

# 晚霜对 13 个梨品种(系)幼果发育及果实品质的影响

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**摘要:**【目的】了解不同梨品种(系)幼果抗晚霜的能力, 为筛选抗晚霜优良品种(系)提供参考。【方法】于 2020 年 4 月 22—23 日霜冻发生后调查 13 个梨品种(系)的幼果受冻情况、花序和花朵坐果率以及霜冻对成熟果实外观和内在品质的影响。【结果】幼果在树冠上的位置越高, 冻害指数越低, 花序坐果率和花朵坐果率越高。受冻害较轻的幼果仍能正常生长发育, 但部分果面受冻产生的斑点和裂纹会形成明显的霜斑和凹陷, 影响果实外观; 部分果实无种子, 对单果质量、果实硬度及可溶性固形物含量影响不大。调查的 13 个品种(系)中, 金光、SJ051105、美玉、黄冠、冠玉在 1.5 m 处幼果冻害指数低于 51%, 平均花序和花朵坐果率分别在 81% 和 32% 以上, 一级以上果所占比例超过 83%, 能够满足生产需要。【结论】初步判断, 金光、SJ051105、美玉、黄冠、冠玉等 5 个品种(系)的抗晚霜能力较强。

关键词: 梨; 幼果; 晚霜; 抗性

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## Effects of spring frost on young fruit development and fruit quality in 13 pear varieties (strains)

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**Abstract:** 【Objective】The large-scale frost damage in the north of China in spring has a great impact on apple, pear and other fruit production in China. Knowing the characteristics and occurrence of this hazard is important for measures to prevent it effectively. Breeding varieties with strong resistance to spring frost is the most effective way to deal with frost damage. Extreme frosts can be utilized to screen varieties (strains) resist to frost and evaluate the resistance of different pear varieties. 【Methods】After the spring frost from April 22 to 23, 2020, young fruits of different pear varieties were divided into four grades according to their damage degrees. The damage grades of young fruit at tree heights of 1.5 m, 2.0 m and 2.5 m in 13 pear varieties (strains) were investigated and the freezing injury indexes were calculated. Two weeks later, the fruit set based on cluster and flower were investigated. After harvest, fruit were divided into four grades according to the degree of damage on fruit surface to investigate the effect of spring frost on fruit external appearance. The weight, hardness and soluble solid content of fruit were measured to investigate the effect of frost on edible quality. 【Results】The lowest temperature on April 22 was  $-4.4\text{ }^{\circ}\text{C}$ , and the duration of sub-zero temperature reached 6.5 h; the lowest temperature on April 23 was  $-3.7\text{ }^{\circ}\text{C}$ , and the duration of sub-zero temperature reached 7.5 h. Symptoms of freezing damages on young pear fruit included whole fruit blacking, fruit wilting, development of blister-like white spots on fruit surface and cracks, and flesh and seed blacking or browning. There were significant differences in frost resistance of young pear fruit among different varieties. Fruit from higher tree cano-

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py had a lower frost damage index. The freezing injury indexes of Jinguang, SJ051105, Huangguan, Meiyu and Guanyu were lower than that of the other varieties, and their freezing injury indexes at 1.5 m were 34.00%, 45.67%, 48.67%, 50.33% and 50.67%, respectively. The young fruits of these five varieties had stronger resistance to spring frost. The freezing injury indexes of 041901, 041890 and Qiulu were 75.00%, 79.00% and 88.33% at 1.5 m, respectively, which showed weak resistance to spring frost. The young fruits with light damage-maintained growth. The fruit set in Jinguang, SJ051105, Guanyu, Huangguan and Meiyu was higher; the average cluster fruit set exceeded 81%; and the average flower fruit set was higher than 32%. The average fruit set based on cluster in Qiuguang, Qiulu, 041025, 041890 and 041901 was lower than 45%; the average fruit set based on flower was lower than 18% and the young fruit setting rate was frail. The freezing injury index of young fruit and average fruit set rates based on cluster were significantly positively correlated at different heights. At the same height, there was a significant negative correlation between freezing injury index and cluster fruit set rate; the same was with the freezing injury index and fruit set based on flower. There was a significant positive correlation between fruit set based on cluster and flower. Spots and cracks developed on young fruit exposed to spring frost. The proportions of normal fruit in Jinguang and SJ051105 reached 95.2% and 93.21%, respectively. They were the only two varieties with almost no defective fruit. Except for SJ051105 and Meiyu, single fruit weight decreased in all varieties, and fruit firmness in Xuehua and 041025 increased. Fruit quality in the other varieties did not change significantly. The results showed that spring frost damage had little effect on the quality of the fruit, which recovered the normal growth and development. Therefore, it is necessary to keep as many fruits as possible after the occurrence of frost damage.

**【Conclusion】** The damage degree of young pear fruit is related to the temperature at the time of frost, and the temperature around the tree increased with tree height and the damage of young fruit at higher canopy position is lighter. Spring frost injury has a great effect on the appearance of the fruit which maintain normal growth and development, but has little effect on their eating quality. Therefore, it is recommended to keep more fruit after the occurrence of frost injury. Jinguang, SJ051105, Guanyu, Huangguan and Meiyu have a better frost resistance than the other investigated varieties. Fruits of some varieties maintain normal growth after freezing injury, but seed development is strongly affected.

**Key words:** Pear; Young fruit; Spring frost; Resistance

我国北方地区春季频发的霜冻灾害(俗称“倒春寒”)经常导致果树大面积减产,甚至绝收<sup>[1-2]</sup>,近年来霜冻发生次数多、时间晚且程度严重。2020年4月下旬突袭的霜冻灾害导致我国北方梨主产区受灾严重,尤其是河北中南部产区,受灾面积较2019年增加70%~80%。此时正值幼果发育初期,抗霜冻能力较差,连续两日夜间长时低温,导致幼果受害严重,给梨产业造成了巨大损失。因此,掌握晚霜对幼果的危害特征及发生发展规律,可以更有效地进行防范。同时,极端气候条件也是发现优良抗性品种的契机。为此笔者对梨树种质资源圃中多个品种(系)的幼果受害情况进行了调查,为进一步筛选抗晚霜优良品种提供参考。

## 1 调查方法

### 1.1 调查地概况

试验地位于石家庄市的河北省林业和草原科学研究院,北纬38°8'28",东经114°28'9",属暖温带大陆性季风气候,最低温一般出现在12月至2月,3—4月易发生霜冻危害。梨资源圃内现保存品种及品系约200份。

安装了杭州路格科技有限公司生产的L95-4型自动温湿度记录仪,记录0(地表)、1.0、2.0、3.0、10.0 m处温度,每0.5 h记录1次。

### 1.2 幼果冻害情况调查方法

霜冻发生后,调查了资源圃内黄冠、雪花、黄金、

冠玉、美玉、迎霜、秋光、秋露、金光、SJ051105、041025、041890和041901共13个品种(系)幼果的受冻情况并拍照。其中秋光、迎霜于2018年通过河北省林木良种审定,2020年冠玉、美玉、秋露、金光等4个品种获得了植物新品种保护授权,SJ051105、

041025、041890和041901为选育的优系。每个品种(系)选取5株树,在距地面1.5、2.0、2.5 m树冠处不同方位随机选取30个花序上的幼果,观察其外观,对幼果进行横切,记录果心、果肉变褐变黑情况。根据冻害表现对其进行等级划分(表1),并计算其冻害指数。

表1 梨幼果晚霜冻害等级划分

Table 1 Grading of spring frost damage in young pear fruits

| 冻害等级<br>Frozen injury rank | 冻害表现<br>Frozen damage  |
|----------------------------|--|
| 0                          | 幼果表面及果心正常,果实未受害<br>The young fruit grows normally without damage   |
| I                          | 幼果表面出现零星斑点,果梗或果萼处出现裂纹,种子正常<br>The surface of young fruit appeared sporadic spots, fruit stem or calyx appeared cracks, and the seeds are normal  |
| II                         | 幼果表面出现白斑或黑斑较多,果面裂纹严重,种子部分变黑或果肉部分变褐<br>There are many white spots, black spots or cracks on the surface of young fruit, and some seeds turn black |
| III                        | 幼果表面及果心完全变褐、变黑或者萎蔫<br>The surface and core of young fruit turn brown, black or wilt completely   |

冻害指数/%= $\sum$ (果实受害级数×该级果实数)/(果实总数×最高级数)×100。

### 1.3 坐果率调查

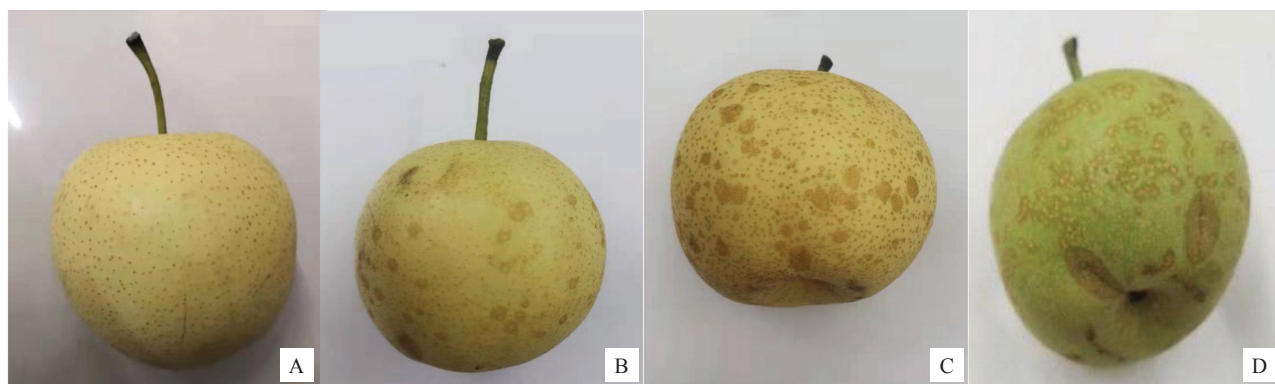
5月6日,在梨树不同高度、不同方位选取30个花序调查不同品种(系)花序坐果率和花朵坐果率。

### 1.4 霜冻果实外观和内在品质调查

果实成熟后,调查不同品种(系)果实的外观表现及内在品质(单果质量、可溶性固形物含量、果实硬度)。随机选取50个果实,按果面受害情况划分

不同等级,记录不同受害等级果实数量,同时测定其单果质量、硬度、可溶性固形物含量。根据果实是否畸形、疤痕大小和数量、霜斑大小和数量等划分为4个等级:①果形端正,无疤痕和霜斑为0级;②果面有零星霜斑或霜环,不影响其整体外观为一级;③果面霜斑或霜环较多,分布面积较大为二级;④果实出现畸形,果面霜斑或霜环遍布,冻害疤痕较多为三级(图1)。

### 1.5 数据处理与分析



A为0级果;B为一级果;C为二级果;D为三级果。

A is normal fruit; B is fruit of Grade I freezing injury; C is fruit of Grade II freezing injury; D is fruit of Grade III freezing injury.

图1 果实表面冻害表现等级划分

Fig. 1 Grading of damage on fruit surface

利用Excel 2010处理试验数据,使用SPSS 20.0进行数据分析。

## 2 结果与分析

### 2.1 霜冻期间温度变化情况

2020年4月22日、23日连续两日发生夜间低温冻害,给梨果生产造成严重损失。实际测定结果显示,4月22日0、1.0、2.0、3.0 m处最低气温分别

为-4.2、-4.4、-3.5、-1.9℃，零下温度持续时间分别为6.5、3.5、2.5、1.0 h；23日0、1.0、2.0、3.0 m处最低气温分别为-3.7、-2.9、-2.4和-2.0℃，零下温度持续时间分别为6.0、7.5、5.0、4.0 h(图2、图3)；10 m处温度

均高于4.6℃。距地面越高，温度越高。本次霜冻主要为冷空气入侵造成的混合霜冻。此次低温冻害发生较晚，0℃以下低温持续时间长、温度低、范围广，而且连续两晚的低温出现了叠加效应，梨幼果期

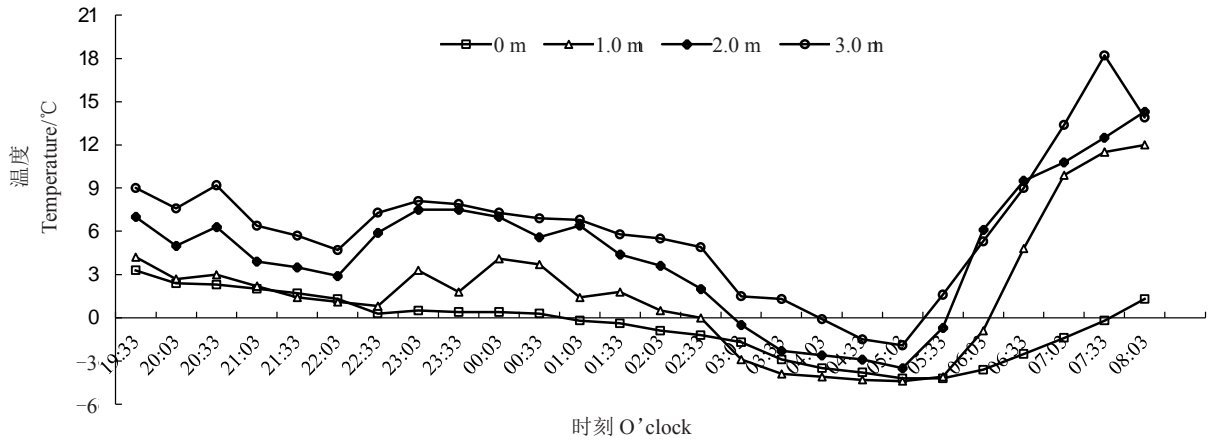


图2 4月21—22日夜间田间不同高度的温度变化

Fig. 2 Temperature changes at different heights in the field during the night of April 21-22

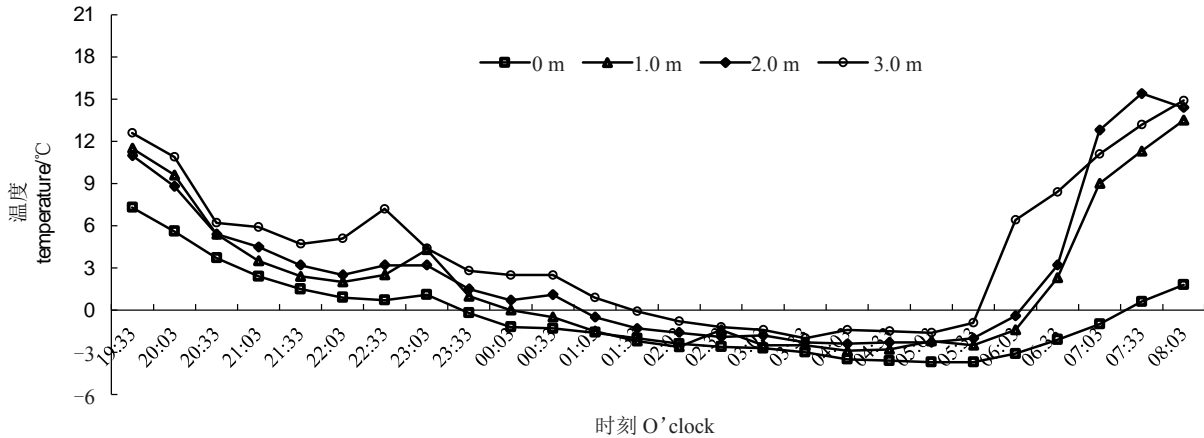


图3 4月22—23日夜间田间不同高度的温度变化

Fig. 3 Temperature changes at different heights in the field during the night of April 22-23

对低温特别敏感，冻害尤为严重。

2.2 幼果霜冻危害表现

晚霜对梨幼果的影响主要表现为：①果实整体变黑、萎蔫(图4)；②果实表面出现大面积烫伤样白斑(图5)；③果实果梗或果萼处出现裂纹(图6)；④果实表面有零星烫伤样白斑(图7)；⑤果心变黑，种子全部或部分变黑，果肉有裂纹(图8)。

对13个梨品种(系)的幼果冻害调查结果(表2)显示，不同品种(系)的梨幼果抗霜冻能力存在明显差异，距地面高度越高，冻害指数越低，幼果受害程度随树体高度依次递减。金光、SJ051105、黄冠、美玉、冠玉幼果冻害指数较低，1.5 m处冻害指数分别

为34.00%、45.67%、48.67%、50.33%和50.67%，这5个品种幼果受晚霜危害较轻。041901和041890在1.5 m处幼果冻害指数分别为75.00%、79.00%，幼果变黑变褐，种子变黑比例较高，受晚霜危害较重。秋露的幼果冻害指数最高，1.5 m处冻害指数为88.33%，受晚霜危害最为严重。

2.3 不同品种(系)坐果率调查

一些品种的梨幼果虽受晚霜冻害，但仍然能够生长发育。由表3可知，金光、SJ051105、冠玉、黄冠和美玉的坐果率较高，平均花序坐果率在81.87%以上，平均花朵坐果率在32.60%以上；雪花、黄金、迎霜花序平均坐果率分别为76.83%、74.67%和



图4 梨幼果萎焉、变黑

Fig. 4 Wilting and blackening of young pear fruit



图7 果实表面有零星白斑

Fig. 7 Sparse white spots on the fruit surface



图5 幼果表面出现大面积白斑

Fig. 5 Large area of white spot on the surface of young fruit



图8 果实内部种子变褐或变黑

Fig. 8 The seed browning or blackening



图6 果实果梗或果萼处出现裂纹

Fig. 6 Cracks on the stem or calyx end of fruit

表2 13个梨品种(系)幼果在不同高度的冻害指数

Table 2 Freezing injury index of young pear fruits

at different heights

%

| 品种(系)<br>Varieties/Strains | 高度 Height/m |       |       |
|----------------------------|-------------|-------|-------|
|                            | 1.5         | 2.0   | 2.5   |
| 金光 Jinguang                | 34.00       | 32.00 | 14.67 |
| SJ051105                   | 45.67       | 35.33 | 30.00 |
| 美玉 Meiyu                   | 50.33       | 32.00 | 28.33 |
| 黄冠 Huangguan               | 48.67       | 38.00 | 36.67 |
| 冠玉 Guanyu                  | 50.67       | 48.67 | 36.67 |
| 雪花 Xuehua                  | 65.67       | 63.00 | 44.00 |
| 黄金 Whangkeumbae            | 71.33       | 53.20 | 31.67 |
| 迎霜 Yingshuang              | 71.67       | 55.00 | 47.67 |
| 041025                     | 72.33       | 64.00 | 61.33 |
| 秋光 Qiuguang                | 72.33       | 63.00 | 53.33 |
| 041901                     | 75.00       | 70.33 | 55.33 |
| 041890                     | 79.00       | 78.33 | 66.67 |
| 秋露 Qiulu                   | 88.33       | 73.00 | 62.33 |

表3 13个梨品种(系)幼果坐果率  
Table 3 Fruit set in 13 pear varieties

| 品种(系)<br>Varieties/Strains | 花序坐果率 Fruit setting rate of cluster/% |       |       |         | 花朵坐果率 Fruit setting rate of flower/% |       |       |         |
|----------------------------|---------------------------------------|-------|-------|---------|--------------------------------------|-------|-------|---------|
|                            | 1.5 m                                 | 2.0 m | 2.5 m | 均值 Mean | 1.5 m                                | 2.0 m | 2.5 m | 均值 Mean |
| 金光 Jinguang                | 98.7                                  | 96.8  | 100.0 | 98.50   | 23.6                                 | 30.7  | 54.1  | 36.13   |
| SJ051105                   | 83.9                                  | 94.7  | 100.0 | 92.87   | 27.7                                 | 25.4  | 44.7  | 32.60   |
| 美玉 Meiyu                   | 50.4                                  | 95.2  | 100.0 | 81.87   | 10.9                                 | 45.5  | 68.2  | 41.53   |
| 黄冠 Huangguan               | 70.2                                  | 80.7  | 100.0 | 83.63   | 20.9                                 | 31.2  | 52.7  | 34.93   |
| 冠玉 Guanyu                  | 73.4                                  | 92.7  | 98.1  | 88.07   | 28.8                                 | 32.5  | 43.3  | 34.87   |
| 雪花 Xuehua                  | 40.5                                  | 93.3  | 96.7  | 76.83   | 8.3                                  | 23.0  | 27.2  | 19.50   |
| 黄金 Whangkeumbae            | 48.6                                  | 81.5  | 93.9  | 74.67   | 9.6                                  | 18.5  | 34.6  | 20.90   |
| 迎霜 Yingshuang              | 14.2                                  | 61.9  | 98.5  | 58.20   | 2.3                                  | 10.9  | 27.6  | 13.60   |
| 041025                     | 23.6                                  | 26.9  | 81.8  | 44.10   | 4.3                                  | 10.0  | 37.3  | 17.20   |
| 秋光 Qiuguang                | 20.8                                  | 32.8  | 74.9  | 42.83   | 4.6                                  | 10.7  | 27.4  | 14.23   |
| 041901                     | 9.5                                   | 11.1  | 67.7  | 29.43   | 2.8                                  | 4.9   | 31.4  | 13.03   |
| 041890                     | 6.7                                   | 15.1  | 49.9  | 23.90   | 1.9                                  | 2.5   | 16.8  | 7.07    |
| 秋露 Qiulu                   | 7.0                                   | 37.0  | 32.4  | 25.47   | 1.9                                  | 3.5   | 8.0   | 3.47    |

58.20%，花朵平均坐果率分别为19.50%、20.90%和13.60%，幼果坐果率中等；秋光、秋露、041025、041890和041901花序平均坐果率均低于45.00%，花朵平均坐果率低于18.00%，幼果坐果率低。综合分析，金光、SJ051105、冠玉、黄冠和美玉幼果坐果率较高，抗晚霜能力较强。

#### 2.4 幼果不同高度冻害指数、花序坐果率和花朵坐果率相关性分析

将13个品种(系)不同高度的冻害指数、花序坐果率和花朵坐果率分别进行相关性分析，结果(表4)显示，3个高度间的冻害指数均呈极显著正相关，

表4 各调查指标不同高度间相关性分析

Table 4 Correlation analysis of investigated indexed at different heights

| 指标 Index                               | 高度 Height | X1      | X2      | X3 |
|--|-----------|---------|---------|----|
| 冻害指数<br>Freezing injury index          | X1        | 1       |         |    |
|  | X2        | 0.918** | 1       |    |
|  | X3        | 0.882** | 0.918** | 1  |
| 花序坐果率<br>Fruit setting rate of cluster | X1        | 1       |         |    |
|  | X2        | 0.837** | 1       |    |
|  | X3        | 0.719** | 0.785** | 1  |
| 花朵坐果率<br>Fruit setting rate of flower  | X1        | 1       |         |    |
|  | X2        | 0.725** | 1       |    |
|  | X3        | 0.640*  | 0.892** | 1  |

注：X1代表1.5 m，X2代表2.0 m，X3代表2.5 m；\*表示在0.05水平上显著相关，\*\*表示在0.01水平上极显著相关。

Note: X1 is 1.5 m, X2 is 2.0 m, X3 is 2.5 m; \* indicates significant correlation at the 0.05 level, \*\* indicates extremely significant correlation at the 0.01 level.

相关系数分别为0.918、0.882、0.918；3个高度间花序坐果率均呈极显著正相关，相关系数分别为0.837、0.791、0.785；花朵坐果率1.5 m与2.0 m、2.0 m与2.5 m之间呈极显著正相关，相关系数为0.725和0.892，1.5 m与2.5 m之间呈显著正相关，相关系数为0.64。表明幼果受害程度与其所处高度有极强的相关性。根据图1、图2中田间温度变化可知，霜冻侵袭时，树体周围的温度随高度的增加逐渐上升，这也表明幼果的冻害程度与温度有显著的相关性，周围温度越高，幼果冻害程度越轻。

#### 2.5 冻害指数、花序坐果率和花朵坐果率间的相关性分析

对3个高度的幼果冻害指数与花序坐果率和花朵坐果率进行了相关性分析。结果(表5)显示，3个高度的冻害指数与花序坐果率和花朵坐果率均呈极显著负相关，高度由低到高的相关系数分别为-0.943和-0.877、-0.883和-0.776、-0.785和-0.787；而花序坐果率与花朵坐果率间均呈极显著正相关，高度由低到高的相关系数分别为0.943、0.75、0.769。

#### 2.6 晚霜对成熟果实品质的影响

观察发现，幼果遭受冻害后形成的裂纹和斑点在后续发育过程中会逐渐增大，裂纹虽可以愈合生长但会形成较明显的疤痕和凹陷。果面受冻害情况调查结果如表6所示，金光、SJ051105正常果所占比例最高，分别达到了95.20%和93.21%，为残次果较少的品种(系)；其次为美玉，正常果占77.27%；冠玉

表5 冻害指数与花序坐果率和花朵坐果率相关性分析  
Table 5 Correlation analysis between freezing injury index and fruit set based on cluster and flower

| 高度Height | 指标 Index | X1       | X2      | X3 |
|----------|----------|----------|---------|----|
| 1.5 m    | X1       | 1        |         |    |
|          | X2       | -0.943** | 1       |    |
|          | X3       | -0.877** | 0.943** | 1  |
| 2.0 m    | X1       | 1        |         |    |
|          | X2       | -0.882** | 1       |    |
|          | X3       | -0.776** | 0.75**  | 1  |
| 2.5 m    | X1       | 1        |         |    |
|          | X2       | -0.785** | 1       |    |
|          | X3       | -0.787** | 0.769** | 1  |

注: X1 代表冻害指数, X2 代表花序坐果率, X3 代表花朵坐果率; \*表示在 0.05 水平上显著相关, \*\*表示在 0.01 水平上极显著相关。

Note: X1 is freezing injury index, X2 is cluster fruit setting rate, X3 is flower fruit setting rate; \* indicates significant correlation at the 0.05 level, \*\* indicates extremely significant correlation at the 0.01 level.

与黄冠再次, 正常果所占比例基本相同, 分别为 64.97%、64.88%; 041890、迎霜、041025、秋光、041901、秋露正常果率为 60.00%~89.00%, 但其坐果率低, 总果数少; 黄金和雪花正常果所占比例最低, 分别为 34.43%和 47.29%。根据果面外观表现, 受晚霜影响比较轻的 5 个品种(系)依次是金光、SJ051105、冠玉、黄冠和美玉。

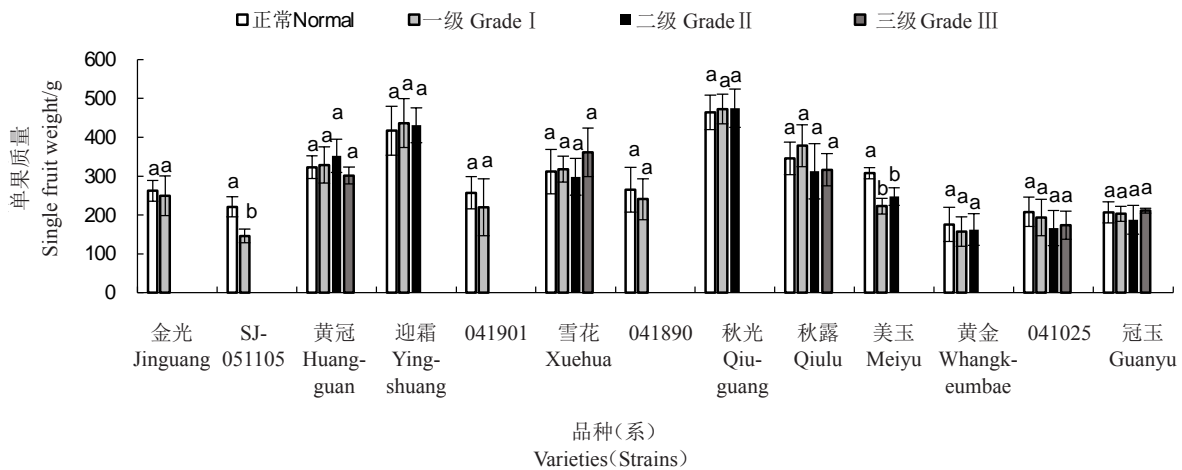
测定果实单果质量、硬度和可溶性固形物含量指标, 结果显示, SJ051105 和美玉正常果单果质量显著高于受冻害果实 ( $p < 0.05$ ), 其余品种不同受害程度单果质量差异不显著(图 9); 雪花和 041025

表6 果实表面受冻害情况

Table 6 Investigation of freezing injury on fruit surface

| 品种(系)<br>Varieties/<br>Strains | 受害等级所占比例<br>Proportion of different freeze injury grades/% |               |                |                 |
|--------------------------------|--|---------------|----------------|-----------------|
|                                | 0级(正常)<br>Normal   | 一级<br>Grade I | 二级<br>Grade II | 三级<br>Grade III |
| 金光 Jinguang                    | 95.20  | 4.80          | 0.00           | 0.00            |
| SJ051105                       | 93.21  | 3.97          | 0.00           | 0.00            |
| 美玉 Meiyu                       | 77.27  | 13.63         | 9.10           | 0.00            |
| 黄冠 Huangguan                   | 64.97  | 28.74         | 3.29           | 2.99            |
| 冠玉 Guanyu                      | 64.88  | 18.45         | 12.50          | 4.17            |
| 雪花 Xuahua                      | 47.29  | 23.63         | 18.18          | 10.90           |
| 黄金 Whangkeumbae                | 34.43  | 37.70         | 27.87          | 0.00            |
| 迎霜 Yingshuang                  | 78.71  | 18.81         | 2.48           | 0.00            |
| 041025                         | 72.41  | 15.52         | 8.62           | 3.45            |
| 秋光 Qiuguang                    | 72.20  | 16.70         | 11.10          | 0.00            |
| 041901                         | 65.46  | 34.55         | 0.00           | 0.00            |
| 041890                         | 89.00  | 11.00         | 0.00           | 0.00            |
| 秋露 Qiulu                       | 60.42  | 31.25         | 4.17           | 4.17            |

受冻害后果实硬度显著高于正常果 ( $p < 0.05$ ), 其余品种不同受害程度硬度差异不显著(图 10); 可溶性固形物含量各品种(系)不同受害程度果实之间差异均不显著(图 11)。冻害可能导致个别品种(系)果实变小和硬度变大, 对大部分品种影响不显著; 对可溶性固形物含量影响较小。说明晚霜冻害对能够恢复正常生长发育果实的品质影响不大, 所以在冻害发生后, 要尽可能地多留果实。此外, 将受冻害果实进行横切发现, 部分品种冻害后其果实也能够正常生长和膨大, 但内部没有正常发育的种子(图 12), 这与生长素由种子产生不符, 原因有待进一步研究。



不同小写字母表示  $p < 0.05$  差异显著。下同。

Different small letters indicate significant differences at  $p < 0.05$ . The same below.

图9 13个梨品种(系)成熟果实单果质量

Fig. 9 Single fruit weight in 13 pear varieties (strains)

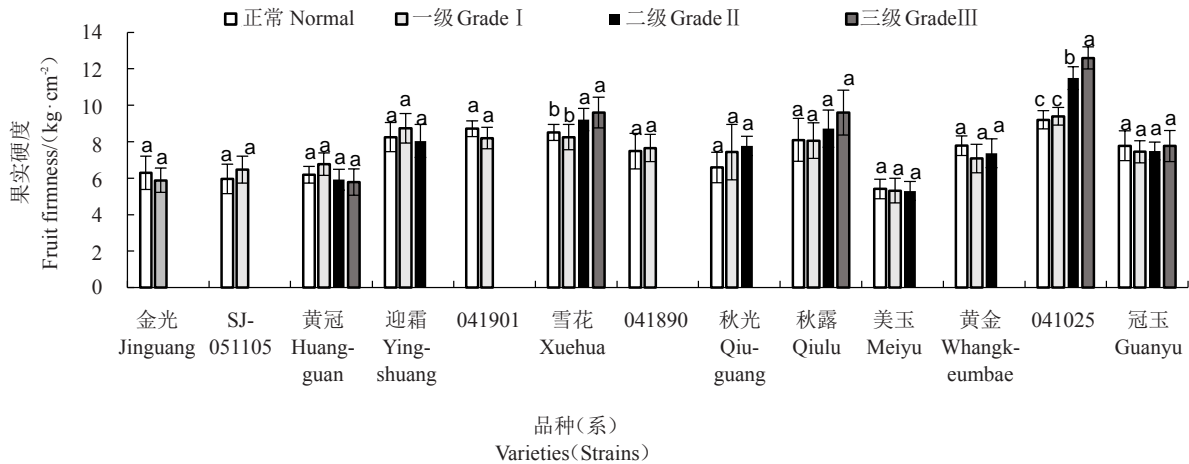


图 10 13 个品种(系)成熟果实硬度  
Fig. 10 Fruit firmness in 13 pear varieties (strains)

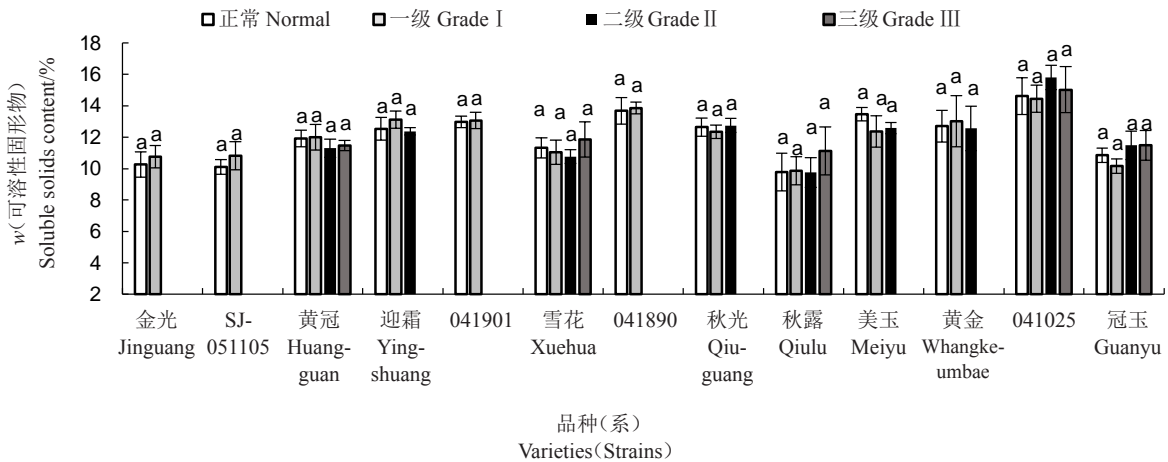


图 11 13 个品种 (系) 成熟果实可溶性固形物含量  
Fig. 11 Soluble solid content of 13 pear varieties (strains)



最左侧为正常果,中间果为冻害表现一级果,右侧为果面冻害表现三级果。

The left is normal fruit; the middle is fruit of Grade I freezing injury; and the right is fruit of Grade III freezing injury.

图 12 黄冠果实横切表现

Fig. 12 Cross section of Huanguan fruit

### 3 讨 论

目前,对果树幼果期的冻害调查一般参照《作物霜冻害等级 QX/T 88—2008》,根据受害果比例进行

分析<sup>[1,3-5]</sup>,但所建立的指标未考虑到不同品种冻害后表现的差异性。笔者在调查过程中主要依据幼果的不同受害表现对其进行等级划分并计算冻害指数。冻害发生后果心未变褐或变褐程度较轻的幼果,有的能够恢复其生长机能,但又会出现畸形果、偏斜果、疤痕果、多锈果等现象,影响其商品价值<sup>[6-8]</sup>。笔者调查了 13 个品种(系)成熟果的冻害表现,发现不同品种(系)幼果受害后恢复能力不同,金光、SJ051105 等恢复能力较强的品种(系),疤痕、畸形果和偏斜果较少;黄金、冠玉等品种(系)畸形果、偏果、疤痕和木栓果较多。田鑫<sup>[9]</sup>研究发现,晚霜冻害会导致坚果显著变小、果壳厚度增加、单果质量增加、出仁率降低,但对果仁脂肪含量影响不大。宁超<sup>[10]</sup>研究发现,3 个杏品种抗霜冻能力不同,但其果实养分含量无显著差异。宋雪娜<sup>[11]</sup>研究发现,苹果

花期冻害会导致其果实偏小,品质下降。但笔者对13个梨品种(系)的单果质量、硬度和可溶性固形物含量的调查发现,除SJ051105和美玉单果质量降低、雪花和041025硬度变大以外,其余品种(系)果实品质变化均不显著。所以在冻害发生后,应该尽可能保留受冻害较轻的幼果。霜冻会影响果实种胚的发育,导致种子较少甚至无种子<sup>[7-8]</sup>。本次调查发现,一些受冻害严重的果实内部种子均未正常发育,但其后期仍能够膨大正常生长,与正常果无显著差异,说明梨果实在种子未发育的情况下也能够生长,果实受害程度与恢复机能之间的关系有待进一步研究。以往,晚霜冻害一般发生在梨树花期,而梨树抗寒性强弱表现为花蕾期>初花期>盛花期<sup>[12]</sup>,因此一些物候期较晚的品种霜冻危害较轻。本次调查的品种(系)盛花期集中在3月29日—4月4日,霜冻发生时均处于幼果期,未发现品种(系)抗寒性与花期物候之间的相关性。王贵平等<sup>[13]</sup>在调查苹果春季冻害时发现,富士的受害程度表现为晚熟品种>中熟品种>早熟品种。本次调查的13个梨品种(系)中,表现较好的金光、SJ051105、冠玉、黄冠和美玉均为中熟品种(系),而表现较差的秋光和秋露均为晚熟品种,成熟期与果实的抗晚霜能力可能存在一定的关系。

为应对霜冻,国内大都采用熏烟、灌水等<sup>[14]</sup>措施,虽有一定作用,但实施较为费力,熏烟又污染环境。一些防冻剂药剂效果也较为有限<sup>[15]</sup>。目前,一些发达国家(如美国、日本)主要采用大功率风机防范霜冻危害,风机可将10 m高处暖空气吹到下部,与冷空气混合,提高果园树冠层的温度,减轻霜冻危害<sup>[16]</sup>。此次田间温度调查显示,2020年4月22日凌晨,10 m处最低温度为4.6℃,持续时间不足30 min,而1.5 m处最低气温-4.4℃,-2℃以下温度持续时间超过3 h,说明霜冻发生时空气上下温差较大,使用风机将冷暖空气混合,可以预防或减轻霜冻危害,但目前国内应用较少,应该加快风机防霜冻的推广工作。由于近几年霜冻对果树的影响日趋严重,选育抗晚霜能力强的品种是新品种选育的一个重要目标。本研究结果仅限于资源圃内梨幼果期受冻后的表现,有一定局限性,花蕾期或开花期各品种(系)受冻后是否还有相同的表现有待进一步研究。对各品种(系)也应研究其不同区域、不同立地条件、不同栽培管理措施的果园中花蕾期、开花期和幼果期

受霜冻的情况,筛选出真正意义上的抗晚霜品种资源。

## 4 结 论

不同品种(系)之间抗晚霜能力存在一定差异,13个品种(系)中,金光、SJ051105抗性最强,幼果可以抵御-4.4℃以上低温;冻害程度与果实在树体的部位有关,位置越高,受冻越轻;梨树幼果期受晚霜冻害后抗性强、冻害轻的幼果能够恢复生长,对果实品质影响不大,但部分果实表现为无种子仍能正常生长,原因有待于进一步研究。

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