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Assessment of frost resistance in species of the genus *Hydrangea* L. according to the degree of damage to shoot parts

Abstract. Temperature fluctuations during the winter period, characterised by alternating thaws and short-term frosts, necessitate the assessment of plant resistance to low temperatures. In this regard, the study of frost resistance in different species of the genus *Hydrangea* L. is of particular relevance. The aim of the study was to assess the frost resistance of various hydrangea species and to determine the degree of damage to individual parts of plant shoots. It was established that the upper part of the shoot is the most sensitive to the effects of low temperatures, with a frost damage index ranging from 10.4 to 65.5 points. The lowest degree of freezing was observed in *Hydrangea arborescens*, while the highest was recorded in *Hydrangea macrophylla*, with frost damage indices at -25°C of 10.4 and 35.8 points, respectively. Similar results were obtained at a freezing temperature of -30°C, where the corresponding damage indices amounted to 22.3 and 65.5 points. In most species, the middle section of the shoot in a cross-section through the bud showed relatively high resistance to freezing. Under these experimental conditions, the frost damage index at -25°C and -30°C was 3.3 and 9.8 points for *Hydrangea arborescens*, 6.7 and 13.8 points for *Hydrangea paniculata*, and 7.1 and 14.1 points for *Hydrangea quercifolia*. The highest values were recorded in *Hydrangea macrophylla*, with indices of 33.7 and 51.2 points, respectively, which exceeded those obtained for the freezing treatment of the middle part of the shoot of this species by 8.8 and 6.7 points. Freezing of the buds caused only minor damage in all hydrangea species, with the exception of *Hydrangea macrophylla*, in which the frost damage index under this treatment reached 26.6 points at -25°C and 53.4 points at -30°C. The results of the multifactor analysis of variance confirmed the significance of the contribution of the factor "hydrangea species", the effect of which accounted for 57.2-75.1% of the variation in frost resistance of different plant parts. The findings have practical significance and may be used in the establishment of resilient ornamental plantings under unstable climatic conditions, as well as in the selection of hydrangea species for breeding genotypes resistant to low-temperature stress

Keywords: artificial freezing; tissue frost injury; plant resistance; hydrangeas; adaptation

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INTRODUCTION

In the current context of ongoing climate change, characterised by sharp temperature fluctuations and frequent winter thaws followed by cold snaps, the risk of low-temperature damage to plants is increasing significantly. This is particularly true of introduced ornamental plant species, which are widely used in landscaping but are not always adapted to local growing conditions. In this regard, studying plant resistance to low temperatures is both relevant and essential for the scientifically informed selection of genotypes when establishing ornamental plantings in the unstable climate of the Right-Bank Forest-Steppe of Ukraine. M. Babarabie *et al.* (2024) highlight in their work the key role of ornamental plantings in fostering the sustainable development of the urban environment and ensuring the psychological and emotional well-being of its residents. They note that the cultivation of ornamental plants is of significant ecological, economic, social and aesthetic importance, as it helps to regulate the climate, enhance the comfort and safety of the urban environment, and improve its visual appeal. In addition to their ornamental function, plants help to strengthen the connection between people and the natural environment within the city and support biodiversity.

As noted by K. Lotterhos (2023), persistent global and regional climate change necessitates the selection of plant species that are tolerant of and adapted to the relevant environmental conditions. Understanding the mechanisms by which organisms respond to abiotic stress factors makes it possible to predict and regulate their impact on ecosystems, which is a key prerequisite for the conservation of biodiversity. This is precisely why, as noted by D.-M. Mircea *et al.* (2025), the scientifically informed selection of ornamental plants resilient to growing conditions is vital for modern environmental management strategies. A. Brovdi & V. Polishchuk (2023) note that the introduction of plants is an important tool for improving the plant communities of urbanised areas and enhancing their ornamental value. Introduction broadens the species composition of plantings and creates conditions for the use of valuable ornamental forms, which, in turn, allows for greater diversity in landscape compositions. However, the effectiveness of introduction depends to a large extent on the plants' ability to adapt to new soil and climatic growing conditions. According to S. Kisvarga *et al.* (2023) and A. Brovdi *et al.* (2025), it is precisely the plants' adaptive capabilities that enable them to adjust to cultivation conditions, increase the organism's resistance and promote its optimal development.

S. Pangtu *et al.* (2025) emphasise the need to study plants' ability to withstand the effects of adverse environmental factors whilst retaining their ornamental qualities. This is particularly important in urban environments, where plants are subjected to a combination of abiotic and biotic stresses. According to A. Bulat (2025), the successful growth and ontogenesis of introduced species depend to a large extent on their ability to withstand abiotic stress factors, in particular prolonged periods of low temperature. Tissue freezing is accompanied by the formation of ice crystals, which damage the structural integrity of plant cells and adversely affect subsequent plant growth and development processes. O. Snarovkina (2023) emphasises that low temperatures are one of the main factors significantly affecting plant growth and development, as freezing stress threatens the integrity of the plant. Plants are most sensitive to low temperatures during bud break, when they actively utilise reserve substances accumulated during cold acclimatisation to resume vegetative growth. As noted by M. Aslam *et al.* (2022), low-temperature stress affects various aspects of plant development, including germination, growth and reproduction. Under low-temperature stress, plants exhibit disruptions to key physiological and biochemical processes, in particular the synthesis of proteins and nucleic acids, respiration, defence responses and secondary metabolism, which subsequently has a negative impact on their growth, development and ornamental qualities. For this reason, research into plant resistance to low air temperatures is relevant and of practical importance for the informed selection of plant varieties and the enhancement of the resilience of biocenoses under modern conditions.

The aim of the study was to determine the level of frost resistance of species of the genus *Hydrangea* L. during the period of forced dormancy, as well as to assess the extent of damage to various parts of the shoots under the influence of low temperatures. During the research, particular attention was paid to identifying the parts of the plants' vegetative organs that are most resistant to frost damage, thereby enabling an objective assessment of their adaptive potential. The results obtained are intended to support the selection of promising species and varieties for use in unstable climatic conditions and in landscaping practice.

LITERATURE REVIEW

In the establishment of cultivated phytocoenoses and park plantings in urban environments, the use of introduced plant species is of considerable importance, and species of the genus *Hydrangea* L. belong to this group; as noted by M. Matusuak & O. Vargatiuk (2019). The use of introduced species makes it possible to significantly expand the range of ornamental plants, enhance the aesthetic appeal of plantings and ensure their functional diversity. According to Y. Sun *et al.* (2022) and F. Murzabulatova *et al.* (2023), hydrangeas are slow-growing shrubs that typically reach a height of 2-5 m. A distinctive feature of hydrangeas is their large, striking inflorescences, formed by numerous star-shaped flowers with four to five sepals, which are characterised by a wide range of colours; in particular, there are plants with blue, purple, pink, white and red flowers. K. Yoshida *et al.* (2021) highlight the unique ability of hydrangeas to change the colour of their sepals throughout the growing season. In particular, the colour of the 'Homigo' chameleon variety changes from white to blue, then to green and, finally, to red as it matures and ages.

Owing to their high ornamental value, hydrangeas are used both as specimen plants and for the creation of hedges. For optimal growth and development, they require fertile, sufficiently moist but well-drained soils. As noted by M. Markovic *et al.* (2025), hydrangeas are sensitive to soil acidity and electrical conductivity. In particular, it has been established that in *H. macrophylla*, pH directly influences the colour of the flower's sepals by altering the availability of aluminium in the soil. Furthermore, according to Q. Wang *et al.* (2022), hydrangeas adapt well to semi-shaded environments, making them valuable for use in the landscaping of urbanised areas, where light levels are often limited. The prospects for introducing most ornamental species, including hydrangeas, depend to a large extent on their resistance to low temperatures. As noted by T. Yurchenko *et al.* (2024), frost resistance is one of the key factors closely linked to the winter hardiness of plants. According to V. Kyrylenko *et al.* (2015), frost hardiness determines a plant's ability to withstand low temperatures without irreversible damage and may vary under the combined influence of other factors, including climatic conditions, cultivation practices and the physiological state of the plants. This characteristic is dynamic in nature and requires detailed study under specific growing conditions.

Research by I. Gravite (2022) on the impact of low temperatures on the distribution and viability of crops has shown that factors such as plant age, soil structure, cultivation methods, fertilisation and pruning are of significant importance for enhancing plant hardiness. Optimal agronomic practices contribute to the formation of more resilient plant communities capable of better withstanding the adverse conditions of the winter period. At the same time, M. Dubchak (2015) notes that the winter hardiness of plants depends, in particular, on the timely cessation of shoot growth and their maturation, the accumulation of sugars in cells, a reduction in physiological activity, and the crop's transition to a dormant stage. Research by V. Kuchma & N. Pavlyukova (2006) revealed that during the overwintering of hydrangeas, storage substances may, depending on ambient temperature conditions, be broken down to form new ones (starch – sugars and fats), which ensure the cells' resistance to adverse factors. The nature of the interconversion of reserve substances is of great importance for diagnosing frost resistance.

One of the biological characteristics of hydrangeas is their winter hardiness, which manifests itself in their resilience to a range of adverse factors during the autumn-winter period, including sharp temperature fluctuations and extreme frosts. This is highlighted in the works of V. Kuchma & N. Pavlyukova (2006) and J. Walliser (2019), who emphasise the importance of a comprehensive assessment of plant hardiness. Different species of the genus *Hydrangea* differ significantly in their level of frost resistance. It has been established that the most frost-hardy are the tree hydrangea (*Hydrangea arborescens*), which withstands temperatures of -35...-40°C; the panicle hydrangea (*Hydrangea paniculata*), which overwinters well at -35°C; the oak-leaved hydrangea (*Hydrangea quercifolia*), which usually survives winters with frosts down to -32°C; and the large-leaved hydrangea (*Hydrangea macrophylla*), which is less hardy and can withstand temperatures down to -24°C. These species are considered frost-hardy, but the extent of damage caused by low temperatures varies. This is precisely why it is important to study in detail the nature of the damage to various organs and tissues; this will not only enable an assessment of the species' level of adaptation to specific conditions, but also justify the appropriateness of their use in landscaping, which is what prompted the need for this research.

MATERIALS AND METHODS

Research into the frost resistance of species of the genus *Hydrangea* L. was carried out between 2020 and 2024 at Uman National University of the Ministry of Education and Science and the National Dendrological Park "Sofiyivka" of the National Academy of Sciences of Ukraine. The method for determining frost resistance was based on anatomical and microscopic examinations following the freezing of shoots in a cold chamber. The experimental protocol involved freezing the one-year-old shoots of three hydrangea species: the large-leaved hydrangea (*Hydrangea macrophylla*), tree hydrangea (*Hydrangea arborescens*), panicle hydrangea (*Hydrangea paniculata*) and oak-leaved hydrangea (*Hydrangea quercifolia*) at temperatures of -25°C and -30°C during the plants' period of forced dormancy.

Freezing was carried out in accordance with the methodological recommendations of M. Dubchak (2015), proceeding slowly by lowering the temperature by 5°C every hour until the target temperature was reached as per the protocol. Temperature changes were monitored using special thermometers fitted into a freezing thermostat. After freezing, the samples were slowly thawed, with the temperature increased by 5°C every hour. Examination of the cross-sections of the shoots was carried out using an MBS-10 microscope. From each sample, three cross-sections were taken in the upper and middle parts of the shoot through the internode, as well as in the middle part through the bud, and the bud was examined separately. The sections were placed on a microscope slide in a drop of glycerine.

Frost resistance was assessed on a point scale, taking into account the average value from three replicates, separately for each part of the shoot, namely: the shoot apex, the middle of the shoot, the middle of the shoot (section through the bud) and the bud. The degree of damage to individual shoot parts was assessed using a six-point scale published by M. Dubchak (2015), where 0 points indicates no damage (0%); 1 point indicates a slight change in colour, with up to 20% of the tissue damaged; 2 points – moderate tissue damage (40%); 3 points – moderate damage, with clearly visible browning of the tissue boundary with adjacent tissues (60%); 4 points – severe damage: the tissue has completely turned brown, and its boundaries with other tissues have turned black (80%); 5 points – complete tissue death, which in some cases cannot be distinguished from other tissues (100%). To determine overall frost resistance, conversion factors for individual tissues were applied in accordance with the recommendations of D. Potanin *et al.* (2005), as published by M. Dubchak (2015): bark – 6, cambium – 8, sapwood – 4, heartwood – 2, bud – 20. The frost damage index was calculated by multiplying the average damage score for each tissue by the corresponding coefficient. The sum of the coefficients is 20, which corresponds to 100 points at the maximum damage score (5.0).

Statistical analysis of the data was carried out using methods of analysis of variance (ANOVA), correlation and regression analysis, following the method proposed by R. Fisher (1934) and in accordance with the generally accepted methodological recommendations of E. Ermantraut *et al.* (2007), using the Statistica 6.0 software package from StatSoft. The reliability of the experimental data was assessed using analysis of variance (ANOVA), followed by the determination of the least significant difference ($LSD_{0.05}$) at a significance level of $p \leq 0.05$. An analysis was carried out of the frost damage index (FDI) values for the shoot apex, the middle of the shoot, the middle of the shoot (cross-section through a bud) and the bud, taking into account the factors of hydrangea species and freezing temperature. The study was conducted in accordance with the ethical standards of the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

RESULTS AND DISCUSSION

According to O. Havryliuk *et al.* (2022), tissue freezing stress in plants is one of the most important limiting factors determining their ecological distribution and cultivation. The risk of frost damage is significant when exposure to extremely low air temperatures is combined with the plants' vulnerability or sensitivity to such conditions. A. Sardoei & B. Fazeli-Nasab (2025) note that low-temperature stress triggers a complex series of biochemical reactions aimed at protecting cells. This response is regulated by hormones, photoperiod, genetic characteristics, and so on. They note that although the acclimatisation process is similar across many plant species, it may exhibit certain differences depending on the genotype. They also point out that different plant organs suffer varying degrees of damage as a result of exposure to low temperatures. As noted by T. Kopilova (2015), the frost resistance of individual organs and tissues of woody plants is not uniform; flower buds and the adjacent parenchymatous tissues containing the conducting system are particularly sensitive to low temperatures. Studies by I. Mykolaiko (2014) on the winter hardiness and frost resistance of *Hippophae rhamnoides* demonstrated that shoot tissues are generally more severely damaged in the apical region, whereas their resistance increases towards the base. An opposite trend was observed in buds, which was attributed to the lower degree of differentiation of apical buds, affecting their tolerance to low temperatures.

According to S. Soualiou *et al*. (2022), the development of effective strategies for enhancing plant frost resistance should be based on an understanding of plant responses to low-temperature stress and the mechanisms underlying adaptation. Analysis of these processes would facilitate the improvement of existing species diversity and the development of plants resistant to this stress factor through breeding and related approaches. In this context, experimental investigations of frost resistance are of particular importance, as they enable quantitative assessment of the degree of injury to different organs and tissues and allow identification of the most vulnerable elements of the shoot. Based on the calculated frost resistance values, the following Frost Damage Index (FDI) ranges were established: 0-20 points – slight damage; 21-40 points – moderate damage; 41-60 points – intermediate damage; 61-80 points – severe damage; and 81-100 points – critical injury or complete tissue death.

It was established that different parts of the same shoot are affected unequally. The upper part of the shoot proved to be the most sensitive to low-temperature stress in all hydrangea species studied. At -25°C, the least freezing damage to shoot tips was observed in *H. arborescens*, *H. paniculata*, and *H. quercifolia*, with frost damage index values of 10.4, 11.8, and 11.9 points, respectively, whereas *H. macrophylla* exhibited the greatest degree of freezing, with an FDI value of 35.8 points (Table 1). A similar pattern of injury to the upper part of the shoot was observed at -30°C. The FDI values for H. arborescens, *H. paniculata*, and *H. quercifolia* amounted to 22.3, 23.1, and 23.1 points, respectively, while in *H. macrophylla* this value increased to 65.5 points, almost 2.8 times higher than in the other species. Considerably less tissue damage was observed in the middle sections of the shoots at both freezing temperatures, -25°C and -30°C. The lowest frost damage index values were recorded for *H. arborescens*, amounting to 7.8 and 12.2 points, respectively. For *H. paniculata* and *H. quercifolia*, the FDI values were slightly higher and reached 5.5 and 6.2 points at -25°C, and 15.8 and 16.2 points at -30°C, indicating sufficient tissue resistance to low-temperature stress in these species. In contrast, the middle section of the shoot in *H. macrophylla* sustained substantially greater injury, with FDI values of 24.9 points at -25°C and 44.5 points at -30°C. Only slight injury caused by low temperatures was recorded in the buds of all hydrangea species except *H. macrophylla*, in which the frost damage index reached 26.6 points at -25°C and increased to 53.4 points at -30°C. In *H. arborescens*, *H. paniculata*, and *H. quercifolia*, bud FDI values were considerably lower, ranging from 4.5 to 8.7 points at -25°C and from 7.7 to 9.7 points at -30°C, indicating relatively high preservation of bud tissues under freezing conditions.

Table 1. Frost resistance of species and cultivars of the genus *Hydrangea* L. during the period of forced dormancy (mean values for 2021-2024)

Species/cultivar	Freezing temperature,°C	Frost Damage Index (FDI) of different shoot parts, points			
		Shoot tip	Middle section of the shoot	Middle section of the shoot (cross-section through the bud)	Bud
Hydrangea arborescens	Control	1.5	0.2	0.0	0.4
	-25	10.4	7.8	3.3	4.5
	-30	22.3	12.2	9.8	7.7
Hydrangea paniculata	Control	0.0	0.0	0.0	0.0
	-25	11.8	5.5	6.7	8.6
	-30	23.1	15.8	13.8	9.5
Hydrangea quercifolia	Control	0.2	0.3	0.1	0.1
	-25	11.9	6.2	7.1	8.7
	-30	23.1	16.2	14.1	9.7
Hydrangea macrophylla	Control	24.2	19.9	21.5	12.8
	-25	35.8	24.9	33.7	26.6
	-30	65.5	44.5	51.2	53.4
$LSD_{0.05}$ (overall)		2.7	1.8	1.8	2.5
$LSD_{0.05}$ (species)		1.5	1.0	1.0	1.4
$LSD_{0.05}$ (temperature)		1.3	0.9	0.9	1.3

Source: compiled by the author

In most of the hydrangea species studied, the middle section of the shoot in a cross-section through the bud proved to be the most resistant to freezing. At temperatures of -25°C and -30°C, the lowest FDI values were recorded for *H. arborescens* (3.3 and 9.8 points, respectively). For *H. paniculata* and *H. quercifolia*, FDI values were similar and did not exceed 7.1 points at -25°C and 14.1 points at -30°C. The greatest damage was observed in all parts of the shoots of *H. macrophylla*, indicating its comparatively low resistance to low temperatures and corroborating the findings of R. Palagecha *et al.* (2007), who reported more severe shoot damage in this species compared with other hydrangea species. The results obtained indicate that the shoots of *H. arborescens* exhibited the highest frost resistance, as reflected by the lowest FDI values, suggesting that this species is particularly suitable for use in hybridisation programmes aimed at developing frost-resistant cultivars. At the same time, considering the results of the assessment of low-temperature resistance in the shoots of all hydrangea species investigated, as well as the current trend of global warming, under which winters are characterised by a reduced frequency of temperatures that pose a serious threat to plants, it appears appropriate to include not only *H. arborescens* but also the other studied species in breeding programmes. These species possess valuable ornamental characteristics and demonstrate relatively high resistance to low-temperature stress. Studies by M. Pagter (2008) on plant frost resistance demonstrated that the species factor has a significant effect on frost hardiness. Species differing in winter hardiness also differ in the development of shoot protective tissues, which collectively regulate water exchange and, consequently, determine plant frost resistance. Evaluation of the factors affecting the frost resistance of different shoot parts, averaged across hydrangea species, showed that the factor "hydrangea species" exerted the greatest influence, accounting for 57.2% of the variation in the shoot tip and up to 75.1% in the middle section of the shoot (cross-section through the bud) (Fig. 1).

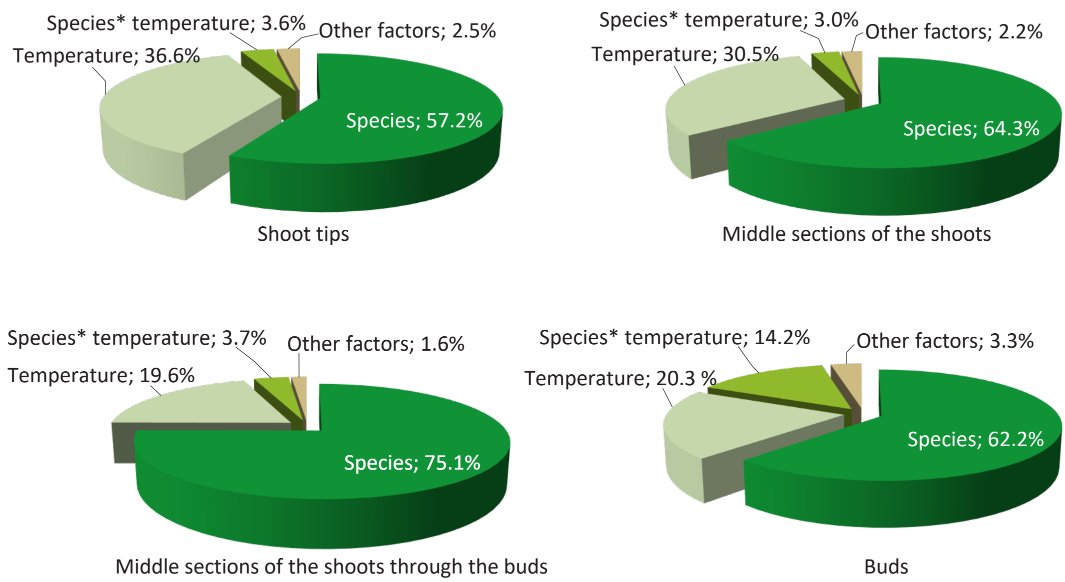

Figure 1. The effect of factors on the frost damage index

Source: compiled by the author

The results obtained indicate that the level of frost resistance in the plants studied is largely determined by genetically controlled species-specific characteristics that influence the degree of tissue maturation and the capacity for adaptation under low-temperature stress. The contribution of the factor "species" to the FDI of the shoot tip, which proved to be the most sensitive to freezing, amounted to 57.2%, representing the lowest value recorded among the shoot parts examined, whereas the effect of the factor "temperature" was relatively high, accounting for 36.6%. This indicates that apical tissues are particularly susceptible to low-temperature stress. The contribution of the interaction between the factors "species × temperature" for this part of the shoot was relatively small, amounting to only 3.6%. For the middle section of the shoot, the significance of the factor "species" increased to 64.3%, whereas the contribution of "temperature" was somewhat lower and accounted for 30.5%. A similar pattern was observed for the middle section of the shoot in a cross-section through the bud, where the contribution of the factor "species" reached its maximum value of 75.1%, while that of temperature was only 19.6%. In the case of buds, the factor "species" also exerted the greater influence, accounting for 62.2% of the variation; however, this shoot part exhibited the highest contribution of the interaction "species × temperature", amounting to 14.2%. This finding indicates that buds of different hydrangea species respond differently to decreasing temperatures, which may be related to differences in bud structure and the degree of their protection. The influence of the factor "temperature" was also substantial but remained lower than that of the factor "hydrangea species", which is likely attributable to the use of frost-resistant species in the experiment. In particular, *H. arborescens* proved to be the most resistant species, followed by *H. paniculata* and *H. quercifolia*, whereas *H. macrophylla* exhibited the lowest frost resistance. The results of the analysis of variance confirm the determining role of genetically controlled species-specific characteristics in shaping the degree of frost resistance in hydrangea shoots, whereas temperature acts as a secondary factor. These findings are fully consistent with the results reported by M. Pagter (2008), who also established the decisive role of the species factor in determining plant frost resistance.

M. Pagter *et al.* (2008) reported that *H. paniculata* possesses significantly higher frost resistance than *H. macrophylla*, which is associated with differences in physiological and biochemical mechanisms of cold adaptation, particularly the accumulation of carbohydrates, abscisic acid, and protective proteins in the bark. The results of the present study indicate that the buds of *H. macrophylla* are more susceptible to frost injury than stems and that the vulnerability of stems to frost damage caused by unstable temperature regimes changes throughout the winter period. However, the present investigation revealed a greater degree of low-temperature injury in the shoot tip (FDI = 65.5) than in the bud, the frost damage index of which amounted to 53.4 points at -30°C. In studies on the effects of low temperatures on the susceptibility of flower buds and annual shoot tissues to frost damage, M. Pagter (2008) demonstrated that different types of injury have different consequences for subsequent plant development. Thus, the loss of flower buds primarily affected crop productivity while exerting only a minor influence on the overall condition of the plant, whereas damage to the cambium resulted in rapid dieback of the shoot or even the entire plant, and xylem injury caused long-term decline and increased susceptibility to fungal infections.

CONCLUSIONS

It was established that different parts of hydrangea shoots exhibit unequal sensitivity to the effects of low temperatures. The shoot tip proved to be the most vulnerable, with a frost damage index (FDI) ranging from 10.4 to 65.5 when subjected to freezing, whilst the middle section of the shoot, when cut through a bud, is relatively resistant to low temperatures, with corresponding FDI values of 3.3-51.2. At a temperature of -25°C, the least damage to shoot tips was recorded in *Hydrangea arborescens*, with a frost damage index of 10.4 points, whilst the greatest damage was observed in *Hydrangea macrophylla* (35.8 points). A similar pattern was observed at a temperature of -30°C. In this experimental variant, the frost damage index for *H. arborescens* was 22.3, for *H. paniculata* and *H. quercifolia* it was 23.1, whilst for *H. macrophylla* it stood at 65.5. The buds of most of the hydrangea species studied were only slightly affected by low temperatures. The exception was *H. macrophylla*, for which the frost damage index at a temperature of -25°C was 26.6 points, rising to 53.4 points at -30°C. The highest resistance to frost damage in most hydrangea species was observed in the middle section of the shoot in a cross-section through a bud. At temperatures of -25°C and -30°C, the lowest frost damage index values were also characteristic of *H. arborescens*, amounting to 3.3 and 9.8 points, respectively. All parts of the *H. macrophylla* shoot sustained the most damage, indicating this species' lowest resistance to low temperatures. It was established that species-specific characteristics constitute the determining factor of frost resistance, accounting for 57.2-75.1% of the variation depending on the shoot part examined. The results obtained indicate the advisability of using *Hydrangea arborescens* and other resistant species in breeding programmes aimed at developing frost-resistant and ornamental varieties. A promising area for further research is to investigate the impact of the extent and nature of plant damage on their growth and development, as well as to develop effective methods for enhancing the frost resistance of *Hydrangea cultivars* under various growing conditions.

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CONFLICT OF INTEREST

None.

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Оцінювання морозостійкості видів роду *Hydrangea* L. за ступенем пошкодження частин пагона

Анотація. Температурні коливання у зимовий період, які характеризуються чергуванням відлиг та короткочасних морозів, зумовлюють необхідність оцінювання стійкості рослин до дії низьких температур. У зв'язку з цим актуальним є вивчення морозостійкості різних видів роду *Hydrangea* L. Метою дослідження було оцінювання морозостійкості різних видів гортензій та визначення ступеня ушкодження окремих частин пагонів рослин. Визначено, що верхня частина пагона рослин гортензії є найбільш чутливою до впливу низьких температур з індексом морозного пошкодження на рівні 10,4-65,5 балів. Найменшим був ступінь промерзання у рослин *Hydrangea arborescens*, найбільшим – у *Hydrangea macrophylla* з індексом морозного пошкодження за температури -25 °C – 10,4 та 35,8 бала відповідно. Аналогічні результати отримано і за температури проморожування -30 °C, де відповідні значення ступеня пошкодження становили 22,3 та 65,5 бала. Відносно стійкою до проморожування у більшості видів була середня частина пагона у розрізі через бруньку. Індекс морозного пошкодження у даному варіанті досліду за температури -25 °C та -30 °C становив для рослин *Hydrangea arborescens* 3,3 та 9,8 бала, *Hydrangea paniculata* – 6,7 та 13,8 бала, *Hydrangea quercifolia* – 7,1 та 14,1 бала, а найвищим він був у *Hydrangea macrophylla* з показниками на рівні 33,7 та 51,2 бала, що на 8,8 та 6,7 бала вище, ніж у варіанті з проморожуванням середньої частини пагона даного виду. За проморожування бруньки спостерігали незначні ушкодження усіх видів гортензій, за винятком *Hydrangea macrophylla*, у якої індекс морозного пошкодження у даному варіанті досліду становив 26,6 бала за температури -25 °C та 53,4 бала за температури -30 °C. Результати багатофакторного дисперсійного аналізу підтвердили значення частки впливу фактору «вид гортензії», яка коливалася у межах 57,2-75,1 % на морозостійкість різних частин рослини. Результати досліджень мають практичне значення та можуть бути використані за формування стійких декоративних насаджень в умовах нестабільного клімату, а також при доборі видів гортензій для селекції стійких до впливу низьких температур генотипів

Ключові слова: проморожування; підмерзання тканин; стійкість рослин; гортензії; адаптація