Ineffectiveness of the First Fungicide Application at Different Initial Disease Incidence Levels to Manage Septoria Blight in Celery

I. W. MUDITA, Graduate Student, and A. C. KUSHALAPPA, Associate Professor, Department of Plant Science, Macdonald Campus of McGill University, 21,111 Lakeshore Road, Sainte-Anne-de-Bellevue, Quebec, Canada H9X 3V9

ABSTRACT

Mudita, I. W., and Kushalappa, A. C. 1993. Ineffectiveness of the first fungicide application at different initial disease incidence levels to manage Septoria blight in celery. Plant Dis. 77:1081-1084.

Five initial (at transplanting stage) blight incidence levels (0, 2, 4, 8, and 16%) were tested to select the optimum level for beginning fungicide application to manage Septoria blight incited by *Septoria apiicola* in celery (*Apium graveolens* var. *dulce*). The experiment was conducted on muck soil at the Agriculture Canada Research farm at Sainte-Clotilde, Quebec, in the summers of 1990 and 1991. An increase in the initial blight incidence levels raised the proportion of area under the disease progress curves. The proportion of yield loss also rose significantly with increased initial blight incidence. A logistic model established to describe yield loss as a function of initial blight incidence levels predicted loss in yield exceeding the cost of one fungicide application at the 0% initial blight incidence level. On the basis of this model, no initial disease incidence threshold to initiate fungicide application could be established. Nevertheless, an analysis of variance indicated no significant difference in yield loss between 0 and 2% initial blight incidence levels. Because the disease increases rapidly, leading to significant loss in yield at very low blight incidence levels at the transplanting stage, fungicide applications must be initiated as soon as the disease is observed. If the disease appears later in the season, however, initiation of fungicide applications can be delayed until a higher disease incidence threshold is reached.

The current heightened awareness of fungicide residues and their environmental impact has resulted in an increased demand for the reduction of fungicide applications on celery (*Apium graveolens* L. var. *dulce* (Mill.) Pers.) (12). Recommendations in Quebec for the management of Septoria blight of celery, caused by *Septoria apiicola* Speg., include fungicide applications initiated at transplant recovery and repeated at 7- to 12-day intervals, depending on rain (3). As many as 10 fungicide applications may be made to manage Septoria blight in the field. In an integrated pest management scouting program in which fungicide application was delayed in some fields until the appearance of disease, the number of sprays was reduced to fewer than eight without noticeable loss in yield.

The final disease levels in a polycyclic disease are determined by both the amount of initial inoculum and the rate of disease increase (2,14). In polycyclic diseases, the effect of the initial inoculum is minor compared with the rate parameter (4). In Septoria blight, restricted dissemination of the initial inoculum (11) and a few initial disease foci (1) account for the slow blight increase at the beginning of an epidemic. Reduction of the initial disease, therefore, could aid in disease control when infection occurs early in the cropping season (8). Since blight incidence in commercial fields in Quebec varies among locations and cropping seasons, timing of the first fungicide application to manage Septoria blight can be based on initial blight incidence levels. Subsequent applications may then be based on either a fixed interval spray schedule or a forecast system.

This study was undertaken to determine the influence of the first fungicide application at different initial blight incidence levels on Septoria blight development and yield loss. The blight incidence threshold for initiation of fungicide applications could be selected according to the level at which the predicted yield loss is equal to the cost of the application.

Present address of first author: Jl Seruni No. 2A, Kupang 85118, NTT, Indonesia.

Accepted for publication 28 June 1993.

MATERIALS AND METHODS

The experiment was conducted at the Agriculture Canada Research farm in Sainte-Clotilde, in the muck soil region of Quebec where most of the celery is produced, during the summers of 1990 and 1991.

Blight incidence levels of 0, 2, 4, 8, and 16% of diseased transplants per plot were tested as the initial source of inoculum. Experimental plots (5 × 5 m) were established in a randomized complete block design with four replicates in both years. Each plot contained six rows and was buffered by 5 m of uncultivated land between blocks and 2.5 m between plots. Seedlings were transplanted 20 cm apart within a row, for a total of 25 plants per row and 150 per plot. In different plots, 0, 3, 6, 12, and 24 seedlings were replaced at random with inoculated seedlings to obtain initial blight incidence levels of 0, 2, 4, 8, and 16%, respectively. Experimental plots for the summers of 1990 and 1991 were located in different fields.

Production of seedlings and inoculation. Seedlings of celery cv. Florida 683 were produced from certified seeds on seedling trays at a commercial greenhouse in Sainte-Clotilde, Quebec. At the fourth-leaf stage, two trays of seedlings (15 × 20 seedlings per tray) were inoculated.

S. apiicola was isolated from a diseased plant in a field in Sainte-Clotilde, and conidia were produced on celery decoction agar at 20 C and an 18-hr photoperiod in a growth chamber. Twelve-day-old cultures were flooded with sterile distilled water containing 0.01% Tween 80 and then rubbed with a curved glass rod. The concentration of suspended conidia was determined with a hemacytometer and diluted to about 2×10^4 conidia per milliliter. Seedlings were inoculated by placing the seedling trays on a bench positioned 1.5 m below the solid-cone-type spray nozzle of an automatic spray chamber. The speed of the horizontally moving spray nozzle was adjusted to deliver 35 conidia per square centimeter of leaf surface at a constant pressure of 172 kPa (9). Trays were then placed in a mist chamber at 20 C with a 14-hr photoperiod for 72 hr.

Transplantation, cultural practices, and fungicide applications. Uninoculated seedlings were manually transplanted to the field. A predetermined number of transplants was replaced on the day of planting with seedlings that had been inoculated 1 wk previously. In the summer of 1990, some inoculated transplants did not produce lesions until 2 wk after being transplanted, and these were inoculated again in the field. During inoculation, each designated plant was covered with a plastic housing to prevent contamination of the neighboring transplants. A small hand sprayer was used to apply an inoculum concentration of 10^4 conidia per milliliter.

The field was fertilized 4 wk prior to transplanting with 55 kg/ha of N, 100 kg/ha of P_2O_5, and 150 kg/ha of K_2O. A second application of 55 kg/ha of N was side-dressed 5 wk after transplanting. To prevent blackheart, a foliar spray of 10 kg/ha of $Ca(NO_3)_2 \cdot 2H_2O$ was applied when plants reached 15 cm. Plots were irrigated when necessary, and no insecticide was applied.

Chlorothalonil (Bravo 500, 500 g a.i./L) was applied to all treatments starting 3 wk after transplanting and repeating at intervals of 10 days when there was no rain and of 7 days when there was rain. Nine sprays were applied in 1990 and eight in 1991. In 1990, sprays were applied with a knapsack sprayer through a conical nozzle; in 1991, sprays were applied with a tractor-mounted commercial boom sprayer at the rate of 2.3 g a.i./L of water and at a pressure of 827 kPa through Tee Jet hollow-cone nozzles.

Disease and yield loss assessment. Blight was assessed at weekly intervals beginning 2 wk after transplanting on every fully opened leaf of 10 plants randomly sampled from four inner rows per plot. The severity rating was based on a three-digit Horsfall-Barratt scale with the aid of diagrams (7). DISPAR, a microcomputer program for the calculation of foliar disease parameters developed by Kushalappa and Carisse (6), was used to calculate: 1) the disease incidence, i.e., the proportion of diseased leaves and the proportion of the area under the disease progress curve (PAUDPC) based on the proportion of leaves diseased, and 2) the disease severity, i.e., the proportion of leaf area diseased and the PAUDPC based on proportion of leaf area diseased.

The crop was harvested 98 and 105 days after transplanting in 1990 and 1991, respectively. A random sample of 10 plants per plot was harvested and trimmed. After all diseased petioles were removed, each plant was weighed. Yield loss was calculated as the proportion of maximum plant weight loss: $YIELD\ LOSS_{ij} = (YIELD_{max0j} - YIELD_{ij})/YIELD_{max}$, where $YIELD\ LOSS$ is the proportion of maximum yield loss, i is the initial blight incidence level, j is the block, and max is the maximum plant weight in kilograms at the 0% initial blight incidence level.

Data analyses. The effect of initial blight incidence levels on the blight progress and on yield loss was evaluated by means of regression analysis (10,13). The initial blight incidence was regressed against the PAUDPC based on disease incidence, the PAUDPC based on disease severity, and the proportion of maximum yield loss (5). All statistical analyses were carried out by the NONLIN procedure of SAS/STAT software for the IBM PC (10). A logistic model was fitted for all three data sets: $Y = b_0/(1 + b_1\ exp(-b_2X))$, where Y represents PAUDPC or proportion of maximum yield loss, X represents initial blight incidence, and b_0, b_1, and b_2 are coefficients of response function. For iteration, the Marquard method with derivatives for all three coefficients was used.

The initial blight incidence level at which the predicted yield loss exceeded the proportion of maximum yield equal to the cost of one fungicide application was considered as the threshold to initiate fungicide application. The cost of one fungicide application was transformed into the proportion of the maximum yield per hectare. The proportion of maximum yield per hectare equivalent to the cost of one fungicide application (PYEF) was calculated as: $PYEF = YEF/YIELD_{max}$, where YEF is the yield, in crates of celery (24 kg per crate), equivalent to the cost of one fungicide application per hectare and $YIELD_{max}$ is the maximum yield in crates of celery per hectare at the 0% initial blight incidence level. The price of celery at the farmer level was $6.50 per crate, and the cost of commercial fungicide applications was $45.00 per application per hectare.

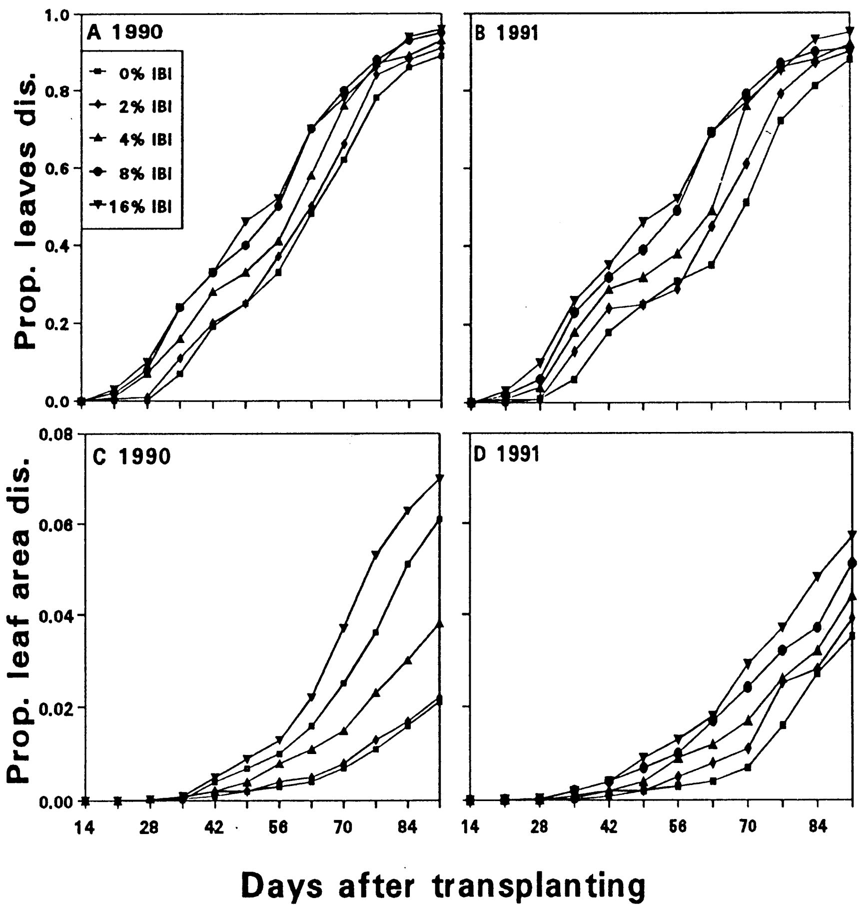

Fig. 1. Progress of Septoria blight in celery, with curves based on the proportion of leaves diseased in **(A)** 1990 and **(B)** 1991 and of leaf area diseased in **(C)** 1990 and **(D)** 1991 at different initial blight incidence levels, provided as source of initial inoculum. All plots were sprayed, starting 3 wk after transplanting and repeating at intervals of 7 or 10 days.

RESULTS

Effect of initial blight incidence levels on blight progress. The disease progress curves of Septoria blight in 1990 and 1991 are shown in Figure 1. For all initial blight incidence levels, the proportion of leaves diseased increased steadily throughout the cropping season, whereas the proportion of leaf area diseased increased slowly at first and markedly after the second week. At the end of the season, no apparent differences were observed in these two disease parameters among the initial blight incidence levels tested.

The PAUDPC based on both disease incidence and severity rose with increases in the initial blight incidence levels (Fig. 2). The experimental errors associated with the two PAUDPC parameters in 1990 and 1991 were homogeneous ($P >$ 0.01), and therefore analyses were performed on the pooled data. The logistic models established to predict the disease incidence and severity from the initial blight incidence were: 1) $PAUDPC = 0.8828/(1 + 0.4452\ exp(-20.0205IBI))$, with $R^2 = 0.71$, and 2) $PAUDPC = 0.0335/(1 + 5.0603\ exp(-30.876IBI))$, with $R^2 = 0.96$, where $PAUDPC$ is the proportion of area under the disease progress curve based on disease incidence and disease severity, IBI is the initial blight incidence, and R^2 is the coefficient of determination. Significant relationships of initial blight incidence levels with both the above disease parameters indicated that the initial inoculum plays a major role in disease development, independent of the influence of other factors.

Effect of initial blight incidence levels on yield loss. The proportion of yield loss rose with increases in the initial blight incidence levels (Fig. 3). The data sets for both years were pooled because the *F* test indicated that the experimental error was homogeneous ($P > 0.01$). A logistic model was fitted to the data: $YIELD\ LOSS = 0.559/(1 + 54.4888\ exp(-59.6236 IBI))$, with $R^2 = 0.99$, where *YIELD LOSS* is the proportion of maximum yield loss.

It is important to note that at the 0% initial blight incidence level, even though the outer leaves of most of the plants were diseased, a marketable petiole had to be removed very rarely during processing because of lesions on it. In the other treatments, the outer leaves and petioles often had more disease than the inner ones. Even in the inner leaves, not all the diseased leaf laminae had diseased petioles.

Prediction of action threshold based on yield equivalent to the cost of one fungicide application. At the 0% initial blight incidence level, the maximum yields in 1990 and 1991 were 2,037.26 and 1,689.66 crates per hectare, respectively, and the gross values of celery at \$6.50 per crate were \$13,242.19 and \$10,982.79 per hectare, respectively. The proportions of maximum yields equivalent to the cost of one fungicide application per hectare were 0.0034 and 0.0041 in 1990 and 1991, respectively. Substitution of $IBI = 0.0$ to the above equation yielded a proportion of maximum yield loss of 0.01, which is higher than the proportion of yield equivalent to the cost of one fungicide application (almost equal to three applications). However, no loss in yield was observed in this study at the 0% initial blight incidence level. On the basis of the equation developed here, it is too dangerous to postpone the initial fungicide application until a blight incidence threshold is reached. This is justified by high crop value, low fungicide application cost, and high rate of yield loss.

DISCUSSION

Determination of an action threshold for timing fungicide applications involves various aspects. For most diseases, such timing is mainly based on the predicted effect of environmental and biological variables on epidemiological processes. In this work, an effort was made to incorporate fungicide cost into the selection of action thresholds for timing the first fungicide application to manage Septoria blight. The first fungicide application is postponed until the initial blight incidence reaches a level at which the resulting disease would cause a yield loss at least equal to the cost of that fungicide application. In this study, however, it was not possible to establish any action threshold because the equation predicted loss in yield even at the 0% initial blight incidence level at transplant time. Nevertheless, at the 0% initial blight incidence level, even though most of the plants were diseased, a marketable petiole had to be removed very rarely during processing because of a lesion on it. Also, an analysis of variance study indicated no significant difference between 0 and 2% initial blight incidence levels. Development of an equation with variables at a lower range of initial blight incidence levels may improve the prediction. Although it is not practical to recommend such a low threshold to growers, it should be possible to postpone fungicide application until the disease is noticed in the field, even though some infected plants with sporulating pycnidia show no symptoms.

The failure to establish an initial blight incidence threshold to begin fungicide application may be attributed to numerous factors. First, yield loss occurred at a very low initial blight incidence level. Second, the risk of yield loss is very high at low initial disease incidence levels, as indicated by high partial regression coefficient values for the yield loss in relation to initial blight incidence. An increase in the initial blight incidence level increased the PAUDPC and the yield loss. Third, since the cost of fungicide application was very low and the value of celery was relatively high, a delay in fungicide application cannot be justified on the basis of economics only.

In establishing an action threshold it was assumed that the disease incidence threshold is reached at the time of transplanting, and following this the fungicides are applied at fixed intervals of 7 or 10 days, depending on the rain. How-

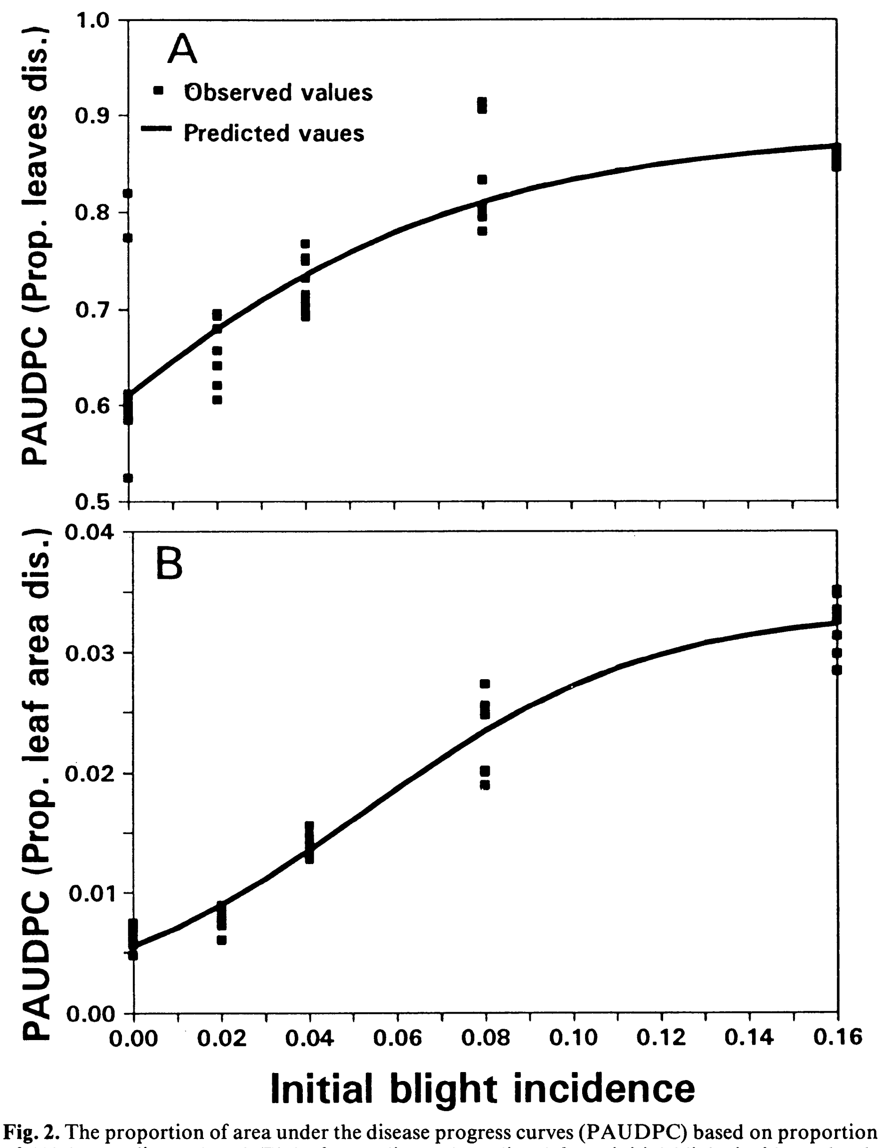

Fig. 2. The proportion of area under the disease progress curves (PAUDPC) based on proportion of **(A)** leaves diseased and **(B)** leaf area diseased predicted from initial blight incidence levels using a logistic fit: (A) $PAUDPC = 0.8828/(1 + 0.4452\ exp(-20.0205 IBI))$, with $R^2 = 0.71$, and (B) $PAUDPC = 0.0335/(1 + 5.0603\ exp(-30.876 IBI))$, with $R^2 = 0.96$, where *PAUDPC* is based on the proportion of (A) leaves diseased or (B) leaf area diseased, *IBI* is the initial blight incidence level, and R^2 is the coefficient of determination (data for 1990 and 1991). All plots were sprayed, starting 3 wk after transplanting and repeating at intervals of 7 or 10 days.

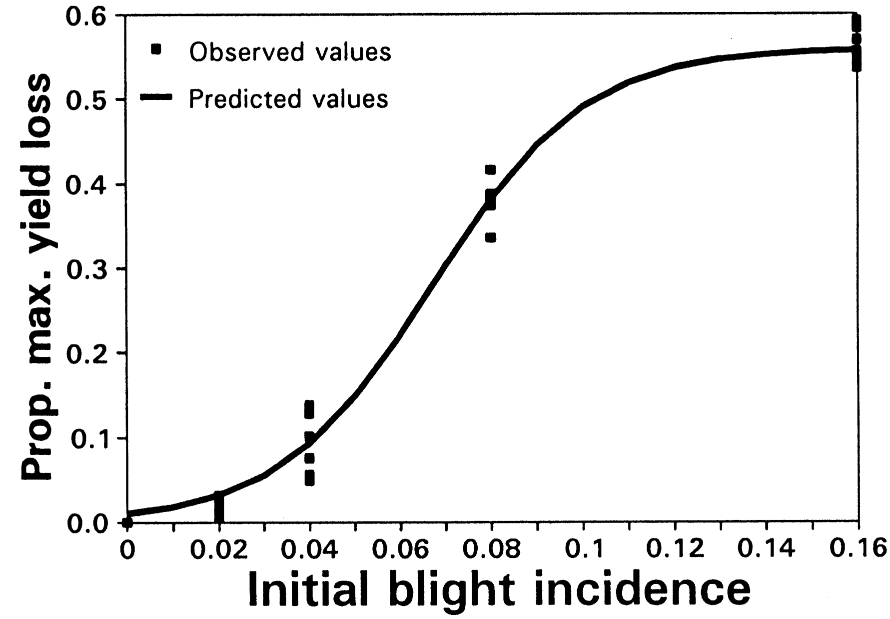

Fig. 3. The proportion of maximum yield loss predicted from the initial blight incidence levels using a logistic fit: *YIELD LOSS* = 0.559/(1 + 54.4888 *exp*(−59.6236*IBI*)), with $R^2 = 0.99$, where *YIELD LOSS* is the proportion of maximum yield loss, *IBI* is the initial blight incidence level, and R^2 is the coefficient of determination (data for 1990 and 1991). All plots were sprayed, starting 3 wk after transplanting and repeating at intervals of 7 or 10 days.

ever, often no blight is seen in commercial fields for at least a month after transplanting. If blight starts late in the cropping season, it is not necessary to apply fungicides until the disease is seen. The number of fungicide applications saved depends on how long it takes for blight to appear in the field. This, in turn, depends not only on the initial inoculum coming from the seedlings but also on the inoculum surviving in crop residue in the field and on other factors affecting blight development.

The current recommendation in Quebec is to begin application of fungicides at transplant recovery, which requires about 2–3 wk. In an integrated pest management scouting program for the Montreal area of Quebec, the fungicide applications are initiated only when the blight is noticed in the field. In 1990, blight did not appear until 40 days after transplanting in any of 14 fields scouted; it appeared within 40–60 days in three of the fields and at 60 days in the remaining 11 fields. Similarly, in 1991, blight did not appear until 30 days after transplanting in any of 14 fields scouted; it appeared within 40 days in two fields, within 40–60 days in four fields, and at 60 days in the remaining eight fields (A. C. Kushalappa and P. Auclair, *unpublished*). In this program the total number of applications was reduced from 10 (in the conventional method) to fewer than seven, depending on the field. It is interesting to note in our study (Fig. 1A and B) that 60 days after transplanting, more than 30% of the plants were diseased at the 0% initial blight incidence level, with almost no loss in yield. Thus, it is possible to use a higher disease incidence threshold to begin fungicide applications at later growth stages of celery and save three or more sprays (0.01/0.0034 or 0.01/0.0041, predicted loss less than the cost of three sprays at 0% *IBI*), compared with the conventional method.

The estimates of yield loss, development of Septoria blight, etc., as determined in small plots may not represent actual commercial field conditions very well. Under commercial conditions, the appearance of blight at the time of transplanting is extremely rare. The time of blight appearance varies according to the amount of initial inoculum surviving in crop debris and coming from infected seeds. Postponing fungicide application until the blight was noticed in the field saved at least three sprays. At the 0% initial blight incidence level, lesions rarely occurred on a marketable petiole even though the plants were severely diseased at harvest. Thus, the first fungicide application can be postponed, without much risk, especially at later growth stages, until blight is noticed in the field. However, more studies under commercial field conditions are required to optimize fungicide sprays, a dynamic disease incidence threshold depending on the plant growth stage.

ACKNOWLEDGMENTS

This research was funded by the Conseil des Recherches en peche et agroalimentair du Quebec. The scholarship provided by the government of Indonesia to the first author is gratefully acknowledged.

LITERATURE CITED

1. Berger, R. D. 1970. Epiphytology of celery late blight. Proc. Fla. State. Hortic. Soc. 83:208-212.
2. Campbell, C. L., and Madden, L. V. 1990. Introduction to Plant Disease Epidemiology. John Wiley & Sons, New York.
3. CPVQ (Conseil des productions vegetales du Quebec). 1987. Legumes protection. Agdex 250/605. Ministere de l'Agriculture des Pecheries et de l'Alimentation du Quebec.
4. Fry, W. E. 1982. Principles of Plant Disease Management. Academic Press, New York.
5. Gomez, K. A., and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley & Sons, New York.
6. Kushalappa, A. C., and Carisse, O. 1990. DISPAR: A microcomputer program to calculate foliar disease-pest parameters in pest-crop modelling. Pages 16-17 in: Proceedings of Workshop on Modelling Pest-Crop Interactions. P. S. Teng and J. E. Yuen, eds. University of Hawaii, Honolulu.
7. Mathieu, D., and Kushalappa, A. C. Effects of temperature and leaf wetness duration on the infection of celery by *Septoria apiicola*. Phytopathology. In press.
8. Maude, R. B., and Shuring, C. G. 1970. The persistence of *Septoria apiicola* on diseased celery debris in soil. Plant Pathol. 19:177-179.
9. Mudita, W., and Kushalappa, A. C. 1991. Effect of media and temperature on sporulation of *Septoria apiicola*, and of inoculum density on septoria blight severity in celery. Phytoprotection 72:97-103.
10. SAS Institute. 1987. SAS/STAT Guide for Personal Computers. Version 6 ed. SAS Institute, Cary, NC.
11. Sherf, A. F., and MacNab, A. A. 1986. Vegetable Diseases and Their Control. 2nd ed. John Wiley & Sons, New York.
12. Skylakakis, G. 1983. Theory and strategy of chemical control. Annu. Rev. Phytopathol. 21:117-135.
13. Steel, R. G., and Torrie, J. H. 1980. Principles and Procedures of Statistics, A Biometrical Approach. 2nd ed. McGraw-Hill Book Co., New York.
14. Vanderplank, J. E. 1963. Plant Disease: Epidemics and Control. Academic Press, New York.