Field Evaluation of Fungicide Spray Advisories Against Lettuce Downy Mildew (*Bremia lactucae*) Based on Measured or Forecast Morning Leaf Wetness

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ABSTRACT

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In a previous field study in coastal California, infection of lettuce by downy mildew (*Bremia lactucae*) occurred primarily on days when leaves dried late in the morning (at 1000 h or later), suggesting that fungicide sprays against the disease could be scheduled according to a morning leaf wetness threshold. Seven field trials were carried out in 1993 to 1994 to test whether sprays of maneb or fosetyl Al, applied when measured or forecast morning leaf wetness ended at 1000 h or later, would lead to a reduction in the number of fungicide applications and/or improved downy mildew control compared with a calendar-based schedule with three sprays. Based on measurements of morning leaf wetness, the total number of sprays in the seven trials was reduced by 67% relative to the calendar-based schedule, with no difference in disease intensity. Based on forecasts of morning leaf wetness, which were generated using a physical dew simulation model with numerical weather forecasts from the National Meteorological Center as input, about 90% of the days were correctly classified as days with or without prolonged morning wet period. However, the occurrence of important wet periods due to fog drizzle was not predicted and the forecasts for the exact time of onset and end of leaf wetness were inaccurate. It is concluded that the number of fungicide applications against lettuce downy mildew can be reduced substantially with sprays scheduled according to a morning leaf wetness threshold of 1000 h and that fog drizzle should be included in leaf wetness forecasts for coastal California.

Lettuce (*Lactuca sativa* L.), California's leading vegetable crop in monetary value, is grown on more than 75,000 ha in the state (3). Because of the large area of lettuce production, all efforts to reduce pesticide use on this crop have the potential to significantly reduce the total load of agrichemicals in the environment and on produce. This applies particularly to chemical control of downy mildew (causal agent: *Bremia lactucae* Regel), a destructive disease in the coastal production areas of California (14,15,22). Lettuce cultivars possessing resistance against all pathotypes of downy mildew are currently not available (11,13). Furthermore, most California isolates of *B. lactucae* are insensitive to metalaxyl (24), the only fungicide with eradicative activity currently registered for use against the disease in that state. Therefore, lettuce growers attempt to control downy mildew with sprays of contact (maneb) or locally systemic (fosetyl Al) fungicides, often applied at weekly to biweekly intervals. Despite frequent fungicide use, downy mildew sometimes causes substantial losses in commercial lettuce production, both in the field and during postharvest transit and storage (10). At other times, disease pressure is low and most or all fungicide applications are unnecessary (9,22). Spray advisories against lettuce downy mildew, based on biometeorological and epidemiological information, could lead to a reduction in the number of fungicide applications and/or improved disease control.

In a 2-year field study in the coastal areas of California, we found that infection of lettuce by *B. lactucae* occurred primarily on days when leaf wetness ended late in the morning (22). The median time at which leaves dried was 1000 h Pacific Standard Time on days with infection and 0800 h on days without infection. Weather variables other than morning leaf wetness were not associated consistently with infection. Based on these results, we suggested that fungicide sprays against lettuce downy mildew be applied if leaf wetness ends at 1000 h or later (27). On days when leaves dry earlier in the morning, no sprays should be applied. Underlying these suggestions is the observation that spore dispersal and infection can occur concurrently during mornings with prolonged leaf wetness (23).

Many operational disease warning systems employ field-based weather stations to monitor environmental conditions that are favorable for disease development (6). These systems predict future disease development and issue fungicide spray advisories based on the observation of past critical periods (e.g., infection periods). Because infection periods of lettuce downy mildew are associated with prolonged morning leaf wetness (22), a weather station–based spray advisory against the disease could be based on measurements of the time at which leaves dry in the morning. Such a system would be uncomplicated and inexpensive, as only leaf wetness sensors are needed for its implementation.

Spray advisories based on past critical periods monitored with weather stations are often used with diseases against which fungicides with eradicative action are available. Because such fungicides are currently not registered for use against lettuce downy mildew in California, and because chemical control with protective fungicides is not very effective once infection has occurred, a weather station–based advisory might not be suitable for predicting downy mildew of lettuce in California. However, if prolonged leaf wetness periods could be predicted 1 or 2 days in advance, lettuce growers could apply fungicides prophylactically rather than after conditions conducive to infection have already occurred. Fungicide sprays timed according to forecasts of prolonged morning wet periods might, therefore, improve chemical control of lettuce downy mildew compared with sprays timed according to measurements of morning wet periods. Forecasts of leaf wetness, although currently not issued routinely by weather forecasting agencies in the U.S., could be generated using standard weather forecasts in combination with empirical (8) or physical (16,21) leaf wetness or dew models.

Based on these considerations, the objectives of this study were twofold. First, we wanted to determine whether leaf wetness duration (LWD) on lettuce can be predicted accurately using a physical dew simulation model with operational weather forecasts as input. Second, we wanted to test whether fungicide sprays timed according to measured or forecast morning

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leaf wetness would lead to a reduction in the number of applications and/or improved disease control compared with a typical calendar-based schedule.

MATERIALS AND METHODS

Dew simulation with weather forecasts. Details of the dew simulation model have been given previously (16,21). Briefly, the model uses energy balance and heat transfer theory for flat plates to calculate condensation and evaporation of dew. Leaf wetness caused by sources other than dew is not considered. The equations are solved for leaf surface temperature, followed by the calculation of the magnitude and direction of the latent energy flux, λE. Negative values of λE indicate evaporation and positive values of λE indicate condensation. The model predicts dew onset when $\lambda E > 0$. The dew period continues until the positive latent energy flux accumulated during the night is compensated by an equivalent amount of evaporation in the morning. All leaves are considered fully exposed to atmospheric long wave radiation and completely shaded with respect to solar short wave radiation. This scenario, which allows for heavy dew deposition at night and slow evaporation in the morning, is believed to resemble the canopy elements with the longest wetness duration (16,21).

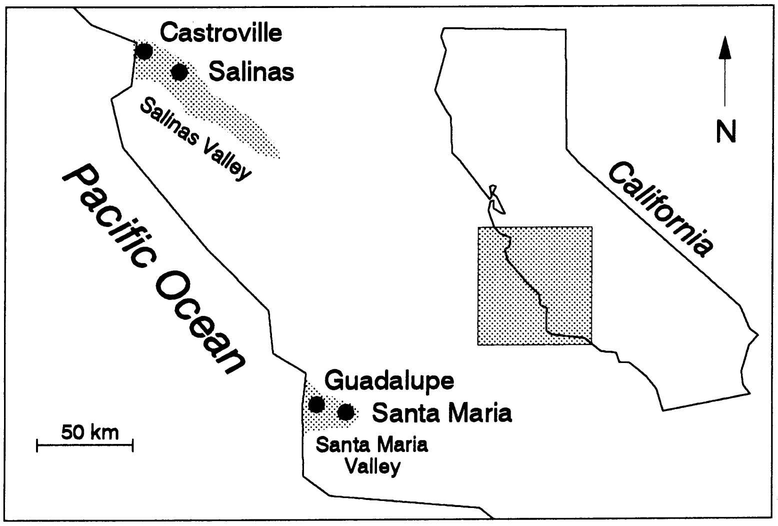

Fig. 1. Map of the study area in coastal California. Field trials were carried out near Castroville, Salinas, and Guadalupe. Weather and dew forecasts were available for Salinas and Santa Maria.

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HDNG FOUS14 NGM-MOS GUIDANCE      7/22/94  1200 GMT

DY/HR  22/18  23/00  23/06  23/12  23/18  24/00  24/06  24/12  24/18

SNS W
NGM MOS GUIDANCE   7/22/94  1200 UTC
DAY /JULY 22 /JULY 23                /JULY 24                /
HOUR   18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00
MN/MX                    56          70          56          67
TEMP   63 66 64 60 58 57 56 58 66 68 66 61 58 57 57 58 63 66 65
DEWPT  54 54 54 53 53 53 53 53 55 55 55 54 53 54 54 54 53 53 53
CLDS   OV BK SC CL CL CL CL SC CL SC CL SC SC CL CL CL CL CL CL
WDIR   30 31 31 30 31 31 33 34 30 30 30 29 31 30 32 27 29 30 30
WSPD   06 13 14 11 08 06 02 03 06 15 13 12 08 07 02 03 07 14 14
POP06           0     0     0     0     0     2     4     5     4
POP12                     0           0           4           6
QPF         0/    0/    0/0   0/    0/0   0/    0/0   0/    0/0
TSV06      2/ 0  2/ 0  0/ 3  1/ 0  0/ 3  0/ 0  0/ 5  2/ 0  2/ 7
TSV12            3/ 0        1/ 2        0/ 2        2/ 4
CIG     4  4  7  3  3  2  3  2  4  7  4     2     3
VIS     5  5  5  5  5  5  5  3  5  5  5     5     4
OBVIS   N  N  N  N
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Fig. 2. Sample weather forecast for Salinas, Calif. Similar forecasts were obtained daily from the National Meteorological Center's Nested Grid Model. The rows contain different weather variables, e.g., TEMP = air temperature (degrees F), DEWPT = dewpoint temperature (degrees F), WSPD = wind speed (knots), CLDS = cloud cover (CL = 0%, SC = 35%, BK = 75%, OV = 100%). The columns consist of 3-h forecasts of these variables. These forecasts were used as input for a dew simulation model to predict infection of lettuce by downy mildew.

Table 1. Aspects of seven trials in which downy mildew spray advisories based on measured or forecast morning leaf wetness were evaluated in lettuce field plots in coastal California

Trial	Duration (days)	Location	Cropping season	Lettuce cultivar
1	39	Salinas	Summer 1993	Bix
2	41	Castroville	Fall 1993	Pybas 251
3	35	Salinas	Fall 1993	Grande
4	34	Salinas	Summer 1994	Bix
5	35	Guadalupe	Summer 1994	Vista Verde
6	35	Guadalupe	Summer 1994	Premier
7	28	Salinas	Summer 1994	Bix

In a previous study, we adapted the dew simulation model to the meteorological conditions of coastal California and performed a preliminary validation study at a weather station near Castroville in the Salinas Valley. The results showed favorable agreement between measured and simulated LWD, with a mean difference of less than 1 h (21).

In its original form, the model uses hourly measurements of air temperature and humidity, cloud cover, and wind speed as meteorological input variables (16), but in the present study we substituted forecast values of these variables. Operational numerical weather forecasts from the National Meteorological Center's Nested Grid Model (NGM-MOS) were obtained from a commercial weather company (Weather Network Inc., Chico, Calif.) for two airport sites in coastal California (Salinas and Santa Maria; Fig. 1). The forecasts were issued twice per day at 0000 and 1200 Greenwich Mean Time (GMT) and predicted weather conditions at 3-h intervals up to 60 h into the future. A sample output is shown in Figure 2. We used the first 30 h of the 1200 GMT forecasts as input for the dew model. Forecast values of air temperature, dewpoint temperature, cloud cover, and wind speed were first imported into a computer spreadsheet program and interpolated linearly to generate hourly values of all variables. After interpolation, the forecasts were imported into the dew model, the source code of which was written in SAS programming language (SAS Institute Inc., Cary, N.C.). The model used the power law profile (16) to adjust forecast values of wind speed from reference height (10 m) to crop height (30 cm). All weather forecasts and the resulting dew forecasts were archived from May through October in 1993 and from May through September in 1994.

Evaluation experiments. Seven field trials were carried out during 1993 to 1994 to test whether LWD on lettuce can be predicted accurately using weather forecasts and whether fungicide applications timed according to measured or forecast morning LWD would lead to a reduction in the number of applications compared with a calendar-based spray schedule. The trials were established in commercial fields planted to crisphead lettuce cultivars susceptible to one or more of the prevalent pathotypes of *B. lactucae* in California (pathotypes IIA, IIB, IIC, IV, and numerous "novel" pathotypes) (13,24) (Table 1). The experimental sites were located near Salinas and Castroville in the Salinas Valley and near Guadalupe in the Santa Maria Valley (Fig. 1). Castroville and Guadalupe, situated less than 5 km from the Pacific Ocean, are sites with a coastal fogbelt climate. Marine stratus clouds and fog occur frequently during summer nights, resulting in a narrow average diurnal temperature range. Salinas is located about 20 km from the coast in the transition zone between the fogbelt and coastal valley climates. Rain is uncommon in the Salinas and Santa Maria valleys during summer and fall.

Measurements of LWD were made with two electronic leaf wetness sensing grids (Campbell Scientific Inc., Logan, Utah) in one of the untreated plots (see below) during each trial. The grids were left unpainted to reduce variation among sensors. (Unpainted sensors tend to dry faster than leaves, but this was accounted for during calibration.) The grids were located between lettuce plants at a height of 10 cm above the soil. They were slightly tipped along their long axes toward the northwest so that they were fully exposed to the sky. They were calibrated to record readings between 0 (completely dry) and 10 (completely wet). A threshold of 5.0 was used for onset and end of the dew period, based on studies with plant leaves in the laboratory and previous field experience. Sensor signals were sampled at 5-min intervals and averaged at 60-min intervals with a data logger. Data were transmitted daily from the experimental sites to the laboratory. Prolonged morning wet periods were defined as mornings with leaf wetness ending at 1000 h or later (22).

Table 2. Evaluation of forecasts of prolonged morning leaf wetness (leaf wetness persisting until 1000 h or later), based on a dew simulation model with weather forecasts as input, during seven trials in lettuce field plots in coastal California

Trial[a]	Number of type I errors[b]	Number of type II errors[c]	Days forecast correctly (%)
1	0	1	97.4
2	2	0	95.1
3	2	0	91.4
4	0	0	100.0
5	2[d]	0	94.3
6	6[d]	0	82.9
7	0	4	85.7

[a] Table 1 explains the trials.
[b] Dew forecast model failed to predict a prolonged morning leaf wetness period that ended at 1000 h or later.
[c] Dew forecast model erroneously predicted the occurrence of a prolonged morning wet period.
[d] Prolonged morning wet periods occurred during fog drizzle.

The fungicides maneb (Manex; 1.8 kg ha^{-1} active ingredient) and fosetyl Al (Aliette 80W; 2.7 kg ha^{-1} active ingredient) were compared for downy mildew control with three spray schedules: 1) sprays applied at thinning, rosette, and early heading growth stages (calendar-based schedule); 2) spray applications timed according to measured morning leaf wetness (weather station advisory); and 3) spray applications timed according to forecast morning leaf wetness (dew forecast advisory). Untreated control plots were also included in each trial. The experimental layout was a randomized complete block design with four replicates. Plots were two beds (2.0 m) wide (= four plant rows), 7.6 or 12.2 m long, and at least 50 cm apart. Crop management followed recommended practices for commercial crisphead lettuce production (1). Irrigation water was applied by furrow irrigation. The seven trials encompassed a total of 247 site-days.

Sprays following the weather station advisory were applied within 1 day after a prolonged morning wet period was measured. Sprays following the dew forecast advisory were applied early during the morning for which a prolonged wet period was forecast. Based on similarities in climate among the sites (2), we used the weather forecasts for Santa Maria to predict wet periods at Castroville and Guadalupe (the fogbelt sites) and the forecasts for Salinas to predict wet periods at Salinas (the site located in the transition zone between fogbelt and coastal valley climates). (NGM-MOS forecasts for Salinas were not available in 1993, so forecasts for Santa Maria were used instead.) Fungicides were applied with a CO_2-charged backpack sprayer (240-275 kPa, 600 liters ha^{-1} water) and a handheld spray boom (100 cm wide) with four flat spray nozzles covering two plant rows at a time. All applications were made early in the morning or late in the evening to avoid spray drift due to gusty onshore winds during the day. After a spray had been applied, no further applications were performed in the same plot within 10 days even if conditions were favorable for infection, because it was assumed that fungicide protection lasts approximately that long (17).

Downy mildew incidence (proportion of plants with at least one lesion) and severity (number of lesions per plant) were recorded at weekly to biweekly intervals on 15 to 20 arbitrarily selected plants per plot. During trial 7 only one disease assessment was made at harvest.

Data analysis. Forecasts and measurements of LWD during the seven trials were obtained as described above. Dew forecasts were evaluated by tabulating forecast values of onset, end, and total duration of leaf wetness against their respective measured values. To evaluate the usefulness of forecasts of morning leaf wetness for downy mildew spray scheduling, the numbers of type I and type II errors were calculated. A type I error indicates that the dew forecast model failed to predict a prolonged morning leaf wetness period that ended at 1000 h or later. The number of type II errors indicates how often the

Table 3. Evaluation of forecasts of onset, end, and total duration of leaf wetness, based on a dew simulation model with weather forecasts as input, during seven trials in lettuce field plots in coastal California

	Forecasts of onset of leaf wetness			Forecasts of end of leaf wetness			Forecasts of duration of leaf wetness		
Trial[a]	Days with no forecast error[b]	Days with forecast error ≤ 1 h	Days with forecast error ≤ 2 h	Days with no forecast error[c]	Days with forecast error ≤ 1 h	Days with forecast error ≤ 2 h	Days with no forecast error[d]	Days with forecast error ≤ 1 h	Days with forecast error ≤ 2 h
1	13.2[e]	13.2	15.8	21.1	34.2	42.1	10.5	13.2	15.8
2	20.0	37.5	47.5	12.5	37.5	57.5	7.5	25.0	30.0
3	26.5	47.1	55.9	35.3	50.0	61.7	14.7	29.4	44.1
4	3.4	20.7	20.7	34.5	62.1	72.4	6.9	17.2	20.7
5	0	25.9	55.6	22.2	70.4	77.8	7.4	22.2	33.3
6	3.3	13.3	30.0	16.7	40.0	63.3	0	6.7	23.3
7	17.9	39.3	64.3	14.3	64.3	75.0	10.7	32.1	39.3

[a] Table 1 explains the trials.
[b] Time of onset of leaf wetness predicted accurately.
[c] Time of end of leaf wetness predicted accurately.
[d] Total duration of leaf wetness predicted accurately.
[e] All values are percentages.

dew forecast model erroneously predicted the occurrence of a prolonged morning wet period.

Where appropriate, disease intensities for the different spray schedules and fungicides were compared with analysis of variance (SAS Institute Inc.) after having ascertained that all statistical assumptions were met. The analysis was done as appropriate for a randomized complete block design. Linear contrasts were computed to determine which spray schedules or fungicides were different at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Evaluation of leaf wetness forecasts. During the seven trials, about 90% of the 247 site-days were forecast correctly as days with or without prolonged morning leaf wetness (threshold 1000 h), based on the dew simulation model with weather forecasts as input (Table 2). Fog drizzle, which is not considered in the dew model, occurred during all mornings with type I errors in 1994 (Alan Fox, Fox Weather, Oxnard, Calif., *personal communication*). Information about the occurrence of drizzle was not available in 1993.

Table 4. Number of fungicide applications when sprays against downy mildew were timed according to measured or forecast morning leaf wetness during seven trials in lettuce field plots in coastal California

	Number of fungicide applications			
Trial[a]	Calendar-based schedule[b]	Weather station advisory[c]	Dew forecast advisory[d]	Grower's schedule[e]
1	3	0	1	1
2	3	2	1	3
3	3	2	0	2
4	3	0	0	2
5	3	2	0	4
6	3	1	0	3
7	3	0	1	0
All trials combined	21	7	3	15

[a] Table 1 explains the trials.
[b] Sprays applied at thinning, rosette, and early heading growth stages.
[c] Sprays applied when measured leaf wetness ended at 1000 h or later.
[d] Sprays applied when forecast leaf wetness ended at 1000 h or later (based on a dew simulation model with weather forecasts as input).
[e] Sprays applied by cooperating growers in adjacent field lots under commercial management (same cultivars and planting dates).

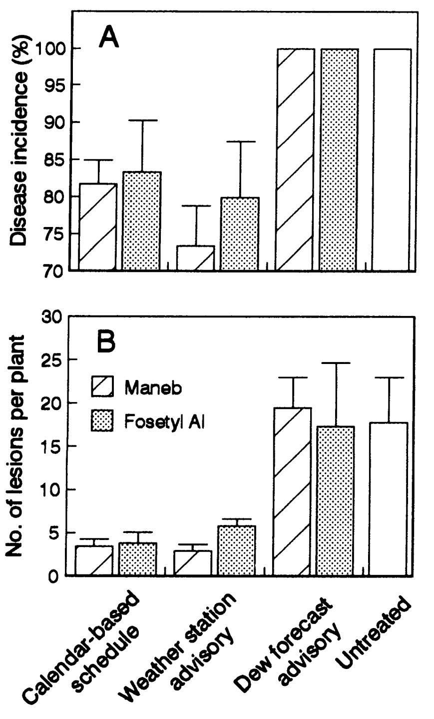

Fig. 3. Disease incidence (A) and severity (B) of lettuce downy mildew in trial 5 following different fungicide spray schedules. Calendar-based schedule = sprays applied at thinning, rosette, and early heading growth stages; weather station advisory = sprays applied when measured leaf wetness ended at 1000 h or later (two applications in this trial); dew forecast advisory = sprays applied when forecast leaf wetness ended at 1000 h or later (no application in this trial). Error bars represent one standard error ($n = 4$).

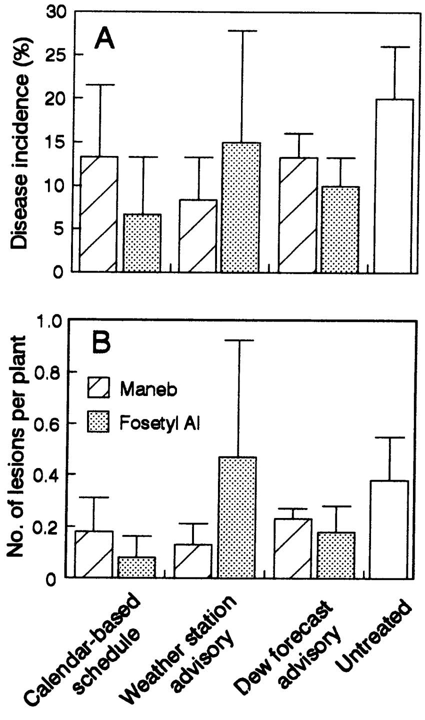

Fig. 4. Disease incidence (A) and severity (B) of lettuce downy mildew in trial 7 following different fungicide spray schedules. Calendar-based schedule = sprays applied at thinning, rosette, and early heading growth stages; weather station advisory = sprays applied when measured leaf wetness ended at 1000 h or later (no application in this trial); dew forecast advisory = sprays applied when forecast leaf wetness ended at 1000 h or later (one application in this trial). Error bars represent one standard error ($n = 4$).

Although the occurrence of prolonged morning wet periods was forecast with reasonable accuracy, the forecasts for the exact time of onset and end of leaf wetness were not very accurate (Table 3). A similar observation was made previously by Wilks and Shen (29) who studied the usefulness of threshold humidity forecasts for plant disease prediction. They found that potato late blight (*Phytophthora infestans*) warnings based on forecasts of air temperature and humidity gave favorable results, although the underlying forecasts of high humidity duration intervals were "disappointingly poor." They explained this apparent contradiction with the discrete nature of the model used to construct disease warnings, by which many different combinations of temperature and humidity produced the same disease warning class. Thus, seemingly poor humidity forecasts generated reasonable disease forecasts so long as the weather forecasts were within the correct range (29). Similarly, the threshold of 1000 h used in our study may have transformed poor forecasts of total LWD into reasonably accurate forecasts of prolonged morning leaf wetness. It should be noted, however, that there would also have appeared to be a high degree of accuracy if one had simply guessed that leaf wetness never ended at 1000 h or later.

Errors in our LWD predictions likely reflect the importance of moisture sources other than dew for leaf wetness on lettuce (e.g., fog drizzle), the sensitivity of the dew model to errors in humidity forecasts (21), the limited spatial resolution of the weather forecasts used as input for the dew model, or a combination of these factors. Because of the high degree of accuracy of the dew model when measured weather data were used as input (5,7,16,21), we expect improved dew forecasts when more accurate, high resolution weather forecasts (12,19,25) are available to replace low resolution NGM-MOS forecasts as input for the leaf wetness model.

Evaluation of disease forecasts. Downy mildew did not occur during trials 1 and 4 because weather was not conducive to infection. (Disease surveys in the Salinas Valley showed that inoculum was present during trial 1, but not during trial 4.) Leaf wetness never ended later than 0800 h during both trials, according to measurements at the field-based weather station. The weather station advisory thus correctly recommended omitting all fungicide sprays (Table 4). The dew forecast advisory erroneously recommended one application during trial 1. The calendar-based schedule resulted in three sprays in both trials, all of which were unnecessary. The cooperating lettuce grower applied one spray during trial 1 and two sprays during trial 4 in adjacent field lots under commercial management (same cultivars and planting dates).

During trials 2 and 3, disease levels were too low to detect differences in downy mildew intensity among the fungicides or spray schedules. All experimental plots remained disease-free, except two plots during trial 2 and four plots during trial 3 with one infected plant each (= 5% disease incidence in these plots). During both trials, inoculum was not present in the region until the plants were close to maturity, according to disease surveys in the Salinas Valley. This resulted in low disease pressure although weather conditions were conducive to infection (two fungicide sprays in each trial scheduled by the weather station advisory; Table 4). The dew forecast advisory recommended only one application during trial 2. It is evident from these results that the availability of initial inoculum must be considered, in addition to weather, for predicting lettuce downy mildew in California. This could be achieved by means of regular field surveys in the major lettuce production areas.

In trial 5, some plants in the experimental area were already infected before the trial was initiated at thinning. Subsequently, high levels of disease developed in untreated plots (Fig. 3), due to conducive weather (two prolonged morning wet periods 10 days apart) and the continuous availability of inoculum. Disease levels were reduced following fungicide applications according to the calendar-based schedule (three applications) and the weather station advisory (two applications). These schedules were not significantly different from each other in disease incidence (linear contrast, $P \leq 0.2159$) or disease severity (contrast, $P \leq 0.8160$). The dew forecast advisory did not predict the two prolonged morning wet periods (both caused by drizzle) and recommended omitting all fungicide applications. Disease incidence and severity in plots treated according to this schedule were, therefore, not different from the untreated control (Fig. 3). There was no difference between the two fungicides (maneb and fosetyl Al) in disease incidence (contrast, $P \leq 0.4735$) or disease severity (contrast, $P \leq 0.8801$).

During trial 6, inoculum was available continuously and six prolonged morning wet periods (all caused by drizzle) occurred, suggesting that conditions were highly conducive to downy mildew development. However, the weather station advisory recommended only one fungicide application (Table 4), because four of the six critical periods occurred within a single 8-day period at the beginning of the trial and the remainder occurred only 2 and 4 days before harvest, when fungicides could not be applied because of preharvest pesticide restrictions. The dew forecast advisory recommended omitting all sprays (Table 4). Final disease levels were too low to detect differences in downy mildew intensity among the fungicides or spray schedules. All experimental plots remained disease-free, except three plots with one infected plant each (= 5% disease incidence in these plots).

Mean disease incidence in trial 7 ranged from 6.7 to 20.0%, with low values of disease severity (Fig. 4). There was no difference among the calendar-based spray schedule (three applications), the weather station advisory (no application), and the dew forecast advisory (one application) ($P \leq 0.7107$ for disease incidence; $P \leq 0.5700$ for disease severity). Although the dew forecast advisory predicted 4 days with prolonged morning leaf wetness (Table 2), it recommended only one fungicide application (Table 4), because all periods occurred within a single 4-day period.

In the seven trials combined, prolonged morning wet periods (with measured leaf wetness until 1000 h or later) occurred on only 5.3% of all mornings. In comparison, leaf wetness ended at 0900 h or later on 23.5% of all mornings, suggesting that a spray advisory based on an earlier wetness threshold would have resulted in too many unnecessary applications. The total number of sprays was greatly reduced (by 67%) with the weather station advisory, compared with the calendar-based schedule (Table 4), with no difference in disease intensity. Thus, the results demonstrate that the number of fungicide applications against lettuce downy mildew can be reduced substantially; but further validation trials with conditions of high disease pressure are needed to compare the weather station and dew forecast advisories more rigorously for accuracy of prediction, disease control, reduction in fungicide use, and economical feasibility.

Several plant disease warning systems based on short-term weather forecasts have been developed and described (e.g., 4,18, 19,20,25,26,28,29). They share the objective of predicting disease-favorable conditions before they actually occur. However, this paper contains the first report of a spray advisory that uses explicit forecasts of LWD, generated with a physical dew simulation model with weather forecasts as input. This approach classified about 90% of the days correctly as days with or without prolonged morning wet period, but it did not accurately predict the occurrence of epidemiologically important prolonged wet periods caused by fog drizzle. Research is currently underway to improve the accuracy of this approach by using mesoscale high resolution weather forecasts as input for the dew model, considering leaf wetness caused by drizzle, and combining disease warnings based on forecast morning leaf wetness with information about the availability of inoculum on local and regional scales. Before an improved weather forecast–based spray advisory against lettuce downy mildew is available, growers could use measurements (or perhaps even visual observations) of the time at which leaves dry in the morning as a simple decision aid for scheduling fungicide applications against the disease.

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