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# Validation of a Warning System to Control Brown Rot in Peach and Nectarine

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**Abstract:** *Monilinia* spp. is the main pathogen that affects stone fruit, causing significant production losses, especially in seasons with favorable climatic conditions for disease development. Currently, the standard practices for controlling this disease are by means of spray programs of synthetic fungicides. Fungicide applications using treatment schedules imply an increase in the number of applications; however, the applications are justified considering the real risk of *Monilinia* spp. infection. Consequently, fruit surface contains a higher number and concentration of residues, but not better control of the disease. From previous studies, the epidemiology of *Monilinia* spp. was deeply studied in one of the main stone fruit regions of Europe, the 'Valle del Ebro', and an epidemiological model was developed to describe the brown rot epidemic pattern in this area. After that, a warning system for fungicide applications in the field was elaborated that included the main factors to be considered as fruit susceptibility, the presence of inoculum in the field, and climatological factors (temperature, leaf wetness, rainfall, or their interaction). In the present study, we present data of the warning system validation during six seasons in 38 fields of peaches and nectarines of the 'Valle del Ebro'. The results indicated that the incidence of disease caused by *Monilinia* spp., recorded in the field and postharvest, was similar in both plot evaluations and the calendar and warning systems. However, the disease level was higher in late varieties (3.2% and 9.3% of infected fruit recorded in the field and in postharvest, respectively) in comparison with earlier varieties (0.6% and 3.1% of infected fruit recorded in the field and in postharvest, respectively). In general, the strategy applied (the calendar or warning system) did not affect the disease level recorded. However, when fungicide treatments were applied following the warning system, the treatment reductions were higher than 50% in 96% of the trials in early varieties; meanwhile, in late varieties, this level of reduction was obtained in 77% of trials. Our data encourage the use of the proposed warning system as an effective strategy to control *Monilinia* spp. in peaches and nectarines, reducing the number of chemical treatments applied in the field with a high level of efficacy.

**Keywords:** brown rot; postharvest disease; field applications; decision support systems; warning system; fungicides

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## 1. Introduction

The highest producers of peaches (*P. persica* L. Bastsch var. *persica*) and nectarines (*P. persica* var. *nucipersica* (Suckow) C. Schneider) in the European Union are Spain, Italy, France, and Greece. The 'Valle del Ebro', located in the northeast of the Iberic Peninsula, includes stone fruit orchards, mainly in the 'Catalunya' and 'Aragón' regions, and contributes 35.3% of the total European Union production in 2021 [1], being fruit harvested from June to September. Stone fruit cultivars need careful handling as they are susceptible to several pests and diseases along the phenological stages of fruit. Brown rot caused by the genus *Monilinia* Honey is the most important disease, and there are three main affecting: *Monilinia.*

*fructicola* (G. Winter) Honey, *M. laxa* (Aderh and Ruhland) Honey, and *M. fructigena* (Aderh Ruhland) Honey that mostly attacks pome fruit (i.e., apple and pear) [2]. Infections caused by *Monilinia* spp. basically occur in the orchard from flowering to harvest, and infections during postharvest are scarce [3]. However, these field infections are mainly developed during the postharvest period during the shelf life, when the temperature is optimal for its development. It especially takes place in seasons with favorable weather conditions; in these cases, the losses at postharvest can be as high as 80% of the production [4]. In this context, the control of *Monilinia* spp. must be mainly undertaken in the field. Currently, the standard commercial control practices are addressed in the field by chemical fungicides applied according to a scheduled spray program. The application of chemical treatments in postharvest is authorized in some European countries [5], and treatments are advised as a complementary undertaking to the field strategy for only mid–late varieties or in the event of adverse meteorological conditions [6]. Conventionally, all these treatments are based on synthetic chemical products [7]. Social pressure created by consumer demands for environmentally friendly fruit production has noticeably increased in recent years. Other considerations also affected the use of pesticides, such as stricter legislation on authorized active ingredients, their allowable presence on fruit, and the risk of these pesticides developing resistant strains. In addition, the new European plant health regulation (EU 2016/2031) aims to strengthen compliance with health and safety standards throughout the agri-food chain, highlighting the importance of using safer products for consumers. These concerns spurred the search for alternatives to chemical products. In the postharvest of stone fruit, many studies were published focusing on a wide range of alternative strategies, such as physical treatments, [8–10] natural or low-toxicity compounds [8,11], and biocontrol [6,12,13]. Moreover, it was demonstrated that its combination generates synergy for improving their efficacy when applied alone [8]. In contrast, in the field, the applications of alternative treatments to the chemicals for controlling *Monilinia* spp. are mainly only focused on the use of BCA [14]. In this sense, Casals et al., 2021 [6] demonstrated that a field strategy by a calendar based on the use of BCAs formulated products (CPA-8 or Pf909) effectively controlled brown rot in most cases. However, it is clear that their efficacydepended on the disease pressure in the field. These results pointed out the need of tools, such as decision support systems for the prediction of disease infection risks, to obtain basic information regarding the expected disease pressure in each orchard and then deciding the best control strategy. The decision support systems also could be implemented in the framework of fungicides rationalization to minimize the number of applications in comparison with strategies based in a schedule spray program.

Previous intensive studies on epidemiological features regarding *Monilinia* spp. on stone fruit in 'Valle del Ebro' were conducted over the last 15 years. All factors that can affect the disease were intensely studied, including the primary [15,16] and secondary inoculum [17] and latent infections [18,19], and they were all joined with the climatological conditions [17]. From that, a theoretical model for understanding the pattern of brown rot development in the field was developed [20], and continuously, a more practical model (warning system) feasible for its commercial use in the field was obtained. The main factors for decision-making to control *Monilinia* spp. were selected and included in the warning system, such as fruit susceptibility, the presence of inoculum in the field, climatological conditions, and their interactions.

This study's main aim was to evaluate and validate a practical warning system that indicated the risk of infection of *Monilinia* spp. in the efficacy for controlling *Monilinia* spp. and in reducing the number of fungicide applications.

## 2. Materials and Methods

### *2.1. Field Plots*

A total of 38 field trials were conducted and evaluated over 6 seasons (2012–2017) (Table 1). The orchards of 0.5 ha minimum were selected within 15 different varieties (harvest time from June until September). Each orchard was divided into two plots: standard and warning system. Both plots were cared for according to the standard commercial practices of the area, except for fungicide treatments in the warning system plot, which were conducted by following the warning system indications 45 days before predicted harvest (dbh). Fungicide applications in the standard plot were conducted by calendar from 1 month before the predicted harvest day. The number of final treatments applied basically depended on the variety (early or late). In all cases, crop management and treatment applications were conducted by the farmer.

**Table 1.** Trials conducted for several seasons (2012–2017) for the validation of the *Monilinia* spp. warning system in stone fruit orchards.

| Year | N° Trial | Variety | Harvest Date | Variety: Early (E) or Late (L) |
|---|---|---|---|---|
| 2012 | 1 | Venus | 2/08 | E |
| | 2 | Roig d'Albesa | 14/09 | L |
| | 3–4 | Red Jim | 21/08–16/08 | L-L |
| | 5 | Stark Red Gold | 16/07 | E |
| 2013 | 6 | Roig d'Albesa | 19/09 | L |
| | 7 | PP-100 | 10/09 | L |
| | 8 | Venus | 31/07 | E |
| | 9–10 | Red Jim | 21/08–26/08 | L-L |
| | 11 | Diamond Ray | 18/07 | E |
| 2014 | 12 | Roig d'Albesa | 12/09 | L |
| | 13 | PP-100 | 2/09 | L |
| | 14 | Venus | 22/07 | E |
| | 15–16 | Red Jim | 13/08–14/08 | E-E |
| | 17 | Diamond Ray | 19/07 | E |
| 2015 | 18 | Roig d'Albesa | 19/09 | L |
| | 19 | PP-100 | 2/09 | L |
| | 20 | Platerina 0778 | 10/07 | E |
| | 21–22 | Red Jim | 20/08–14/08 | L-E |
| | 23 | Diamond Ray | 13/07 | E |
| 2016 | 24 | Tardibelle | 5/09 | L |
| | 25 | Ruby Reach | 16/06 | E |
| | 26 | Diamond Ray | 15/07 | E |
| | 27 | Red Late | 14/09 | L |
| | 29–30 | Necta Gala | 18/08–17/08 | L |
| | 31 | P1F09A069 | 21/07 | E |
| 2017 | 32 | Ruby Reach | 15/06 | E |
| | 33 | Diamond Ray | 11/07 | E |
| | 34/36 | Necta Gala | 16/08–22/08 | L-L |
| | 35 | Tarderine | 17/08 | L |
| | 37 | Tardibelle | 5/09 | L |
| | 38 | Red Late | 12/09 | L |
| | 39 | Fruit Future | 19/07 | E |

Note. Trial 28 was not considered, and it is not included in the table.

### *2.2. Warning System Validation*

From several studies related to the epidemiology of *Monilinia* spp. in 'Valle del Ebro' a theoretical prediction model was developed to identify the risk infection of *Monilinia* spp [20]. The practical version of this model (warning system) was designed and was based on the following criteria (Figure 1):

(1) Low risk of infection: until 30 or 45 predicted dbh for early–mid varieties and mid–late varieties, respectively. Within this period, no treatments were recommended to be applied.

(2) Medium risk of infection: from 30 or 45 predicted dbh for early–mid varieties and mid–late varieties, respectively, to one week before harvest. The first requirement for fungicide applications was the presence of inoculum in the field (a minimum of 5 rotten fruits in

10 randomly selected full trees/0.5 ha). In this period, the field sampling for the presence of inoculum detections was conducted weekly. Once inoculum was detected, the second requirement for fungicide application was the climatological conditions: higher rainfall than 10 L/day, more than 15 followed hours of leaf wetness or more than 10 followed hours of leaf wetness hours and 15 °C of medium temperature during the leaf wetness period. After application, fruit was considered protected for 7 days.

(3) High risk of infection: one week before harvest until harvest. During this period, field samplings for the presence of inoculum detections were continued in the case that inoculum was not detected during the medium-risk period described above. In the case of presence of inoculum in the field (first requirement), fungicide application was conducted according to the following meteorological conditions: higher rainfall than 3 L/day, more than 10 followed hours of leaf wetness hours. After application, fruit was considered protected for 5 days.

Three exceptional conditions were considered to indicate the need for a fungicide application: (1) Number of rotten fruit detected in the first sampling higher than 10 in 10 full trees/0.5 ha; (2) In the case of the hailstorm; (3) For mid–late varieties, when no fungicide application in the field was conducted, a postharvest application should be applied.

When a postharvest application was needed according to the warning system indications, at harvest time, an extra set of 100 healthy fruit was sampled for each plot of the orchards (standard and warning system) for each replicate. Fruit was transferred to the laboratory, and a postharvest application was conducted on harvest day. Treatment was conducted by dipping fruit in 50 L of water solution amended with fludioxonil at 0.2% (Scholar—Syngenta) for 1 min. Then, fruit was dried out and incubated with the rest of fruit sampled.

The fungicide treatments applied in the field to control *Monilinia* spp were conducted in the warning system plot to validate the warning system, according to the above criteria described.

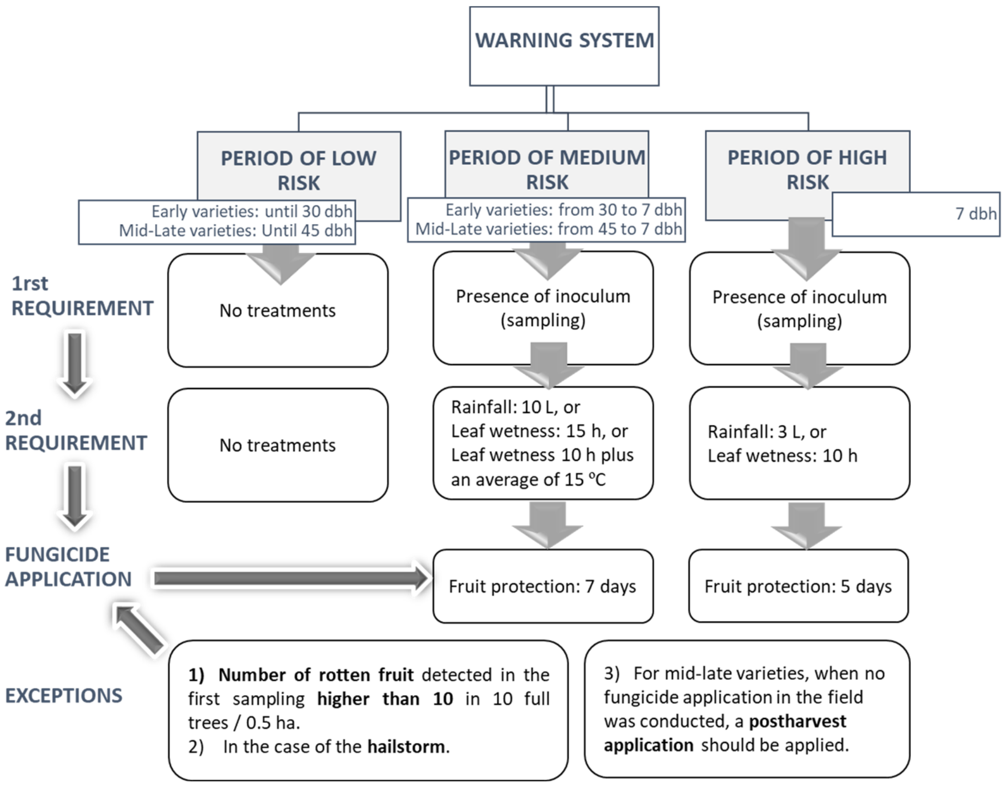


**Figure 1.** Diagram of the warning system designed and validated. Note: dbh means days before harvest.

### 2.3. Warning System Efficacy

#### 2.3.1. Field Evaluations

Field evaluation was performed at commercial harvest time. One full tree per replicate for each treatment was evaluated, and the total number of fruit, healthy and affected by *Monilinia* spp., were recorded in the same tree. A similar procedure was conducted for fruit located on the ground. In all cases, one tree per replicate was used, and four replicates were used per plot. The number of fruit infected by *Monilinia* spp. was expressed as the incidence of infected fruit.

#### 2.3.2. Postharvest Evaluations

Healthy peach or nectarine fruit were randomly collected from each plot (standard and warning system) at harvest time and placed in packing trays (20 fruit each) to avoid contact among them and consequent cross-contaminations. One hundred fruit per replicate was used, and four replicates (trees) were used per plot. Fruit was incubated directly at 20 °C and 85% of relative humidity for 7 days. The number of fruit affected by *Monilinia* spp. was recorded after 5 and 7 days of incubation.

### 2.4. Climatological Factors Monitoring

Air temperature, relative humidity, leaf wetness, and rainfall were measured hourly using a weather station (Secagon Serviced Inc., Pullman, WA, USA) placed in each field. Recorded weather observations were transferred via satellite and downloaded in the PC visor 3 times per day.

### 2.5. Statistical Analysis

Data on disease incidence recorded at preharvest and postharvest evaluations were analyzed using ANOVA. Normality data distribution (Shapiro test) and homogeneity of variances (Levene and Barlett tests) were checked, and data were transformed when needed. In all cases, JMP®8 statistical software (SAS Institute, Cary, NC, USA) was used. Statistical significance was determined at $p < 0.05$. When the analysis was significant, Student's LSD test was used for separation of means (though the LSD test controls the comparison-wise type I error rate rather than experiment-wise type I error rate).

## 3. Results

### 3.1. Disease Incidence in the Field

Fungicide treatments applied in the field to control *Monilinia* spp. by calendar or following the warning system did not significantly affect the incidence of infected fruit recorded in the field at harvest time according to the ANOVA analysis (Table 2). In this context, our results also showed that the disease level recorded in the field in calendar plots was highly correlated with the disease recorded in warning system plots ($r^2 = 0.7$ and m = 1.28) (Figure 2). Moreover, a value of 'm' around 1 means that the level of disease recorded in the calendar plot is similar to the warning system plot.

**Table 2.** Summary of analysis of variance of brown rot incidence recorded in the field at harvest time among 38 trials conducted during 6 seasons (2012–2017).

| Source of Variation | df | Mean Square | $Pr > F^z$ |
|---|---|---|---|
| Treatment (A) | 1 | 6.51 | 0.606 |
| Variety Early/Late (B) | 1 | 507.91 | <0.0001 |
| Replicate | 3 | 9.42 | 0.9431 |
| A × B | 1 | 14.16 | 0.4468 |

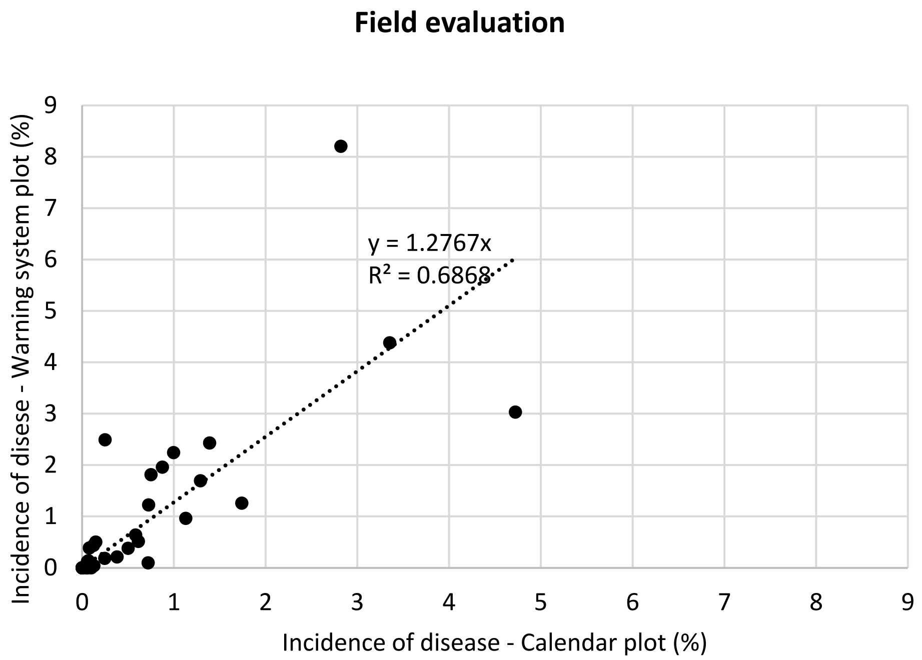


**Figure 2.** Correlation between the incidence of disease recorded in the field in the warning system and calendar plots plotted in Axis Y and X, respectively. Outliers were not included in the correlation.

The data were analyzed according to the harvest dates (early or late varieties, harvested before or after the 16th of August, respectively), which statistically affected the level of disease recorded ($p$-value < 0.0001) (Table 2). The mean incidence of disease recorded for early and late varieties was 0.6 and 3.2%, respectively (Figure 3). Despite that, in all varieties, the statistical analyses showed that the chemical treatments' efficacy in the calendar or warning system plots had the same behavior, independent of the variety evaluated (A × B, $p$-value = 0.4468, Table 2).

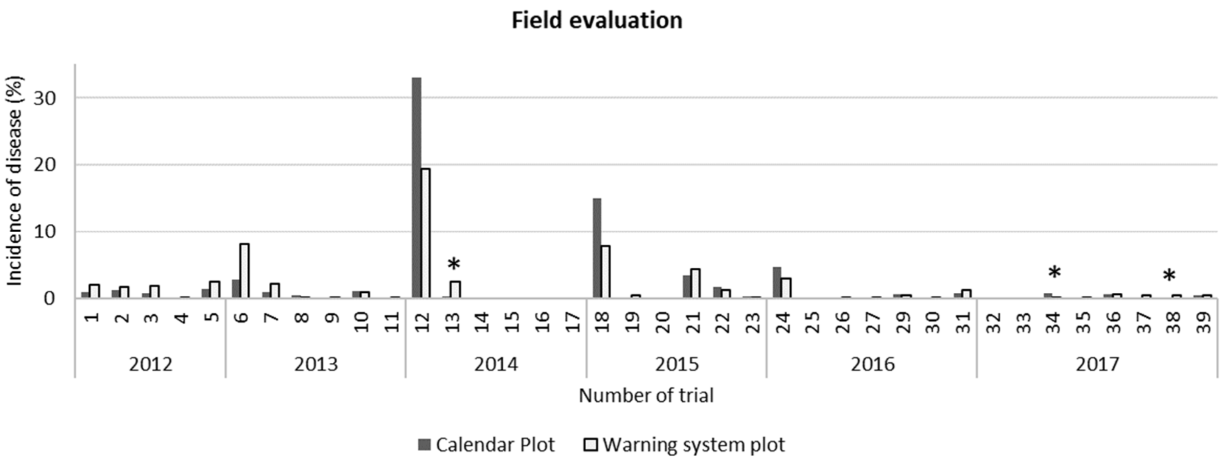


**Figure 3.** Incidence of disease recorded in the field in each trial conducted along 6 seasons in calendar plot (■) and warning system plot (□). Mean values with (*) mean statistical differences between the incidence of disease recorded in the calendar plot in comparison with the warning system plot according to Student's LSD ($p$-value < 0.05).

The incidence of disease caused by *Monilinia* spp. recorded in the field ranged between 0 and 33% of infected fruit. However, the disease level was under 10% of infected fruit in 36 out of 38 trials along the six seasons evaluated (Figure 3). When the effect of the treatment (calendar or warning system) was analyzed by trial, only in 3 out of 38 trials conducted was the $p$-value lower than 0.05 (trials 13, 34, and 38) (Figure 3). In all three cases, the disease incidence was extremely low (less than 5% of infected fruit), and these differences between plots (calendar and warning system) were not observed in the postharvest evaluations.

### *3.2. Disease Incidence in Postharvest*

Data obtained in the postharvest evaluation showed a similar profile to data previously recorded in the field. Fungicide treatments applied in the field by calendar or following the warning system indications did not significantly affect the incidence of infected fruit recorded in postharvest ($p$-value > 0.05) (Table 3). Data also indicated that the disease level recorded in calendar plots was highly correlated with the disease recorded in warning system plots (r = 0.7, m = 0.97) (Figure 4). In addition, as the value of 'm' was around 1, the values of infected fruit recorded in the calendar plot were similar to those recorded in the warning system plot.

**Table 3.** Summary of analysis of variance of brown rot incidence recorded in postharvest at harvest time among 38 trials conducted during 6 seasons (2012–2017).

| Source of Variation | df | Mean Square | Pr > F[z] |
|---|---|---|---|
| Treatment (A) | 1 | 6.51 | 0.1719 |
| Variety Early/Late (B) | 1 | 507.91 | <0.0001 |
| Replicate | 3 | 9.42 | 0.9126 |
| A × B | 1 | 14.16 | 0.1589 |

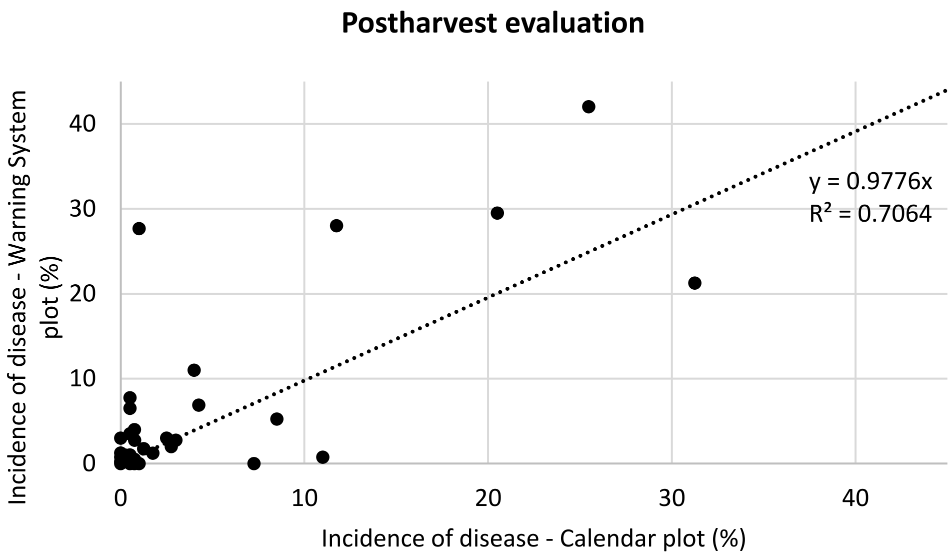


**Figure 4.** Correlation between the incidence of disease recorded in postharvest in the warning system and calendar plots plotted in Axis Y and X, respectively.

Postharvest results, as in the field, indicated that the level of disease was statistically higher for late varieties (harvested after the 16th, an average of 9.3% of infected fruit) in comparison with early varieties (harvested before the 16th of August, 3.1% of infected fruit), $p$-value < 0.0001 (Table 3). The results profile indicated that the chemical treatment efficacy applied by the calendar or the warning system was statistically the same (A × B, $p$-value = 0.1589, Table 3).

The disease incidence recorded in the 38 trials was generally higher than in the field evaluation and ranged between 0 and 42% (Figure 5). The disease distribution along the trials was according to three different levels: incidence of infected fruit lower than 2% (18 out of 38), between 2 and 35% (19 out of 38), and higher than 35% (only 2 out of 38). When the effect of the treatment (calendar or warning system) on the percentage of infected fruit was analyzed by trial, a total of 9 out of 38 trials obtained a $p$-value lower than 0.05, indicating statistical differences between the infected fruits recorded in the calendar plot in comparison with the warning system plot. For trials 2, 5, 7, 17, 27, 27, and 33 (6 out of 9), the disease incidence recorded was statistically higher in the warning system plot, and the disease average was 3.9 and 12.1% of infected fruit for the calendar and warning system plots, respectively. It must be considered that, in trial 27, the postharvest treatment indicated by the warning system was not conducted, explaining the high level of disease in the warning system plot compared to the calendar plot. Then, in 3 out of 9 trials (21, 29, and 37), the incidence of disease was statistically higher in the calendar plots, an average of 5% compared with 0.9% of disease in the warning system plots. Using the above information, only 5 trials (27 were discarded) had a higher infection level when fungicide treatments were applied according to the warning system, representing an 87% success rate.

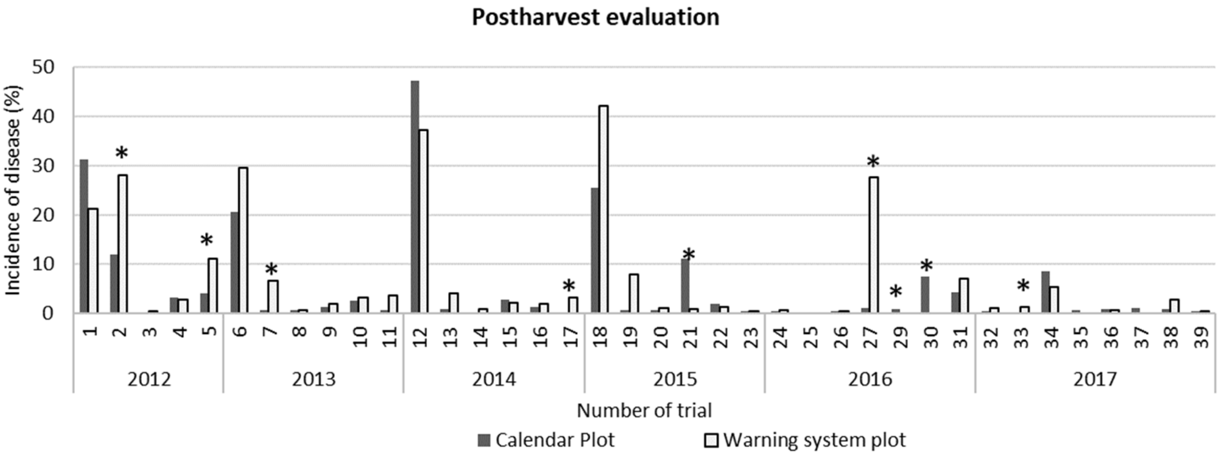


**Figure 5.** Incidence of disease recorded in postharvest, after 7 days a 20 °C and 85% RH for trial conducted along 6 seasons in calendar plot (■) and warning system plot (□). Mean values with (*) mean statistical differences between the incidence of disease recorded in the calendar plot in comparison with the warning system plot according to Student's LSD ($p$-value < 0.05). Note: In trial 27, the postharvest treatment indicated by the warning system was not applied to fruit.

### *3.3. Fungicide Applications*

The number of fungicide treatments applied in the field from 30 or 45 predicted dbh until harvest time for early or late varieties (harvested before or after 16th August, respectively) to control *Monilinia* spp. are shown in Figure 6. The number of treatments applied ranged between zero to three or two to six for the warning system or calendar plots, respectively. Meanwhile, for early varieties, the average of treatments applied were 2.8 and 0.8 in the calendar and warning system plots, respectively. For late varieties, the number of applied treatments was increased by 3.1 and 1 in the calendar and warning system plots, respectively.

The reduction of fungicide treatments applied in the field in the warning system plot or calendar plot was lower in late varieties in comparison with the earlier ones. Thus, for early varieties, 94% of trials had reductions higher than 50% (6 trials with total control). For late varieties, only 77% of trials had reductions higher than 50% (7 trials with total control). In the case of late varieties, the data indicated a new scenario where four trials had a lower reduction than 50%, including a 0% reduction in one trial.

Postharvest treatments applied by the warning system indications occurred in trials 21, 29, 30, 36, and 37 (Figure 7). Only in trial 30 was the need to use the postharvest treatment clearly demonstrated, since the disease was reduced to 0% of infected fruit in comparison with 7% and 37.5% recorded in the calendar plot and warning system plot, without the postharvest treatment, respectively. In the other trials (21, 29, 36, and 37) where the warning system indicated the need for a postharvest treatment, the level of disease was reduced, but without statistical differences, and the level of disease in the calendar plot was statistically the same in comparison to the warning system, only in the field.

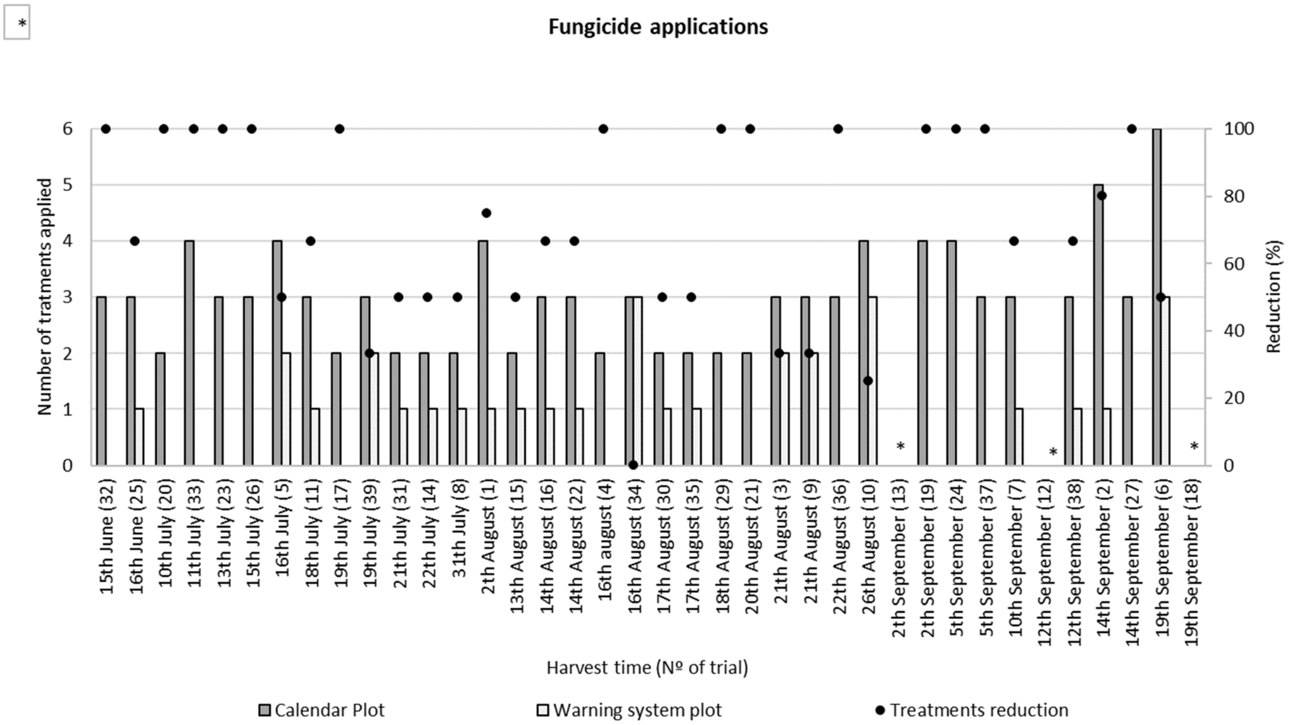


**Figure 6.** Number of treatments applied in the field in the calendar plot (■) and warning system plot (□) in the main Y axis along the 38 trials conducted, chronologically ordered by harvest time in axis X. Reduction of treatments applied in warning system plot in comparison with the calendar plot are plotted in secondary Y axis (●). * Means data not shown. Note: data do not include the postharvest treatments.

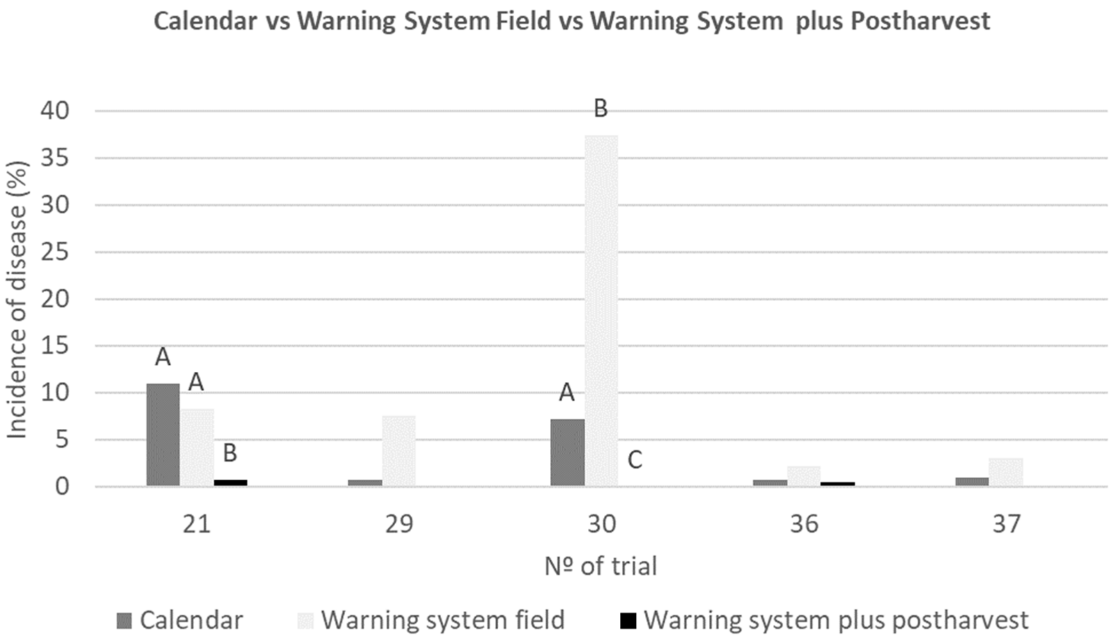


**Figure 7.** Incidence of disease recorded in postharvest, after 7 days a 20 °C and 85% RH in fruit treated by calendar (■), by warning system applied in the field ( ) and warning system applied in the field plus the postharvest treatment (■). For each trial, when mean values have different letters indicated statistical differences between the incidence of disease recorded according to Student's LSD ($p$-value < 0.05).

*3.4. Climatological Data*

The climatological data for each orchard during the assay are plotted in Figure 8. The periods of leaf wetness and rainfall recorded clearly varied between the year and the orchard. Thus, the profile data from 2014 and 2015 indicated crucial higher levels of both compared with 2016 and 2017. In relation to the mean temperature recorded during the trial, the profile indicated that its variation was more affected by the trial in the same year than between years.

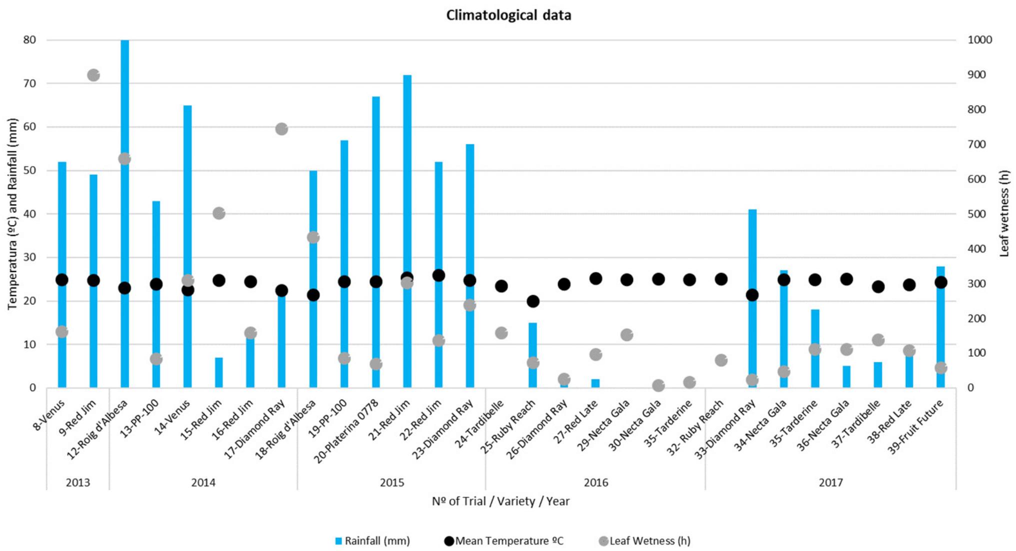


**Figure 8.** Temperature (°C), rainfall (mm), and Leaf wetness (h) for each treatment evaluated along the 6 seasons in the period within the warning system were validated. Note: data from 2012 and trials 6, 7, 10, and 11 are not plotted in Figure 6.

## 4. Discussion and Conclusions

In the case of stone fruit, *Monilinia* spp. are the main pathogens causing disease worldwide. The current control strategy applied in the field is based on chemical fungicide applications by the calendar, where it is not considered to be the real risk of infections, implying treatments by default. For example, Australian growers apply fungicides weekly during flowering to protect against blossom blight caused by *Monilinia* spp., at 3–4 weekly intervals to protect immature fruit, and they resume weekly spraying prior to the harvest [21]. In the Ebro Valley, producers spray chemical fungicides by the calendar, mainly from one month before harvest, from two to four applications for early and late varieties, respectively. In this framework, it is important to consider the new requirements imposed by the European Union. The Directive 2009/128/EC aims to achieve sustainable use of pesticides in the EU by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management and alternative approaches or techniques, such as non-chemical alternatives to pesticides [22]. Accordingly, disease management in the field needs to focus on more sustainable fruit production requiring the integration of technology, science, and technical criteria. In this study, we present a warning system that may help avoid fungicidal treatments when they are not necessary.

In the case of *Monilinia* spp., the epidemiology was deeply studied on stone fruit, providing a large amount of information. A model for the progression of brown rot in fruit orchards was developed, which permitted the evaluation of the consequences of different agricultural practices on fruit, quantity, and quality [23]. A recent approach to modeling the epidemics of brown rot caused by *Monilinia* spp. in Ebro Valley was developed for our teams that also permits evaluating the effectiveness of different control strategies [20]. This model incorporates several complexities, such as two sources of inoculum, different phenological stages, and large infection periods. Herein, this model was simplified and designed for a feasible and more practical application (warning system). In this new proposal, three main points were considered: (i) the warning system proposed requires field samplings to detect the presence of inoculum; (ii) the threshold for infection depends on the fruit growth stage; (iii) climatological conditions, including temperature, rainfall and leaf wetness, are factors that play a key role in the brown rot infection process [24]. This system was validated under commercial conditions over six seasons, conducting a total of 38 trials to ensure its proper functioning as a tool to be integrated into the strategy to control brown rot in both peaches and nectarines. Our results demonstrated that the number of fungicide applications in the field could be reduced without affecting the incidence of disease caused by *Monilinia* spp. For the field and postharvest evaluations, the disease level recorded in the calendar plot was highly correlated with the level of disease recorded in the warning system plot ($r^2$ = 0.8, m = 1.28 and $r^2$ = 0.8, m = 0.97, for field and postharvest evaluations, respectively). The direct consequence of integrating the warning system as a decision support for fungicide applications in the field was the reduction of chemical fungicide applications conducted. Altogether, this represents an important contribution to more sustainable agriculture and minimizes the risk of fungicide resistance compared to the application of fungicide programs (often on products with the same mode of action). Regarding the reduction of fungicide applications, the results profile was different according to the group of varieties evaluated (early or late varieties, harvested before 16th August or after 16th August, respectively). For early varieties, in 96% of the trials, the treatment reductions were higher than 50% in the warning system plot compared to the calendar plot. For late varieties, the value is still very high (77%). The different behavior between groups of varieties is clearly explained by the climatological conditions between groups around one month before harvest. For late varieties, leaf wetness duration is longer, and rainfalls often occur, increasing the number of alerts in the warning system and, consequently, the fungicide applications conducted in the field. This implies difficulty reducing the number of treatments compared with the calendar plot. In fact, climatological conditions also play a key role in the epidemiology of *Monilinia* spp. in other stone fruit cultivars, such as cherry [25] and prune [18].

Regarding other concerns that also affect brown rot control, the registered active ingredients and limits of residues detected on fruit surfaces must be considered. This, combined with consumer demands for more eco-friendly and health-conscious fruit production, drives the need for alternative treatments to the chemicals used in crop protection. In this sense, in addition to the warning systems, other strategies could also be integrated into the conventional crop management strategy for brown rot control as treatments based on biological products. According to the warning system indications, chemical treatments applied in the field could be replaced by biological products. Postharvest biocontrol has been studied for the last 35 years; however, some constraints affect its commercial feasibility [26]. Little information is available regarding the integration of BCAs into conventional cropping systems. However, recent results have already shown the efficacy and viability of these kinds of integrations for brown rot control [14]. Our recent studies have already demonstrated that a field program strategy based on a biologically formulated product effectively controlled brown rot, in most cases, at similar levels of efficacy to chemical strategies [6]. Moreover, it was demonstrated that our biological products were compatible with most chemical products applied to stone fruit conventional production [27]. On cherry, it was also demonstrated that using BCAs, combined with a fungicide, successfully controlled *M. fructicola* [28]. In this context, chemicals could also be replaced by plant essential oils such as tea tree oil. Plant essential oils such as tea tree oil could also replace the use of chemical fungicides applied in the field integrated with the warning system. This substance exhibited high antifungal activity against *M. fructicola*; however, it was concluded that it still needs to be optimized [29].

Another key strategy that can also be integrated, combined with the warning systems to improve the final efficacy in a sustainable control strategy, is the practice of reducing the level of inoculum as a first step in disease management. It was already reported that removing infected fruit during the growing season could significantly improve the brown rot control in stone fruit. *M. fructigena* in apples was reduced by removing dropped and thinned fruits [30]. Finally, improving disease control by using warning systems can also be improved by incorporating information related to cultivar susceptibility [31].

This study proposes a warning system as a tool to be integrated into the design of the brown rot control strategy of peaches and nectarines. Now our growers will have the option to apply fungicides in peaches and nectarines only when a real risk of infection occurs. Several fundamental factors have to be considered before commercial implementation: (1) training technicians for inoculum identification in the field; the method of sampling must be simple, rapid, and inexpensive [32] to be practically applied; (2) protocol description for the proper use of weather stations; (3) algorism automatization of the warning system risk visualization. Certainly, this new tool will contribute to the control *Monilina* spp. in both peaches and nectarines, reducing the number of fungicide treatments applied in the field as becoming stone fruit production becomes more competitive, sustainable, and healthy.

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