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COULD CACTUSES ENDURE WINTER IN ROMANIAN CLIMATIC CONDITIONS?

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Abstract

Cacti are one of the most interesting group of plants, because of their unique and special way of life. Due to their impressive beauty of their flowers and spines, are used nowadays as potted plants in different areas beside their native habitat. Moreover, for this reason growers are testing their amelioration to frost endurance. Frost resistant at is a complex physiological trait with a genetic basis. For the present study we have selected ten cacti species as followed: Cylindropuntia imbricata, Cylindropuntia whipplei, Opuntia basilaris, Opuntia fragilis, Opuntia polyacantha, Opuntia rutila, Echinocereus coccineus, Echinocereus reichenbachii var. baileyi, Escobaria leei and Escobaria vivipara var. radiosa on which we have analysed the damages caused by frost and winter injuries. The selected cacti species were subjected to two experimental conditions, first, when plants were covered and second, when remained uncovered. Results indicated that frost hardiness of some species was greatly influenced by the coverage, while at other no differences were observed. In conclusion, the present work strengthens the possibility of using some of the cacti species in the Romanian landscape design.

Key words*: bonitation score, cacti, frost resistant, coverage.*

INTRODUCTION

Cactaceae are one of the most interesting plant families on earth, several of the species are members of the arid vegetative regions of America (Edwards et al., 2005; Guerrero et al., 2019). They have a special unique way of life, compared to other known plants. Because of their impressive beauty, nowadays the landscapers or the consumers are trying to incorporate them in the landscape architecture. Cacti are one of the first plants that were brought back from the American continent by the Europeans in the 15th century (Howard and Touw, 1981). The spread of many species could be explained by the fact that the horticulturist trades, them and propagate for their unique way of life (Walters et al., 2021).
Cactuses can make some of the most dramatic modifications observed in the plant kingdom (Guerrero et al., 2019), these changes can occur at all phenotypic levels (Gibson & Nobel, 1986), and can be known as succulent syndrome (Edwards & Ogburn, 2012). This syndrome allows the cactuses adaptation to different dry environments, which rely on the water storage in their tissues to avoid dehydration (Guerrero et al., 2019).
Cacti in general are plants of warm climates stretching through the American continent. Frost resistant is characteristic of the plant, being an inherited biological feature that can be very little influenced in a new environment with gradual adaptation (Sakai and Larcher, 2012). To get a frost-resistant variety in a group of frost-sensitive plants millions of years of climatic adaptation are needed. Frost resistant is complex, it is a physiological trait that is genetically based. In plant cells that adapted to frost occur complex phenomena: while preparing for hibernation, cell components regroup and grains of starch crystals are formed in the cell, the chloroplasts form nodules, so they get disorganized. At the same time, a phenomenon that can be seen with the naked eye: the evergreen leaves get yellow and red

and lose their rigidity cacti in their tissues lose moisture to install contraction. Frost resistant means that a plant can survive on certain low temperature (Szabó-Mohácsi, 2007).
The aim of the present study was to test ten species/varieties of cactuses, if they can strive and overwinter the cold conditions in the Romanian landscape, without freezing or getting frost injuries, which can decrease their decorative values. Furthermore, which species/variety of cactus from the selected ones is more resistant to frost and could be used probably as a landscaping design plant in the future.

MATERIALS AND METHODS

The study was carried out in the village of Bozeni, Mureș County between October and March (46°31′48″ N 24°40′26″ E) as an open field experiment.
The average temperature during the experiment was between 0.42 and 9.99°C, and the lowest minimum temperature -21.9°C (Figure 1).

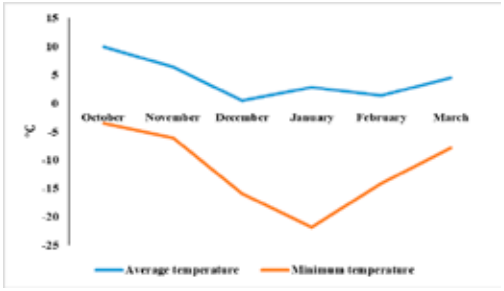

Figure 1. Average and minimum temperature during the open field experiment (October and March)

The lowest average precipitation was recorded in January 43.7 mm, and the highest in October with 93.4 mm quantity (Figure 2).

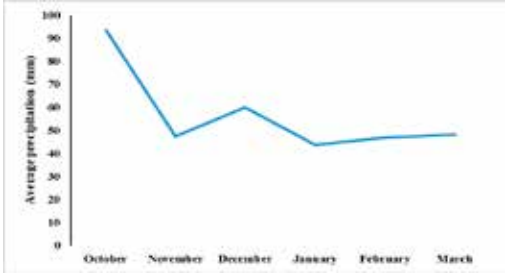

Figure 2. Average precipitation during the open field experiment (October and March)

We have selected ten cactuses for this experiment, which were purchased from a Hungarian cacti collector, 20 seedlings per species/variety.
Cylindropuntia imbricata (Figure 3): Mature plants can reach a height of 1.5 to 3 m; shoots can branch, they are becoming woody. Every areola has 10-30 pieces of 2-3 cm long, reddish brown spines. The flowers grow at the end of the shoots, they are 4-6 cm long and 8-9 cm wide with bright red colour. They are native to Colorado, Arizona, New Mexico, Kansas, Oklahoma, Texas as well as Northern and Central Mexico (Virág, 2000a).

Figure 3. *Cylindropuntia imbricata*

Cylindropuntia whipplei (Figure 4): Forms a rich shrub and can reach a height of 1.5 m. It grows straw-coloured spines that get a silver colour and are about 8-12 cm in length. It blooms in May with yellow-green flowers with a diameter of 2 to 3.75 cm. Are native to Northern Arizona, Navajo, Sitgreaves National Forest, and New Mexico (Szutorisz, 2004).

Figure 4. *Cylindropuntia whipplei*

Opuntia basilaris (Figure 5): Has a height of 12-20 cm, the shoots are about 12-20 cm, gray-blue, velvety. Areolas are sunken, the tuft of glochids are reddish-brown and fall early. The flower has a diameter of 6 cm, bright red. Are native to Southern Utah, Nevada, Western Arizona and South-eastern part of California (Debreczy, 1976).

Figure 5. *Opuntia basilaris*

Opuntia fragilis (Figure 6): The specie is short, thallophytes, with a height of 5-10 cm. Shoots are round, ovoid, 2-4 cm long, 1.2 to 5 cm long and 1.2 to 2 cm thick. Spines are tipped gray brown. Their length is 1.2 to 1.5 cm, sometimes 2.5 cm. The areola contains 1-6 spines. The flower has a diameter of 4-5 cm, yellow, yellow-green. Are native to Canada - British Columbia: Manitoba, Ontario, USA - Washington, Michigan, Illinois, California and south Texas (Virág, 2000b).

Figure 6. *Opuntia fragilis*

Opuntia polyacantha (Figure 7): Forms a shrub of 7.5 to 15 cm high, the shoots having a length of 5-10 cm and 1 cm thick. Each areola has spines which are stiff, firm and smooth. Spine length is 0.6 to 1.2 cm long at the bottom and 2.5 to 3.8 cm long above. The flowers are 4.5 to 8 cm in diameter, 4.5 to 6 cm long, its colour is yellow, sometimes pink. These cactuses are native to Canada - British Columbia, Alberta, Saskatchewan, USA - Idaho, Dakota, North-eastern Nevada, Utah, New Mexico, North-eastern Kansas, South-western Missouri, Oklahoma, Texas (Virág, 2000).

Figure 7. *Opuntia polyacantha*

Opuntia rutile (Figure 8): It is a creeping specie with ovoid stems, 4-10 cm long, cylindrical, 2-5 cm long with some spines. These spines are white or white brown-tipped. Their number alternates between 1-6 pieces on the areola and are 0.5 to 3 cm long. It has a flower with a diameter of 6 cm, yellow to reddish. They are native to Western Colorado, Wyoming (Virág, 2000c).

Figure 8. *Opuntia rutile*

Echinocereus coccineus (Figure 9): It is a plant with numerous stems, which has a length of 3.8 to 7.5 cm and 2.5 to 5 cm in diameter and 9-10 ribs. The colour of the spines is gray, white, pink or yellowish brown, sometimes yellow with a length of 2.5 to 6.2 cm. Spines are straight, smooth and rarely rugged. The flowers

have the diameter of 2.5 to 3.8 cm and the length of 3-5 cm. Are native to USA - California, Nevada, Utah, Colorado, Arizona, New Mexico, Texas, Mexico - Western Sierra Madre, Durango, San Luis Potosi (Virág, 2000d).

Figure 9. *Echinocereus coccineus*

Echinocereus reichenbachii var. *baileyi* (Figure 10): It has a cylindrical shape with a length of 10-15 cm and the width of 5-7 cm. The number of ribs is about 16. The flowers are near to the top with 6-7 cm in diameter and length with bright red colour. Are native to Oklahoma (Virág, 2001).

Figure 10. *Echinocereus reichenbachii var. baileyi*

Escobaria leei (Figure 11): It is a specie with highly branched stems. The largest being green, cylindrical, with a length of 2.5 to 7.5 cm and 1.2 to 2.5 cm in diameter. The spines are very dense, covering the stems with a number of 6-9/areoles. Their colour is white with pink tip and with the length of 4.5 to 9 cm. The diameter and length of the flowers are 1.2 to 2 cm, brownish-pink. Are native to New Mexico (Virág, 2000).

Figure 11. *Escobaria leei*

Escobaria vivipara var. *radiosa* (Figure 12): Has a round shape, it grows isolated or in small groups with a height and width of 5 cm. Spines are white or brown with 1 to 4.2 cm in length. Flower length and width is 3.5 cm which are near to the top of the plant and their colour is pink. Are native to from Kansas to western Texas (Szutorisz, 2006).

Figure 12. *Escobaria vivipara var. radiosa*

The selected cactuses were planted in the start of October on a 10 sqm alpine garden. The experimental field was divided into two parts one where the uncovered cactuses were planted and the other where the covered ones (10–10 for each species/variety).

In the end of March, we have determined the frost effect on the biological material used in the experiment.

The bonitation scale was determined as followed:

- 1 point if the cactus has not suffered any damage during the winter;
- 2 points if the cactus is 20% damaged;
- 3 points if the cactus is 50% damaged;
- 4 points if the cactus is 80% damaged;

- 5 points if the cactus is 100% damaged (the bud is completely dead).

Data were analysed using Past 4 statistical software (Oslo, Norway). Data were tested for normality of errors and homogeneity of variance.

All data were normally distributed. The significance of the differences between the treatments was tested by applying ANOVA, at a confidence level of 95%. When the ANOVA null hypothesis was rejected, Tukey's post hoc test was carried out to establish the statistically significant differences at $p < 0.05$.

RESULTS AND DISCUSSIONS

Considering the frequency of the injuries (Figure 13) caused by the frost, could be determined that the most injuries were observed at the cactuses which were remained uncovered during the winter season.

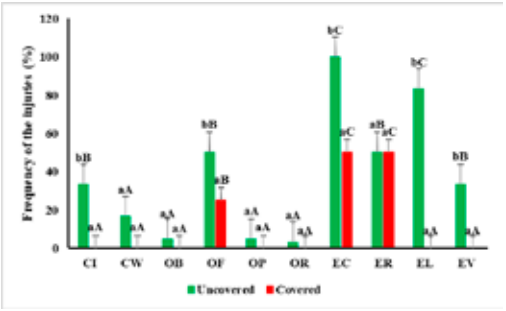

Figure 13. Frequency of the injuries caused by the winter frost on the selected cactuses. Different lowercase letters above the bars indicate significant differences between the uncovered and covered cactuses, and different uppercase letters indicate the significant differences between the species/varieties, according to Tukey test ($p = 0.05$).

However, is important to note that some of the selected plants suffered a higher damage from the frost, even EC (Figure 16a) plants have died. CW (Figure 15b), OB (Figure 15c), OP (Figure 15e), and OR (Figure 15f) reported a higher resistance against the cold days.

At the previously mentioned cactuses the damages were almost undetectable after the frosty days. Regarding the covered cactuses it was observed that, the coverage improved their resistance against the frost. EC and ER (Figure 16b) reported higher damages, even if they were protected.

On the other hand, CI (Figure 15a), CW, OB, OP, OR, EL (Figure 16c), and EV (Figure 16d) did not suffer any frost damage, during our experiment.

When comparing the coverage type on the same plants, could be concluded that at CI, OF (Figure 15d), EC, EL, and EV reported significant changes.

Is important to mention, that the uncovered *Echinocereus coccineus* suffered the most during the winter, in the spring these species all individuals had wilted/died.

In previous research was found that the most common damage to cacti species was dieback and not individual mortality (Alvarez-Yepiz et al., 2018).

In a study was reported that *Opuntia fragilis* survived several harsh winters in southern Finland with no frost damages, even the next year produced flowers (Leppänen, 2018). Guevara et al., (2000) recommends that is important to protect the cacti in the winter season at least for 1–2 years after planting.

From the data can be observed that *Cylindropuntia* and the *Opuntia* species obtained a better bonitation score compared to *Echinocereus* and *Escobaria*.

This could be explained by a species-dependent process. Significant changes were observed when comparing the species one to another. Also, a significancy was detected at EC between the uncovered and covered experimental conditions.

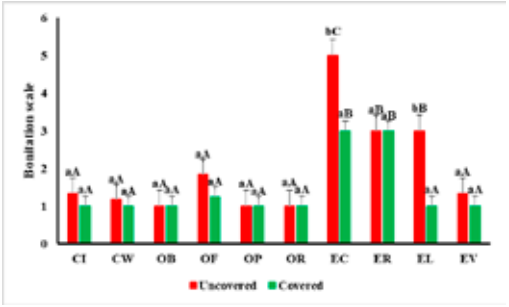

Figure 14. Bonitation scale of the injuries caused by the winter frost on the selected cactuses. Different lowercase letters above the bars indicate significant differences between the uncovered and covered cactuses, and different uppercase letters indicate the significant differences between the species/varieties, according to Tukey test ($p = 0.05$).

(a) (b) (c)

(d) (e) (f)

Figure 15. The selected cactuses after the winter frost. (a) - *Cylindropuntia imbricata*; (b) - *Cylindropuntia whipplei*; (c) - *Opuntia basilaris*; (d) - *Opuntia fragilis*; (e) - *Opuntia polyacantha*; (f) - *Opuntia rutila*

(a) (b) (c) (d)

Figure 16. The selected cactuses after the winter frost. (a) - *Echinocereus coccineus*; (b) - *Echinocereus reichenbachii* var. *baileyi*; (c) - Escobaria leei; (d) - *Escobaria vivipara* var. *radiosa*

CONCLUSIONS

In ornamental landscaping day by day an innovation appears, which can be explained by the landscapers' ideas or by the consumer expectation. However, these new innovations not every time are suitable or can be put in practice. The present study provides new experimental data on the comparison of ten cactus species/varieties regarding to frost resistant. According to the results, it can be concluded that some of the selected cactuses in this experiment tolerated in a positive way the winter season, on the other hand some did not. From the results could be concluded that the covered cactuses endure in a much higher way the frost, than the uncovered ones. Furthermore, when comparing the species/varieties between them, can be concluded that EC, ER, and EL are less tolerant to frost than the other selected cactuses, but future experiments need to be conducted. However, due to the high frequency of absolute minimum temperatures in the experimental site, it appears to be necessary to protect/cover the plants in winter.

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