Journal of Energy Technology

JET Volume 14 (2021) p.p. 69-78
Issue 4, December 2021
Type of article 1.01
www.fe.um.si/en/jet.html

FROST PROTECTION MEASURES: SURVEY RESULTS

ZAŠČITNI UKREPI PROTI POZEBI: REZULTATI ANKETE

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Keywords: Spring Frost, Active Frost Protection, Passive Frost Protection, Survey Results

Abstract

In Slovenia, frosts occur often and it causes great damage for growers. Various passive and active methods are known for frost protection. Pasive methods can be implemented throughout the year. They are used to enable easier implementation of active methods, which are in use when a period of frost occurs. The aim of this research is, with the help of a survey, to assess whether growers in Slovenia implement active or passive methods of frost protection, and if not, why not. The survey contained 24 questions and was intended primarily for fruit and wine growers in Slovenia. The results of the survey show that frost happens to Slovenian growers on average every other year, and destroys on average 50% of their crop. Despite frequent frosts and the damage they cause, growers are not implementing any active measures, nor are they willing to invest in them. The reasons for this may be the large investments required for active measures, the small sizes of farms in Slovenia (on average 12 ha according to the survey answers), or that farmers are insufficiently informed about the various measures.

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Povzetek

V Sloveniji je pogostost pozeb zelo velika, kar pridelovalcem povzroča veliko škode. Za zaščito proti pozebi poznamo različne pasivne in aktivne metode. Pasivne metode lahko izvajamo skozi vso leto, z njimi pa omogočimo lažje izvajanje aktivnih metod, ki jih uporabimo, ko nastopi obdobje pozeb. Cilj te raziskave je bil s pomočjo ankete oceniti, v kolikšni meri pridelovalci v Sloveniji izvajajo aktivne oziroma pasivne ukrepe za zaščito pred pozebo in če jih ne, zakaj ne. Anketa je vsebovala 24 vprašanj in je bila namenjena predvsem sadjarjem in vinogradnikom v Sloveniji. Rezultati ankete kažejo, da slovenski pridelovalci utrpijo škodo zaradi pozebe v povprečju vsako drugo leto, ta pa jim uniči 50 % pridelka. Kljub pogostim pozebam in veliki škodi, ki jo le-te povzročijo, pa se pridelovalci za različne aktivne ukrepe ne odločajo, niti niso pripravljeni v njih investirati. Razlog za to je lahko v visokih investicijah, ki so potrebne za aktivne ukrepe, majhnosti kmetij v Sloveniji (povprečno 12 ha glede na odgovore ankete) ali pa v tem, da so kmetje o različnih ukrepih premalo informirani.

1 INTRODUCTION

As a consequence of climate changes, an increased variability has been recorded in the frequency and timing of frost events. Such events have a strong impact on agriculture, as cold temperatures affect plant survival. Higher average temperatures in spring mean earlier phenological development of plants, and, thus, an increased risk of frost damage when sudden low temperatures occur [1].

In Slovenia, frosts occur often, and it causes great damage for growers. Since 1987, it has been observed that spring phenological phases appear earlier, due to higher air temperatures, which means that plants bloom faster, and, thus, increase the risk of spring frost. Every decade the air temperature rises slightly, and because of this, fruit trees bloom earlier, e.g. apples 2 days earlier, pears 4 to 5 days earlier and cherries 3 days earlier per ten years. Frost not only causes damage due to crop loss, but we must also account for economic costs due to small fruits with shorter storage time, the costs of various measures to preserve the fruits left after the frost, as well as the costs of measures to take care of the affected plants in the following years [2].

Frost inflicts damage to plant tissues caused by low temperatures. If the cell juice freezes in the plant, it causes mechanical damage to cell organs and cell destruction [3]. For most fruit plants, the freezing of flowers is caused by temperatures below -2 ° [4]. The damage caused by the frost depends mainly on the fruit species or variety, and on the development phase of the plant [5]. Depending on the time of the occurrence, we divide frost into autumn, winter and spring frosts. Late spring frosts do the most damage. There are also several types of frost, namely radiation, advection, combined and evaporative frost [6].

Plantations can be protected from frost by active or passive methods. Passive methods are usually cheaper, and are used before the onset of frost. However, they cannot protect the plantation completely from frost, but, because they are quite effective against advection frost, they can be combined with active methods. Active methods are used during the onset of frost, and are usually much more expensive due to the maintenance and manual labour costs [7].

The aim of this research is, with the help of a survey, to assess whether growers in Slovenia have implemented active or passive methods of frost protection, and, if not, why not. The survey contained 24 questions and was intended primarily for fruit and winegrowers in Slovenia.

2 DATA AND METHODS

2.1 Passive frost protection methods

Passive protection includes methods that are implemented before frost events to help avoid the need for active protection. Passive methods are usually less costly than active methods, and are often beneficial to eliminate the need for active protection [8].

Possible passive measures for new plantations are location selection, which includes taking into account the location temperatures during the frost season, removal of cold air from the plantation, if cold air can be guided out of the orchard, tree architecture – trimming and cultivating trees in an appropriate manner to reduce damage by the radiative hoarfrost, and an appropriate selection of fruit species, varieties and rootstocks. For each fruit species, breeders can select and cross more resistant varieties that are less susceptible to frost, drought, diseases and pests. Possible passive measures for existing plantations include timely and correct cutting of plants, hail nets and other protective foils and textiles, fruit plants, tree trunk bleaching, and soil care and irrigation [3].

2.2 Active frost protection methods

Active protection measures are implemented during a frosting event to mitigate the effects of sub-zero temperatures. The cost varies, depending on local availability and prices [8].

Heaters provide protection against frosting events by direct radiation to the plants and by causing convective mixing of air within the inversion layer. They are reported to be less efficient when there is no inversion layer [9]. The energy requirement to match plant heat losses during a radiation frost night is in the range of 10-50 W/m^2, and the common heater energy output range is 140-280 W/m^2. Because the energy output is greater than the energy losses, much of the energy output from the heaters is lost, and modern heaters have little control over the temperature of the gases emitted [8].

Wind machines are used to prevent or mitigate the adverse effects of frost events in spring, and they reduce the plant heat losses by eroding the thermal inversion, and warm air is blown downward from aloft into the cold canopy. In [10], for example, they record an effective temperature increase area of 3-5 ha around the wind machine.

Sprinkler irrigation has been applied for frost protection in orchards, and has achieved good frost protection effects. The protection is based on a method of reducing the heat losses from the plants by increasing the temperature of the leaves above a certain temperature. In this way, a lower portion of heat is lost (around 83.7 kJ/kg), as opposed to the phase change that occurs at the freezing temperatures of water (around 334.5 kJ/kg) [11]. The energy consumption of sprinklers is lower than that of heaters, so the variable costs are low. The disadvantages are the high installation costs and the large amount of water needed [8].

Helicopters move warm air from aloft in a temperature inversion to the colder surface. The area covered by a single helicopter depends on the helicopter`s size and weight and the weather conditions. The estimated coverage area by a single helicopter varies between 22 and 44 ha [12].

2.3 Survey

As part of the Student Innovative Project for Social Benefit (ŠIPK) we conducted a survey, and thus obtained information on the impact of frost on local agriculture. The survey was conducted in electronic form with the help of the online provider 1 ka.

The survey included 24 questions on the topic of frost and frost protection measures. The target respondents were agricultural landowners, especially fruit growers, winegrowers and berry growers. Data collection took place from 10. 6. 2020 to 25. 6. 2020. A total of 35 respondents completed the survey at least in part.

In the survey we wanted to get the followinginformation :

a) The frequency of frost among growers,
b) The damage caused by frost,
c) The frost prediction accuracy,
d) The use of active/passive methods,
e) The reasons for not using protection,
f) Willingness to invest in frost protection.

3 RESULTS

35 surveys were conducted with farmers who are engaged mainly in fruit growing or viticulture. The majority (39%) of respondents have a size of production areas from 0-6 ha, followed by farms of 7-12 ha (24%), 13-18 ha (15%), and then the remaining farms larger than 19 ha (21%). On average, these are small to medium-sized plantations (Figure 1).

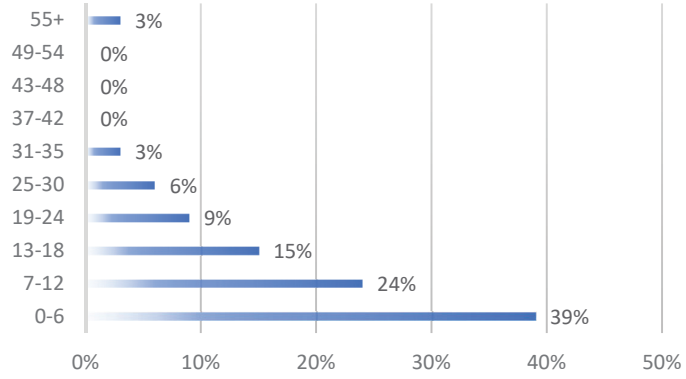

Figure 1: *What is the total size of your cultivable land (ha)? (n=33)*

Most of the agricultural plantations of the respondents lie at altitudes of 171 to 425 meters (Figure 2).

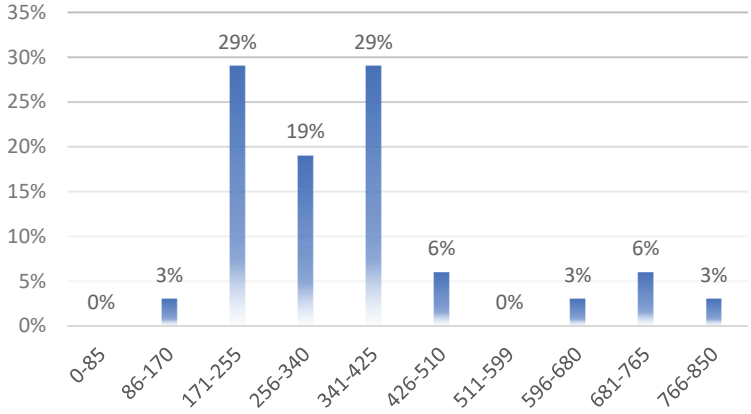

Figure 2: *What is the average altitude of your cultivable land (m)? (n=31)*

The survey data show that on the farms of the respondents frost occurs on average twice a year (48%), 39% of frost occurs once a year, and a small proportion also have frost five or six times a year. Altogether, this means that 87% of respondents experience frost at least once a year (Figure 3).

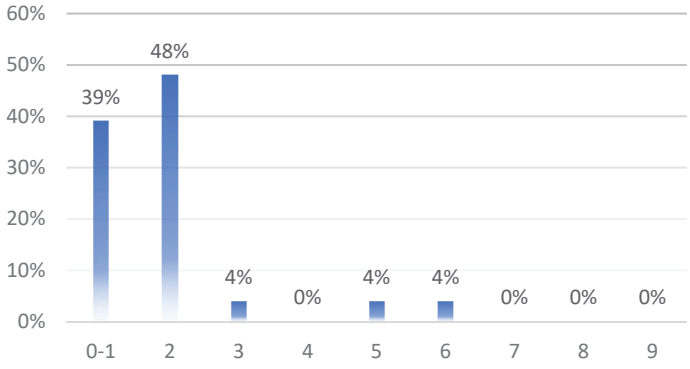

Figure 3: *How many times a year does frost occur on average on your farm? (n=23)*

Based on the answers to the survey, it is evident that, in Slovenia, respondents experience frost in a plantation 4.5 times in 10 years, which means that frost occurs on average approximately every other year (Figure 4).

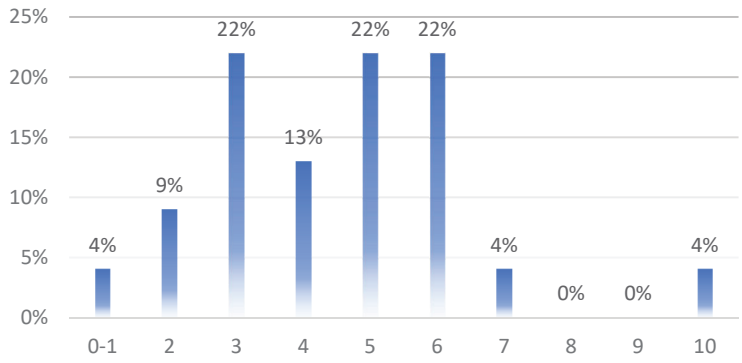

Figure 4: *How many frosty years have you had in the last ten years? (n=23)*

The survey shows that, on average, for respondents, the frost destroys a little more than half of the crop (50.7%) (Figure 5).

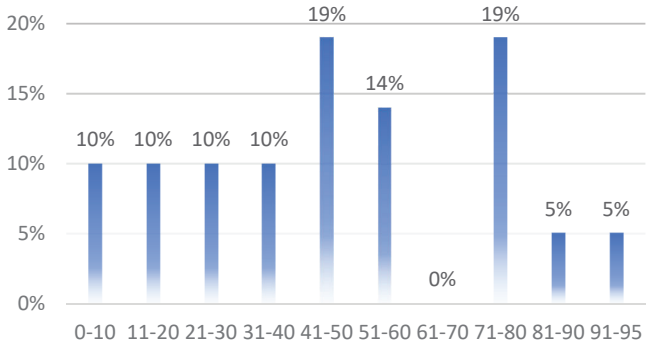

Figure 5: *On average, what percentage of your crop was destroyed by frost [%]? (n=21)*

Most respondents are moderately satisfied with the frost forecasts. Growers mostly use forecasts available on the Internet and on television, and rarely use the meteorological portal of the Slovenian Environment Agency. The vast majority of growers do not use other methods to obtain weather data (Figure 6).

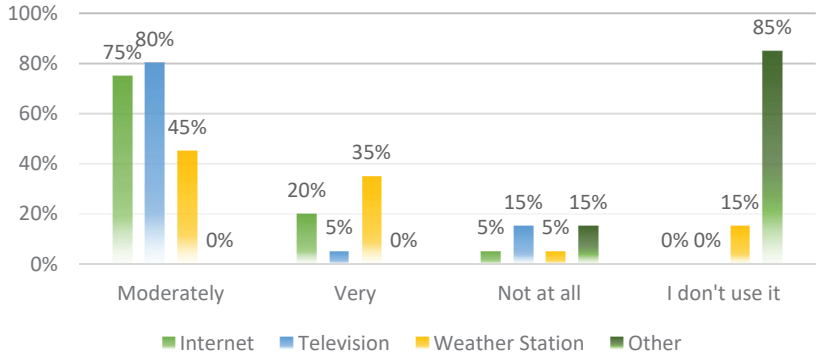

Figure 6: *How satisfied are you with frost forecasts? Are the predictions accurate? (n=25)*

The analysis shows that growers use preventive measures, especially choosing fruit species that are less sensitive to frost (50% of respondents). Among other commonly used measures, growers listed valerian spraying and biostimulators (29%). 25% of them use protective foils or textiles, 17% of them preventively bleach trunks. Only 13% of respondents plan new plantations on the shady side, where the possibility of frost is lower, and only 13% make proper nutrition plans. Only 8% of respondents started directing the air past the plantation.

Most respondents are well aware of active measures against frost, but only 10% of them use smoking, 5% use classical sprinkling and 5% paraffin candles, and, altogether, 80% of the respondents do not use any active measure to protect against spring frost.

In the next question, the respondents answered that active measures are too expensive for them (76%), or that they think they are ineffective, or they do not know about them (24%). Passive measures are too expensive for 55% of respondents, 30 % do not know them well enough, and 15% consider them ineffective (Figure 7).

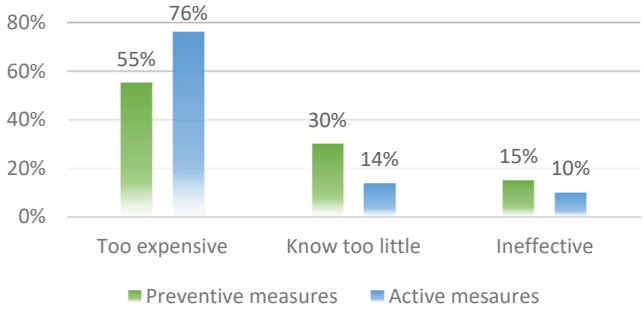

Figure 7: *In case you decided not to use preventive/active measures, why not? (n=21)*

When asked how much they would be willing to invest for frost protection that would be effective, most answered that they are willing to invest less than €500 per ha (59%), and a good third would be willing to invest up to €1000 per ha (Figure 8).

Also, respondents are not prepared to invest more than €500 per ha per year for the operation or maintenance of a frost protection system (Figure 9).

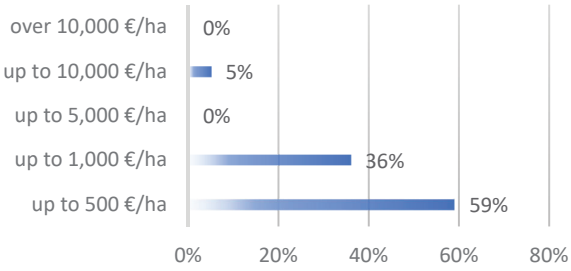

Figure 8: *How much would you be prepared to invest in frost protection that would be effective? (n=22)*

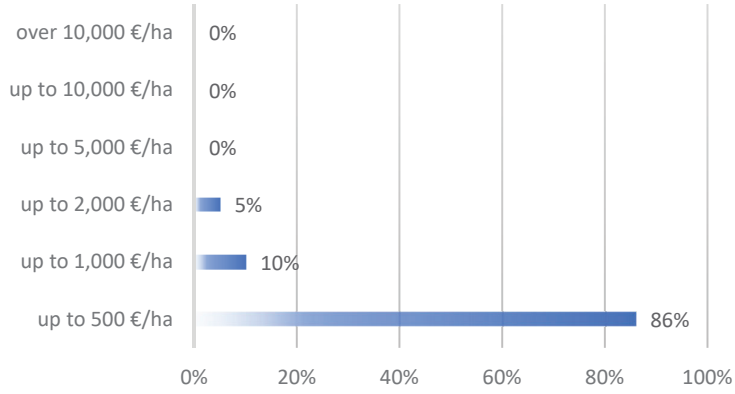

Figure 9: *How much money are you prepared to pay annually for the maintenance or operation of such a system? (n=21)*

4 CONCLUSION

Based on the survey data from 35 farms, ranging from 1 to 55 hectares, we concluded that 87% of the surveyed fruit growers are affected by frost every season, many twice or more per year. On average, 50.2% of fruit is destroyed during frosting events. Only 50% of farms use passive frost protection measures, and only 5-10% are using active frost protection measures. Despite this, only 12% of them are looking into the possibilities of investing in frost protection systems. When asked how much they were willing to invest in frost protection, 59% of the respondents are willing to invest in an efficient system up to €500 per ha. When asked why they do not opt for active/passive measures, most of them answered that they are too expensive for them. In conclusion, farm owners would more likely implement active and passive measures if the acquisition costs or operation costs of the protection methods were lower. One possible solution is to use passive protection measures, which can be beneficial in reducing the frost damage to plants, while being considerably cheaper than active protection measures. Also, when deciding on investing in an active system, farmers should make a long-term economic analysis to evaluate the potential economic benefit of the installed protection measures.

5 REFERENCES

[1] M. Hadad, . J. C. Tardif, F. Conciatori, . J. Waito and A. Westwood, "Climate and atmospheric circulation related to frost-ring formation in Picea mariana trees from the Boreal Plains, interior North America," *Weather and Climate Extremes,* vol. 29, 2020.

[2] Agencija Republike Slovenije za okolje, "Mesečni bilten Republike Slovenije za okolje," *Naše okolje,* vol. 4, pp. 53-60, 2017.

[3] EIP-AGRI, "Zaščita pridelka sadja pred pozebo," 2019.

[4] A. Žust, "Spomladanska pozeba v Primorju 8. aprila 2003," *UJMA,* vol. 17/18 (2003/2004), pp. 135-138, 2003.

[5] I. Kodrič, M. Lukačič and J. Prošek, Zaščita pred spomladansko pozebo, Ljubljana: Ministry of Agriculture, Forestry and Food of Slovenia, 2006.

[6] A. Žust and A. Sušnik, "Spomladanska pozeba," *UJMA,* vol. 10, pp. 59-63, 1996.

[7] I. Zhou, J. Lipman, M. Abolhasan, N. Shariati and D. W. Lamb, "Frost Monitoring Cyber–Physical System: A Survey on Prediction and Active Protection Methods," *IEEE Internet of Things Journal,* vol. 7, 2020.

[8] R. Snyder, P. d. M.-A. J. and S. Matulich, Frost Protection: fundamentals, practice and economics, Rome: Food and Agriculture Organization of the United Nations, 2005.

[9] R. Snyder, "Principles of Frost Protection," University of California, Davis, 2000.

[10] V. Heusinkveld, A. Hooft, B. Schilperoort, P. Baas, M. Veldhuis and B. Wiel, "Towards a physics-based understanding of fruit frost protection using wind machines," *Agricultural and Forest Meteorology,* Vols. 282-283, no. 107868, 2020.

[11] H. Yongguang, C. Z., L. Pengfei, A. Amoah and L. Pingping, "Sprinkler irrigation system for tea frosting protection and the application effect," *International Journal of Agricultural and Biological Engineering,* vol. 9, no. 5, pp. 17-23, 2016.

[12] A. Soršak, Z. Gutman-Kobal, I. Kodrič and D. Koron, Tehnološka navodila za zaščito pred spomladansko pozebo, 2018.

Nomenclature

(Symbols)	(Symbol meaning)
ŠIPK	Študentski inovativni projekti za družbeno korist (Student innovative projects for social benefit)
n	Number of respondents