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Seasonal Production of Conidia of *Monilinia laxa* from Mummified Fruits, Blighted Spurs and Flowers of Sweet Cherry

Produktion von *Monilinia laxa*-Konidien an mumifizierten Früchten, Fruchttrieben und Blüten von Süßkirschen während der Saison

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Summary

Seasonal production of spores (conidia) of *Monilinia laxa* (Aderh. & Ruhl) Honey on overwintered mummified fruits, blighted flowers and fruit spurs, and newly infected flowers of sweet cherry (*Prunus avium* L.) was investigated in Norway in 1997–1999. Infected plant parts were incubated in saturated air for 48 h prior to washing in distilled water, followed by a quantification of conidia from the spore suspensions with a light microscope. Mummified fruits or fruit spurs containing blighted flower and leaf parts, placed on the ground in the spring or the preceding autumn, more quickly depleted their inoculum compared to similar plant parts still hanging in trees. Conidia were produced in high numbers on mummified fruits left hanging in trees for 2–3 years after infection. In 1997, the conidial production on fruit mummies in trees was relatively even during the growing season. The year after, the highest sporulation on mummified fruits in trees occurred prior to flowering, and by harvest the sporulation was reduced by 92 %. The wet weather that occurred in 1998 probably depleted the inoculum earlier than in 1997, when the summer was drier. The major production of conidia from fruit spurs occurred prior to or around bloom, and very few conidia were observed at harvest. Infected flower and leaf parts attached to the overwintered fruit spurs contained higher numbers of conidia than the fruit spurs themselves. Flowers infected in the spring produced most conidia during the first two months after infection, however, if remaining attached to the fruit spurs, they produced conidia during the entire season. Infected, overwintered flowers produced 3–10 % as many conidia as newly infected flowers in May and early June. The maximum production of conidia from single, overwintered, mummified fruits was more than 10 times the conidial production from an overwintered fruit spur or newly infected flower at their respective times of peak sporulation.

Zusammenfassung

In den Jahren 1997–1999 wurde in Norwegen die während der Saison abhängige Produktion von *Monilinia laxa*-Konidien an überwinternden mumifizierten Früchten, bereits befallene Blüten und Fruchttrieben und frisch infizierten Blüten von Süßkirschen (*Prunus avium* L.) untersucht. Infizierte Pflanzenteile wurden 48 Stunden in wassergesättigter Atmosphäre inkubiert, bevor sie mit destilliertem Wasser abgewaschen und die dabei gewonnenen Konidien unterm Lichtmikroskop ausgezählt wurden. Die Inokulummenge von mumifizierten Früchten oder Fruchttrieben, die abgestorbene Blüten und Blattteile aufwiesen, und im Frühjahr oder im vorherigen Herbst auf dem Boden ausgelegt worden waren, war wesentlich geringer als dies von vergleichbaren Pflanzenteilen, die am Baum verblieben waren. Eine große Anzahl Konidien bildeten sich an mumifizierten Früchten, die 2–3 Jahre nach der Infektion noch im Baum hingen. 1997 war die Konidienproduktion auf im Baum verbliebenen mumifizierten Früchten sogar während der Vegetationsperiode verhältnismäßig konstant. Im Jahr danach, trat die höchste Sporulationsrate vor der Blüte auf, zum Zeitpunkt der Ernte war sie um 92 % reduziert. Das nasse Wetter des Jahres 1998 führte vermutlich dazu, daß sich das Inokulum früher erschöpfte als 1997, als der Sommer trockener war. Die höchste Konidienproduktionsrate auf Fruchttrieben wurde vor oder während der Blüte erreicht, zum Erntezeitpunkt wurden nur wenige Konidien beobachtet. Infizierte Blüten und Blattteile an überwinternden Fruchttrieben enthielten mehr Konidien als die Fruchttriebe selbst. Im Frühjahr infizierte Blüten produzierten in den ersten zwei Monaten nach der Infektion die meisten Konidien, wenn sie am Fruchttrieb verblieben, produzierten sie jedoch die ganze Saison Konidien. Infizierte überwinternde Blüten produzierten nur 3–10 % der Konidienmenge verglichen mit den im Mai oder zu Beginn des Juni neu infizierte Blüten. Die höchste Konidienproduktionsrate einer einzigen überwinternden mumifizierten Frucht betrug mehr als das 10-fache der Produktionsrate auf überwinternden Fruchttrieben oder frisch infizierten Blüten an deren jeweiligem Sporulationshöhepunkt.

Introduction

In sweet cherry (*Prunus avium* L.), *Monilinia laxa* (Aderh. & Ruhl) Honey causes blossom blight, spur blight, and brown rot in fruits. The teleomorphic stage of the fungus is very rare (BYRDE and WILLETS 1977, OGAWA and ENGLISH 1991), and has never been detected in Norway. Thus, the anamorph stage totally domi-

nates as primary inoculum. *M. laxa* survives from one season to the next in twig cankers, blighted flowers, peduncles, and mummified fruits (BYRDE and WILLETS 1977, OGAWA and ENGLISH 1991).

By decreasing inoculum density of *Monilinia* spp. in orchards, the possibility for both flower blight (WILCOX 1989) and fruit decay (BIGGS and NORTHOVER 1988, BROWN and WILCOX 1989, CORBIN 1963, NORTHOVER and BIGGS 1990, 1995, WILCOX 1990) is greatly reduced. Inoculum sources and dispersal patterns in *M. laxa* (CORBIN and OGAWA 1974) and *Monilinia fructicola* (Wint.) Honey (JENKINS 1965, KABLE 1965, LANDGRAF and ZEHR 1982, BIGGS and NORTHOVER 1985, WILCOX 1989) have previously been studied in other *Prunus* spp. By means of a spore trap, release of conidia of *Monilinia* sp. (species not specified) from mummified sweet cherry fruits was monitored in a Swiss experiment during one season (RÜEGG and HILBER-BODMER 1997). Conidia were released from mid April to early June, with the major release from late April to late May, concurrent with time of flowering to the end of the green fruit phase.

When fruits approached maturity in peach orchards in Ontario, Canada, the main inoculum sources of *M. fructicola* were thinned fruits on the ground and nonabscised, aborted fruits in the trees (BIGGS and NORTHOVER 1985). Similar observations were made in peach in South Carolina, USA (LANDGRAF and ZEHR 1982) and nectarine in California, USA (HONG et al. 1997). For *M. fructicola* in sour cherries in New York, USA, mummified fruits seemed to be more important as inoculum for fruit rot than infected flowers (WILCOX 1989). From New South Wales, Australia (KABLE 1965) and North Carolina, USA (SUTTON and CLAYTON 1972) it was reported that fruit peduncles were overwintering sites for *M. fructicola* in peach. In two early reports from the USA on *M. fructicola* in peach (JEHLE 1913, ROBERTS and DUNEGAN 1926), it was emphasized that infected flower parts adhering to the fruit spurs during summer were important inoculum sources for the maturing fruits. Dispersal patterns of conidia of *M. laxa* were investigated in California, USA, in an orchard containing apricot, peach, prune, and almond (CORBIN and OGAWA 1974). Fruit mummies, twig cankers, limb cankers, pedicels, and peduncles all contained the fungus, but there was no evaluation of the relative importance of the various inoculum sources.

The aim of the present study was to investigate seasonal production of conidia of *M. laxa* from mummified fruit, blighted fruit spurs, and infected flowers of sweet cherry.

Materials and Methods

Mummified fruits

In 1997, mummified fruits, infected the previous growing season, were collected from a sweet cherry orchard at the Norwegian Crop Research Institute, Ullensvang Research Centre in southwestern Norway (hereafter called the Ullensvang orchard). Fruits collected on 26 February were brought to the Plant Protection Centre at Ås in southeastern Norway, where they were kept frozen at –18 °C until they were placed in a sweet cherry orchard at Ås (hereafter called the Ås orchard) 16 April. From the Ullensvang orchard, fruit mummies were also collected on 11 March and were kept in the same orchard. The orchards at both Ås and Ullensvang contained a mixture of cultivars. Approximately 150 fruits were placed in each of 3 (Ås) or 2 (Ullensvang) onion bags (plastic fiber, 1 cm^2 mesh size). The bags were left hanging just beneath the canopy in each of 3 or 2 trees (1–1,5 m above ground), respectively. Underneath each of the trees approximately 150 mummified fruits were placed directly on bare soil on the orchard floor. The fruit mummies on the ground were kept in place with a fine meshed plastic fiber net (0.25 cm^2 mesh size). Mummified fruits collected in the spring of 1997 were left hanging in the onion bags during 1998 and 1999, and occasionally examined for conidia production.

In the autumn of 1997, mummified fruits previously infected the same season were collected in the Ås orchard. Fruits were either placed on bare soil under sweet cherry trees 6 November 1997 or they were left hanging in the trees over winter. On 16 April 1998 half of the fruits hanging in the trees were placed on bare ground, and the rest were left hanging in the trees throughout the growing season. For each treatment (on the ground in the autumn 1997; on the ground in the spring 1998; left hanging in the trees) there were 150 fruits in each of 3 replicates. In the 1998 experiments all fruits were kept inside hazel nut bags (plastic fiber, 1 cm^2 mesh size), with ten fruits in each. All the hazel nut bags in each replicate were kept inside one onion bag if hanging in the trees or placed under one fine meshed plastic fiber net if kept on the ground.

All fruits, either hanging in the trees or placed on the ground, were exposed to natural precipitation. Both years 10 fruits from each treatment/replicate were collected for further examination in the laboratory every second week throughout the growing season. Both years, almost all fruits had the peduncle still attached to the fruits during the experiments, and the peduncle was not removed when the production of conidia was recorded as described below.

Fruit spurs

Fruit spurs were collected from the cultivar Van in the Ås orchard. In 1997, fruit spurs infected the previous year were cut from the trees at each date of collection. In 1998, one hundred fruit spurs infected the previous year were cut on 16 April and placed on bare ground under a sweet cherry tree as described above for mummified fruit. Both samples from the trees and the ground were collected at each sampling day. On 1 December 1998, sixty fruit spurs infected the same year were placed on bare ground under a sweet cherry tree. Throughout the growing season of 1999, fruit spurs were sampled from the trees and from spurs placed on the ground in December 1998.

For each sample brought into the laboratory there were 10 fruit spurs, and sampling took place every two weeks. For many of the fruit spurs cut from the trees in the early part of the season, old infected flower and leaf parts and bud scales were still attached to the spurs. This debris was not removed from the spurs during the experiments. To compare the production of conidia

from flower and leaf debris to the production in fruit spurs containing bud scales, dead flowers and leaves were removed from the spurs during two assessment dates in May and June 1997.

Flowers

In the Ås orchard in 1997 and 1998, sweet cherry flowers, either naturally infected with *M. laxa* or artificially inoculated, were sampled every two weeks from the cultivars Ulster and Van for as long as the flowers were attached to the fruit spurs. Artificial inoculation was carried out during bloom both years. A suspension with 10^5 conidia per ml was made up from mummified fruits naturally infected with *M. laxa* the previous year and sprayed onto flowers by means of a hand sprayer. After inoculation, the flower clusters were covered with a double layer of white polyethylene bags for 4 days to ensure humid conditions for infection.

Each sample brought into the laboratory contained 10 flowers, and it was not distinguished between the two cultivars. In 1997, there were two replicates for each sampling, and in 1998 three replicates. In early July 1997, it was difficult to find artificially inoculated flowers left on the trees. From then on and until September only naturally infected flowers were brought into the laboratory. In 1998, only artificially inoculated flowers were used, but most of them dropped early from the trees included in the investigations, and examination of conidial production in flowers ended in early July.

In the spring of 1999, trees of the cultivar Van from another part of the Ås orchard were found to contain fruit spurs with flowers infected the previous year. Every two weeks, from early May to early July, overwintered flowers (10 flowers each time) were collected.

Laboratory tests

Each sample was placed on wet filter paper in plastic boxes. The boxes were covered with polyethylene bags (to ensure saturated air inside the boxes), and kept at room temperature (20–25 °C) for ca. 48 h. After incubation, each sample was shaken by hand for 1 min in a 100 ml bottle containing 50 ml distilled water. The samples were then removed from the water suspensions, and two suspension droplets were placed in a haemacytometer and examined with a light microscope. When the concentrations of conidia were high, the suspensions were diluted to make the counting easier. This was adjusted for afterwards. The number of conidia of *M. laxa* per well in 48 wells of the haemacytometer was recorded, and for each sample the number of conidia per ml was calculated. Viability of the conidia, i.e. the ability to germinate with a germ tube length of more than 3 times the width of the conidia after 24 hours incubation of conidial suspension droplets in saturated air, was occasionally examined. In the earlier parts of the experiments the germination varied greatly. From August 1997, and for the remaining experimental period, a droplet of sweet cherry juice was added to each suspension droplet to improve the germination.

Weather data

Data for daily means of temperature and rainfall were provided from meteorological stations in close vicinity (within 1 km) of the orchards at Ås and Ullensvang.

Statistical analysis

Analyses were performed using the statistics software package Statview 5.0.1 (SAS Institute, Inc., Cary, NC, USA). Analysis of variance was performed with the ANOVA or GLM procedures, and Least Significant Difference ($P = 0.05$) was used to compare sampling dates or treatments. The P-values given below depict the level of significance in the analysis of variance.

Results

Fruit bud development

Both for Ullensvang in 1997 and Ås in 1997–99, bud burst (time of first green tissue emerging from the flower buds) of the sweet cherry cultivar Van occurred either during the last week of April or in the first week of May; bloom was around 15–20 May; harvest was from the last week of July to the second week of August.

Weather

Monthly data for temperature and precipitation during the growing seasons are given in table 1. The 1997 season was characterized by cool weather in May, and warm, relatively dry weather in June, July and August. In 1998, it was very wet and cool during June, July and August, with 54 days with more than 0.2 mm rain and total precipitation of 280 mm during these three months at Ås. In 1999, June was very wet, but in July and August temperatures and rainfall were close to normal.

Table 1. Mean temperature and precipitation, and number of days with 0.2 mm or more precipitation in May–August at Ås in 1997–99 and Ullensvang in 1997.
Durchschnittstemperatur und Niederschlagsmenge sowie Anzahl der Tage mit 0.2 mm oder mehr Niederschlag in den Monaten Mai bis August in Ås in den Jahren 1997–99 und in Ullensvang im Jahr 1997.

Location and year	Temperature (°C)				Precipitation (mm)				Number of days with rain			
	May	June	July	August	May	June	July	August	May	June	July	August
Ås 1997	9.1	15.8	18.4	19.9	56.5	53.3	53.4	63.4	12	9	8	11
Ås 1998	11.1	12.9	15.1	13.9	20.9	123.5	60.7	95.6	10	17	19	18
Ås 1999	8.8	13.4	16.7	15.0	57.6	143.5	63.9	47.4	13	19	9	10
Ullensvang 1997	9.8	15.8	17.8	18.6	57.0	13.6	28.9	54.6	12	8	14	11

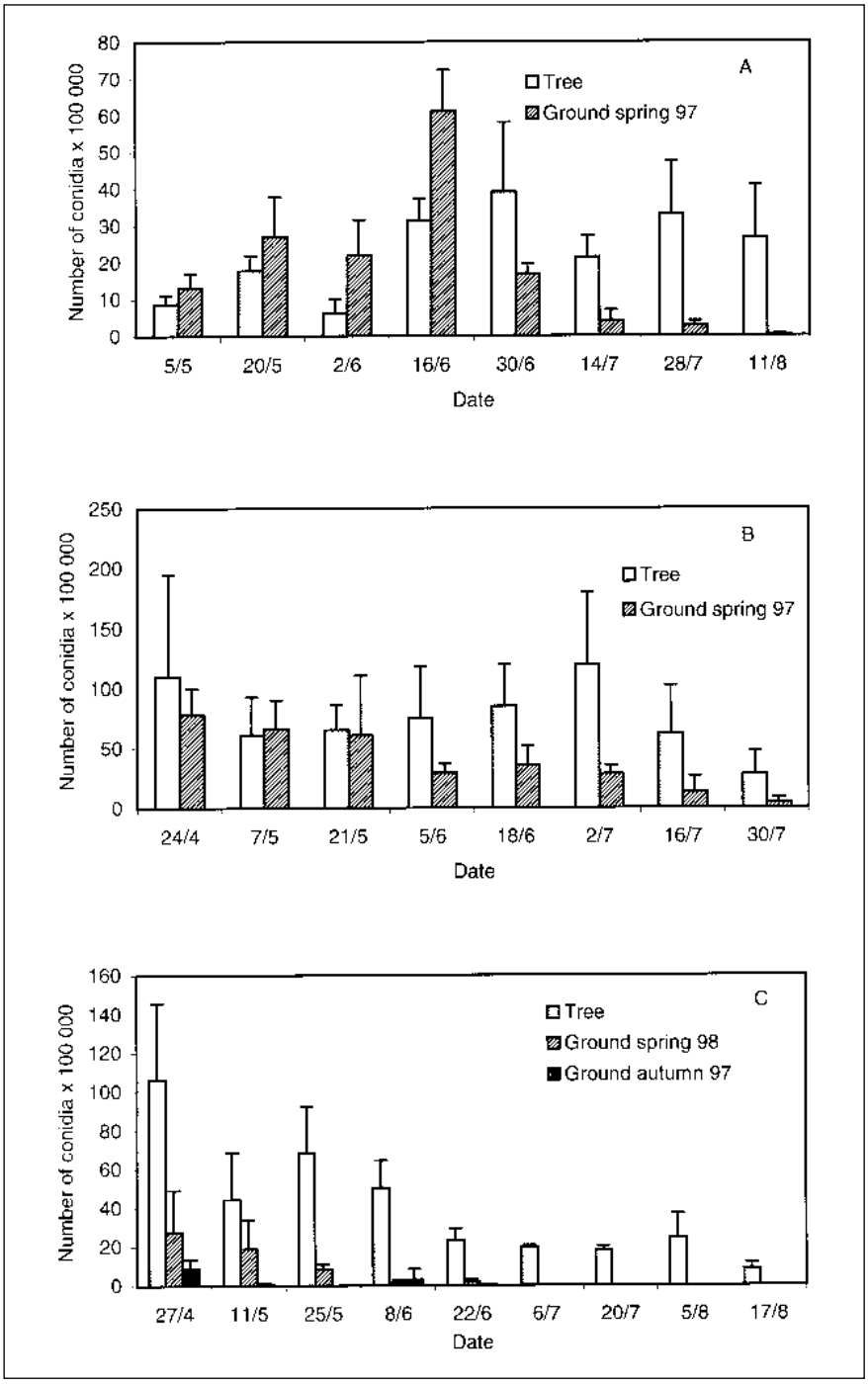


Fig. 1. Seasonal production of conidia of *Monilinia laxa* on overwintered mummified fruits of sweet cherry in 1997 at Ås (A) and Ullensvang (B) and 1998 at Ås (C). Bars are mean of 3 (A and C) or 2 (B) replicates (vertical lines = standard deviation), each showing number of conidia from 10 fruits. Sampling dates are designated day/month. Fruits were either hanging on the trees throughout the season, placed on the ground prior to or around bud break, or on the ground the preceding autumn (only C).
Produktion von Monilinia laxa-*Konidien an überwinternden mumifizierten Früchten von Süßkirschen in den Jahren 1997 in Ås (A) und Ullensvang (B) und 1998 in Ås (C).Die Säulen stellen Mittelwerte aus 3 (A und C) oder 2 (B) Wiederholungen (Vertikale Linien = Standardabweichung) der Anzahl Konidien von 10 Früchten dar. Der Tag der Probennahme wurde mit Tag/Monat bezeichnet. Die Früchte hingen entweder während der gesamten Saison im Baum oder waren vor oder während derKnospenentfaltung oder bereits im vorherigen Herbst (nur C) auf den Boden gelegt worden.*

Mummified fruits

In the first part of the 1997 season at Ås, the number of conidia produced was slightly higher on mummified fruits placed on the ground in the spring compared with fruits in the trees, but the difference was not significant (Fig. 1A). The conidial production on fruits on the ground was significantly reduced compared with fruits on the trees on 14 July ($P = 0.024$), 28 July ($P = 0.0001$) and 11 August ($P = 0.0001$). Numbers for Ullensvang 1997 (Fig. 1B) showed the same tendency, but there were no significant differences in conidia production at any date when comparing fruit mummies on the ground and on the trees. At Ås in 1998 (Fig. 1C), the conidial production on either fruit mummies placed on the ground in the previous autumn or in spring was significantly reduced already on 27 April ($P = 0.008$) compared to mummies on the trees.

At Ås in 1997 (Fig. 1A), there was no significant reduction in the conidial production on mummified fruits hanging on the trees between the maximum in June and the two observations around harvest (28 July and 11 August). For fruits on the ground there was a gradual and significant ($P = 0.0001$) decline in production from mid June to harvest. For mummified fruits on trees at Ullensvang in 1997 (Fig. 1B), there was a de-

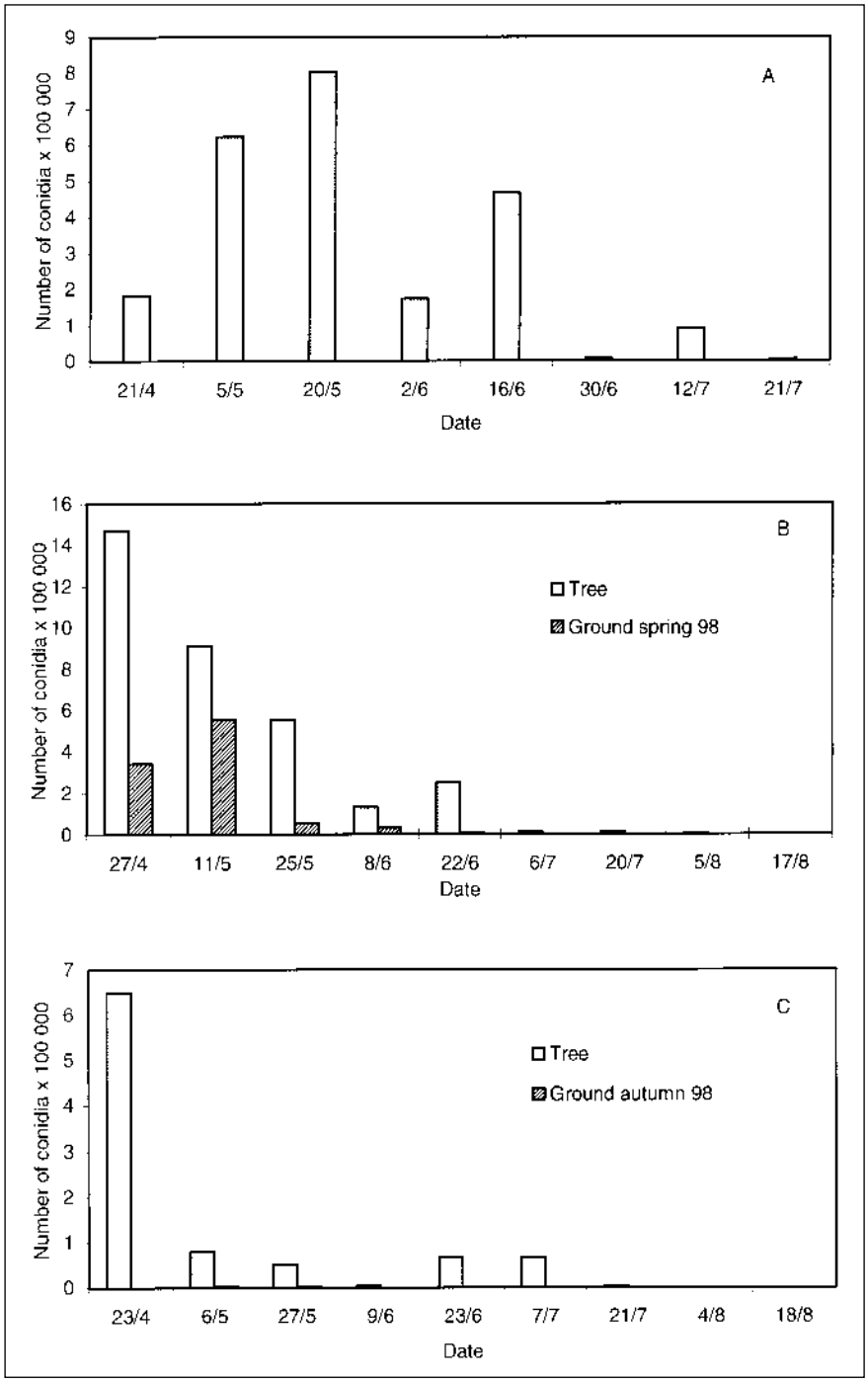


Fig. 2. Seasonal production of conidia of *Monilinia laxa* on overwintered fruit spurs of sweet cherry in 1997–99 at Ås. Bars represent numbers of conidia from 10 fruit spurs. Sampling dates are designated day/month. A: 1997, fruit spurs hanging on the trees. B: 1998, fruit spurs either hanging on the trees or placed on bare ground around bud break. C: 1999, fruit spurs either hanging on the trees or placed on bare ground the preceding autumn.

Produktion von Monilinia laxa-*Konidien an überwinternden Fruchttrieben von Süßkirschen in den Jahren 1997–99 in Ås. Die Säulen stellen die Anzahl Konidien von 10 Fruchttrieben dar. Der Tag der Probennahme wurde mit Tag/Monat bezeichnet. A: 1997, Fruchttriebe im Baum. B: 1998, Fruchttriebe waren entweder am Baum verblieben oder während derKnospenentfaltung auf den Boden gelegt worden. C: 1999, Fruchttriebe waren entweder am Baum verblieben oder im vorherigen Herbst auf den Boden gelegt worden.*

cline in conidial production towards harvest, but it was not statistically significant. Production on fruit mummies on the ground gradually and significantly ($P = 0.015$) decreased from maximum 24 April to the lowest 30 July (last observation). At Ås in 1998 (Fig. 1C), the maximum sporulation was recorded 27 April for both fruits on the trees and on the ground, and after that date there was a gradual and significant decline for all three categories; fruits on trees ($P = 0.0001$), fruits on ground in the spring 1998 ($P = 0.018$) and fruits on ground in autumn 1997 ($P = 0.006$).

Even if there was a decline in sporulation over the season, fruits placed on the ground in the spring of 1997 at Ås and Ullensvang released conidia until harvest. The last conidia observed from fruits placed on the ground in November 1997 at Ås were recorded on 22 June 1998, while fruits placed on the ground in the spring of 1998 ceased to produce conidia one month later (1–2 weeks prior to harvest).

Mummified fruits sampled in the spring 1997 (infected in 1996) were kept hanging on the trees over two (Ås) or three (Ullensvang) years. Samples containing 10 fruits each (two replicates for each date) were collected at Ås on 25 May, 20 July and 17 August 1998. The conidial production 25 May 1998 was lower ($P = 0.0008$) than the maximum occurring 30 June 1997, but was not

significantly different from any other observations in 1997. The numbers for 20 July and 17 August were lower, but not significantly different from the sporulation occurring in May and early June 1997. Similar samples were collected at Ullensvang on 10 May, 29 June and 20 August 1998 and 15 June 1999. The numbers of conidia recorded in 1998 and 1999 were significantly lower than the four highest counts in 1997 ($P = 0.013$), but were not different from the four lowest counts. At Ås and Ullensvang in 1998 and Ullensvang in 1999, the magnitude of the sporulation was 8.8–55.6 %, 4.5–10.3 %, and 3.3 %, respectively, of the highest count at the two locations in 1997. Viability of the conidia was 80–100 % in samples collected on 20 August 1998 and 15 June 1999 at Ullensvang.

Fruit spurs

The major conidial production in 1997 was around bloom, and it ceased towards the end of July, and there was more than a two-fold difference in the number of conidia recorded 20 May than two months later (Fig. 2A). In both 1998 and 1999 (Fig. 2B and C), the maximum in conidia production on fruit spurs infected the previous year occurred prior to bloom. In 1998 (Fig. 2B), detached fruit spurs placed on the ground in the spring ceased to release conidia in early July, while fruit spurs on the trees ceased to release conidia in early August. The number of conidia recorded around harvest on 5 August from spurs on the trees was only 0.2 % of the number recorded around bud break on 27 April. In 1999 (Fig. 2C), conidia production from fruit spurs on the trees decreased rapidly from 23 April to 6 May. In early July, the number of conidia was at the same level as in early May. However, towards the end of July, production became very low, and no conidia were detected around harvest in August. From fruit spurs placed on the ground in the autumn of 1998, conidia were observed only twice in 1999, and in low numbers (4–7 % of the sporulation on spurs on the trees).

When examining dead fruit spurs from the field incubated in the laboratory for two days, mycelium containing conidia were always observed close to the margin of the spurs, i.e. in the wood just below the bud scales from the last season or on the same bud scales. Flower and leaf parts infected in the previous year, remaining attached to the fruit spurs, were separated from the fruit spurs and bud scales during two assessments of conidia production in 1997. The flower and leaf parts produced 2.4 and 4.8 times as many conidia as the remaining fruit spurs on 20 May and 2 June, respectively. In all three years of the experiments, most flower and leaf parts attached to the fruit spurs on the trees had dropped to the ground by late July or early August.

Flowers

Both in 1997 and 1998 (Fig. 3), the highest number of conidia on flowers was observed 2–4 weeks after bloom (time of infection). In 1997 (Fig. 3A), production of conidia from infected flowers was observed until September, and there was a gradual and significant ($P = 0.001$) decline in sporulation from the maximum in June to after harvest. The following year (Fig. 3B) most flowers infected during bloom fell off the spurs in early July, and no further observations were made later. Flowers infected in 1998, still attached to the fruit spurs in 1999, produced conidia in May and early June (one year after infection), but no conidia were observed at the end of June and in early July (Fig. 4). The magnitude of the conidia production on one-year-old flowers was approximately 3–10 % of the sporulation on newly infected flowers.

Size of conidia production

On an average, the size of the conidia production from a single mummified fruit was more than 10 times higher than from a fruit spur or a newly infected flower at their respective times of maximum sporulation. Up to $6x10^7$ conidia were sampled per fruit in the peak period of sporulation at Ullensvang (one month prior to harvest). For mummified fruits placed on the ground in the spring, peak production of conidia was $3–4 \times 10^7$ conidia per fruit in the spring and early summer. For fruits detached from the trees in late autumn and placed on the ground, production was more than 4×10^6 conidia per fruit the following April.

Viability of conidia

In the early parts of the experiments, germination varied and was often low. However, when sweet cherry juice was added to the conidial suspensions, viability (germ tube size more than 3 times the width of the conidia) 24 h after start of incubation was always more than 70 %.

Discussion

The experiments showed that mummified fruits, blighted flowers, and fruit spurs infected the previous season, and flowers infected in the spring could serve as inoculum sources for *M. laxa* in sweet cherries throughout the entire growing season. The potential number of conidia produced by a single mummified fruit was more than 10 times higher than the production of conidia from a single fruit spur, and even higher compared with sporulation from a single flower. The continued ability for conidial production on mummified fruits was further demonstrated in samples from both Ås and Ullensvang, where they kept sporulating for 2–3 years after infection.

The progressive seasonal decline in sporulation on fruit mummies occurring at Ås in 1998 could be explained by a very wet growing season. The frequent rain events that year probably enhanced sporulation, and thus increased the depletion of the fungal tissue in the mummies. In 1997, sporulation was more evenly distributed, and the weather both at Ås and Ullensvang, was characterized by a wet spring and relatively warm, dry summer. In sour cherries in New York, USA, the highest level of sporulation of *M. fructicola* occurred towards harvest, while sporulation was at a low level before and during bloom (WILCOX 1989). The reason for low sporulation in the spring was explained by a general lack of rainfall before bloom during the three years

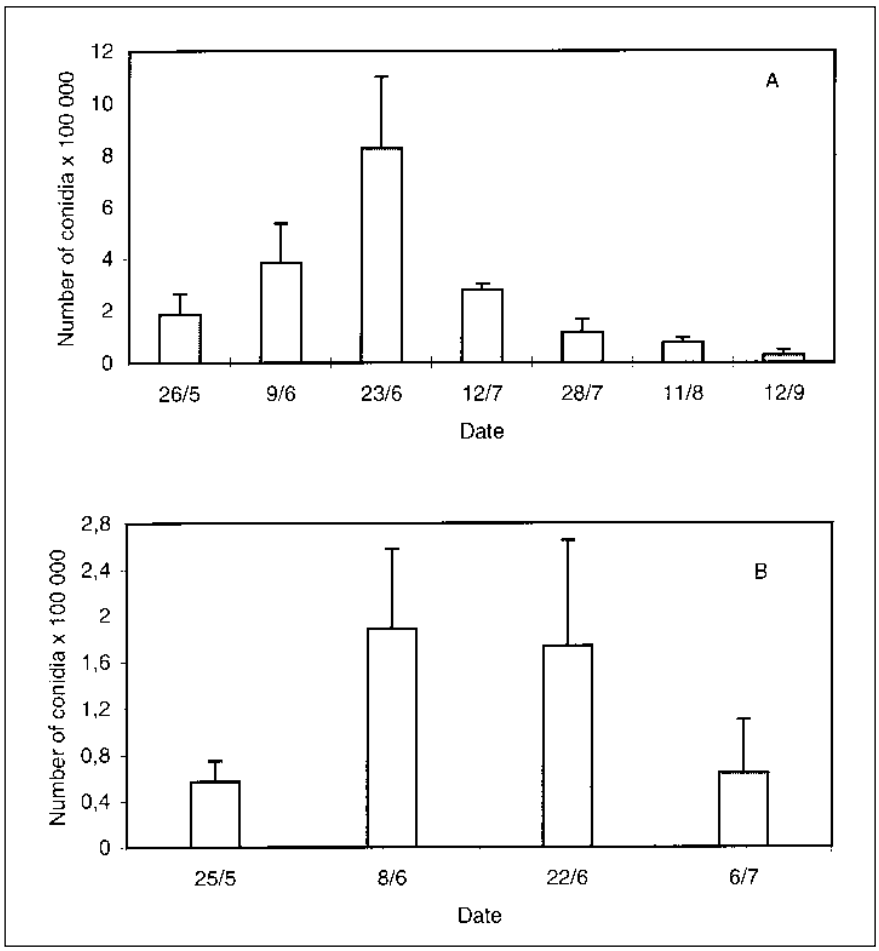


Fig. 3. Seasonal production of conidia of *Monilinia laxa* on sweet cherry flowers infected at bloom in 1997 (A) and 1998 (B) at Ås. Bars represent mean numbers of 2 (A) or 3 (B) replicates (vertical lines = standard deviation), each showing number of conidia from 10 flowers. Sampling dates are designated day/month.
Produktion von Monilinia laxa-*Konidien an während der Blüte infizierten Blüten von Süßkirschen in den Jahren 1997 (A) und 1998 (B) in Ås. Die Säulen stellen Mittelwerte aus 2 (A) oder 3 (B) Wiederholungen (Vertikale Linien = Standardabweichung) der Anzahl Konidien von 10 Blüten dar. Der Tag der Probennahme wurde mit Tag/Monat bezeichnet.*

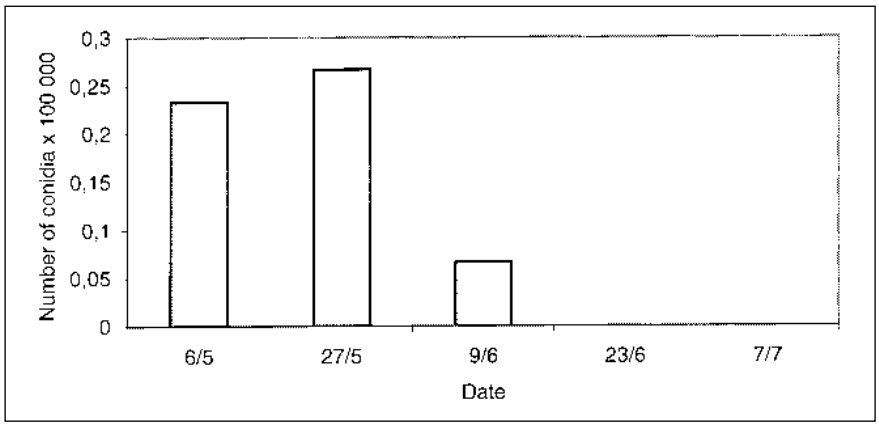


Fig. 4. Seasonal production of conidia of *Monilinia laxa* on overwintered sweet cherry flowers in 1999 at Ås; infections took place at bloom the preceding year. Bars represent number of conidia from 10 flowers. Sampling dates are designated day/month.
Produktion von Monilinia laxa-*Konidien an während der Blüte des Vorjahres infizierten Blüten von Süßkirschen im Jahre 1999 in Ås. Die Säulen stellen die Anzahl Konidien von 10 Blüten dar. Der Tag der Probennahme wurde mit Tag/Monat bezeichnet.*

studied. In a report from Switzerland, almost all *Monilinia* sp. conidia from mummified sweet cherry fruits were captured in a spore trap from the time of flowering and during the green fruit phase (RÜEGG and HILBER-BODMER 1997). Very few conidia were detected after the fruits changed colour. The weather was very wet during the whole time of spore sampling. The weather conditions occurring in Switzerland in 1997 were similar to the situation in Norway in 1998. In a laboratory study from Australia, a close relationship between moisture content in mummified apricot fruits infected with *M. fructicola* and ability to sporulate was reported; a high water content in the fruits coincided with high sporulation (CORBIN and CRUICKSHANK 1963). From field observations discussed in the same report, it was evident that sporulation from mummified fruits always occurred during or after rainy periods, and never during dry periods.

A higher moisture content and frequency of decomposers, such as earthworms and various microorganisms, present in the soil can probably explain the quicker decline in sporulation in fruits kept on the ground compared to fruits hanging on the trees. Winters in Norway are colder than in most countries further south. A higher winter temperature and fewer days with snow cover would most likely enhance degradation of inoculum on the ground. Thus, for countries with a milder winter climate, depletion of inoculum from

sources kept on the ground would presumably occur more quickly than shown in this report.

From mummified fruits of the sour cherry cultivar Montmorency infected by *M. fructicola*, WILCOX (1989) sampled more than 10^6 conidia per fruit in the peak period of sporulation in late May and in June (harvest in early July). Counts of conidia of *Monilinia fructigena* (Schröter ex Aderh. & Ruhl.) Honey indicated that a mummified apple might produce up to $4x10^6$ conidia during early summer the year following infection (BYRDE 1952). The reason for more than a ten fold higher number of conidia on single fruits in the present experiments, compared to the figures mentioned above by BYRDE (1952) and WILCOX (1989), is most likely due to the 48 h incubation period prior to washing the fruit mummies, which allowed high numbers of conidia to develop.

In the present investigation, the highest sporulation in overwintered, blighted spurs was observed early in the season, with a decline in sporulation towards harvest, when very few spores were observed. In Ontario, peach spurs infected with *M. fructicola* only sporulated in late May and early June (BIGGS and NORTHOVER 1985), and it was concluded that blighted fruit spurs did not contribute to fruit infections later in the season. Even if the spore numbers were low towards harvest, our observations showed that spurs infected the previous year remaining on the trees, can be a source of inoculum from flowering to harvest. However, as observed in Ontario (BIGGS and NORTHOVER 1985), inoculum from fruit spurs is most important early in the season, i.e. during flowering and early fruit development. From the two observations in May and June 1997, where flower and leaf parts were separated from the fruit spurs, it was obvious that there was a higher conidia production on the old flowers and leaves than on the remaining parts of the spurs which included bud scales. If much of the old foliage commonly fall off the spurs by the last month prior to harvest, as observed in these experiments, this can further explain the sharp decline in conidia production from fruit spurs in the latter part of the season.

In 1998, most newly infected flowers fell off one month prior to harvest and did not serve as an inoculum source at the end of the season. However, the preceding year some of the infected flowers remained attached to the infected spurs past harvest time. Furthermore, both in the spring of 1997 and 1998, many of the flowers infected the preceding years (1996 or 1997, respectively) remained attached to the spurs and served as a source of inoculum over two seasons. In peaches in South Carolina, the highest sporulation on flowers infected with *M. fructicola* was early after infection, and sporulation declined as the season progressed (LANDGRAF and ZEHR 1982). It was concluded that blighted flowers appeared to have little importance as a secondary inoculum in the preharvest period. This is in contrast with the observations made with *M. fructicola* in peaches from both the southeastern (ROBERTS and DUNEGAN 1926) and northeastern (JEHLE 1913) USA, where the importance of flower parts adhering to the fruit spurs until maturation of fruits was emphasized. From the present study on *M. laxa*, it can be concluded that if flowers infected in the spring remain attached to the blighted spurs, they will serve as inoculum until harvest.

Seasonal production of conidia of *M. laxa* on nonabscised, aborted fruits was not studied in this investigation. However, we have frequently observed *M. laxa* and other fungi causing fruit decay, especially *Botrytis cinerea* (grey mould) and *Glomerella cingulata* (bitter rot), to sporulate on aborted fruits. The importance of nonabscised, aborted fruits as inoculum source prior to harvest has been emphasized for *M. fructicola* in peach (BIGGS and NORTHOVER 1985; LANDGRAF and ZEHR 1982).

The effect of inoculum level on possibilities for infection has been pointed out in severeal reports on *M. fructicola* in *Prunus* spp. (BIGGS and NORTHOVER 1988, BROWN and WILCOX 1989, CORBIN 1963, NORTHOVER and BIGGS 1990, 1995, WILCOX 1990). Successful attempts have been made to reduce spring inoculum from overwintered sources of *Monilinia* spp. with applications of fungicides during winter and early spring (GILPATRICK 1973, KABLE 1970, 1976, 1983, RAMSDELL and OGAWA 1973, WENZL 1951, WICKS 1981, WILSON 1942). However, prevention of sporulation following such treatments has not been absolute, and negative focus on increased fungicide use has prevented this becoming a generally accepted method to lower spring inoculum. Thus, there should be more emphasis on removal of infected plant parts to reduce the inoculum. It is probably not economically feasible to remove blighted spurs after flowering, and thus a careful spraying is necessary during bloom to avoid flower and spur infections. This study has shown that if infected plant material is placed on the ground, sporulation declines more rapidly than if left on the trees, and the earlier a source of inoculum is placed on the ground, the quicker will the inoculum be depleted. To reduce next year's inoculum, decaying fruit and blighted spurs should be removed and dropped to the ground during or immediately after harvest.

Conclusions

Mummified fruits, blighted flowers and fruit spurs infected by *M. laxa*, could produce conidia and serve as inouculum sources from bud break to harvest in sweet cherry. Infected plant parts placed on the ground in the autumn or spring more quickly depleted their inoculum than if left hanging on the trees. A mummified fruit produced more than 10 times as many conidia as single fruit spurs or flowers at the time of maximum production. Significant production of conidia was observed in fruit mummies three years after infection.

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