Influence of some weather parameters on the susceptibility of apple fruit to postharvest grey mould attack

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Abstract

Several cultural and weather factors during the season influence the susceptibility of apple fruit to post-harvest pathogens. In the present study, the effect of different weather parameters on postharvest susceptibility of apples of the cv. 'Ingrid Marie' to grey mould was investigated. In 2015, apple fruit were collected from orchards in Southern Sweden, where local weather stations monitored different parameters. After harvest, the fruit were tested for susceptibility to grey mould by artificially inoculating them with B. cinerea*. Lesion development was monitored over a 10-day-period. Analysis of results for a few orchards showed that cold weather for over a month preceding harvest and a low total number of growth degree days gave apples that were more susceptible to grey mould. This study was carried out in conventional orchards, but the conclusions can be important also for organic production, since they deal with the general effect of sunshine, temperature and rain, factors that may strengthen fruit during cultivation, regardless of production type. Future studies may focus on organic production to investigate whether these effects are general and also apply to organic production.*

Keywords: Sun, temperature, apple, *Botrytis cinerea*, prediction

Introduction

The susceptibility of apple fruit to post-harvest pathogens depends on several factors, such as apple cultivar, cultural practices, pest and pathogen pressure during the season, fertilization regimes, and specific weather events, such as frost at bloom, the incidence of hail or wind storms in the season or rainy weather at harvest. The presence of rain and sunshine in appropriate amounts and at appropriate time intervals during the season influences fruit size and quality. High temperature and high light may induce an increase in the level of antioxidants, i.e phenolics and ascorbic acid in apples and other plants (Solovchenko & Schmitz-Eiberger, 2003; Davey *et al*., 2000; Li *et al.,* 2013). Flavanols is of the major groups of phenolic compounds in apples, accumulating in the fruit following exposure to light. Ascorbic acid also accumulates in plants exposed to high-light (Awad & De Jager, 2000; Davey *et al.,* 2000). Since apple tissues rich in antioxidants, especially in ascorbic acid, were less susceptible to *Botrytis cinerea*, the causal agent of grey mould (Davey *et al.,* 2007), the present study focused on investigating whether - for example - sun exposure in the field could prepare apples to better withstand artificial grey mould infection after harvest. The effect of many different weather parameters on the subsequent susceptibility of apples of the cv. 'Ingrid Marie' to the grey mould pathogen (*Botrytis cinerea)* was investigated.

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Material and Methods

In the season of 2015, apple fruit were collected from orchards in Southern Sweden, where weather stations in the orchards were monitoring temperature, rainfall, soil wetness and wind. Data on solar irradiation was collected or downloaded as global irradiation values for the GPS coordinates of the orchard location from the Swedish Meteorological and Hydrological Institute website (www.SMHI.se). After harvest, when fruit were to be treated, Streif index measurements were carried out to ensure the maturity of the apples. The fruit were washed and allowed to dry, and subsequently tested for susceptibility to the grey mould pathogen by inoculating a spore suspension of *B. cinerea* into each wound, on two opposite cheeks, one on the sun-exposed and one on the shaded sides of each apple. The fruit were placed in moist chambers at 16 °C and the diametres of developing lesions were monitored over a 10-day-period. Correlation coefficients were calculated for several weather parameters and lesion sizes 6 days after inoculation. Correlation analysis was done in the statistics software R using the rcorr function in package hmisc. Correlations were considered singificant at p<0.05 (and indicating a trend at p<0.1). Principal components analysis (PCA) was done in statistics software R using the PCA function in package FactoMineR.

Results and Discussion

Apples with most tolerance to grey mould after harvest originated from orchards with a high total number of growth degree days over the season (regardless of whether 6°C or 8°C was used as the base temperature), in combination with sunny weather the last 7 days before harvest, and with lowest number of days with temperatures below 8°C prior to harvest (Table 1).

Table 1: Response of apples from four different orchards to inoculation with *Botrytis cinerea* 6 days after inoculation and some calculated weather parameters for the orchards.

Orchard No.	Lesion sizes (mean values in cm diametre)[a]	N days<8°C before harvest					Growth degree days (GDD)		GDD*sun n days before harvest			
							6°C base	8°C base	6°C base		8°C base	
		14	21	28	35	42			7	14	7	14
1	1.53a	10	13	13	15	17	1 475	1 114	941	3682	142	1118
2	2.07a	8	9	12	12	12	1 524	1 135	1258	2484	326	520
3	2.17a	9	13	18	20	20	1 509	1 123	1129	1833	273	331
4	3.23b	12	16	21	24	25	1 401	1 033	522	1205	27	76

[a]Mean values followed the same letter are not significantly different at p ≤ 0.05, based on a t-test.

Correlation analysis also found that warm weather throughout the season, and especially during the 7-14 days prior to harvest, preferably in combination with sunshine, prepared the apples better to resist grey mould. The following weather parameters were negatively (p ≤ 0.05) correlated to lesion size: total average temperature during the 14 days before harvest, GDD (base temp 6°C), GDD (base temp 8°C), GDD (base temp 6°C) during the 14 days harvest and GDD (base temp 6°C) multiplied by sunshine during the 7 days preceding harvest.

Table 2: Factor loadings based on a PCA for lesion sizes 6 days after inoculation and some calculated weather parameters for the 4 Swedish orchards, showing explained cumulated proportion of variation in percent.

Characters[a]	Component 1 (61.7%)	Component 2 (19.9%)	Component 3 (14.5%)
Lesion size	0.291	0.302	-0.271
14 days<8°C	0.542	0.824	-0.161
21 days<8°C	0.736	0.669	0.103
28 days<8°C	0.962	0.232	-0.146
35 days<8°C	0.938	0.339	-0.062
42 days<8°C	0.871	0.491	-0.003
Total Gdd(6°C)	-0.498	-0.812	0.300
Total Gdd(8°C)	-0.601	-0.675	0.424
Total Gdd(6°C)*sun	-0.851	-0.463	-0.243
Total Gdd(8°C)*sun	-0.891	-0.440	-0.103
Gdd(6°C)_14days	-0.841	-0.369	0.394
Gdd(6°C)*sun_7days	-0.525	-0.812	0.252

[a]N days<8°C, number of days prior to harvest with a temperature <8°C; Total Gdd(X°C), the total growth degree days over the season using X°C as base temperature; *sun, the value is multiplied by total sunshine over the season; _14days, the last 14 days before harvest; *sun_7days, multiplied by sunshine over the last 7 days before harvest.

The PCA showed that a factor that is associated with susceptible fruit is cold weather during the period of 14-42 days prior to harvest. The factors that make fruit less prone to infection are again high total growth degree days, especially combined with sunshine (in general, and also 7 days before harvest) and high growth degree days during the final 14 days prior to harvest. Other results (not shown here) from the same dataset and from other unpublished work (Bui et al. manuscript in preparation) has shown that the sun-exposed sides of the 'Ingrid Marie' fruit are less susceptible to the pathogen. This indicates that sunshine and warmth are important, especially when approaching the harvest period, in order to render the fruit less prone to postharvest disease caused by grey mould.

Exposing apple fruit to sunshine leads to an upregulation of the phenylpropanoid pathway, which in turn explains why flavonols, e.g. quercetin glucosides, accumulate to high levels in sun-exposed tissues, especially in peel (Li *et al.,* 2013; Zupan *et al.,* 2014; Solovchenko & Schmitz-Eiberger, 2003) and in particular during the final phase of ripening in the field (Awad & De Jager, 2000). *Botrytis cinerea* provokes the oxidative burst and massive ROS (reactive oxygen species) production in plant tissues, which ultimately leads to plant cell death (van Kan, 2007). Antioxidant activity in apples may thus contribute to defence against *B. cinerea*. In apples, certain phenolic compounds are more active as radical scavengers; and among these, flavonols are very active even at lower concentrations than some other phenolics (Chinnici *et al.,* 2004). Some apple phenolics also have documented antifungal activity (Martínez *et al.,* 2017). The ascorbate-glutathione cycle plays a central role in maintain redox equilibrium in plants (Foyer & Noctor, 2011). The role of high intensity light in increasing the levels of ascorbic acid in plants may explain why high sunlight can prepare fruit better in dealing with postharvest grey mould attack. In the future, these results can be developed into warning systems that indicate favourable or unfavourable weather for obtaining resilient fruit for postharvest storage.

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