From the laboratory to the field: litter management for control of *Botrytis cinerea* in boysenberry gardens

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Abstract — Introduction. Litter on the ground is a primary source of *Botrytis cinerea* inoculum in boysenberry (*Rubus* hybrid) gardens. The effect of litter management on primary inoculum production, and flower and berry infections was determined. **Materials and methods**. A series of experiments ranging from laboratory to large-scale field evaluations were conducted in New Zealand during 1997-2002 to evaluate litter management options for control of *B. cinerea*. The laboratory trial investigated the effect of litter size (shredded vs. unshredded litter) and debris amendments on tissue degradation and *B. cinerea* colonization. The field trial (four sites) investigated the effect of litter amendments (compost, urea and fungicide) and piling litter on *B. cinerea* sporulation. In the 4-year commercial-scale study (three properties), the effect of litter treatment (piling, compost and microbial extracts/suspensions) on primary inoculum, flower and berry infections was assessed. **Results and discussion**. The laboratory trial showed that bark + sewage sludge compost amendment enhanced litter decomposition and reduced *B. cinerea* sporulation on infected tissue after 8 weeks. The field trial indicated that piling of shredded boysenberry debris was more important than litter amendments in reducing the amount of *B. cinerea* harbored within the litter. Commercial field-scale evaluation of litter management options verified that piling of shredded litter is the most important step in *B. cinerea* inoculum control from debris. It also showed that microbial litter amendments (compost, solutions or extracts) can be beneficial. While *B. cinerea* inoculum control also reduced the amount of flower infections, berry infections at harvest were not affected, indicating that other sources of *B. cinerea* inoculum contribute to berry infection post-flowering.

New Zealand / *Rubus* / plant diseases / *Botrytis cinerea* / control methods / mulches / management / infection / flowers / fruits

Du laboratoire au champ : gestion de la litière pour le contrôle de *Botrytis cinerea* en verger de mûriers.

Résumé — Introduction. La litière du sol est une source primaire d'inoculum de *Botrytis cinerea* en vergers de mûriers (hybride de *Rubus*). L'effet de la gestion de la litière sur la production primaire d'inoculum et la contamination de fleurs et de baies a été évalué. **Matériel et méthodes**. Une série d'expérimentations menées du laboratoire au champ a été entreprise en Nouvelle-Zélande de 1997 à 2002 pour évaluer des possibilités de gestion de la litière pour le contrôle de *Botrytis cinerea*. Un essai en laboratoire a étudié l'effet de la dimension des résidus de taille (déchiquetés ou non) et de la modification des débris sur la dégradation des tissus et leur colonisation par *Botrytis cinerea*. Un essai en champ a étudié, sur quatre sites, l'effet de l'amendement de la litière (compost, urée, fongicide) et du tassement de la litière sur la sporulation de *Botrytis cinerea*. Une étude à l'échelle commerciale a été effectuée sur quatre ans chez trois cultivateurs pour évaluer l'effet du traitement de la litière (tassement, compost, extraits et/ou suspensions microbiens) sur l'inoculum primaire, et les infections de fleurs et de baies. **Résultats et discussion**. L'essai en laboratoire a montré qu'un amendement en compost de boue d'eaux usées + écorce a permis d'améliorer la décomposition de la litière et de réduire la sporulation de *Botrytis cinerea* sur les tissus infectés depuis 8 semaines. L'expérimentation en champ a indiqué que le tassement des débris de mûriers déchiquetés était plus efficace que des amendements de litière pour réduire la quantité de *Botrytis cinerea* hébergé dans la litière. L'étude à l'échelle commerciale des diverses possibilités de gestion de la litière a vérifié que le tassement de la litière déchiquetée était l'étape la plus importante du contrôle de *Botrytis cinerea* dans les débris. Elle a également prouvé que des amendements microbiens de la litière (compost, solutions ou extraits) pouvaient être salutaires. Alors que le contrôle de l'inoculum de *Botrytis cinerea* a permis de réduire également le taux d'infection des fleurs, l'infection des fruits à la récolte n'a pas été affectée. Cela indiquerait que d'autres sources d'inoculum de *Botrytis cinerea* contribueraient à l'infection des mûres après floraison.

Nouvelle-Zélande / *Rubus* / maladie des plantes / *Botrytis cinerea* / méthode de lutte / mulch / gestion / infection / fleur / fruits

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1. Introduction

Epidemiological studies [1] have shown that litter on the ground is the primary source of *Botrytis cinerea* Perk.: fries inoculum in boysenberry (*Rubus* hybrid) gardens. Research by Walter *et al.* [2] also showed that the major pathway of berry infection (> 90%) is via the boysenberry styles. The aim of this research was to reduce *B. cinerea* inoculum from litter and subsequently reduce flower and berry infections.

Microorganisms, in the form of specific biological control agents, composts [3] and compost extracts [4] have been studied for their disease suppressive abilities. Mulches (organic and inorganic) used as alternative soil management methods were widely evaluated during the 1980s for their effects (including economic) on intensive apple and vegetable production as reviewed by Himmelsbach *et al.* [5] and Singh [6], respectively. Organic mulch applications were found to increase microbial activity and biomass [7], and reduce the severity of some above-ground diseases [8]. Limited literature, however, is available on the use of organic mulches for control of *B. cinerea* infections. For example, Sauvage [9] reported that mulching in grape-vines controlled erosion, but no significant effects on yield and vine sensitivity to *B. cinerea* were observed in the short term. Mundy and Agnew [10] found that the number of colony-forming units of soil fungi increased under mulched plots compared with bare soil treatments under grape-vines and *B. cinerea* bunch rot incidence was less in mulched plots than bare soil treatments. However, no literature was found on the use of mulches and litter management for *B. cinerea* inoculum control.

In the past, New Zealand boysenberry growers coarsely shredded prunings with a mower, leaving the debris scattered in the aisle, thereby creating a major source of *B. cinerea* inoculum [1]. The effect of litter management on *B. cinerea* survival, inoculum production and flower/berry infections was studied in a series of experiments during 1997–2002 ranging from the laboratory, preliminary field to commercial-scale evaluations.

2. Materials and methods

2.1. Laboratory trial (1996/1997)

Shredded [(20–40) mm] and unshredded [(100–200) mm] boysenberry debris was collected from a commercial boysenberry garden (September 1996, Nelson) and moisture adjusted to 60% water-holding capacity (WHC). Debris treatments consisted of two commercial composts (compost 1: bark + offal, Laings Gardenmakers; compost 2: bark + sewage sludge, Attwoods) at a ratio of [compost:debris] = [1:3] (w/w; wet weights); control (unamended); and urea at the rate of 8 g to 100 g debris (wet weight) in order to sterilize the mix. The [C:N] ratio of the different mixes and the nutritional composition of the composts were determined (*table I*, AgResearch Soil Fertility Service). Mixes were placed into polystyrene boxes [(230 × 150 × 150) mm^3] at a height of approximately 100 mm. There were, therefore, four debris amendments (bark + sewage sludge compost; bark + offal compost; control; and urea) × two debris sizes (shredded and unshredded). Each treatment combination was replicated four times.

Washed and air-dried kiwifruit leaf discs (∅ 20 mm) were γ-irradiated (Shering Plough, Wellington), placed between sterile stainless steel mesh strips (2.28 mm hole size), rehydrated with sterile water on saturated filter paper (Whatman 1), centrally inoculated with 30 µL *B. cinerea* conidial suspension (10^5 conidia·mL^{-1}) and incubated at 20 °C for 4 days in the dark. The conidial suspension was prepared from a 3-week-old *B. cinerea* culture (isolate BC126 from boysenberry) grown on oatmeal agar (20 g Fleming oatmeal + 20 g Merck water agar per liter distilled water) as described by Walter *et al.* [1]. Kiwifruit leaf discs were chosen over boysenberry leaf discs because they are thicker and were more readily colonized by *B. cinerea* (data not presented).

Six strips of the steel mesh containing five inoculated leaf discs and six strips of steel mesh containing five uninoculated control discs were placed in each debris mix. Inoculated and control discs were placed at half the depth of the mix at least 20 mm apart from each other on separate sides of the polystyrene containers in order to prevent

Table I.
Nutritional analysis of composts used to study litter management regarding control of *Botrytis cinerea* in boysenberry gardens (New Zealand). All results are expressed as concentrate (v/v) in the extract. Total nitrogen, total phosphorous, total sulfur, total potassium and organic carbon were analyzed on a dried and ground sample (AgResearch Soil Fertility Service).

Compost	Total nitrogen (%)	Total phosphorous	Total sulfur	Total potassium	Calcium	Potassium	Magnesium	Sodium	pH	Dry matter (%)	Organic carbon (%)
		← µg·g^{-1} →									
Laboratory trial											
Bark + offal[1]	1.8	7180	4850	3080	90	170	7	84	7.4	53	23
Bark + sewage sludge	1.1	5480	2480	6250	10	380	5	60	6.9	47	18
Field trial											
Bark + offal[2]	0.6	1120	760	4000	9	47	3	15	5.1	43	18
Commercial-scale evaluation											
Sawdust + fish waste	0.1	25	110	nd	nd	120	nd	nd	3.9	27	24

[1] Supplied by Laings Gardenmakers.

[2] Supplied by Motueka Abattoir.

nd = not determined.

cross-contamination. The containers were covered with fitted lids and incubated at room temperature [(22 ± 3) °C]. The containers were arranged in completely randomized positions within the incubation area. The lids were removed twice a week for 8 hours to allow some air circulation and moisture was re-adjusted gravimetrically by misting tap-water onto the surface of the debris using a hand-held sprayer.

Two randomly chosen strips of each uninoculated and *B. cinerea*-treated leaf disc were removed after 0, 4 and 8 weeks of incubation from each of the four replicate containers per treatment. Leaf disc decay (%) was assessed immediately and *B. cinerea* sporulation (% area covered per leaf disc) was measured after a further 3 days' incubation at 100% relative humidity at 20 °C using a compound microscope (× 10 magnification). Analysis of variance (ANOVA) was used to describe main effects and Fisher's Least Significant Difference (LSD) test was used to determine treatment differences using the statistical package Systat.

2.2. Preliminary field trial (1997/1998)

Debris amendments were further tested in the field on four growers' properties in the Nelson area. Due to newly implemented industry health and fruit quality control measures, no sludge or manure-containing products are allowed to be released in New Zealand boysenberry gardens. Therefore, the [bark + sewage] sludge compost could not be further evaluated in the field. All litter from the spent floricane prunings was left between the aisles and shredded by the growers 2 or 3 days prior to the experimental setup. The debris was shredded with a mulch mower [debris size (40 to 100) mm]. In a commercial garden, depending on the pruning method, the average amount of shredded debris from spent floricanes ranges from

Table II.
Sample size and data used to study different treatments for litter management regarding control of *Botrytis cinerea* in boysenberry gardens (New Zealand).

Treatment	Year			Total *n*
	1999/2000	2000/2001	2001/2002	
Spread control[1]	36	36	36	108
Piled control[2]	36	36	36	108
SC27[3]	18	18	–	36
Ecogrow[4]	–	–	18	18
Compost[5]	18	–	–	18
Bio-Start[6]	–	18	18	36
Total *n*	108	108	108	324

[1] Spread control: all debris left scattered in the aisle.

[2] Piled control: all debris piled underneath the vine.

[3] SC27 (Ecogrow New Zealand Ltd.): microbial suspension (plant growth-promoting microbes) sprayed on top of debris piled under the vine; two applications (4 weeks apart), application rate according to product specification.

[4] Ecogrow (SC27 replacement, Envirocorp NZ Ltd.) microbial suspension (liquid soil fertility microbes) sprayed on top of debris piled under the vine; two applications (4 weeks apart), application rate according to product specification.

[5] Compost consisting of (sawdust + fish waste) (Agro-nutrient Products Ltd.) spread on top of debris piled under the vine, manually applied, 25 ± 3 L per plant.

[6] Bio-Start Digester (Compost replacement, Bio-Start Ltd.) enhances litter decomposition (non-viable blend of biologically produced fermentation extracts and selected minerals), sprayed on top of debris piled under the vine; two applications (4 weeks apart), application rate according to product specification.

15–25 L per plant. The following treatments were applied in the preliminary field trial:

– unamended debris left scattered in the aisle (control),

– unamended debris piled under the vine,

– unamended debris piled in the aisle,

– compost amendment of [bark + offal] (Motueka Abattoir) applied on top of debris piled under the vine at a ratio of [debris:compost] = [2:1] (v/v),

– urea (1 g·10 L^{-1} debris) applied on top of debris piled under the vine,

– fungicide (400 g·L^{-1} active ingredient pyrimethanil (Scala®); 20 mL·10 L^{-1} debris, 1000 L·ha^{-1}) applied on top of debris piled under the vine using a knapsack.

The treatments were applied on the 7 August 1997 to complete plant rows (> 20 m) with a buffer row (unamended debris left scattered in the aisle) between treatment rows. The experiment was set up with eight replicates per treatment (i.e., two replicates per grower). Debris [C:N] ratios were measured at each block for each treatment from a combined sub-sample of all plots immediately taken after treatments were applied and the compost nutritional information was obtained (AgResearch Soil Fertility Service).

B. cinerea colonization was assessed on debris collected on the 7 August (post-treatment applications), 22 September, 17 November, 15 December 1997 and 12 January 1998. At each assessment time, three debris samples were collected randomly from each treatment row using a (100 × 100) mm^2 grid. All debris within the grid was collected. The sample was then chilled (4 °C) and couriered overnight to the laboratory for *B. cinerea* assessment [1]. Briefly, debris samples were incubated by spreading them into one or two surface-sterilized plastic trays [(300 × 350) mm^2], lined with two sterile water-saturated paper towels and incubated at 100% relative humidity at room temperature [(22 ± 3) °C]. If the debris was dry, it was misted gently (just before run-off) with tap-water using a hand-held sprayer. The total area of *B. cinerea* sporulation (mm^2) was assessed after 6 days' incubation. ANOVA was used to describe main effects and Fisher's LSD test was used to determine treatment differences using the statistical package Systat.

2.3. Commercial-scale evaluation (1998–2002)

During the 4-year trial, all litter management treatments (*table II*) were applied during the last week in August. Prior to the treatment applications (2 or 3 days), all litter was shredded with a mulch mower [(40–100) mm]. Some treatments (except the two control treatments) changed due to unforeseen circumstances. For example, in year 3, the compost treatment was replaced with two Bio-Start Digester applications due to changes in the compost (sawdust + fish waste) make-up (pers. comm. with supplier). A suitable

replacement compost was not found based on economic consideration (alternative products would have tripled the compost application costs per ha). In year 4, treatments were as in year 3, except the microbial SC27 treatment was replaced with a different microbial suspension (Ecogrow) as the product SC27 was no longer available. The microbial extract and suspension (*table II*) applications were conducted using the growers' sprayers equipped with a herbicide boom (nozzles targeting the piled debris underneath the vines) at a tractor speed of 4 $km \cdot h^{-1}$ and water rate of approximately 1400 $L \cdot ha^{-1}$.

Treatments were applied to blocks (for application rates please refer to *table II*'s footnotes). Each treatment was applied across at least five to seven rows per block, replicated over four blocks at three growers' properties. In each block, treatments were assigned to the groups of rows at random. The total research area was approximately 0.7 ha per grower.

B. cinerea debris and flower assessments in years 1 to 4 were carried out in spring during early (20% flowers opened) and mid-flowering (> 50% flowers opened). From each replicate treatment block, three designated collection sites (plots) were labeled (in the center row of each treatment group) for litter, flower and berry collections. The same sites were re-visited for the 4-year duration of the trial:

– Debris infections were assessed for total area of *B. cinerea* sporulation as described above for the preliminary field trial.

– Flower infections were determined by randomly picking flowers (open for 1–3 days) from each plot (approximately 33 flowers in years 1 and 2; 20 flowers in years 3 and 4). After chilling (4 °C) and couriering overnight to the laboratory, flowers were surface-sterilized for 5 min in 1% sodium hypochlorite solution, thoroughly rinsed in tap-water and blotted dry with sterile paper towels [1]. Ovaries with styles attached were removed with sterile tweezers and up to ten ovaries were placed (styles facing the agar) onto PDA (potato dextrose agar, Gibco) amended with 1% triton (Sigma) to reduce colony growth. The presence of *B. cinerea* was assessed after 5 days (and verified after 10 days) of incubation at 20 °C with a 12-h photoperiod.

– Berry infections were conducted at early and mid-harvest for years 2 to 4. Berries picked had developed from flowers that were just open at the corresponding flower assessment times. These were identified by labeling indicator flowers at the flower assessment times. Ripe berries (30–36) were picked from each plot at random and placed into surface-sterilized kiwifruit plix trays (one berry per compartment) and the proportion of berry infection (% berries with *B. cinerea* present) determined after (48 and 96) h of incubation under 100% relative humidity at room temperature [(22 ± 3) °C]. Incubation allowed the latent infections to develop.

In year 3, one grower applied the product Digester across all treatments, thus this grower's data (although collected) was not included in the year 3 analysis. The same grower then opted to withdraw from the trial in year 4. This study provides analysis of years 2 to 4 across all treatments applied during this time. Because of the trial changes during the 4 years of the experiment, weighted statistical analysis was conducted (Univariate Analysis of Variance, Corrected Model) providing estimated marginal means using Systat. Year 1 data was omitted, because only flower infection assessments were available. Treatment effects on debris, flower and/or berry infection were also analyzed for each year separately using ANOVA (General Linear Model, Systat).

3. Results and discussion

3.1. Laboratory trial

[C:N] ratios were [5:1] for the urea, [25:1] for the (bark + sewage sludge), [30:1] for the unamended debris (control), [32:1] for the fungicide and [34:1] for the (bark + offal) treatments. This implies that some composts may not alter the [C:N] ratio of boysenberry debris and the application of composts as a nitrogen source needs to be considered carefully.

Debris size did not affect ($P > 0.05$) decomposition of the leaf discs and there were no

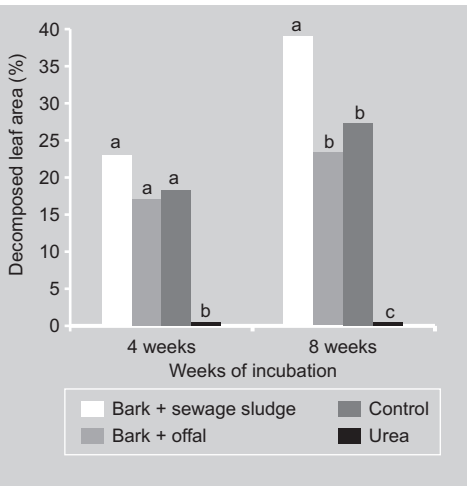

Figure 1.
Effect of boysenberry litter treatment on leaf decomposition. Bars with the same letter are not significantly different ($P < 0.05$). Debris amendments were (bark + sewage sludge) compost, (bark + offal) compost, control = unamended, urea = 8% urea (wet weight).

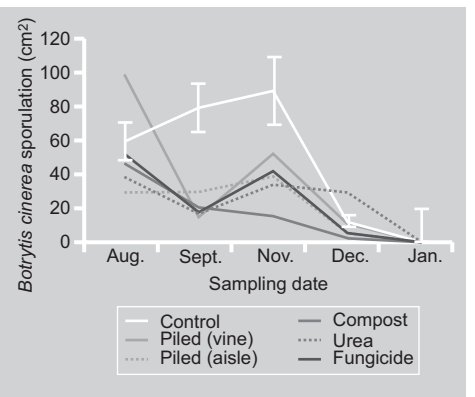

Figure 2.
Effect of amendments to and piling of shredded boysenberry debris on *B. cinerea* sporulation at four growers' properties. Debris treatments were: control = scattered in the aisle; piled (vine) = unamended, piled underneath the vine; piled (aisle) = unamended, piled in the center of the aisle; compost = amended with (bark + offal) compost, piled underneath the vine; urea = amended with urea, piled underneath the vine; fungicide = sprayed with pyrimethanil, piled underneath the vine. For clarity, standard error bars are only presented for the control treatment.

significant interactions ($P > 0.05$) between amendment and debris size at either assessment. Therefore, data were pooled for analysis. Debris treatment influenced ($P < 0.001$) leaf decomposition after 4 and 8 weeks of incubation (*figure 1*).

For all treatments, no viable *B. cinerea* was found on the non-inoculated control leaf discs after 0, 4 and 8 weeks of incubation. Sporulation of *B. cinerea*-inoculated leaf discs was not affected ($P > 0.05$) by debris size and declined ($P < 0.001$) over the three assessment times. At day 0, *B. cinerea* sporulation covered 100% of the leaf disc area for all treatments. At the 4-week assessment, no difference ($P = 0.85$) in sporulation was observed for the debris amendments, with the average area covered by conidiophores ranging from (7.7 to 11.5)%. At the 8-week assessment, average *B. cinerea* sporulation was more difficult to assess due to partial leaf decomposition (*figure 1*); the urea-treated debris (leaf discs completely intact) showed the highest sporulation at 3.6%. No sporulation could be detected for the (bark + sewage sludge) treatment. Both the control and (bark + offal) treatments showed less than 0.25% sporulation. Treatment differences were significant ($P < 0.01$) between all treatments except for the control and (bark + offal) compost treatment.

This experiment indicated that compost amendments to boysenberry debris may inhibit *B. cinerea* development and may accelerate the decomposition process within a mulch.

3.2. Field trial

Average [C:N] ratios were [29:1]. There was no treatment or grower effect ($P > 0.05$) on [C:N] ratios. For microbial decomposition of organic matter under temperate conditions a [C:N] ratio of approximately [30:1] is ideal [11]. Boysenberry debris, with and without amendments, was at this recommended level, making it a suitable substrate for microbial degradation.

There were grower differences ($P < 0.05$) with respect to *B. cinerea* sporulation in the litter; however, no grower treatment interactions ($P > 0.05$) were observed, thus data was pooled for analysis. The amount of *B. cinerea* sporulation in the litter decreased ($P < 0.05$) over the period of sampling (*figure 2*). This is in agreement with earlier findings [1]. For the August, December and January samples, no differences ($P > 0.05$) in the area of *B. cinerea* sporulation were observed between treatments. For the September sample, there was less ($P < 0.10$) *B. cinerea* on the debris treated with compost, urea and fungicide and on the unamended debris piled in the aisle or underneath the vine compared with the control treatment. For the November sample, the debris piled underneath the vine and treated with (bark + offal) compost showed less ($P < 0.10$) *B. cinerea* sporulation than the control.

Piling of the debris appears to be the most crucial step in reducing *B. cinerea* inoculum in litter. Based on these results, large-scale commercial evaluation of litter management on *B. cinerea* control, flower and berry infection was conducted.

3.3. Commercial-scale evaluation

Based on treatments (*table II*), univariate analysis of variance showed that the amount of surviving *B. cinerea* in the debris on the ground (*B. cinerea* measured as area sporulation on the litter) was affected by year ($P < 0.001$), grower ($P < 0.001$) and litter treatment ($P < 0.08$). The average percent *B. cinerea* flower infections in spring were significantly different between years ($P < 0.001$) and growers ($P < 0.001$), whereas average percent berry infections at harvest were significantly affected by season only ($P < 0.001$) (*table III*). It should be noted, however, that in the years 1999/2000 and 2000/2001 the litter treatments affected *B. cinerea* flower infection in spring ($P < 0.05$). Treatment and grower effects were different regarding *B. cinerea* infection of debris, flowers and berries (*table IV*).

Depending on the season and the corresponding weather pattern, reduced primary inoculum also resulted in reduced flower infections in spring (as observed in 2 years out of the 4 years studied). This reduction, however, did not translate into reduced berry

Table III.
Estimated marginal means for *Botrytis* sporulation (mm^2) on litter, *Botrytis* flower infection (%) in spring and *Botrytis* berry infection (%) at harvest for 3 years, three growers and six treatments (means are estimated marginal means based on Univariate Analysis of Variance, Corrected Model and therefore relative to the 'real' observations).

Variable	Mean (estimated marginal mean)		
	B. cinerea sporulation on litter (mm^2)	Flower infection (%)	Berry infection (%)
Year - across all growers and litter treatments			
1999/2000	0.1 b	48 a	–30 c
2000/2001	17.2 a	–1 b	9 b
2001/2002	–1.5 b	–4 b	89 a
Grower – across all years and litter treatments			
Grower F	14.2 a	25 a	ns
Grower R	3.0 b	7 b	ns
Grower W	–1.5 b	11 b	ns
Litter treatment – across all years and growers			
Biostart[1]	1.0 c	ns	ns
Piled control[1]	2.7 bc	ns	ns
Ecogrow[1]	3.4 bc	ns	ns
Spread control[1]	6.1 ab	ns	ns
Compost (Zoomgro) [1]	7.6 ab	ns	ns
SC27[1]	10.9 a	ns	ns

[1] Same treatment as that explained for *table I.*

ns = no significant difference observed.

Numbers followed by different letters in a column indicates significant differences ($P < 0.05$).

Table IV.
Main treatment and grower effects on *Botrytis cinerea* inoculum assessed on debris, and flower and berry infections for the 4 years of a commercial-scale evaluation.

Year	Season	Treatment effect on *B. cinerea* inoculum infection of			Grower effect on *B. cinerea* inoculum infection of		
		debris	flowers	berries	debris	flowers	berries
1	1998/1999	nd	ns	nd	nd	ns	nd
2	1999/2000	*	**	ns	ns	**	**
3	2000/2001	**	**	*	*	**	**
4	2001/2002	ns	ns	ns	**	**	**

nd = not determined.

ns = no significant difference observed ($P > 0.05$).

*, ** = significant differences at $P < 0.1$ and $P < 0.05$, respectively.

infection at harvest, except for the trend observed in the 2000/2001 season (*table IV*). Earlier research [2] has shown that there is a clear relationship between stylar infections and berry infections. The previous work also showed that styles remain susceptible to *B. cinerea* infection from flowering to harvest (boysenberry styles remain intact on the developing drupelets). Therefore, not only the primary sources of *B. cinerea* inoculum during flowering (litter [1]) need to be considered as important sources for infection but also the secondary sources of inoculum such as litter, desiccated primocanes and receptacles at harvest [1].

4. Conclusion

Summarizing the results of the orchard floor management, it can be concluded that litter treatments had an effect on *B. cinerea* primary inoculum production. Litter on the ground is the primary source of *B. cinerea* inoculum in boysenberry gardens [1]. The laboratory trials showed that compost amendment not only enhanced litter decomposition but also reduced *B. cinerea* sporulation on infected tissue. The preliminary field trial then found that piling of shredded boysenberry debris was more important than litter amendments to reduce the amount of *B. cinerea* harbored within the debris. This trial confirmed earlier research [1] that *B. cinerea* inoculum from the litter is highest in winter (August) and spring (October/November), and gradually declines during the production season. The large-scale commercial evaluation of litter management options verified that piling of shredded litter is indeed the most important step in *B. cinerea* inoculum control from debris. We also found that microbial litter amendments can be beneficial. The balanced [C:N] ratio of the boysenberry debris makes it a suitable substrate for microbial breakdown. This may explain the weaker impact of the litter amendments on *B. cinerea* sporulation compared with the piling of the debris. Piling resulted in improved moisture retention in the debris compared with the scattered control treatment (data not presented), which in turn aids microbial degradation [11].

While *B. cinerea* inoculum control also reduced the amount of flower infections, berry infections at harvest were not affected. This and the decline in the amount of *B. cinerea* sporulation from litter during the production season indicate that other sources of *B. cinerea* inoculum contribute to berry infection post-flowering. Control of secondary inoculum therefore remains paramount.

Besides the annual fluctuations, the greatest effect on *B. cinerea* flower and berry infection observed, however, was the grower effect. Further research is required to determine the effect of site and grower management differences on the incidence of *B. cinerea* infection on flowers and berries.

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Del laboratorio al campo: gestión de la hojarasca para el control de *Botrytis cinerea* en plantaciones de moreras.

Resumen — Introducción. La hojarasca del suelo es una fuente primaria de inóculo de *Botrytis cinerea* en huertas de moreras (híbrido de *Rubus*). Se evaluó el efecto de la gestión de la hojarasca en la producción primaria de inóculo y en la contaminación de flores y frutos. **Material y métodos**. Se realizaron experimentos en laboratorio y campo, en Nueva Zelandia de 1997 a 2002, para evaluar las posibilidades de gestión de la hojarasca para el control de *Botrytis cinerea*. Una prueba en laboratorio estudió el efecto de la dimensión de los restos de corta (desmenuzados o no) y de la modificación de la broza en la degradación de los tejidos y su colonización por *Botrytis cinerea*. Un ensayo en campo estudió, en cuatro lugares, el efecto de la enmienda de la hojarasca (compost, urea, fungicida) y de la compactación de la hojarasca en la esporulación de *Botrytis cinerea*. Durante cuatro años, se efectuó un estudio a escala comercial, siguiendo a tres agricultores, para evaluar el efecto del tratamiento de la hojarasca (compactación, compost, extractos y/o suspensiones microbianas) en el inóculo primario, y las infecciones de flores y bayas. **Resultados y discusión**. El ensayo en laboratorio puso de manifiesto que una enmienda con compost (lodo de aguas residuales + cortezas) permitió mejorar la descomposición de la hojarasca y reducir la esporulación de *Botrytis cinerea* en los tejidos infectados desde hacía 8 semanas. La experimentación en campo indicó que la compactación de la broza de moreras desmenuzada era más eficaz que las enmiendas de la hojarasca para reducir la cantidad de *Botrytis cinerea* hospedada en la hojarasca. El estudio a escala comercial de las distintas posibilidades de gestión de la hojarasca confirmó que la compactación de la hojarasca desmenuzada era la etapa más importante del control de *Botrytis cinerea* en la broza. También demostró que las enmiendas microbianas de la hojarasca (compost, soluciones o extractos) podían ser beneficiosas. Aunque el control del inóculo de *Botrytis cinerea* permitió reducir también la tasa de infección de las flores, la infección de los frutos en la cosecha no varió. Eso indicaría que, tras la floración, otras fuentes de inóculo de *Botrytis cinerea* contribuirían a la infección de las moras.

Nueva Zelandia / *Rubus* / enfermedades de las plantas / *Botrytis cinerea* / métodos de control / material orgánico de cobertura / gestión / infección / flores / frutas