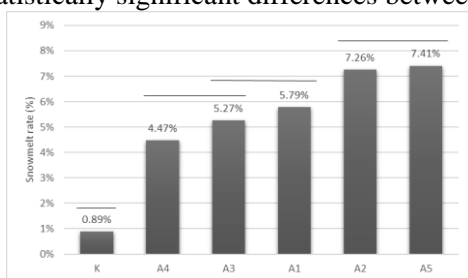
Based on Table 1, a definite, average and percentage decrease in snow mass is shown, monitored over a time interval of one hour and one day, i.e., one day, when treated at temperatures from 0⁰ to 5⁰C. The use of A1 solution, within one hour, resulted in a decrease of snow mass by 5.79%, and A2 solution by 7.26%, while solution A3 resulted in a decrease by 5.27%, A4 by 4.47% and A5 by 7.41%. The untreated control group of

snow reduced, i.e., melted the snow mass by 0.89%. In melting snow per hour, solutions of different urea concentrations, reduced on average the snow mass by 4.47-7.41% of the total mass of snow.

Based on percentage changes in snow mass over a period of one day it was determined that solution A1 melted 50,38% of snow on average, solution A2 53.11%, solution A3 57.71%, solution A4 36.07%, and solution A5 54.75% of the total snow mass. The control group reduced the mass of snow by an average of 7.68% of the total mass. Different concentrations of urea solutions melted snow in the range of 36.07-57.71% of the total snow mass, over a period of one day.

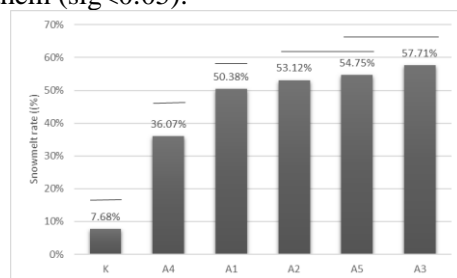
The results of the analysis of variance indicate a statistically significant influence of the solvent used on the dynamics of melting the snow mass in both studied cases, monitored over a period of one hour and one day, at temperatures above zero ($\text{sig}<0.05$). This leads to a conclusion that some concentrations of urea work better than others, and significant differences between different concentrations were recorded. These differences, monitored through changes over one hour, are shown in Graph 3.

The blue lines above each column on the graph represent the result of the Tukey test, which compares all tested urea concentrations to the control sample. Columns below these lines show no statistically significant difference ($\text{sig}>0.05$), while others show no statistically significant differences between them ($\text{sig}<0.05$).



Graph 3. Differences in snowmelt rate per hour at temperatures from 0⁰ to 5⁰ C

Grafikon 3. Razlike u topljenju mase mase snijega po jednom satu na temperaturama od 0⁰ do 5⁰ C



Graph 4. Differences in snowmelt rate per day at temperatures from 0⁰ to 5⁰ C

Grafikon 4. Razlike u topljenju mase snijega po jednom danu na temperaturama od 0⁰ do 5⁰ C

The graph shows that the statistically significantly best result in snow melting per hour was achieved by the application of solutions A2 and A5, which melted on average over 7% of snow mass per hour. Significantly lower rate of melting of the snow mass was achieved by solutions A1 and A3 (which do not differ significantly), followed by solution A4 (which does not differ significantly from solution A3). The mass of snow melted the slowest in untreated control samples, at a rate of just 0.89% of snow mass per hour.

Graph 4 shows the changes observed over a period of one day. The lines in graph 4, located above each column, represent the result of the Tukey test, which compares all solvents used to the control sample. The graph shows that the statistically significantly

best result in snow melting per day was achieved through the application of solutions A3 and A5 (which do not differ significantly), over 54% of the snow mass in one day. They are followed by solution A2 which showed a significantly weaker result compared to solution A3, but not compared to solution A5. A significantly weaker result than the aforementioned solutions was produced by solution A1, followed by solution A4. Statistically significantly, snow melted most slowly in untreated control samples, only 7.68% of snow mass per day.

During the research, the test was performed at sub-zero temperatures, i.e., at temperatures ranging from 0⁰ to -5⁰C. Table 2 shows the average changes in snow mass for all concentrations of urea solutions and the control group, monitored over a period of one hour and one day, at sub-zero temperatures. Table 2 provides the average percentage changes in the snow mass decrease, monitored over a period of one hour and one day, i.e., one day, when treated with different concentrations of urea solution at temperatures ranging from 0⁰ to -5⁰C.

When using solution A1, observed over a period of one hour, there was a loss of snow mass of 3.46%, and when solution A2 was used, the mass of snow decreased by 2.69%. The application of solution A3 reduced the mass of snow by 1.31%, A4 by 1.27%, and A5 by 1.66%. In the untreated control group, there was a loss of snow mass by 0.68%. At sub-zero temperatures, the application of different concentrations of urea solution resulted in melting of the snow mass within the range of 1.27-3.46% of the total snow mass.

Table 2. Average changes in snow mass (in percent) at temperatures from 0⁰ to -5⁰ C
Tabela 2. Prosječne promjene u masi snijega (u procentima) na temperaturama od 0⁰ do -5⁰ C

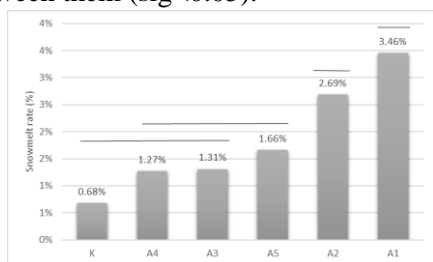
Solution	Average per hour (%)	Average per day (%)
A1	3.46	18.28
A2	2.69	29.93
A3	1.31	7.81
A4	1.27	15.71
A5	1.66	16.28
K	0.68	3.78
ANOVA	F=45.4 P=0.000***	F=249.7 P=0.000***

A1- 5% urea solution, A2- 10% urea solution, A3- 15% urea solution, A4- 20% urea solution, A5- 30% urea solution, K- control

When it comes to the average percentage change in the snow mass, observed over a period of one day, the application of solution A1 resulted in the melting of snow by an average of 18.28%, and the application of solution A2 by 29.93%. The application of solution A3 resulted in the loss in snow mass of 7.81%, solution A4 by 15.71%, and solution A5 of 16.28% of the total snow mass. In the control group, there was a loss in snow mass by an average of 3.78% of the total snow mass. Different concentrations of

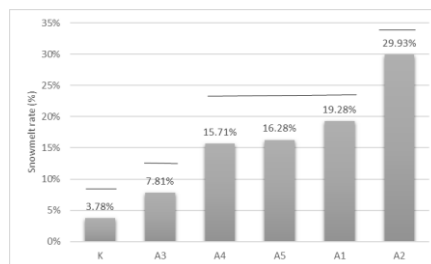
urea solution melted the snow on average in the range of 7.81-29.93% of the total snow mass, over a period of one day.

In order to examine the statistically significant influence of the solvent used on the dynamics of snow mass melting at temperatures down to -5°C , a one-way analysis of variance (ANOVA) was performed. The results of the variance analysis indicate a statistically significant influence of the solvent used on the dynamics of snow mass melting in both studied cases, monitored by hour and day, at sub-zero temperatures ($\text{sig}<0.05$). It is also concluded that some concentrations of urea solution work better compared to others, and significant differences were recorded between different concentrations. These differences, monitored over a period of one hour, are shown in graph 5. The columns of Graph 5 positioned under the same line do not differ statistically significantly according to the results of the Tukey test ($\text{sig}>0.05$), while the columns that are not under the same line indicate statistically significant differences between them ($\text{sig}<0.05$).



Graph 5. Differences in snow mass melting per hour at temperatures from 0° to -5°C

Grafikon 5. Razlike u topljenju mase snijega po jednom satu na temperaturama od 0° do -5°C



Graph 6. Differences in snow mass melting per day, at temperatures from 0° to -5°C

Grafikon 6. Razlike u topljenju mase snijega po jednom danu na temperaturama od 0° do -5°C

Graph 5 shows that statistically significantly the best result in snow melting per hour, at temperatures above zero, was achieved by the application of solution A1, while snow melted equally slowly in the application of solutions A3, A4 and untreated control samples.

Graph 6 shows that the application of A2 achieved a statistically significantly best result in snow melting per day A2 (Tukey test, $\text{sig}<0.05$), while slow melted at the slowest rate in untreated control samples. Such results are representative at sub-zero temperatures.

The results presented here indicate the generally best effect of urea solution in smaller concentrations (5% and 10%). Both of these solvents work very well at temperatures above and below zero, however, a better effect is evident at positive temperatures. This could be concluded based on the previously presented results, however, it is necessary to compare all types of solvents at positive and negative temperatures. An independent

t-test was used for direct comparison and with the aim of showing the significance of differences in solvent at the mentioned temperatures.

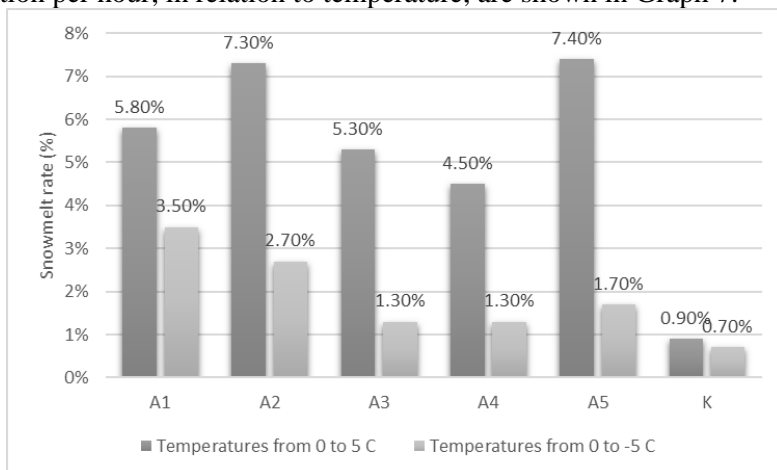
Table 3. Comparison of solvent action at temperatures below and above 0⁰ C through changes per hour

Tabela 3. Poređenje djelovanja otapala na temperaturama ispod i iznad 0⁰ C kroz promjene po 1 h

Solution/Solid	Temperatures from 0 to 5 C (%)	Temperatures from 0 to -5 C (%)	T-test
A1	5.79	3.46	Sig=0.000***
A2	7.26	2.69	Sig=0.000***
A3	5.27	1.31	Sig=0.001**
A4	4.47	1.27	Sig=0,001**
A5	7.41	1.66	Sig=0,000***
K	0.89	0.68	Sig=0.005**

*** statistically significant differences at 0.001 level; ** statistically significant differences at 0.01 level

Based on the results presented in the table above, it can be concluded that there are statistically significant differences in the efficiency of snow mass melting in all concentrations of solvents when comparing their efficiency at temperatures above and below zero, over a period of one hour (sig<0.05). This indicates that solvents are significantly more efficient at temperatures above zero than at sub-zero temperatures, as could be expected. Differences in the efficiency of solutions of different concentration per hour, in relation to temperature, are shown in Graph 7.



Graph 7. Efficiency of certain solvents per hour, at different temperatures
 Grafikon 7. Efikasnost pojedinih otapala po satu na različitim temperaturama

The largest differences in efficiency were achieved with the application of solution A5 which is by approximately 5.7% more efficient at positive than at negative temperatures. A similar result was achieved with the application of solution A2 which is by 4.6% more efficient at positive than at negative temperatures. With the application of solution A3, about 4% higher efficiency was achieved at positive compared to negative temperatures. The use of solution A4 also achieved a better efficiency of approximately 3.2% at positive compared to negative temperatures. The application of solution A1 achieved about 2.3% higher efficiency at positive compared to negative temperatures. The smallest differences in melting efficiency were recorded in untreated control samples, where melting rate was about 0.2% better at positive versus negative temperatures. Table 4 provides a comparison of the action of solutions at temperatures above and below 0⁰ C, observed over a period of one day. Based on the results shown in Table 4, it can be concluded that there are statistically significant differences in the efficiency of snow mass melting in all concentrations of urea solution, when comparing their efficiency at temperatures above and below zero, over one day (sig<0.05). This indicates that solvents are much more efficient at temperatures above zero than at sub-zero temperatures, monitored through changes in one day.

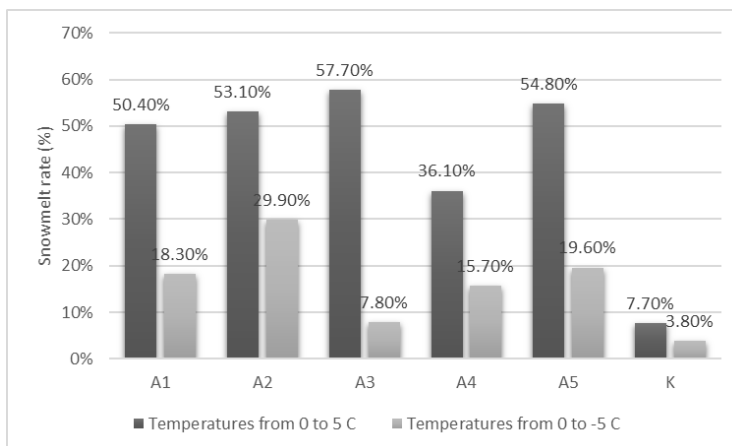
Table 4. Comparison of solvent action at temperatures below and above 0⁰ C in one day

Tabela 4. Poređenje djelovanja otapala na temperaturama ispod i iznad 0⁰ C kroz promjene po jednom danu

Solution/Solid	Temperatures from 0 to 5 C (%)	Temperatures from 0 to -5 C (%)	T-test
A1	50.38	18.29	Sig=0.000***
A2	53.12	29.93	Sig=0.000***
A3	57.71	7.81	Sig=0,000***
A4	36.07	15.71	Sig=0,000***
A5	54.75	19.61	Sig=0,000***
K	7.68	3.78	Sig=0.000***

*** statistically significant differences at 0.001 level

Graph 8 shows the effect of outside temperature on the snow melting rate and provides better insight into the efficiency of different solvents.



Graph 8. Efficiency of certain solvents within one day, at different temperatures

Grafikon 8. Efikasnost pojedinih otapala po jednom danu na različitim temperaturama

For all solvents used, better efficiency was confirmed at temperatures above zero. The largest differences in efficiency were achieved with the application of solution A3 where the melting efficiency at positive temperatures was about 50% higher than at negative temperatures. Slightly larger differences in efficiency were also achieved with the application of solution A5 which is by about 35% more efficient at positive than negative temperatures. A similar result was achieved with the application of solution A1, which is also about 32% more efficient at positive than at negative temperatures. By applying solution A2, approximately 23% better efficiency was achieved at positive compared to negative temperatures. The use of solution A4 also resulted in approximately 20% higher efficiency at positive versus negative temperatures. The smallest difference in melting efficiency were recorded in untreated control samples, where melting rate was about 3.9% better at positive versus negative temperatures.

CONCLUSION

Based on the conducted examination of the dynamics of snow mass melting under the influence of different solvents, different urea concentrations, as well as their analysis and comparison, the following is concluded. Comparison of snowmelt (per hour or per day) at positive and negative temperatures for all concentrations of urea showed statistically significantly better results were achieved at positive temperatures compared to negative ones. At positive temperatures, snowmelt was on average 2 to 3 times higher. The best results were achieved by urea solution in a concentration of 10%, therefore the use of a higher concentration of urea would be economically unjustified as it does not produce significantly better results. The temperature of urea solution has an important impact on efficiency of snowmelt, in addition to urea concentration. Focus of further research should be temperature-based to show a more accurate effect. The advantage of

using urea in snowmelt, over the salt, is the possibility of applying urea solution for fertilizing crops produced in the greenhouse after snowmelt.

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PRIMJENA RAZLIČITIH KONCENTRACIJA UREE U ZAŠTITI STAKLENIKA I PLASTENIKA OD SNIJEGA

Rezime

Staklenici i plastenici u Bosni i Hercegovini u toku zimskog perioda često su izloženi prekomjernim snježnim padavinama. Da bi se spriječio neželjeni efekat zadržavanja većih količina snijega (na staklenicima i plastenicima), neophodno je sprovesti preventivne mjere. Cilj ovog istraživanja je zasnovan na utvrđivanju brzine topljenja snijega primjenom različitih koncentracija uree (5%, 10%, 15%, 20% i 30%), pri različitim temperaturama.

Rezultati istraživanja su pokazali da se snijeg na temperaturama od 0 do 5⁰ C, u toku jednog sata, najbrže topi primjenom otopine uree 10% i 30%, dok pri koncentraciji 20% djelovanje je najsporije. Najbolji djelovanje u brzini topljenja snijega u toku 24 sata pri navedenim pozitivnim temperaturama su pokazale koncentracije uree 15% i 30%, dok je najslabije pokazala koncentracija od 20%. Na temperaturama od 0 do -5⁰ C najbrže topljenje snijega je ostvareno koncentracijom uree od 10% u toku jednog sata i jednog dana, a najslabiji koncentracijom od 15%. U sprovedenim istraživanjima sve koncentracije uree su pokazale statistički značajno bolje rezultate na pozitivnim temperaturama u odnosu na negativne, u prosjeku za 2 do 3 puta.

Ključne riječi: *zaštićeni prostori, snijeg, urea, topljenje.*