1-MCP Can Prevent Ethylene-Induced Damage to Fruit Trees during Cold Storage

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Abstract

At present, about 50% of the young fruit trees is stored for more than one month in cold rooms between lifting in the nursery and planting in spring in the orchard with a maximum storage duration of 5-6 months. Storage of fruit trees requires the absence of ethylene in the storage room, as this gaseous plant growth regulator may induce damage to the trees during storage, which eventually may lead to the death of branches or the whole trees after planting the tree in the orchard. In 2007 a series of experiments was carried out to find out the sensitivity of 'Conference' pear trees to ethylene. In addition, the possible use of 1-MCP treatment before storage of the pear trees was examined as a means to prevent ethylene-induced damage. Tree damage was monitored during and directly after storage as well as after planting the trees in the orchard in spring following the storage period in winter. Ethylene-induced symptoms are the discoloration and death of local areas of bark tissue, death of buds and the occurrence of local cracks in the bark followed by the growth of callus tissue. Ethylene-induced damage was observed only when trees were exposed to 5 mg/L ethylene for 1 month at a temperature of 4°C. No damage occurred in case trees were only exposed to this concentration for 1 week at 4°C or for up to 1 month when stored at a temperature of 0°C. Trees treated with 1-MCP before storage did not develop any damage when exposed to 5 mg/L ethylene for 1 month at 4°C, demonstrating that 1-MCP is also taken up by trees harvested after leaf drop. Sensitivity towards ethylene seemed to be dependent on the time of lifting of the trees in the nursery. A trend was observed that trees grubbed in January developed less symptoms after a month exposure to 5 mg/L ethylene at 4°C than trees given the same treatment but lifted in November or March. This suggests that fully dormant trees are less sensitive to ethylene than trees lifted in autumn or spring. Amelioration of the damage after planting the trees in the field was strongly dependent on the amount of damage occurred during storage. Trees with only a little damage recovered quite well, but those with more severe damage often did not recover. Branches or even the whole tree died as result of the damage symptoms developed during storage. Trees treated with 1-MCP before storage showed a normal development after planting in the orchard and were indistinguishable from the untreated control trees. Further research is needed to more accurately determine the concentration, duration and temperature during exposure at which ethylene becomes harmful to pear trees in storage in order to prevent damage and optimise the use of 1-MCP.

INTRODUCTION

In the Netherlands many growers prefer to plant young fruit trees in spring when soil and weather condition are usually better than those in the autumn or early winter. At present, about 50% of the young fruit trees planted in spring is stored in cold rooms for more than one month between the moment of lifting in the nursery and planting in spring, with a maximum storage duration of 5-6 months. Occasionally, this cold storage results in damage to the young fruit trees, especially in 'Conference' pear trees. Visible damage occurred as local areas of discoloured bark tissue, death buds, and local cracks in the bark followed by the growth of callus tissue, these damage symptoms in pear trees resembled those earlier described for nursery trees exposed to ethylene during storage (Curtis and Rodney, 1952). This paper describes the results of a series of experiments aimed to find out the sensitivity of 2-year old ‘Conference’ trees to ethylene during cold storage and the use of 1-MCP to prevent ethylene-induced to fruit trees. Storage temperature, duration of exposure to ethylene and treatment of the trees with 1-methylcyclopropene (1-MCP) before exposure to ethylene were the variables tested in these experiments.

MATERIALS AND METHODS

Plant Material

‘Conference’ pear trees on rootstock Quince MC used in this study were obtained from two commercial nurseries. The trees were either 1-year old trees (Nursery B) or 2-year old feathered ‘knip’ trees (Nursery A) harvested at three different times: 1) beginning of November (trees not yet fully dormant); 2) middle of January (dormant trees); 3) beginning of March (non-dormant, after breaking of winter rest).

Trial Setup and Observations

After lifting in the nursery, the trees were stored in a cold room for one week at a temperature of 1 to 2°C and at high relative humidity before the onset of the storage treatment. The storage treatments were carried out in special containers with a volume of 1 m^3. These containers were placed in a cold room with a temperature of either 0 or 4°C. In case of a treatment with 1-MCP, the trees were exposed to 1 mg/L (1 ppm) Smartfresh[SM] (http://www.smartfresh.com) by dissolving this amount in water inside a closed container. After 24 h the containers treated with 1-MCP were placed outside the cold room and ventilated for 1 hour to remove all traces of 1-MCP. To prevent the accumulation of CO_2 inside the storage containers 1 kg of slaked lime (calcium hydroxide) was placed in each container. Regular measurements of the CO_2 and O_2 concentrations in the containers showed that this proved to be sufficient to keep their levels similar to those of outdoor atmospheric conditions. Ethylene levels in the container were established by injection of the gas. At 2 times a week the ethylene concentration was measured by using gas chromatography and re-established if necessary. Each treatment was carried out with 5 trees per container in two replications. In total 96 treatments were compared. Treatment variables were:

- Storage temperature: 0 or 4°C.
- 1-MCP pre-treatment: 0 or 1 mg/L Smartfresh for 24 h.
- Ethylene exposure: 0 or 5 mg/L from second day of storage period.
- Duration of treatment: 1 week or 1 month.
- Origin plant material: 1- or 2-year old nursery trees.
- Time of lifting trees at nursery: November, January or March.

At the end of the 1-week or 1-month storage period, the trees were removed from the storage containers and placed into a humidified cold room at a temperature of 1°C for five days. Then, the level of damage to the bark tissue was recorded visually by counting the number of damage spots per tree assumed to result from ethylene exposure during storage. Figure 1 provides an overview of the types of ethylene-induced damages to the bark that were observed in ‘Conference’ trees in this study. The damage to a tree was indexed on a scale of 0 to 4 (0 = no damage; 1 = light damage, 1-10 damage spots/tree; 2 = moderate damage, 11-20 damage spots/tree; 3 = severe damage, 21-30 damage spots/tree; 4 = very severe damage, >30 damage spots/tree). After the damage symptoms were recorded, the trees were planted outdoors in the orchard at a planting distance of 2 x 0.2 m in plots of 5 trees per treatment. During the growing season the development of the trees and the fate of the damaged bark spots were monitored.

RESULTS AND DISCUSSION

Observations after Storage Treatments

Damages to the bark tissue of 'Conference' trees (Fig. 1) were only observed in trees exposed to ethylene for 1 month at a temperature of 4°C (Table 1). Treatment of the trees with 1-MCP before a similar exposure to ethylene prevented the development of these bark damage symptoms. Damage spots neither developed when trees were exposed to ethylene at 0°C. The moment the trees were lifted in the nursery between November and March did not substantially affect the sensitivity of the trees to ethylene. Although not always significantly different from trees lifted in November or March, trees lifted in January were the least sensitive toward ethylene (Table 1). The origin of the trees clearly had a much higher influence on the ethylene sensitivity of the trees than the time of lifting. Trees grown in nursery B (1-year old trees) showed much more bark damage after exposure to ethylene than those grown in nursery A (2-year old trees). The reason for this difference in sensitivity is unknown. Apart from the difference in age of trees, the trees of nursery B might have been less hardened (winter hardy) when lifted in the nursery than those of nursery A, maybe as a result of difference in fertilization conditions and growth rate of the tree during the preceding growing season. Besides 'Conference' also a limited number of trees of cultivars 'Beurré Alexander Lucas' were exposed to ethylene. Exposure to 5 mg/L ethylene for 4 weeks at 4°C resulted in similar damage to this cultivar as was observed for 'Conference' (data not shown). Similar ethylene-induced bark damages have been reported many decades ago for young apple trees (Curtis and Rodney, 1952) as well as for apple scions (Janick, 1975).

No ethylene was measured in the gas samples taken from the containers containing the control trees in which no ethylene was injected. Therefore, it can be concluded that pear trees do not produce ethylene during storage. Thus, the ethylene damage symptoms, which have been observed in commercial nurseries, most likely are caused by ethylene from other sources, such as nearby stored fruits or the combustion of fuels by machines used in the vicinity of the storage rooms. Further research at these nurseries is needed to find out the origin of the ethylene and to determine the duration and concentrations of ethylene to which the trees may be exposed during storage.

Observation of the Treated Trees after Planting in the Orchard

Growth and development of the trees, which had been treated during storage, was observed after planting of the trees in the orchard several times during the growing season of 2008. Trees treated with 1-MCP developed well and similar to the control trees that had not been exposed to ethylene or 1-MCP. Trees with small symptoms of ethylene damage (scale 1) started grew quite normally and hardly any differences in growth and development could be detected at the end of the growing season. This was not the case for trees graded with moderate to very severe damage symptoms (scale 2 to 3). These trees showed branches that did no show any growth and which died during the growing season. Depending on the severity of the damage, growth of the trees only occurred in the top of the tree. Often, the apical bud had died and growth of the tree started from axillary buds or buds at lower position on the branches. Growth of the trees with very severe damage symptoms (scale 4) was severely hampered, unevenly distributed, and many shoots and sometimes the whole tree died. Trees with ethylene-induced damage to the bark did were not more susceptible to fungal diseases such as twig lesions on the bark caused by *Venturia pirina* (pear scab).

CONCLUSIONS

The results of this study clearly demonstrate the sensitivity of young pear trees to ethylene during storage. Visible damage symptoms varied from small cracks in the bark, followed by callus growth, the death of buds, and brown discoloration and loosening of bark tissue, which in case of complete ringing the branch or main stem caused the death of the branch or whole tree, respectively. Trees with light damages of the bark showed normal growth and development after planting in the orchard. More severely damaged trees often did show hampered development or in the worst case no growth at all after planting in the orchard. However, damage symptoms only occurred in trees exposed for 4 weeks to ethylene concentration as high as 5 mg/L at a temperature of 4°C. Since neither an exposure at 4°C for only 1 week to 5 mg/L ethylene, nor a 4-week exposure to 5 mg/L ethylene at 0°C resulted in any damage to the trees, the risk for this type of damage for nurseries of fruit growers storing their new trees a couple of months before planting, is low as long the temperature in their storage rooms is kept close to 0°C. Treatment of the trees with 1-MCP can make the trees completely insensitive to ethylene without any negative effect for the development of the trees once planted in the orchard. However, 1-MCP treatment is expensive and at present the commercial product Smartfresh^{SM}, used to increase the storability and shelf life of fruits, is only registered for the treatment of harvested fruits.

ACKNOWLEDGEMENTS

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Literature Cited

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Tables

Table 1. Bark damage of ‘Conference’ pear trees observed after cold storage at 0 or 4°C. Trees were lifted in two nurseries in November, January or March and directly exposed for 1 month to 0 or 5 mg/L ethylene after pre-treatment with 0 or 5 mg/L Smartfresh (1-MCP). Data represent the means of 5 trees ± standard deviation. Only in case of the treatments in which ethylene-induced damage occurred (4°C, + ethylene, - 1-MCP) both replicates are listed separately.

T	Ethylene	1-MCP	Nursery A			Nursery B		
(°C)			Nov	Dec	Jan	Nov	Dec	Jan
			Bark damage (number of damage spots per tree)					
0	-	-	0	0	0	0	0	0
0	-	+	0	0	0	0	0	0
0	+	-	0	0	0	0	0	0
0	+	+	0	0	0	0	0	0
4	-	-	0	0	0	0	0	0
4	-	+	0	0	0	0	0	0
4	+	-	34 ± 13	15 ± 9	23 ± 8	56 ± 9	36 ± 3	37 ± 13
4	+	-	21 ± 5	11 ± 2	36 ± 10	71 ± 12	34 ± 18	108 ± 12
			Bark damage graded on scale 1 (no damage) to 4 (severe damage)					
4	+	-	3.4 ± 0.9	2.0 ± 0.7	3.0 ± 1.0	4.0 ± 0.0	3.2 ± 1.1	3.6 ± 0.5
4	+	-	2.4 ±0.5	1.6 ± 0.5	3.6 ± 0.5	4.0 ± 0.0	3.2 ± 1.1	4.0 ± 0.5

Figures

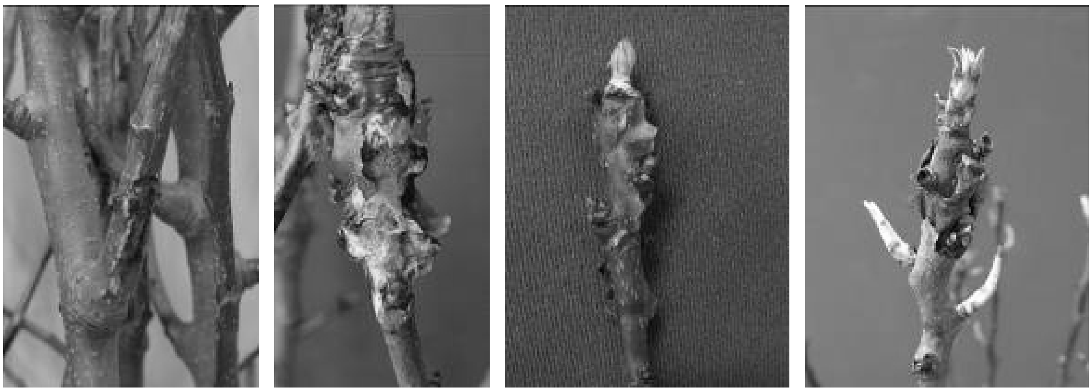

Fig. 1. Symptoms of ethylene-induced damage to 'Conference' trees developed during a one month cold storage period.