Evaluation of Cold Resistance and Semi-lethal Low Temperature (LT_{50}) of Nine Pear Cultivars

Huan LIU, Lijuan GAO, Jintao XU, Minghui JI, Longfei LI, Baofeng HAO*

Changli Institute of Pomology, Hebei Academy of Agriculture and Forestry Sciences, Changli 066600, China

Abstract [**Objectives**] To evaluate the cold resistance and semi-lethal temperature of pear cultivars, and provide a theoretical basis for the regional extension and breeding of cold-resistant pear cultivars. [**Methods**] Nine pear cultivars were used to study the changes in relative conductivity and cell injury rate of pear branches under low temperature stress, and the semi-lethal temperature (LT_{50}) of pear branches was analyzed by fitting Logistic equation. [**Results**] The relative conductivity and cell injury rate of pear branches took on the trend of slow increase, rapid increase, and slow increase the decrease of treatment temperature. The LC_{50} of the nine pear cultivars were as follows: Nanguo pear -33.9 ℃, Wanyu -32.3 ℃, Red D'Anjou -31.8 ℃, Jinfeng -31.3 ℃, Wujiuxiang -29.2 ℃, 20th Century Pear -29.1 ℃, Hanxiang -35.1 ℃, Yuluxiang -27.9 ℃ and Korla Fragrant Pear -29.2 ℃. [**Conclusions**] The semi-lethal temperature could reflect the cold resistance of pear trees, and Wanxiang had better cold resistance. The evaluation of cold resistance and semi-lethal temperature of pear cultivars can provide theoretical basis for regional extension and breeding of cold-resistant pear cultivars.

Key words Pear, Cold resistance, Semi-lethal temperature (LT_{50}), Low temperature

1 Introduction

Pyrus plant belongs to Rosaceae, Pyriaceae or Maloideae[1]. It is the third largest fruit in China, and its cultivation area and yield are in the forefront of the world[2]. Low temperature environment will cause freezing injury to pear trees, resulting in yield reduction or even destruction of orchards[3-4]. Therefore, the study on the cold resistance of pear trees provides a theoretical basis for the regional extension of pear cultivars and the breeding of cold-resistant varieties. It is one of the most convenient and fast methods to determine the cold resistance of pear by conductivity method. At present, many scholars have used this method to identify the cold resistance of fruit trees, such as *Hylocereus undatus* (Haw.) Britton & Rose[5], *Vitis vinifera*[6-7], *Prunus salicina*[8], *Malus pumila*[9], *Vaccinium vitis-idaea*[10-11] and so on.

In this study, the cold resistance of pear cultivars was evaluated by measuring the changes in relative conductivity and cell injury rate of pear branches under low temperature stress, and combining with the semi-lethal temperature (LT_{50}) obtained from Logistic curve equation.

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Huan LIU, assistant researcher, research fields: pear breeding and cultivation technology.

* Corresponding author. Baofeng HAO, researcher, research fields: pear breeding, cultivation physiology and plant protection.

2 Materials and methods

2.1 Experimental materials The experiment was carried out in pear orchards of Kongzhuang Village Base (119°05′ 41″ E, 39°42′ 29″ N), Changli Institute of Pomology, Hebei Academy of Agriculture and Forestry Sciences. The nine pear cultivars were Nanguo pear, Wanyu, Red D'Anjou, Jinfeng, Wujiuxiang, 20th Century pear, Hanxiang, Yuluxiang and Korla Fragrant Pear. The experiment was carried out in 2023, and the pear trees with healthy tree body, consistent tree age and similar tree shape were selected for the experiment.

2.2 Experimental methods Seventy annual dormant branches with uniform growth, strong growth and no diseases and insect pests were collected, and the middle sections were selected. The collected branches were washed twice with tap water and distilled water in turn, dried with white clean gauze, and the cut openings at both ends of the branches were sealed with paraffin. Each cultivar was divided into 7 groups, one group was stored at 4 ℃ as control (CK), and the other 6 groups were stored in self-sealing bags at -15, -20, -25, -30, -35 and -40 ℃, respectively. The temperature drop rate was 4 ℃/h, and the conductivity was measured by thawing after 12 h after reaching the treatment temperature. Each treatment was repeated 3 times.

2.3 Data processing and analysis Microsoft Excel software was used to arrange data and plot, and Origin software was used to fit Logistic equation. The Logistic equation $y = k/(1 + ae^{-bt})$ was used to fit the relative conductivity and treatment temperature. In the equation, y is the relative conductivity; t is the treatment temperature; k is the saturation capacity of the relative conductivity; a and b are the equation parameters. The values of a and b and the correlation coefficient (R^2) were calculated to obtain the semi-lethal temperature (LT_{50})[12-15], and the relative conductivity and cell injury rate were calculated according

to the method of Deng Renju *et al.* [16].

3 Results and analysis

3.1 Relative electrical conductivity of nine pear cultivars under different low temperature treatments As shown in Fig. 1, with the decrease of treatment temperature, the relative conductivity of the nine pear cultivars showed an upward trend. The relative conductivity increased slowly at the beginning of low temperature treatment, then increased sharply with the decrease of temperature, and finally increased slowly and tended to be stable. From 4 ℃ to −20 ℃, the relative conductivity of 9 pear cultivars increased slowly, and most of them were less than 40%. However, the relative conductivity increased greatly between −20 ℃ and −35 ℃, and the relative conductivity was greater than 50% after low temperature treatment at −35 ℃. The relative conductivity of different pear cultivars branches changed differently with the decrease of temperature. Specifically, the relative conductivity of Nanguo Pear, Wanyu and Wanxiang increased slowly before −30 ℃, and increased significantly at −35 ℃, and separately increased by 27.9%, 21.2% and 23.3% from −30 ℃ to −35 ℃; however, Wujiuxiang, 20th Century Pear, Yuluxiang and Korlar Fragrant Pear increased significantly at −25 ℃, and increased by 14.1%, 19.9%, 32.5% and 27.4%, respectively.

It can also be seen from Fig. 1 that under the same low temperature treatment, the relative conductivity of different pear cultivars was different. At 30 ℃, the relative conductivity of Nanguo Pear and Wanxiang was significantly lower than that of the other seven pear cultivars, indicating that Nanguo Pear and Wanxiang had higher cold resistance, and the relative conductivity of Yuluxiang was higher than that of the other 8 pear cultivars.

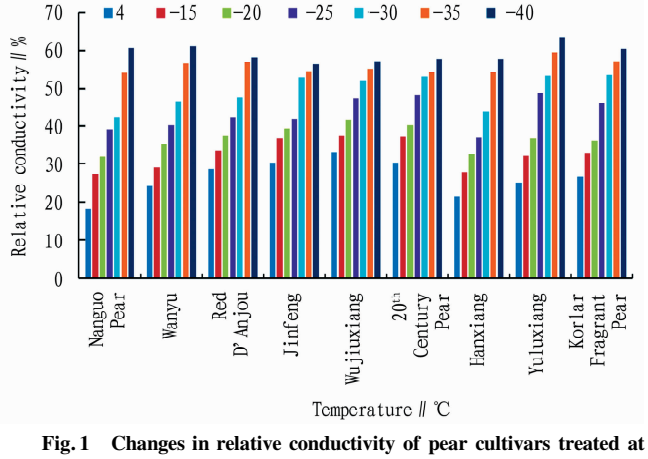

Fig. 1 Changes in relative conductivity of pear cultivars treated at low temperatures

3.2 Cell injury rates of nine pear cultivars under different low temperature treatments From Fig. 2, it can be seen that the cell injury rate of the 9 pear cultivars increased with the decrease of the treatment temperature. When the temperature is between −15 ℃ and −20 ℃, the cell injury rate is slowly increased, and the cell injury rate below −20 ℃ was lower than 20%. When the temperature was dropped to −30 ℃, the cell injury rate of most pear cultivars was greater than 30%. The cell injury rates of different pear cultivars were different with the decrease of temperature. Specifically, the injury rates of Nanguo Pear, Wanyu, Red D'Anjou and Wanxiang separately increased by 48.9%, 44.5%, 49.1% and 45.7%, from −30 ℃ to −35 ℃. The results showed that Nanguo Pear, Wanyu, Red D'Anjou and Wanxiang had better cold resistance.

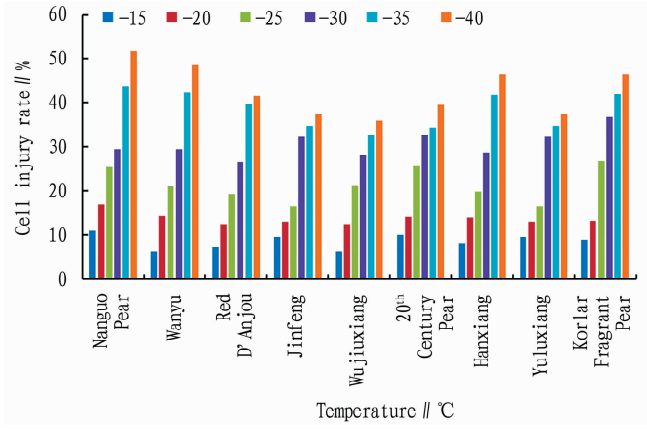

Fig. 2 Changes in cell injury rate in different pear cultivars treated at low temperatures

3.3 Evaluation of cold resistance and semi-lethal temperature of pear cultivars Logistic regression equation was used to analyze the relative conductivity of pear branches under different low temperature treatments, and the semi-lethal temperature (LT_{50}) was calculated. The results showed that the relationship between the relative conductivity and temperature of the nine pear cultivars could be well fitted by Logistic curve equation, and the fitting degree R^2 was 0.900 6 − 0.950 8. It can be seen from Table 1 that the LT_{50} of Wanxiang and Nanguo Pear branches was lower, which was −35.1 ℃ and −33.9 ℃, indicating that Wanxiang and Nanguo Pear had stronger cold resistance. The LT_{50} of Wujiuxiang, 20th Century Pear and Yuluxiang was higher. Among them, Yuluxiang was the highest, indicating that its cold resistance was weak, and the LT_{50} of Wanyu, Red D'Anjou and Jinfeng was lower than that of Wujiuxiang, 20th Century Pear and Yuluxiang, and higher than that of Wanxiang and Nanguo, indicating that their cold resistance was moderate.

Table 1 Parameters of Logistic fitting equation and semi-lethal temperature

No.	Cultivars	Parameter of equation		LT_{50} // ℃	Fitting degree (R^2)
		ln (a)	b		
1	Nanguo Pear	1.506 0	−0.044 3	−33.9	0.950 8
2	Wanyu	1.218 5	−0.037 7	−32.3	0.902 2
3	Red D'Anjou	0.975 3	−0.030 6	−31.8	0.900 6
4	Jinfeng	0.844 2	−0.026 9	−31.3	0.908 7
5	Wujiuxiang	0.720 7	−0.024 7	−29.2	0.916 7
6	20th Century Pear	0.812 7	−0.027 9	−29.1	0.947 9
7	Wanxiang	1.348 0	−0.038 4	−35.1	0.910 0
8	Yuluxiang	1.120 8	−0.040 3	−27.9	0.919 1
9	Korlar Fragrant Pear	1.053 4	−0.036 0	−29.2	0.919 8

4 Discussion and conclusions

Under low temperature stress environment, the permeability of cell membrane of fruit trees is enhanced, which leads to the leakage of electrolyte in cells and the increase of conductivity. Therefore, the relative conductivity is used as an important indicator to identify the damage of fruit tree cells caused by low temperature[5]. In this study, the relative conductivity of the 9 pear cultivars increased with the decrease of treatment temperature, which was similar to the results of Wang Hongping *et al.*[17]. The cell injury rate can reflect the degree of cell membrane injury of pear trees. The results of this study show that with the decrease of temperature, the cell membrane injury rate shows an overall upward trend, which is similar to the results of Jiang Yuan *et al.*[18].

Low semi-lethal temperature refers to the temperature at which the plant reaches a semi-lethal state. At present, many scholars have used the semi-lethal temperature to evaluate the cold resistance of plants, such as *Juglans regia*[19], *Vitis vinifera*[20] and so on. In this study, we found that the LT_{50} of the nine pear cultivars were as follows: Nanguo pear −33.9 ℃, Wanyu −32.3 ℃, Red D'Anjou −31.8 ℃, Jinfeng −31.3 ℃, Wujiuxiang −29.2 ℃, 20th Century Pear −29.1 ℃, Hanxiang −35.1 ℃, Yuluxiang −27.9 ℃ and Korla Fragrant Pear −29.2 ℃. The semi-lethal temperature can reflect the cold resistance of pear trees, and Wanxiang has better cold resistance, which is similar to the research results of Li Jinpu *et al.*[21].

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