Research Progress on Peony under High Temperature Stress Caused by Climate Warming

Bingxue Zhao[1, a], Qingjun Huang[1, b*]

[1]College of Ecological Technology and Engineering, Shanghai Institute Of Technology, 201418 Shanghai, China

Abstract: Global warming and worsening environmental problems have worsened the heat resistance of peony and difficult maintenance and management. The high temperature stress caused by the environment has become an important environmental factor for the growth and development of peony. The article summarizes the morphology, yield, physiological and biochemical indicators and research status of peony under high temperature stress; summarizes the research status of peony heat tolerance evaluation index screening, germplasm heat tolerance evaluation and heat-resistant peony breeding, in order to promote tolerance Selection and breeding process of hot peony germplasm resources. At present, related researches on peony mainly focus on pharmacological effects and germplasm resources. The physiological mechanism of high temperature and breeding of heat-resistant varieties of peony are relatively lagging behind. In-depth study of the physiological mechanism of high temperature in peony combined with multi-omics will help to adopt technical measures to improve the heat tolerance of high plants and reduce heat damage, so as to speed up the selection and breeding of heat-resistant peony germplasm, and meet the survival and medicine of peony in harsh environments. Use and other needs.

1 Introduction

Peony (*Paeonia suffruticosa Andr.*) is an ornamental flower of the peony group of the genus Paeoniaceae[1]. It has rich fragrance, large flower shape and bright colors, and enjoys the reputation of "the king of flowers". As a traditional flower in our country, peony is widely sought after by scholars and scholars in classical gardens. Nowadays, the demand for peonies is increasing. On the one hand, with the increasing demand for the diversity of landscape plant varieties in urban garden construction, peonies have both ornamental and cultural value, and are often used in park green spaces, temple gardens, etc. in the form of solitary planting, cluster planting, group planting, and flower belts, Garden beautification, most botanical gardens set up special peony gardens and peony gardens in order to enhance the diversity of landscape species and beautify the living environment[2-3]; on the other hand, peony is a medicinal and food with nutritional value and economic benefits. For dual-purpose plants, enterprise nurseries and scientific research institutes use a large number of peonies for product processing and new varieties selection. Therefore, peony has a demand for "migrating from the north to the south" in the Jiangnan region.

Peony loves warm and cold climate, the average suitable temperature is 12℃-15℃, and the critical temperature for growth is 10℃-18℃[4]. Summer in Jiangnan is hot and humid, and the temperature is continuously higher than 26℃, which inhibits the normal growth of peony and makes it enter semi-dormant[5], resulting in stunted growth of peony, shortened growth period, and increased artificial maintenance costs. This restricts the greening of peony in Jiangnan area. The primary factors for cultivation and promotion[6]; secondly, the peony varieties used in garden landscapes are mainly‘Yulouchun’, ‘Hu Hong’, ‘Fengdanbai’, ‘Luhe Red’, ‘Hui Zi’, etc. Most of them are introduced in Japan and the Central Plains of China. Compared with other flower varieties, they are relatively single and lack new peony strains with Jiangnan characteristics[7]. In addition, the greenhouse effect has caused frequent high-temperature weather in the south of the Yangtze River, sometimes even as high as 40℃. High temperature is often accompanied by serious pests and diseases, which affects the vegetative growth, morphological structure and floral organ characteristics of the peony, resulting in a decline in peony quality, weak plant growth, and reduced ornamental properties, And ultimately restrict the application scope of peony[8].

2 The effect of high temperature on the morphology, yield and quality of peony

Plant morphology is one of the key indicators to measure plant heat tolerance. Sustained high temperature causes

[a]15201817697@163.com
[*]Corresponding author’s e-mail: [b]huangqingjun@163.com

peony growth obstacles, which are mainly reflected in the damage to the leaves of the vegetative organs, such as leaf scorching, tissue damage, and growth retardation [9]. Zheng Yanwei[10] observed the field morphological indicators of 6 Jiangnan peony varieties, and the results showed that with the prolonging of high temperature, the leaf lesions increased, the texture became thicker, and gradually changed from green to yellow or even scorched; compared with heat-resistant varieties 'Fengdanbai', Compared with 'Yuhong', the heat-sensitive varieties 'Huhong' and 'Yunfang' took shorter time to scorch the leaves, and the symptoms of heat damage were serious. Li et al.[11] found that with the prolongation of high temperature treatment, the leaf stalks of potted 'Fengdan' became soft and drooping, and the root vigor of the plant inoculated with AM fungus (Arbuscular Mycorrhizal) was higher than that of the control; Guo et al.[12] Inoculate 2 kinds of AM fungi, compare their leaf anatomical structure (palisade tissue and sponge tissue), the study found that the AM fungus G. mosesii's 'Fengdan' leaf cells are arranged more tightly and plants are compared with AM fungus G. mosesii The growth is better; Ren et al.[13] used epibrassinolide (EBR) at a concentration of 1.0 mg/L to treat the ultrastructure of 'fengdan' leaves under heat stress, and found that the cell membrane, chloroplast and other structures were compared The control is more complete. It shows that heat-resistant peony varieties have stronger ability to resist heat damage, and AM fungus or EBR treatment can reduce the damage of peony cell structure.

The continuous high temperature aggravated the heat damage to the stems and leaves of the peony, resulting in the hindrance of the growth of the underground root system of the peony, the decline of the plant, and the reduction of the yield and quality of the peony[14]. Zhang and Wu[8,15] sprayed three exogenous substances on peony seedlings in the late stage of high temperature stress (>4 d), and the results showed that the concentrations were 40 mg/L abscisic acid (ABA) and 100 mol/L salicylic acid (SA), 40 mmol/L calcium chloride ($CaCl_2$) can significantly improve the dry quality of each part of peony and relieve high temperature damage.

It can be seen that high temperature stress causes scorching, growth retardation, and dry weight reduction of peony leaves; the stronger the heat tolerance of peony varieties, the less affected by high temperature stress; the inoculation of AM fungi or spraying of $CaCl_2$, ABA, SA, EBR, etc. has hormones Exogenous substances with regulatory effects can adapt peony to high temperature to a certain extent and improve the heat tolerance of plants[16]. The study of exogenous hormones provides a basis for alleviating the problem of high temperature stress in peony.

3 The effect of high temperature on the physiology and biochemistry of peony

Under high temperature stress, plant enzyme activity, chlorophyll content, cell membrane permeability, antioxidant system and other indicators are all affected. The physiological and biochemical indicators of peony are mainly developed through the following aspects.

3.1 The effect of high temperature on the permeability of peony cell membrane

High temperature adversity increases plant plasma membrane permeability and electrolyte osmotic pressure, which leads to an increase in the electrical conductivity of the plant tissue extract[17]. The relative permeability and relative electrical conductivity (Rec) of the cell membrane are used to determine the high temperature adaptability of plant tissues. Important indicators[18]. Qian Guang et al.[19] found that with the increase of temperature(30, 35, 40℃), the relative permeability of the leaf cell membrane of the three peony varieties increased, which is consistent with the results of Luo et al.[20]; in 40℃, the relative permeability of the leaf cell membrane of 'Fengdanbai' increased the least, followed by 'Yingjinhong', and 'Luoyanghong' was the most significant, indicating that the heat tolerance of 'Fengdanbai' was higher than that of the other two varieties. Ren et al.[13] found that with the increase of EBR concentration, the Rec of 'Fengdan' leaves showed a trend of first decline and then rise. The above studies show that the relative permeability and Rec of peony cell membrane are proportional to temperature. Rec is an important indicator to measure the heat resistance of peony; EBR can reduce the effect of high temperature on lipid membrane permeability to a certain extent, inhibit the rise of Rec, and protect the cell membrane. Completeness.

Malondialdehyde (MDA) is the final product of plant cell membrane lipid peroxidation. The more its content, the greater the degree of membrane lipid peroxidation. Therefore, MDA content can be used as an important physiological index to measure the degree of plasma membrane damage. Liu Chunying et al.[21] and Qian Guangyao et al.[19] treated 'Rut Furong' and 'Fengdanbai', 'Ying Jinhong', and 'Luoyang Red' respectively at 30, 35, and 40 ℃ high temperature and strong light, and found that their leaves MDA content showed an upward trend; Zheng et al.[10] showed that the MDA content of 6 peony varieties increased first and then decreased with the prolonging of high temperature adversity time. The increase rate of different peony varieties was different, and the increase rate of heat-resistant peony varieties was relatively less than that of temperature-sensitive peony varieties. Variety: The decrease in MDA content may be due to damage to the cell membrane of peony leaves and disorder of defense function, which hinders the synthesis of MDA. The experimental results of the above research on the effect of high temperature on the MDA content of peony are different, but the conclusion that high temperature increases the degree of membrane lipid peroxidation in peony leaves is consistent. Ren et al.[13] found that the MDA content of'Fengdan' leaves decreased first and then increased with the increase of EBR concentration, indicating that EBR can inhibit the accumulation of MDA and reduce the degree of membrane lipid damage; Zhang Minhuan and Wu et

al.[8,15] showed that Spraying SA, $CaCl_2$, and ABA can alleviate the increase in MDA content of peony leaves, inhibit membrane lipid peroxidation, and promote plant recovery.

3.2 The effect of high temperature on peony osmotic adjustment substances

High temperature stress causes plant water stress and osmotic stress, leading to the destruction of plant cell system balance. Under mild to moderate stress, plant cells actively accumulate various solutes, reduce osmotic potential, and increase the ability of cells to absorb and retain water in a short period of time, thereby maintaining the stability of the biofilm structure[22]. Osmotic adjustment substances have the functions of regulating and protecting plant cell systems, including free proline (Pro), soluble protein (SP), soluble sugar (SS) and so on.

Xu et al.[6] found that the Pro content of the 5 peony varieties increased with the intensification of high temperature adversity, and then decreased relative to a certain peak after accumulation. The decrease of 'Rushi Furong' was the smallest, the decrease of 'Luhe Red' was the largest, and the relative decrease of Pro content was possible. It is due to the oxidation environment in the plant that limits the degradation of Pro; the accumulation of Pro of heat-resistant peony varieties is higher than that of temperature-sensitive varieties, indicating that Pro can be used to identify plant heat tolerance. Qian et al.[19] studied the three peony varieties of 'Fengdanbai', 'Yingjinhong' and 'Luoyanghong' and found that the SP content of different peony varieties under high temperature stress had different trends (the SP content of 'Luoyanghong' (Fengdanbai and Yingjinhong rise first and then fall). The SP accumulation of heat-resistant variety 'Fengdanbai' is higher than that of temperature-sensitive variety 'Luoyanghong'. Experiments have shown that high temperature promotes the increase of SP content , SP accumulation is positively correlated with plant heat resistance, indicating that SP can also be used to identify plant heat resistance. Zhang et al.[8] found that as the time of high temperature stress prolonged, the Pro content of 'Fengdan' increased sharply and then decreased rapidly, and the Pro content of 'Xiangdan' increased slowly and then gradually decreased; the SP content of the two peony cultivars were both expressed as First rise and then fall, 'Xiangdan' is always higher than 'Fengdan'; the SS content of the two peony first tends to be flat, then rises sharply and then drops sharply, 'Fengdan' is always higher than 'Xiangdan', indicating different peony varieties The osmotic adjustment substances of peony are different, and the time for different osmotic adjustment substances of the same peony variety to play the role of adjustment and protection is different. Spraying EBR, SA, $CaCl_2$, ABA on peony leaves in the late stage of high temperature stress can effectively increase the content of Pro and SP, reduce the content of SS, and reduce the high temperature damage of peony[8,13,15].

3.3 The effect of high temperature on the activity of peony antioxidant enzymes

Under high temperature stress, activating enzymes in plant tissues are inactivated to generate a large amount of reactive oxygen species (ROS), resulting in impaired plant functions, and the antioxidant enzyme system can remove excess ROS, thereby reducing the degree of cell oxidation. Superoxide dismutase (SOD) is a key enzyme for plant oxygen metabolism. It prevents oxygen free radicals from damaging cells and relieves membrane lipid peroxidation through disproportionation reaction; peroxidase (POD) can remove H_2O_2 and other oxides and reduce oxidation capacity Stronger -OH production, reducing membrane system damage, is one of the commonly used indicators of plant antioxidant stress[19, 23].

Luo et al.[20] compared the POD activity of peony leaves under the stress of 25, 30, 35, and 40 ℃, and found that the change of POD activity first decreased and then increased (30℃ reached the lowest value), which may be due to the high environmental temperature Caused short-term physiological disorders of peony, leading to the hindrance of POD synthesis, and POD continued to exert its defense function after the adaptation period; under the same temperature conditions, Xu et al.[6] found that the change trend of POD activity of 5 peony varieties was in line with the research results of Luo et al.[20] The increase in POD activity of heat-resistant varieties 'Roufurong and Wulong Pengsheng' is less than that of temperature-sensitive varieties 'Luhehong' at 35～40℃, indicating that high temperature has more damage to the POD activity of temperature-sensitive varieties. Significantly, Qian et al.[19] compared the SOD activity of 'Fengdanbai', 'Yingjinhong', and 'Luoyanghong' at high temperatures of 25, 30, 35, and 40 ℃, and found that the SOD activity of each peony variety showed an upward trend and then a downward trend. (The peak value is reached at 35℃), which is consistent with the results of Xu et al.[6], Liu et al. and others[21]; and the decrease in SOD activity of the heat-resistant peony variety 'Fengdanbai' is smaller than that of the temperature sensitive variety 'Luoyanghong'.

3.4 The effect of high temperature on photosynthesis, respiration and transpiration of peony

Chlorophyll (Chl) content is an important indicator to measure the light absorption and light conversion of plants. Under high temperature adversity, the reversible chlorophyll thylakoid membrane leaks, the chloroplast structure is damaged, and the vitality is reduced, which leads to the hindrance of plant chlorophyll synthesis and the reduction of photosynthetic rate[24,25]. Zhang et al.[8] found that with the prolonging of high temperature (40℃) adversity time, the Chl content of 'Fengdan' and 'Xiangdan' both showed a downward trend, and the decline of'Fengdan' was less than that of'Xiangdan'; spraying SA, $CaCl_2$ ABA and ABA can alleviate Chl degradation of peony leaves. The above results indicate that high temperature stress reduces the Chl content of

peony, and the chlorophyll of heat-resistant peony varieties is not easily destroyed and decomposed, and has better heat resistance, which may also be the reason why the plants undergo heat tempering.

High temperature stress directly affects plant photosynthesis, transpiration and respiration rate. At present, a large number of experiments have carried out research on the chlorophyll fluorescence parameters of peony[21], net photosynthetic rate (Pn)[19,26], stomatal conductance (Gs)[12] and other indicators. High temperature causes physiological damage to peony leaves, which is manifested in the relative decrease in stomatal conductance, net photosynthetic rate, and respiration rate. Studies have shown that the smaller the decrease, the stronger the heat resistance[19,26]. The measurement indicators of chlorophyll fluorescence parameters include the excitation energy capture efficiency (Fv'/Fm'), maximum photochemical efficiency (Fv/Fm), maximum fluorescence yield (Fm), photochemical quenching coefficient(qP), Actual optical quantum efficiency, non-photochemical quenching coefficient (NPQ), etc.

4 Peony response to high temperature stress related genes

At present, there are many related researches on peony response to low temperature stress, mainly focusing on the effect of specific genes on peony dormancy[27,28], while the research on peony heat-resistant genes is relatively lagging, mainly focusing on heat shock transcription factors (HSF). HPS70 family is a kind of heat shock protein. HPS70 gene can prevent protein degradation under heat stress, improve plant heat tolerance, and can be used as an important indicator for evaluating plant heat shock[30]. Li et al.[31] cloned the full-length cDNA of the HPS70 gene of ‘Juan Yehong’ and found that it has extremely high amino acid homology with the HPS70 amino acid of the same genus Paeonia lactiflora, proving that *PsHPS70* is a peony heat shock protein gene. Zhang et al.[29] sequenced the transcriptome of peony leaves under high temperature conditions and identified 24 potential heat shock protein genes (HSF) in peony. Jiang Changhua et al.[32] used heat-resistant variety ‘Fengdanbai’ and heat-labile variety ‘Haihuang’ as experimental materials, and found that the PseIF5A gene of peony can be expressed after heat shock treatment in ‘Fengdanbai’, but in ‘Fengdanbai' Haihuang’ does not express, verifying that the heat tolerance of peony varieties is positively correlated with the expression level, while the heat-labile varieties are weakly expressed or not expressed; studies have shown that the recombinant strain of ‘Fengdanbai’ gene can respond to high/low temperature stress, high Abiotic stresses such as pH, heavy metals, and high salinity.

5 Conclusions and prospects

Cross breeding is the most common peony breeding technology. However, the selection of cross parents affects the compatibility of crosses, leading to problems such as fertilization obstacles, stunted growth, and reduced resistance. The use of pollination methods, cross combination selection, embryo rescue and other technologies Improve the efficiency of peony germplasm innovation; Polyploidy has more excellent ornamental traits such as thick leaves and large flowers in other flowers, and is relatively resistant. The application of polyploidy to the breeding of peony varieties will help restore the fertility of hybrid parents and improve the compatibility of distant hybrids. Sexual and genetic parental resistance of hybrid offspring; The use of SSR molecular marker technology to assist genetic engineering is conducive to increasing the gene transformation rate, and also conducive to clarifying the genetic diversity and genetic relationship of peony planting resources, providing a basis for the utilization and innovation of peony germplasm resources.

Therefore, drawing on the advanced technology of selection and breeding of other flower varieties at home and abroad, and combining the ornamental characteristics, resistance, economic benefits and maintenance costs of peony to carry out high-temperature resistant peony germplasm innovation can not only provide new materials for urban garden construction, but also meet the requirements of landscape greening, Garden decoration and other needs, and play an important role in promoting the development of the peony medicine and food industry and carrying forward the Chinese peony culture.

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