Scientific Papers. Series B, Horticulture. Vol. LXX, No. 1, 2026
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

HIGH TEMPERATURE TOLERANCE IN FRAGRANT ROSE CULTIVARS

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Abstract

The rose, the most appreciated species in the world's floricultural industry, has become a prosperous business for those who cultivate and exploit this plant in our country, being widely used by landscapers due to its versatility and diversity of shapes, colors, and fragrance. This paper investigated the behavior and tolerance at high temperatures of nine cultivars of fragrant roses ('Acapella', 'Caprice de Meilland', 'Cristiana', 'Fisherman's Friend', 'Nobilia', 'Pasiune în mov', 'Romstar', 'Sandra' and 'Snow Owl'), existing in the UASVM - HRS Cluj-Napoca field collection, in the context of climate change. Biometric measurements highlight, in addition to the genetic characteristics of the cultivars, the significant negative influence of temperatures above 30°C, which affect the vegetative tips by 37% in the `Fisherman's Friend' cultivar compared with the other cultivars. Chlorophyll biosynthesis occurs optimally at 26°C, while at temperatures below 16°C and above 32°C the photosynthesis process is affected. Among the alcoholic extracts, determined at 24 h from rose petals, the `Fisherman's Friend' cultivar presents the most intense fragrance and the highest degree of persistence, followed by `Cristiana'. As a result, in scented roses, high summer temperatures reduce the persistence of the fragrance while also affecting the overall health of the flowers.

Key words*: morpho-biometrical measurements, chlorophyll, alcoholic extracts, rose scent.*

INTRODUCTION

Roses were among the first ornamental plants used to decorate the environment. Their cultivation dates back millennia, with the earliest records appearing around 500 BC in Mediterranean countries, Persia, and China. In Romania, rose cultivation is a distant past; the plants were grown in gardens for their ornamental value by the Dacians (Wagner, 2002; Toma, 2009). Rose plants belong to the family Rosaceae, genus Rosa, which comprises more than 200 species and over 30,000 cultivars that continue to enhance and decorate lives worldwide (Salcă Roman et al., 2024).

The major rose-producing countries are the Netherlands, Colombia, Kenya, Israel, Italy, the United States, and Japan (Desta et al., 2022). In recent years, approximately 20 edible rose cultivars have been exploited in China. Rosa 'Crimson Glory' is one of the most important edible rose cultivars and is often referred to as "the king of edible flowers" (Qiu et al., 2022; Xie et al., 2023). Roses are widely cultivated as cut flowers and hold significant economic value as sources of natural fragrance and flavoring (Xie et al., 2023).

Today in Romania, beyond their aesthetic importance, roses are also valued for their ecological, nutritional, therapeutic, and cosmetic uses, making rose cultivation a prosperous business for growers and processors (Chelariu et al., 2017; Șoltuzu, 2019).

The rose also carries numerous symbolic and spiritual connotations, frequently representing love, beauty, harmony, and elevated emotions (Gudin, 2000).

Recent studies have highlighted the potential of roses in functional foods containing biologically active compounds that may enhance human health or reduce the risk of disease, as well as in nutraceuticals with medicinal effects (Smulders et al., 2011). The best-documented effect of rosehips is their beneficial influence on

osteoarthritis; more recent research suggests that this effect may also be attributed to the fatty acids present in the seeds-α-linolenic and linoleic acids (Jäger et al., 2008). There is also evidence that rosehip extracts, combined with small amounts of blueberry, blackberry, and grapevine extracts, may help reduce the risk of cardiovascular diseases by lowering levels of inflammatory markers associated with early myocardial infarction (Kornman et al., 2007). Landscapers widely use roses because of their versatility, diversity of shapes and colors, fragrance, and especially their resistance to harsh environmental conditions and their adaptability to recent climate changes (Iliescu, 1998; Iuroaea et al., 2020).

Rose (*Rosa* L.) plants are among the most important ornamental flowers, used as cut flowers. They have been cultivated for centuries for their flowers and fragrance and serve as valuable sources of essential oil (Shalit et al., 2023; Roccia et al., 2019).

The fragrance of roses has a long and rich history. Rose fragrance and rose oil were used throughout the Middle Ages for medicinal purposes and to mask unpleasant odors. In the 12th and 13th centuries, Crusaders brought Damask roses back from the Middle East because of their exceptional fragrance, and perfume was made from the petals. Numerous species and thousands of varieties possess fragrance; therefore, for growers, the selection of fragrant varieties that also tolerate high temperatures has considerable economic value (Salcă Roman et al., 2024).

Over time, many researchers have worked to develop fragrant varieties (Wagner, 2010; Salcă Roman et al., 2024). Many factors influence rose fragrance, including soil pH, water availability, humidity, time of day, season, and geographical origin (Elgar, 2024 –https://rose.org/the-fragrance-of-roses-past-and-present/).

Damask roses are renowned for their strong fragrance and are considered to have originated in Persia (present-day Iran). The most commercially significant Damask rose is the 30-petaled *R. damascena* 'Trigintipetala', which is cultivated for rose oil production. This oil is used by the perfumery industry in Bulgaria, Turkey, Iran, India, China, and North Africa (Smulders et al. 2011). Bulgaria has maintained its position as the world's largest producer of high-quality rose oil, accounting for approximately 70–75% of global production, with annual output ranging between 2.5 and 4.5 tonnes (2,500–4,500 kg). In 2025, Bulgarian rose oil production is expected to decline by 20–30% compared with previous years due to adverse weather conditions, including a cold May, frost, and hail (Bonchev, 2025). Bulgarian rose oil is exported to more than 30 countries, including the United States, China, Japan, South Korea, France, and the United Kingdom (https://bnrnews.bg/en/post/114893/rose-oil-production-up-by-10-in-2024).

Climatic factors play a critical role in the production of quality roses, influencing not only growth and yield but also flower quality. Among these factors, light, temperature, and relative humidity directly affect plant growth (Szekely-Varga, 2020). Light intensity is the most important factor influencing the growth and flowering of rose plants (Desta et al., 2022; Wagner, 2002). The timing of flowering flushes is influenced by both environmental conditions and plant health (Shinwari et al., 2003; Wagner, 2002; Wagner, 2010). The ideal temperature range for rose production is 20-25°C during the day and 13-16°C at night, combined with at least 8 hours of sunlight and relative humidity below 75% (Cui et al., 2022). Below 15°C, roses can still be grown, but the time between flowering flushes becomes longer, and bullheads (deformed, flat-topped, unmarketable buds caused by temperatures below 5°C) may form. At temperatures above 30°C, flowers of poor quality, often with fewer petals (Martin, 1980) are produced. Temperature directly affects key physiological processes such as photosynthesis, shoot formation, and plant growth. Climate change affects roses through elevated temperatures and greater thermal instability, often causing premature flowering (sometimes by as much as one month), heat stress, and increased water requirements. Large day/night temperature fluctuations (greater than 10°C) and early springs followed by late frosts disrupt normal plant development. High temperatures above 30°C (86°F) induce heat stress in roses, resulting in scorched leaves, wilted foliage, smaller or deformed blooms with fewer petals, reduced flowering, and, in severe cases, premature dormancy. Prolonged heat disrupts photosynthesis, degrades chlorophyll, and

causes cellular damage, leading to accelerated bloom cycles but overall poorer plant quality (Hatfield & Prueger, 2015).
High temperatures also favor the proliferation of pests and diseases. According to a study by the Research and Development Institute for Floriculture in Bucharest, the incidence of fungal diseases in urban-grown roses has increased by more than 17% over the last 10 years (www.icdf.ro). In Buzău County, during the summer of 2022, a collection of over 300 rose varieties lost 20% of its plants due to a prolonged heat wave followed by torrential rains (https://www.pasiuneaplantelor.ro/impactul-schimbarilor-climatice-asupra-trandafirilor-prevenire-si-solutii-pentru-gradinari/).
Dobrotă (2013) noted that high temperatures also cause drying of plant parts containing secretory tissues-particularly the petals-due to intensified water evaporation.
In the context of global warming, the present research focused on identifying the effects of high temperatures on the photosynthetic process that supports plant growth and, indirectly, the synthesis of secondary metabolites responsible for the fragrance of rose petals.
The study also aimed to select and introduce rose cultivars specially adapted to high temperatures and to diseases associated with the changing climate.

MATERIALS AND METHODS

The research was conducted in the experimental field of the rose breeding laboratory and in the biochemistry laboratory at the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca – Horticultural Research Station Cluj-Napoca (USAMV-SCH Cluj-Napoca). The rose collection contains over 350 varieties from different groups. This genetic resource was developed over more than 70 years of research, with particular emphasis on the selection of parents for winter frost resistance and black spot tolerance (Salcă Roman et al., 2024).
The biological material consisted of nine rose cultivars: 'Acapella', 'Caprice de Meilland', 'Cristiana', 'Fisherman's Friend', 'Nobilia', 'Pasiune în mov', 'Romstar', 'Sandra', and 'Snow Owl' (Figure 1).
These cultivars were selected considering their fragrance intensity, petal color, and potential use in the cosmetics industry. According to the literature, all selected varieties are assumed to contain valuable biologically active compounds. Previous studies have shown a direct relationship between petal color intensity and fragrance intensity. Although the cultivars 'Cristiana' and 'Snow Owl' do not fully meet the color-intensity criteria, they were included because of the exceptional intensity and uniqueness of their fragrance.

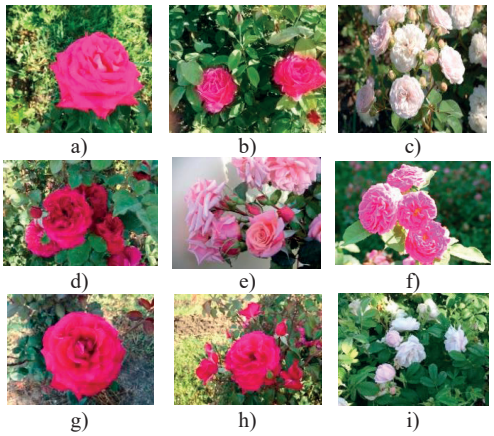

Figure 1. Rose cultivars: a) 'Acapella'; b) 'Caprice de Meilland'; c) 'Cristiana'; d) 'Fisherman's Friend'; e) 'Nobilia'; f) 'Pasiune în mov'; g) 'Romstar'; h) 'Sandra'; i) 'Snow Owl'

The purpose of research on the impact of high temperatures on roses (genus *Rosa*) is to understand how heat stress affects plant physiology, with a focus on the photosynthesis process and, consequently, on the biosynthesis of secondary metabolites responsible for flower fragrance.
The main objective was to establish the correlation between temperature and the synthesis of chlorophyll pigments and the development of photosynthesis processes in plants. The second objective was to obtain extracts from rose petals of selected fragrant varieties, extracts that can subsequently be tested for antibacterial and antifungal activity.
The experiment was a multifactorial one; the independent variable was the temperature with three levels (16°C, 26°C, and 32°C) and the dependent variables were represented by biometric growth measurements, chlorophyll index, chlorophyll fluorescence, and the dry matter of leaves and petals.

Morphometric measurements of rose plant growth were recorded monthly from June to August 2022. All observations were conducted in the morning between 7:00 and 7:30 AM. The data presented represent the mean values derived from three consecutive replicates.

Chlorophyll content was estimated in situ and non-destructively using a CCM-200 chlorophyll content meter (Opti-Sciences). Measurements were made on the terminal leaflet of the third fully expanded leaf, from the tip of the woody branches. Three consecutive replicates were performed for each plant at different temperatures. Chlorophyll fluorescence was measured using a modulated fluorometer (OS1-FL, Opti-Sciences). The terminal leaflet of the third leaf from the tip of the woody branches was selected for analysis. Measurements were taken in series of three consecutive replicates per plant at different temperatures.

Dry matter content in leaves and petals was determined using fresh material manually harvested. The dry matter percentage was calculated as follows:

$$\text{Dry matter (\%)} = \frac{\text{mdry}}{\text{mfresh}} \text{ x } 100$$

The petals were harvested in July, during maximum temperatures of 26°C, as this is the time when photosynthesis is optimal for these rose cultivars.

For the preparation of the extracts, the flowers were harvested manually in July at a temperature of 23°C. The petals from the nine cultivars were separated from the other flower components, chopped, and weighed. A total of 200 g of petals was used for the aqueous extract (using an original method). For the alcoholic extract, petals from four cultivars ('Cristiana', 'Fisherman's Friend', 'Romstar', and 'Snow Owl') were used, with a total petal weight of 40 g. For the oily extracts from rose petals, a mixture of petals from the same four cultivars was used, with a total petal weight of 8 g. In all variants, the chopped petals were placed in 2000 ml Erlenmeyer flasks. Over the petals, the following were added: 1500 mL of distilled water for the aqueous extract, 80 mL of food-grade 96% ethyl alcohol (brand Croisiere) for the alcoholic extract, and for the oily extracts - in the first flask: linseed oil (Nature's Sense); in the second flask: cold-pressed olive oil (*Hypericum* Plant); in the third flask: jojoba oil (*Hypericum* Plant); and in the fourth flask: coconut oil (Steaua Divina). The mixture of petals and water was placed in the refrigerator at +7°C. After seven days, the mixture was removed from the refrigerator and filtered into 100 mL Erlenmeyer flasks in fractions, which were sealed with parafilm and stored in the refrigerator at +7°C. The alcoholic compositions were kept at +24°C for maceration over 14 days, after which they were filtered and placed in Erlenmeyer flasks, covered with parafilm, and stored in the refrigerator at +7°C.

The containers with petals and oily extracts were completely covered with aluminum foil and kept at +24°C for 14 days to allow maceration. Afterward, they were ground in a mortar and pestle and then filtered first through funnels lined with cotton wool and a second time using filter paper. The oil extracts were subsequently placed in Erlenmeyer flasks, completely covered with aluminum foil, and stored in the refrigerator at +7°C. Using the volumetric values of the distillation fractions, the distillation yield was calculated with the following formula:

Yield (%) = (a/b) × 100 where:

a - is the total volume of distillate obtained;

b - is the initial volume of the filtrate.

RESULTS AND DISCUSSIONS

The results obtained from morpho-biometric growth measurements of rose cultivars at different temperatures are presented in Table 1.

Analyzing Table 1, it can be observed that at 16°C, the cultivar showing the highest mean value of the biometric measurements is `Caprice de Meilland` (165 cm), while the cultivars with the lowest value of 100 cm are 'Fisherman's Friend' and 'Romstar'.

Table 1. Morpho-biometric Growth Response of Rose Cultivars to Different Temperature Regimes

Cultivar	Plant height (cm)		
	at 16°C	at 26°C	at 32°C
Acapella	120	130	128
Caprice de Meilland	165	180	179
Cristiana	115	130	130
Fisherman's Friend	100	110	109
Nobilia	125	130	130
Pasiune în mov	120	120	120
Romstar	100	120	119
Sandra	135	140	138
Snow Owl	120	125	125

At 26°C and 32°C, the cultivar that continues to show the highest mean value of the biometric measurements is 'Caprice de Meilland', while the one with the lowest value is 'Fisherman's Friend'. The month of June was characterized by relatively low temperatures for that time of the year and abundant precipitation. August, however, was characterized by constant temperatures above 32°C and low humidity. As a result, the vegetative tips of the plants were affected, and their average height was lower than in the previous period at 26°C. Sensitivity to temperature manifests differently among cultivars, with the most sensitive ones being 'Fisherman's Friend', which suffered the most at 32°C, recording a 37% destruction of vegetative tips compared with the other cultivars.

Maximum flower yield, stem length, and flower quality have been reported in plants growing at 23.9°C day temperature (Holcomb & Tsinaraki, 1987). Studies conducted by Iliescu (1998) and Wagner (2010) show that, when it comes to ambient temperature, the behavior of roses varies; only a few cultivars can survive very low temperatures during winters. Regarding the tolerance of roses to positive temperatures, the upper limit at which vital functions can still occur under normal conditions is around 35°C. Above this threshold, the plant suffers because the losses caused by respiration are significantly higher than the gains from assimilation. Photosynthesis takes place with the help of energy provided by solar radiation and is conditioned by the presence of chlorophyll (Burzo et al., 1999; Dobrotă, 2010; Dobrotă & Roba, 2012). Photosensitive pigments are organic biomolecules specialized in receiving solar radiation (Burzo et al., 1999; Busuioc & Bălan, 2003; Dobrotă, 2010).

Light, temperature, oxygen, and minerals are environmental factors that influence the biosynthesis of pigments (Busuioc & Bălan, 2003; Dobrotă, 2010). The process of photosynthesis can occur in a wide temperature range, from –6°C to +47°C. For mesothermic plants, the optimal temperature for photosynthesis - that is, the temperature at which photosynthesis proceeds with the highest intensity - is between 20°C and 30°C (Burzo et al., 1999; Dobrotă, 2010). The results obtained from measuring the chlorophyll index at different temperatures are presented in Table 2.

Table 2. Effect of Temperature on Chlorophyll Index Measurements

Cultivar	**The chlorophyll index**		
	at 16°C	at 26°C	at 32°C
Acapella	37.03 ± 2.66	42.40 ± 5.22	10.10 ± 1.08
Caprice de Meilland	31.73 ± 2.05	83.30 ± 4.11	8.80 ± 0.46
Cristiana	23.90 ± 3.99	43.90± 3.22	11.37 ± 4.24
Fisherman's Friend	24.60 ± 1.04	59.20± 1.81	11.77 ± 3.24
Nobilia	20.17 ± 3.38	66.03± 5.83	13.33 ± 2.23
Pasiune în mov	18.40 ± 3.22	62.10± 2.79	5.53 ± 1.33
Romstar	53.60 ± 3.75	37.00± 4.87	14.47 ± 0.75
Sandra	40.47 ± 2.54	52.90± 2.00	11.33 ± 2.06
Snow Owl	26.57 ± 4.75	18.93± 1.50	8.97 ± 0.95

From the analysis of the data in Table 2, it can be observed that at 16°C, the 'Romstar' cultivar shows the highest chlorophyll index value (53.60), while the 'Pasiune în mov' cultivar shows the lowest chlorophyll index value (18.40). The percentage differences between the `Romstar` cultivar and the cultivars `Acapella`, `Caprice de Meilland`, `Cristiana`, `Fisherman's Friend`, `Nobilia`, `Pasiune în mov`, `Sandra`, and `Snow Owl` are 30.91%, 40.80%, 55.41%, 54.10%, 62.38%, 65.67%, 24.50%, and 50.44%, respectively. The largest difference is recorded compared to the `Pasiune în mov` cultivar, with a difference of 65.67%.

At 26°C, the `Caprice de Meilland` cultivar shows the highest chlorophyll index value (83.30), while the Snow Owl cultivar shows the lowest value (18.93). The percentage differences between the `Caprice de Meilland` cultivar and the cultivars `Acapella`, `Cristiana`, `Fisherman's Friend`, `Nobilia`, `Pasiune în mov`, `Romstar`, `Sandra`, and `Snow Owl` are 49.10%, 47.30%, 28.93%, 20.73%, 25.45%, 55.58%, 36.49%, and 77.27%, respectively. The largest difference is recorded compared to the `Snow Owl` cultivar, with a difference of 77.27%.

Figure 2 highlights the differences between the chlorophyll indices of different cultivars at 26°C, the best temperature for the good development of the rose cultivars studied. Studies conducted by Shin et al. (2001) led to similar results, stating that the ideal temperature for rose production is 20-25°C during the day and 13-16°C at night, along with 8 hours of sunlight and <75% relative humidity.

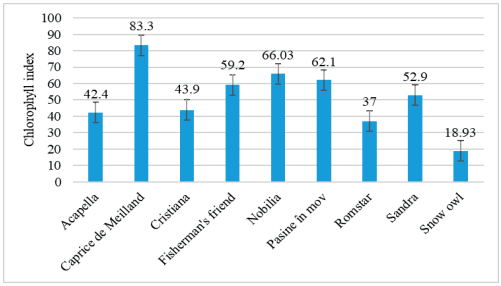

Figure 2. Chlorophyll index for rose cultivars at 26°C

At 32°C, the `Romstar` cultivar shows the highest chlorophyll index value (14.47), while the `Pasiune în mov` cultivar shows the lowest value (5.53). The percentage differences between the `Romstar` cultivar and the cultivars `Acapella`, `Caprice de Meilland`, `Cristiana`, `Fisherman's Friend`, `Nobilia`, `Pasiune în mov`, `Sandra`, and `Snow Owl` are 30.15%, 39.15%, 21.39%, 18.63%, 7.79%, 61.73%, 21.61%, and 37.99%, respectively. The largest difference is recorded compared to the `Pasiune în mov` cultivar, with a difference of 61.73%.

Chlorophyll biosynthesis is affected by temperatures above 30°C and proceeds optimally between 16°C and 25°C. For low chlorophyll content values, there is a direct proportionality between this parameter and the progress of photosynthesis. Above average values, chlorophyll pigments accumulate in excess, and there is no longer a direct proportional relationship between them and photosynthesis.

Below 15°C, roses can be grown, but the interval between flushes becomes longer, and bullheads (a physiological problem in some roses caused by low temperatures below 5°C, resulting in flat-topped, unmarketable buds instead of pointed tips) are produced.

At higher temperatures above 30°C, poor-quality flowers with fewer petals are produced (Martin, 1980; Lerner & Dana, 2003).

Photosynthesis is among the plant cell functions that is highly sensitive to high-temperature stress and is often inhibited before other cell functions are impaired (Sonal et al., 2014). Photosynthetic pigments, the two photosystems, the electron transport system, and CO_2 reduction pathways are a few important components of photosynthesis, and damage to any of them is enough to inhibit the overall photosynthetic mechanism of a plant (Alison et al., 1990).

The chlorophyll fluorescence measuring device displays four indices: Initial (basal) fluorescence (F_0) is given by the absorption of light by the pigment antennae. It indicates the degree of organization and operational efficiency of the pigments in the antenna complexes. The high value of this index indicates low efficiency of energy transfer to the pigments in the reaction center of photosystem II. Maximum fluorescence (Fm) indicates the maximum level of chlorophyll fluorescence when all plastoquinone molecules (a component of photosystem II) are saturated.

A low value of this index shows that the primary photochemical reactions within photosystem II are disturbed.

Variable fluorescence (F_v) is the fluorescence of dark-adapted leaves and represents the difference between maximum fluorescence and initial fluorescence. The ratio between variable fluorescence and maximum fluorescence reflects the maximum possible (potential) quantum yield of photosystem II, i.e., the extent to which the absorbed energy can be used by converting it into chemical energy. It usually ranges between 0.75 and 0.85, and a drop below the minimum value or an increase above the maximum value indicates inhibition of photochemical processes under the action of stress factors. The results obtained from measuring chlorophyll fluorescence at different temperatures are presented in Table 3.

Table 3. Chlorophyll fluorescence for rose cultivars at 16°C, 26°C and 32°C

Temp °C	Cv. / Indices	Acapella	Caprice de Meilland	Cristiana	Fisherman's Friend	Nobilia	Pasiune în mov	Romstar	Sandra	Snow Owl
16	**F_0**	0.284	0.326	0.272	0.323	0.347	0.288	0.349	0.316	0.362
	Fm	0.689	1.032	0.940	0.940	1.171	0.803	1.073	0.857	1.124
	Fv	0.405	0.706	0.668	0.617	0.824	0.515	0.724	0.541	0.762
	Fv/Fm	0.588	0.684	0.711	0.656	0.704	0.641	0.675	0.631	0.678
26	**F_0**	0.425	0.349	0.309	0.434	0.434	0.473	0.396	0.365	0.376
	Fm	1.533	1.595	1.628	1.652	1.589	1.798	1.303	1.230	1.562
	Fv	1.108	1.246	1.319	1.218	1.155	1.325	0.907	0.865	1.186
	Fv/Fm	0.723	0.781	0.810	0.737	0.727	0.737	0.696	0.703	0.759

Temp °C	Cv. / Indices	Acapella	Caprice de Meilland	Cristiana	Fisherman's Friend	Nobilia	Pasiune în mov	Romstar	Sandra	Snow Owl
32	**F_0**	0.409	0.389	0.358	0.372	0.367	0.387	0.416	0.425	0.369
	Fm	1.451	1.669	1.532	1.708	1.646	1.573	1.509	1.628	1.677
	Fv	1.042	1.280	1.174	1.336	1.279	1.186	1.093	1.203	1.308
	Fv/Fm	0.718	0.767	0.766	0.782	0.777	0.754	0.724	0.739	0.780

FO -Initial (basal) fluorescence; Fm-Maximum fluorescence; FV -Variable fluorescence.

From the data in Table 3 at 16°C, it can be observed that the basal fluorescence (F_0) value is maximum in the `Snow Owl` cultivar (0.362) and minimum in the `Cristiana` cultivar (0.272). The highest value of maximum fluorescence (F_m) is shown by the `Snow Owl` cultivar (1.124), while the lowest value is shown by the `Acapella` cultivar (0.689). The difference between maximum fluorescence (F_m) and basal fluorescence (F_0), i.e., variable fluorescence (F_v), is maximum in the `Nobilia` cultivar (0.824) and minimum in the `Acapella` cultivar (0.405). Due to variations in the fluorescence indices among the different cultivars, the value of the ratio between variable fluorescence (F_v) and maximum fluorescence (Fm) is maximum in the `Cristiana` cultivar (0.711) and minimum in the `Acapella` cultivar (0.588). The fact that these values fall between 0.75 and 0.85 indicates that the environmental conditions are optimal for photosynthesis.

Data from Table 3, indicates that a temperature of 16°C is sub-optimal for photosynthesis in rose plants, as all F_v/F_m ratio values recorded for the different cultivars are below the minimum value of 0.75.

At 26°C (Table 3), it can be observed that the basal fluorescence (F_0) value is maximum in the `Pasiune în mov` cultivar (0.473) and minimum in the `Cristiana` cultivar (0.309). The highest value of maximum fluorescence

F_m) is shown by the `Pasiune în mov` cultivar (1.798), while the lowest value is shown by the `Sandra` cultivar (1.230). Variable fluorescence (F_v) is maximum in the `Pasiune în mov` cultivar (1.325) and minimum in the `Sandra` cultivar (0.865). Due to variations in the fluorescence indices among the different cultivars, the value of the ratio between variable fluorescence (F_v) and maximum fluorescence (F_m) is maximum in the `Cristiana` cultivar (0.810) and minimum in the `Romstar` cultivar (0.696). The fact that three cultivars fall within the 0.75-0.85 range according to Table3 indicates that the environmental conditions are optimal for photosynthesis, exceeding the minimum value of 0.75.

At 32°C, it can be observed that the basal fluorescence (F_0) value is maximum in the `Sandra` cultivar (0.425) and minimum in the `Cristiana` cultivar (0.358). The highest value of maximum fluorescence (F_m) is shown by the `Fisherman's Friend` cultivar (1.708), while the lowest value is shown by the `Acapella` cultivar (1.451). Variable fluorescence (F_v) is maximum in the `Fisherman's Friend` cultivar (1.336) and minimum in the `Acapella` cultivar (1.042). Due to variations in the fluorescence indices among the different cultivars, the value of the ratio between variable fluorescence (F_v) and maximum fluorescence (F_m) is maximum in the `Fisherman's Friend` cultivar (0.782) and minimum in the `Acapella` cultivar (0.718).

The fact that most cultivars fall within the 0.75-0.85 range indicates that the environmental conditions are optimal for photosynthesis in most cultivars, with only three F_v/F_m ratio values falling below the minimum of 0.75 (Table 3). A temperature of 32°C represents a supra-optimal value for the photosynthesis process in the rose cultivars studied.

Studies conducted by Grodzinski & Jiao (1998) and Chimonidou (2003) show that temperature has a direct impact on processes such as photosynthesis, shoot formation, and plant growth.

Higher temperatures affect the formation of small flowers with fewer and smaller petals. Lower temperatures also affect the formation of "bullhead" flowers, which have a flattened appearance. Moldovan et al. (2023) reported in *Pelargonium zonale* that significant differences were observed between different fertilization strategies in terms of chlorophyll content and quantified nitrogen content.

Following the determination of the water content in the leaves and petals, the data presented in Table 4 were obtained.

From the data presented in Table 4, it can be observed that the leaves of the `Romstar` and `Sandra` cultivars (0.64%) show the highest

percentage of dry matter and the lowest percentage of water content (99.36%). On the other hand, the `Acapella` cultivar shows the lowest percentage of dry matter (0.55%) and the highest percentage of water content (99.45%). From the analysis of the data, it can be noted that there are no significant differences between the cultivars analyzed regarding this parameter.

Table 4.The amount of water in the leaves and petals

Cultivar	Dry matter in fresh leaves (%)	Water in fresh leaves (%)	Dry matter in fresh petals (%)	Water in fresh petals (%)
Acapella	0.55	99.45	0.86	99.14
Caprice de Meilland	0.57	99.43	0.84	99.16
Cristiana	0.61	99.39	0.83	99.17
Fisherman's Friend	0.62	99.38	0.88	99.12
Nobilia	0.63	99.37	0.84	99.16
Pasiune în mov	0.58	99.42	0.86	99.14
Romstar	0.64	99.36	0.90	99.10
Sandra	0.64	99.36	0.86	99.14
Snow Owl	0.58	99.42	0.85	99.15

Analyzing the data presented in Table4, it is noted that the petals of the `Romstar` cultivar show the highest percentage of dry matter (0.90%) and the lowest percentage of water content (99.10%). On the other hand, the `Cristiana` cultivar shows the lowest percentage of dry matter (0.83%) and the highest percentage of water content (99.17%). From the analysis of the data, it can be noted that there are no significant differences between the cultivars analyzed regarding this parameter.

Studies conducted by Moldovan et al. (2023) on the geranium cultivar `Tango Dark Red` led to results similar to those obtained by us, with mean fresh mass values in leaves of 80.50% and 92.70% in flowers. The distillation yields calculated for the aqueous extracts from rose petals are 98.2%. Following the qualitative tests regarding the intensity and persistence of the fragrance of the aqueous extracts, determined at 24 h, it was found that the distillate of the extract presents an intense and persistent fragrance. As a result of the qualitative tests regarding the intensity and persistence of the fragrance of the alcoholic extracts, determined at 24 h, it was found that they decrease in the following order, depending on the cultivar: `Fisherman's Friend`, `Cristiana`, `Snow Owl`, and `Romstar`. Yeon & Kim (2020) showed the negative impact of short-term heat stress on the synthesis of pigments or scent compounds. After performing the qualitative tests regarding the intensity and persistence of the fragrance of the oily extracts, determined at 24 h, it was found that they decrease in the following order, depending on the oil used: jojoba oil, coconut oil, olive oil, and linseed oil.

CONCLUSIONS

Studying the behavior and tolerance of fragrant rose cultivars to high temperatures, within the context of climate change, can contribute to optimizing productivity, improving the quality of aromatic compounds, and selecting heat-stress resistant genotypes.

The optimal temperature for rose production is 20-25°C. High temperatures (over 30°C) negatively affect production, being directly involved in photosynthesis. Rose plant height differs for each cultivar, being a genetic characteristic, but is also shown to be significantly influenced by temperature; temperatures over 30°C affect the vegetative tips of the plants, with significant differences recorded compared to measurements made at lower temperatures.

Temperatures over 30°C also affect chlorophyll biosynthesis, which occurs optimally between 16°C and 25°C. Under certain limits, there is a direct correlation between chlorophyll content and the intensity of photosynthesis. Regarding chlorophyll fluorescence, the optimal photosynthesis temperature for the studied cultivars is 26°C, while 16°C and 32°C are suboptimal and respectively supra-optimal temperatures.

Among the distilled aqueous extracts, the alcoholic extract from the petals of the `Fisherman's Friend` cultivar shows the most intense fragrance and the highest degree of persistence at 24 hours. Among the oil extracts, jojoba oil demonstrated the best ability to extract and the best persistence of the scent.

The research sought to elucidate how heat stress influences plant physiology, focusing on the process of photosynthesis - which supports growth - and the resulting biosynthesis of secondary metabolites, such as those responsible for the fragrance of rose petals.

The information obtained through our research can be useful to rose breeders, especially in regions where hot and humid conditions prevail.

ACKNOWLEDGEMENTS

The authors thank the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca-Horticultural Research Station for supplying all facilities and cooperation in carrying out this research.

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