SUMMARY

In recent years a postharvest disease of kiwifruit caused by *Cadophora luteo-olivacea*, characterized by a pitting of the skin appearing after 3 or more months of storage, has been reported in most Italian packinghouses. This work reports the disease occurrence in northern Italy over a period of five years and the effects of commercial storage practices and kiwifruit dry matter or mineral composition on disease development. Throughout the experiments, *C. luteo-olivacea* was identified based on morphology and sequencing the ribosomal region ITS1-5.8S-ITS2. Monitoring of seven packinghouses in 2001-2003, showed that skin pitting occurred during storage in which CA was established with 2% O₂ and 4.5% CO₂ was established within 8 to 12 days from the beginning of storage, while, when CA was established within 25 or more days, *C. luteo-olivacea* was absent. In 2002, the kiwifruit of 19 orchards were monitored during storage in which CA was established within 8 to 12 days. Before storage, the dry matter (DM), nitrogen, calcium and magnesium content were measured. DM was inversely related to the incidence of *C. luteo-olivacea* (R² = 0.5269) and the nitrogen content was directly related to skin pitting (R² = 0.5015). During 2004-2005 and 2005-2006 different batches of kiwifruit, healthy or infected by *C. luteo-olivacea*, were analysed at the end of their storage. The disease incidence was significantly associated with dry matter (Pearson’s correlation coefficient: -0.853) and nitrogen content (0.815). A significantly lower calcium content was registered in some infected compared to healthy batches in 2004-2005. Batches with predisposing factors, such as low DM and high nitrogen content, should be more carefully managed, reducing storage life and avoiding an excessively fast and stressing CA establishment.

Key words: *Actinidia delicosa*, calcium, controlled atmosphere, nitrogen, *Phialophora luteo-olivacea*.

INTRODUCTION

Kiwifruit (*Actinidia deliciosa* (Chev) Liang et Ferguson) cv. Hayward, is a member of the family Actinidiaceae originating from south-east Asia. It was introduced from China into New Zealand in 1906 and, from there, its cultivation rapidly expanded to other continents. It is a relatively recent commercially-grown fruit, with significant quantities being produced only after the 1980’s. In Italy, kiwifruit industry was established at the end of the 1960s. Today, Italy is the world leader for kiwifruit production, with over 450,000 tons produced in 2007 (FAO, 2008).

Kiwifruit can be stored for over 6 months at 0±1°C (Feng et al., 2006). However, fruit rots can cause severe losses during cold storage, transit, marketing and in retail stores. The most important cause of decay in kiwifruit after harvesting is grey mould caused by *Botrytis cinerea* Micheli ex. Pers (Snowdon, 1990).

In recent years a postharvest disease of kiwifruit, characterized by skin pitting appearing after 3 or more months of storage (Fig. 1), has been observed in most Italian packinghouses. The causal agent is *Cadophora luteo-olivacea* (van Beyma) Harrington & McNew, originally identified as *Phialophora* sp. (Gorini, 1991; Marchi et al., 1994; Piano et al., 2001), or *Phialophora luteo-olivacea* van Beyma (Gams, 2000). Initially, this new postharvest disease was sporadic and economically negligible, mostly affecting kiwifruit produced in southern Italy (Gorini, 1991). However, its incidence increased greatly in the years 1998 and 1999, reaching a maximum of 20-30% in the year 2000 on kiwifruit batches from the main Italian kiwifruit-producing regions (Piano et al., 2001). The disease develops in packinghouses after 100-120 days storage when relevant storage costs have already been sustained, compromising the packinghouse reputation, because the symptoms show on batches delivered to the distribution chain. Symptoms, which often appear as minor lesions at the opening of the storage rooms, become conspicuous when the fruits reach the distribution channels and the consumers (Snowdon, 1990).

Skin pitting is not recorded every year, so understanding the pathogen epidemiology was necessary. In
2001 a survey was carried out with the aim of ascertaining the possible agronomic factors and storage techniques predisposing disease development (Gilardi et al., 2007). The survey involved 16 packinghouses located in Piedmont (northern Italy), processing an average 82,800 tons of kiwifruit a year (around 6.9% of the world production and 18.2% of the Italian production). An incidence of 2.3% (1,850 tons) fruits infected by C. luteo-olivacea was registered in 2001. Among the agronomical factors considered important by the producers for the development of the disease, the excessive yield/ha and fertilization, especially nitrogen, and the very frequent and sometimes excessive irrigation were the most quoted. Also an effect of the commercial controlled atmosphere practices adopted was considered important. For instance, Lallu et al. (2003) reported that the incidence of physiological pitting on kiwifruit was reduced by slowing down the rate of CO₂ concentration in the storage room.

The recommended conditions for commercial storage of kiwifruit are 0°C with 90 to 95% relative humidity (RH). Fruit that are properly handled before storage can be maintained in good condition for 4-5 months. Kiwifruit respond favourably to controlled atmosphere (CA). The potential for benefit is very high storage-life (RH). Fruit that are properly handled before storage age of kiwifruit are 0°C with 90 to 95% relative humidity.

MATERIALS AND METHODS

Packinghouse monitoring. During 2001 and 2002, seven packinghouses in the Cuneo province (Piedmont, northern Italy) were monitored for the incidence of skin pitting caused by C. luteo-olivacea to evaluate the influence of commercial storage practices. In the first year, fruits were harvested in October 2001 and stored until March 2002, while the second year fruits were harvested in October 2002 and stored until March 2003. C. luteo-olivacea incidence was evaluated at the end of storage as percentage of infected fruits in all fruit batches processed by the packinghouse. The pathogen was isolated from symptomatic fruits. The controlled atmosphere (CA) level (percentage of oxygen and carbon dioxide) and the establishment conditions (days to realize O₂ reduction and CO₂ increase) were registered. The CA conditions were 2% O₂ and 4.5% CO₂ at 0.5°C.

Pathogen identification. Throughout the experiments, fruit unusually soft or showing pitting symptoms (Fig. 1) were analysed in the plant pathology laboratory of AGROINNOVA, University of Turin. Part of the fruit pulp was plated on Petri dishes containing potato dextrose agar (PDA) with 50 µg l⁻¹ streptomycin sulphate. After 14 days at 26°C, developed colonies were observed morphologically and under the microscope. DNA extraction, PCR amplification and sequencing were performed for some strains isolated in the different years of the experiments. Thirty-day-old isolates, grown on PDA, were used for the extraction. The DNA

![Fig. 1. Symptoms of Cadophora luteo-olivacea on kiwifruit.](image-url)
was extracted using the NucleoMag 96 Plant Kit (Macherey Nagel, Switzerland) and the Kingfisher magnetic particle processor (Thermo Labsystems, UK), following the manufacturer’s protocols. About 100 mg of mycelium were ground to powder in liquid nitrogen with a mortar and pestle prior to DNA extraction. Genomic DNA was amplified using universal primers ITS1 and ITS4 (White et al., 1990) and PCR amplification was performed using a TGradient thermal cycler (Biometra, Germany). Each 20 µl PCR reaction contained 1 µl of DNA template (50 ng), 200 mM each deoxynucleotide triphosphate, 2 µl of 10x buffer (Taq DNA polymerase, Qiagen, USA), 0.7 mM each primer, and 1.0 U Taq DNA Polymerase (Qiagen, USA). The PCR program consisted of: heating at 95°C for 3 min followed by 34 cycles of 94°C, 15 sec; 55°C, 45 sec; 72°C, 7 min. A 10 µl aliquot of PCR products from each reaction was electrophoresed in 2.0% agarose gel, then stained with SYBR SAFE (Invitrogen, USA). Gel images were acquired with a Gel Doc 1000 System (Bio-Rad Laboratories, USA). PCR amplification products were cloned into the PCR4 TOPO vector (Invitrogen, USA) using the TOPO TA cloning kit following the manufacturers’ protocol and custom sequenced by Genome Express (Padua, Italy). The sequences were analyzed using the softwares BLASTn for homology and ClustalW for alignment.

**Storage trials.** Nineteen kiwifruit orchards were chosen for carrying out the experiments in collaboration with three packinghouses of Cuneo province (P.A.V. of Verzuolo, Lagnasco Frutta of Lagnasco and KiwiUno of Verzuolo). The orchards were chosen based on the incidence of *C. luteo-olivacea* symptoms during the three preceding years.

At harvest, on October 17 2002, 800 fruit per orchard were collected from the bins containing fruits from 50 plants per orchard. Part of the fruits (100 per sample) were delivered to the Regional Agrochemical Laboratory of Ceva (Piedmont, northern Italy) for the chemical determinations. About 100 mg of mycelium were ground to powder in liquid nitrogen with a mortar and pestle prior to DNA extraction. Genomic DNA was amplified using universal primers ITS1 and ITS4 (White et al., 1990) and PCR amplification was performed using a TGradient thermal cycler (Biometra, Germany). Each 20 µl PCR reaction contained 1 µl of DNA template (50 ng), 200 mM each deoxynucleotide triphosphate, 2 µl of 10x buffer (Taq DNA polymerase, Qiagen, USA), 0.7 mM each primer, and 1.0 U Taq DNA Polymerase (Qiagen, USA). The PCR program consisted of: heating at 95°C for 3 min followed by 34 cycles of 94°C, 15 sec; 55°C, 45 sec; 72°C, 7 min. A 10 µl aliquot of PCR products from each reaction was electrophoresed in 2.0% agarose gel, then stained with SYBR SAFE (Invitrogen, USA). Gel images were acquired with a Gel Doc 1000 System (Bio-Rad Laboratories, USA). PCR amplification products were cloned into the PCR4 TOPO vector (Invitrogen, USA) using the TOPO TA cloning kit following the manufacturers’ protocol and custom sequenced by Genome Express (Padua, Italy). The sequences were analyzed using the softwares BLASTn for homology and ClustalW for alignment.

During 2005-2006, using the same procedure of the previous season, two batches with a high incidence of *C. luteo-olivacea* infection at the end of the storage (March 2006) were compared with two healthy batches stored...
Factors favouring Cadophora luteo-olivacea on kiwifruit under the same controlled atmosphere conditions.

Data analysis. The values of C. luteo-olivacea incidence of the batches harvested in 19 orchards in 2002 and stored until March 2003 were plotted on the values of kiwifruit DM and nitrogen content at harvest and linear regression was performed, by calculating the equation of the regression equation and the R² value. The means of DM, nitrogen, calcium and magnesium contents of the healthy and infected batches stored in the same packinghouse during 2004-2005 and 2005-2006 were analyzed with Student's t test (p-value < 0.05). Evaluations of the association of fruit quality parameters and storage room conditions were performed using Pearson's correlation. Statistical analysis was performed using the SPSS software (SPSS Inc., version 17.0, USA).

RESULTS

Pathogen identification. Throughout the experiments, C. luteo-olivacea was identified by means of colony and conidial morphology and molecular traits, amplifying the genomic DNA with species-specific primers and sequencing the PCR products. The sequences obtained through the amplification of ribosomal region ITS1-5.8S-ITS2 (accession Nos GQ214536, GQ214537 and GQ214538) showed 100% similarity to the same ribosomal sequence of C. luteo-olivacea already deposited in GenBank.

Packinghouse monitoring. Kiwifruits of the seven packinghouses monitored for two years (Table 1), were stored in different controlled atmospheres (CA) and the time to reach the oxygen and carbon dioxide levels were different. In four packinghouses C. luteo-olivacea losses were recorded either in the 2001-02 season or in the 2002-03 season. Whereas oxygen and carbon dioxide levels did not seem to influence the incidence of skin pitting, the time needed to reach the wanted CA influenced directly C. luteo-olivacea incidence. In particular, when CA was established within 8 to 12 days, skin pitting symptoms were present in both years. When the period to establish CA lasted 25 days or longer, C. luteo-olivacea infections were apparently absent. By comparing skin pitting incidence in the two years, a significantly higher presence of skin pitting was recorded in 2001-2002 according to the Student's t test (p-value < 0.05).

Storage trials. In 2002, nineteen kiwifruit orchards were chosen to carry out the trials. Before storage, the DM, nitrogen, calcium and magnesium contents of the fruit were measured. At the end of the storage, fruits infected by C. luteo-olivacea were counted. The DM was plotted on the values of disease incidence and was inversely related to the incidence of C. luteo-olivacea (Fig. 2), with an R² of 0.5269 and y = -0.1944x + 15.384 as regression equation. The intercept indicated that kiwifruit batches with values of DM equal or higher than 15.384% were less susceptible to skin pitting. The two samples showing the highest disease incidence at the end of the storage (15.33% and 15.04%) had a significantly lower DM (13.66% and 10.55% respectively) compared to the other samples (14.70% in average).

Higher nitrogen content was correlated with increasing incidence of C. luteo-olivacea (Fig. 3). The dispersion graph of the values of disease incidence and nitrogen content showed that the two parameters were directly related, with an R² of 0.5015 and the relationship between the two parameters was represented by the regression equation y = 0.0187x + 0.9848. By considering the regression equation, when x=0 (no disease incidence), nitrogen content should be lower than 0.9848%. The two samples showing the highest number...
of infected fruits also showed a high nitrogen content (1.341% and 1.176%), compared to the other samples. The magnesium content (ranging from 0.177% to 0.201%), was not related to C. luteo-olivacea symptoms but the calcium content (ranging from 0.274% to 0.726%), seemed to be inversely related to disease incidence, although a very low R² value (0.2085) was found (data not shown).

Dry matter and mineral composition on kiwifruit harvested in 2004 and 2005. During 2004-2005, five packinghouses were surveyed at the end of the storage (March 2005) to identify C. luteo-olivacea infection, and three batches highly infected were identified (Table 2). An analysis of the DM and of the mineral composition was performed on the three infected and on three healthy batches stored in the same packinghouse under the same CA conditions for the same number of days.

The three healthy batches had DM (range: 14.71-15.83%) always significantly higher than that of the three infected batches (range: 12.30-13.49%). Higher DM was related to lower disease incidence, when storage conditions were the same. Also the nitrogen content in the three infected batches (range: 1.137-1.460%) was significantly different from the value recorded for the three healthy ones (range: 0.751-0.904%). Higher nitrogen content was related to higher susceptibility to the pathogen, confirming the results previously obtained.

The calcium content in the fruits from packinghouses 1 and 2 was significantly higher in the healthy compared to the infected batch. In the infected batch of the third packinghouse, the calcium content (0.169), although lower, was not significantly different from the value of the healthy batch (0.219). The magnesium content was not statistically different among the different batches, although a higher content was observed in the healthy batches.

During the season 2005-2006, the same packinghouses were surveyed at the end of the storage (February-March 2006) and two batches coming from different packinghouses had a high skin pitting incidence (Table 2). The batch from the first packinghouse was severely infected by C. luteo-olivacea (65% of the fruit) so that its storage was shortened to 97 days.

In both packinghouses, the healthy batch had significantly higher DM, and the batch with the highest infection had the lowest DM (10.38%). The nitrogen content in the two infected batches was significantly higher than the content found in the healthy batches stored in the same CA conditions. Moreover, in the batch showing the highest losses, the nitrogen content was significantly higher (1.418%) than in any other batch.

The calcium and the magnesium content were not significantly different among the batches, although the magnesium content was higher in the two healthy batches.

All the fruit quality parameters (dry matter, nitrogen, calcium, and magnesium) and the storage room conditions of the two years were analyzed using Pearson’s correlation. A significant association at the 0.01 level (2-tailed) was found for disease incidence and dry matter (-0.853; significance: 0.002), disease index and nitrogen content (0.815; significance: 0.004), and dry matter and nitrogen content (-0.865; significance: 0.001). The other parameters were not significantly associated with the disease incidence (p=0.01; 2-tailed).

Table 1. Monitoring of C. luteo-olivacea incidence (%) on kiwifruit in seven packinghouses located in Piedmont (northern Italy) to evaluate the influence of commercial storage practices. Kiwifruits were harvested in October 2001 or 2002 and stored up to March 2002 or 2003.

<table>
<thead>
<tr>
<th>Packinghouse</th>
<th>CAa conditions</th>
<th>CAb establishment (days)</th>
<th>C. luteo-olivacea incidence (%) on kiwifruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O₂ (%)</td>
<td>CO₂ (%)</td>
<td>(days)</td>
</tr>
<tr>
<td>1</td>
<td>3.0</td>
<td>4.5</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>3.0</td>
<td>4.5</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>4.0</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>5.0</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
<td>4.5</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>3.3</td>
<td>4.7</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>3.3</td>
<td>4.7</td>
<td>12</td>
</tr>
</tbody>
</table>

*Incidence of C. luteo-olivacea in the same packinghouse between 2001-2002 and 2002-2003 was significantly different based on the Student’s t test (p-value < 0.05).

aCA conditions = percentage of oxygen and carbon dioxide in controlled atmosphere.
bCA establishment = number of days required for O₂ reduction and CO₂ increase.
DISCUSSION

*C. luteo-olivacea* is a dangerous postharvest storage pathogen of kiwifruits. In the course of this study, *C. luteo-olivacea* was identified in every batch and in every year by plating on agar substrate, observing colony morphology and conidia, by sequencing the ribosomal region ITS1-5.8S-ITS2 amplified with the universal primers ITS1 and ITS4 (White et al., 1990) and aligning with BLASTn. Nucleic acid-based techniques have several potential advantages, including a greater accuracy and specificity.

A closely related species, *Cadophora malorum* can also infect pome fruit, such as apples and pears (Snowdon, 1990). In particular, side rot, caused by *C. malorum*, is an important postharvest disease of pear in long-term storage (Bertrand et al., 1977). On pears symptoms are rarely observed before 3 months at -1°C and more commonly appear 4-6 months after fruit is placed in cold storage (Sugar and Spotts, 1992). Similarly, on kiwifruit skin pitting symptoms occurred after 3-4 months of storage and they were not recorded every year, so the disease was difficult to study because of its erratic occurrence.

During the two-year packinghouse monitoring, a common feature of the 4 packinghouses out of 7 where skin pitting losses occurred was the short period required for reaching the wanted CA conditions. These packinghouses realized the CA establishment in 8-12 days, while the other three, where skin pitting symptoms did not occur, established the CA in significantly longer periods of 25-45 days. These findings tally with those by Lallu et al. (2003), who reported that the speed of CO₂ establishment could greatly influence physiological pitting since the incidence of the disorder was reduced by a longer delay prior to or by a slower rate of CO₂ establishment. Moreover, postponing the CA establishment by 30-50 days postharvest, could avoid the negative impact of CA storage on the development of another key postharvest disease of kiwifruit, *Botrytis cinerea*, without any adverse effect on fruit firmness (Tonini et al., 1999). Finally, step-wise low oxygen storage effectively reduced side rot caused by *C. malorum* on pear fruit during storage (Chen et al., 1995).

Besides the atmosphere management, also the fruit variables at harvest can greatly influence the susceptibility of kiwifruit to fungal skin pitting. During fruit ripening, the starch is almost completely converted to soluble sugars (Richardson et al., 1997). As a large proportion of the DM at-harvest is starch plus soluble sugars, this DM value can be related to the soluble sugars that will be present in the ripe fruit. Moreover, DM is an important index to evaluate the fruit quality to endure prolonged storage (Jackson and Harker, 1997). In the nineteen kiwifruit orchards chosen to carry out the storage experiments in 2002-2003, the DM was inversely related

<table>
<thead>
<tr>
<th>Packinghouse 1</th>
<th>Packinghouse 2</th>
<th>Packinghouse 3</th>
<th>Packinghouse 4</th>
<th>Packinghouse 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA conditions (%)</td>
<td>3.0 O₂ - 4.5 CO₂</td>
<td>3.5 O₂ - 5.0 CO₂</td>
<td>3.0 O₂ - 4.5 CO₂</td>
<td>3.5 O₂ - 5.0 CO₂</td>
</tr>
<tr>
<td>CA establishment (days)</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Storage (days)</td>
<td>115</td>
<td>110</td>
<td>110</td>
<td>119</td>
</tr>
<tr>
<td>C. luteo-olivacea incidence (%)</td>
<td>Healthy</td>
<td>Infected</td>
<td>Healthy</td>
<td>Infected</td>
</tr>
<tr>
<td>N (%)</td>
<td>0.751*</td>
<td>1.460</td>
<td>0.852*</td>
<td>1.291</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>0.265*</td>
<td>0.203</td>
<td>0.404*</td>
<td>0.302</td>
</tr>
<tr>
<td>Mg (%)</td>
<td>0.203</td>
<td>0.196</td>
<td>0.193</td>
<td>0.170</td>
</tr>
</tbody>
</table>

*The means of the healthy and infected batches from the same packinghouse were significantly different based on the Student's t-test (p-value < 0.05).*

*aCA conditions = percentage of oxygen and carbon dioxide during controlled atmosphere.  
bCA establishment = number of days required for O₂ reduction and CO₂ increase.*
to the skin pitting incidence, although the $R^2$ was not very high and two of the data points obtained influenced the result. It should be noticed that all fruit batches were stored in CA after a rapid CA establishment. Most of the physiological disorders of kiwifruit, such as premature softening, fruit rots and physiological disorders including ‘soft patches’, low temperature breakdown and physiological pitting, are related to the DM content of the fruits (Hewett et al., 1999). Thus, kiwifruits with higher DM are less affected by physiological disorders (Feng et al., 2006) and are also less susceptible to fungal pathogen decays, such as B. cinerea (Greaves et al., 2001).

In some infected kiwifruit batches analysed throughout the experiments a very low level of DM was measured. In Italy, especially in the north, the first frosts occur at the beginning of November, so kiwifruit producers cannot go beyond a certain harvest date. “Hayward” kiwifruit at harvest may have DM in the range of 12-20% of the fresh weight, with most its fruits having a DM content in the range of 14-17% (Burdon et al., 2004). In Piedmont (northern Italy) a DM of 14-15% is considered a very good level, while in Latium (central Italy) a DM of 18% can be easily reached. The high variability in the DM among the different years could depend on the season (Snellgrove et al., 2005), the timing of harvest, the fertilizer applied (Thorp et al., 2003), the orchard location and the canopy management (Mowat and Maguire, 2007).

In the orchards chosen to carry out the experiments in 2002-2003, the nitrogen content was directly related to skin pitting incidence. Also a lower calcium content, although less significantly, contributed to create favourable conditions for C. luteo-olivacea infections. In the experiments carried out on kiwifruits harvested in 2004 and 2005, a high level of nitrogen and a low level of calcium were generally associated with a higher susceptibility to skin pitting after 3 to 4 months of storage. The nitrogen, calcium and magnesium content constitute important parameters in the maturity and storage of kiwifruit (Hopkirk et al., 1990; Prasad and Spiers, 1991). The nitrogen content and the N:Ca ratio were positively correlated with the percentage of unmarketable kiwifruit after storage at -0.5°C (Tagliavini et al., 1995). In the experiments carried out to determine the relationship between the fruit nutrient status and the development of physiological pitting in kiwifruit, a generally higher skin pitting incidence was noticed in vines with lower fruit calcium concentrations, but the trend was not consistent in all orchards (Thorp et al., 2003). CaCl$_2$ sprays increased the fruit Ca content and firmness at harvest, favouring a slower softening of the kiwifruit and increasing storage life potential by 10-12 weeks. Significant results were obtained also by Sugar et al. (1991) who found that incidence and level of side rot of pears caused by C. malorum were reduced in fruit from trees treated with CaCl$_2$ sprays during the growing season, and the calcium concentration in the mature fruit peels was related to the level of CaCl$_2$ treatment. Different cultural practices, including the quantity and type of nitrogen fertilizer used, can influence the DM and mineral composition of kiwifruit, and also the susceptibility to C. luteo-olivacea infection.

When the fruit are characterized by low level of DM and high nitrogen content, they could be more susceptible to C. luteo-olivacea infection that not only reduces the quantity of marketable fruit, but also the storage life of the fruit. As an example, the highly infected batch obtained in the year 2005-06 (65% of the fruit) was stored for a period (97 days) much shorter than usual (around 120-150 days).

On pear, the fungus C. malorum is soil-borne and appears to be deposited on fruit via dust from the orchard floor or through soil introduced into dump tanks on contaminated fruit or harvest bins (Sugar and Spotts, 1993). Also in kiwifruit orchards C. luteo-olivacea is normally a soil-borne microorganism (Gilardi et al., 2007) that can reach the surface of the fruits through soil, staying alive in a latent phase. At the end of storage, when the pear fruit defences are decreasing (Sugar and Spotts, 1992), C. malorum can infect mainly stressed fruit, which have undergone rapid CA establishment and have low DM and high nitrogen and low calcium content.

C. luteo-olivacea represents an economically significant problem, especially for the packinghouses in Italy. When present, it can affect even more than half of the production. Identification of orchards as suitable for CA storage is not based simply on the characteristics of fruit at harvest, but storage operational factors, particularly those affecting atmosphere management, are likely to be at least, if not more, as important than variables at harvest for the development of C. luteo-olivacea on kiwifruit. For this reason, an accurate estimate of the possible susceptibility of the kiwifruit batches entering the packinghouse is necessary. In particular, batches with predisposing factors, such as low DM and high nitrogen content, should be more carefully managed, reducing the storage life and avoiding an excessively fast and stressing CA establishment.

ACKNOWLEDGEMENTS

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