Integrated Control of Potato Late Blight —Effects of Polygenic Resistance and Techniques of Timing Fungicide Applications

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ABSTRACT

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The efficiency of fungicide (as determined by degree of control per unit fungicide) used for control of potato late blight caused by *Phytophthora infestans* was enhanced when applied according to a "forecasting" technique. Fungicides usually were more effective if applied according to "Blitecast" than if applied after each 1.27 cm (0.5 in) of rain. The effect of polygenic resistance was maintained regardless of the method of fungicide timing. Therefore, the most efficient use of fungicide was to apply a reduced level of fungicide to a cultivar with polygenic resistance according to the "Blitecast" prediction. Analysis of apparent infection rates rather than final disease ratings reduced the error due to interexperiment interference.

Additional key words: *Solanum tuberosum*, horizontal resistance.

In northeastern USA, the climate during the growing season is frequently conducive to potato late blight caused by *Phytophthora infestans* (Mont.) d By. The major approach to preventing late blight development has been application of protectant fungicides, and in 1971, 96% of the potato acreage in northeastern USA was sprayed with protectant fungicide (1). Use of race-specific oligogenic resistance (4) or vertical resistance (19) has not contributed effectively to efforts to control late blight because the pathogen rapidly overcame such resistance (16). There are currently no commercial cultivars with sufficient polygenic resistance (4) or horizontal resistance (19) to allow commercial potato production in northeastern USA in most years without fungicides.

Risks associated with pesticide use have received considerable publicity and awareness of these risks has stimulated further efforts to devise procedures which will increase the efficiency of pesticide use. One procedure has been to apply less fungicide to cultivars with moderate levels of polygenic resistance (PR). Both polygenic resistance and periodic applications of protectant fungicide reduce the rate of epidemic development (18) and the effects of both factors can be combined (6, 8). Among the commercially important North American potato cultivars, Sebago probably has the highest level of PR (5, 6, 11). However, the PR in Sebago is only low-to-moderate compared to the high levels of PR in some breeding lines (H. D. Thurston, *personal communication*). Grower practice in Prince Edward Island, Canada, reflects the benefit of combining the effects of periodic fungicide application with PR. There, growers applied less fungicide to Sebago than to other mid- or long-season cultivars (11). In a previous report the difference in PR between Sebago and Russet Rural (a cultivar with very little PR) was predicted to be equivalent to the effects of 0.42-0.67 kg mancozeb active ingredient (a. i.)/ hectare (ha) applied weekly (6).

A second procedure which may increase fungicide efficiency is the use of a procedure to time fungicide applications so that fungicide is applied only when environmental conditions are conducive to disease development. Various procedures have been devised for timing fungicide applications to control potato late blight (3, 7, 9, 20). A recent innovation is "Blitecast" (13) which has combined a system based on relative humidity and temperature (20) with a system based on rainfall and temperature (9). A different and very simple timing system which might be useful in climates in which rainfall and high relative humidity (RH) are positively correlated is one that prescribes fungicide application after an accumulation of 1.27 cm (0.5 in) of rain (3).

The goals of the investigation reported herein were to test the predicted fungicide equivalency of the PR in Sebago relative to that in Russet Rural and to determine whether a combination of a fungicide timing procedure and PR could further enhance fungicide efficiency. Two types of methods for assessing the effect of fungicide or PR on disease development are compared.

MATERIALS AND METHODS

Field plot design.—Small plots in randomized complete blocks were treated with three (1975) or five

(1973, 1974) replications per treatment. In 1973, plots were seven rows wide (0.9 m between rows) and 7.3 m long. In 1974 and 1975, plots were five rows wide and 4.6 m long. Plots were separated from each other by fallow soil (3.7 to 4.6 m).

Cultural conditions.—All experiments were located on a 1.4 ha field in which the environment was favorable to *Phytophthora infestans*. Based on the pattern of disease increase, this experiment was downwind from an adjacent area in which there were other experiments with late blight. This adjacent area served as an inoculum source for the experiments described in this paper.

Foundation or certified potato seed was planted at approximately 23 cm spacing in the row on 7 June 1973; 5 June 1974; and 26 May 1975. Katahdin seed was used in 1973 and 1974, and Sebago and Russet Rural were used in 1975. Potato seed consisted of small tubers or of pieces of tubers (each about 50 g). Seed was treated with a zinc ion-maneb dust in 1973 and 1974 only. Herbicide [Linuron 50 WP, 1.7 kg (a.i.)/ha], was applied after planting, but prior to plant emergence. Fertilizer (168 kg N, 336 kg P, 168 kg K/ha) was applied at planting time. Plants were hilled when 25-50 cm tall. Insecticide [0.9-1.1 kg carbaryl (a. i.)/ha, 1 kg oxydemeton (a. i.)/ha or 0.77-1.1 kg methamidophos (a. i.)/ha] was applied as necessary. Fungicide was applied in a spray volume equivalent to 935 liters/ha with a hand-held spray gun attached to a John Bean Spartan sprayer. In 1973 and 1974, the fungicide used was a coordination product of zinc ion and maneb (mancozeb), 80% WP (Dithane M-45) and in 1975 the fungicide was a mixture of mancozeb (Manzate 200) plus 2-cyano-N-(ethylaminocarbonyl)-2-(methoxyimino) acetamide DPX-3217) supplied by E. I. duPont de Nemours & Co. Vine killer (3.5 liters dinoseb in 47.5 liters diesel fuel/ha) was applied during the second week of September each year.

Disease estimations.—The proportion of tissue diseased (which included assessment of percent defoliation as well as percent infected) was estimated every 2-5 days after symptoms first became apparent and continued until vines were killed. An assessment key published by the British Mycol. Soc. (2), and modified with the aid of an assessment key published by James (10), was used in the estimations. The modifications were: 0.1% disease = about five infected leaflets per plant or two lightly infected leaves per plant, and that 0.01% disease = five infected leaflets per 10 plants or two lightly infected leaves per 10 plants. Whenever the amount of disease did not fit precisely a level described in the key, the amount of disease was estimated by interpolation. An estimate was made for each of four quadrants, each containing 20-25 plants, and these individual assessments were averaged to attain the percent disease for the entire plot. At the time when symptoms began to appear, each plant had about 200 leaves, and the disease estimates were not corrected for new plant growth during the remainder of the season. For some analyses, apparent infection rates (r) were obtained by calculating the regression of $\log_e x/(1-x)$ on time where x = proportion of disease (17). Regressions were calculated for the intervals in which disease increased from 1-3% to 97-99%. The arcsin transformation was used in analysis of the final percent disease rating, and proportion of tubers blighted except where indicated differently. Orthogonal comparisons were made as described by Snedecor and Cochran (15).

Timing procedures.—Fungicide was applied according to one of three timing procedures. The first was to make weekly applications (7-day system). The second was to begin applications when the plants were 35-50 cm in height and subsequently after accumulations of 1.27 cm (0.5 in) of rainfall (3). However, applications were not made more frequently than once every five days. The third procedure was to make applications according to "Blitecast" (13). Rainfall, RH, and temperature were monitored from the date of 50% plant emergence to vine kill, and these data were incorporated weekly into the "Blitecast" computer program at The Pennsylvania State University.

Fungicide-cultivar combinations.—The difference in polygenic resistance between Sebago and Russet Rural was predicted to be equivalent to weekly applications of 0.42-0.67 kg mancozeb (a.i.)/ha (6), which is approximately 25% of the maximum recommended dosage (1.79 kg/ha). Therefore, late blight development in plots of Russet Rural receiving the recommended dosage of fungicide was expected to approximate late

TABLE 1. Amount of late blight in plots of potatoes (*Solanum tuberosum* 'Katahdin')[a] sprayed with fungicide according to different timing procedures

Year	Timing technique[b]	Fungicide applications (no.)	Final amount of foliar blight (%)[c]	Yield of tubers total (kg/ha)	Yield of tubers (%) blighted
1973	7-day	10	0.3 x[d]	45,200 a	-
	1.27 cm (0.5 in) of rain	9	0.9 y	44,800 a	-
	"Blitecast"	6	0.2 x	43,200 a	-
1974	7-day	9	<0.1 X	37,500 A	3.2 a
	1.27 cm (0.5 in) of rain	5	2.6 Y	37,300 A	8.1 a
	"Blitecast"	5	<0.1 X	40,000 A	7.8 a
	Untreated	0	89.0 Z	24,400 B	59.2 b

[a]Fungicide used was the coordination product of zinc ion and maneb, 80 WP (Dithane M-45) 1.79 kg (a. i)/ha applied in 935 liters water/ha.

[b]Fungicide was applied every 7 days, after an accumulation of at least one-half inch (1.27 cm) of rain, or according to "Blitecast".

[c]Proportion of tissue infected and/or defoliated.

[d]Values within a given year followed by the same letter are not significantly different ($P = 0.05$) as determined by Duncan's new multiple range test.

blight development in plots of Sebago receiving 75% of the recommended dosage. Similarly, late blight development in plots of Russet Rural that received 75% of the recommended dosage was expected to be greater than that in either of the other treatments. The recommended dosage of the fungicide combination used was 1.34 kg (a. i.) mancozeb (Manzate 200) + 0.112 kg (a. i.) DPX-3217/ha. Three fungicide-cultivar treatments were used: Russet Rural treated with the recommended dosage (RR-1.00); Russet Rural treated with 75% of the recommended dosage (RR-0.75); and Sebago treated with 75% of the recommended dosage (Seb-0.75).

TABLE 2. Spray dates and "Blitecast" severity units in 1975

	Fungicide applications[a] (no.)			
Week of	7-day	(1.27 cm) rainfall	"Blitecast"	Blitecast severity units[b]
15 June				3
22 June	1	1		1
29 June	1			1
4 July	1	2		10
11 July	1	1		6
18 July	1	1	1	5
25 July	1	1	1	1
3 Aug.	1			15
8 Aug.	1	1	1	22
15 Aug.	1	1	2	8
22 Aug.	1	1	1	13
20 Aug.	1	1	1	8
Totals	11	10	7	93

[a]Fungicide was applied either every 7 days, after an accumulation of 1.27 cm (0.5 in) of rain, or according to "Blitecast".

[b]"Blitecast" severity units are described in reference 13. Low numbers indicate that weather was less conducive to late blight, whereas high numbers indicate that weather was conducive to late blight.

RESULTS

Comparison of fungicide timing methods in 1973 and 1974.—At the end of the 1973 season there was less than 1% foliar late blight in all of the plots, but plots treated according to the 1.27 cm (0.5 in) of rain method had the most foliar blight (Table 1). In 1974, plots treated according to the 1.27 cm of rain method again had the most foliar blight (2.5%). In 1974, the average final amount of blighted foliage was less than 0.1% for plots treated every 7 days or according to "Blitecast" (Table 1). Plants in plots not treated with fungicide in 1974 had an average apparent infection rate (r) of 0.55 per unit per day. The proportion of tissue affected increased from about 1% to about 90% during the last 18 days of the season. There were no significant differences among yields in either year or in the proportion of infected tubers from plants sprayed according to the different methods. Fungicide application according to "Blitecast" resulted in the fewest sprays, whereas weekly application resulted in the most sprays (Table 1).

Late blight development in plots in 1975. —Late blight developed rapidly in plots of untreated plants located in a different area of the same field, because the environment was conducive to *P. infestans* during August and September (Table 2). Vine killer was applied on 10 September 1975. The effect of the environment was reflected by the late blight epidemics in unsprayed plots. In plots of Russet Rural, there was almost no green tissue

TABLE 3. Effect of three fungicide[a]-cultivar combinations and fungicide timing techniques on final disease rating and rate of late blight development in 1975

	Fungicide-cultivar combinations							
	RR-0.75		RR-1.00		Seb-0.75		Means	
Timing Technique[b]	%[c]	Rate[d]	%	Rate	%	Rate	%	Rate
7-day	31.8	.157	15.0	.112	13.2	.130	20.0 C[e]	.133 Z
1.27 cm (0.5 in) of rain	59.2	.164	46.7	.145	27.2	.103	44.2 D	.138 Z
"Blitecast"	33.2	.129	44.2	.129	23.5	.120	33.5 D	.126 Z
Means[g]	41.4 B	.150 Y	35.3 B	.129 XY[f]	21.3 A	.118 X		

[a]Fungicide was a tank mixture of the coordination product of zinc ion and maneb, 80 WP (= mancozeb) (Manzate 200) + 2-cyano-N-(ethylaminocarbonyl)-2-(methoxyimino) acetamide, 80 WP (DPX-3217) applied in 935 liters/ha. The full dosage (1.00) was 1.344 kg mancozeb (a. i.)/ha + 0.112 kg DPX-3217 (a. i.)/ha. In adjacent nonsprayed plots the rates of epidemic development in Russet Rural and Sebago were 0.469 and 0.233 per unit per day, respectively. The final average amount of disease was 100% for Russet Rural (attained 5-7 days before application of vine killer) and 96.5% for Sebago.

[b]Fungicide was applied either every 7 days, after an accumulation of one-half inch of rain, or according to "Blitecast".

[c]Disease percentages were estimated as described in the text. The value reported is the average of assessments made during the final two days prior to application of vine killer.

[d]Epidemic rates were the slopes of regression lines of $\log^e x(1-x)$ on time, where x = proportion of tissue diseased. These slopes have the units -per unit per day. Slopes were calculated in the intervals of x = 1-3% to x = 97-99%.

[e]Means followed by the same letter are not significantly different ($P = 0.05$), as determined by orthogonal comparisons.

[f]The apparent infection rate for RR-0.75 was greater than that for RR-1.0 at $P = 0.1$.

[g]There were significant differences among replications when final disease ratings were analyzed. The ratings for replications 1, 2, and 3 were 39.6 (A), 36.6 (A), and 21.8 (B), respectively ($P = 0.05$). There were no significant differences among replications when apparent infection rates were analyzed. The ratings for replications 1, 2, and 3 were 0.131 (X), 0.142 (X), and 0.124 (X), respectively ($P = 0.05$).

at the end of the season whereas plots of Sebago were about 96% affected. Apparent infection rates were 0.47 and 0.23 per unit per day for Russet Rural and Sebago, respectively.

Fungicide-cultivar combinations affected the rate of epidemic development whereas fungicide timing procedures did not. The apparent infection rate (r) in plots of Seb-0.75 (0.118 per unit per day) did not differ significantly from r for RR-1.0 (0.129 per unit per day) (Table 3) although less fungicide was applied to plots of Seb-0.75 than was applied to RR-1.0. However, r in plots of RR-0.75 (0.150) was significantly greater than r for Seb-0.75. The greater value of r in plots of RR-0.75 (0.150) than in RR-1.0 (0.129) was significant only at $P=0.1$. The method used to time fungicide application did not affect significantly the apparent infection rates although fewest sprays (7) were applied according to "Blitecast" and most sprays (11) were applied according to the 7-day schedule. Fungicide was applied 10 times according to the 1.27 cm of rain method.

Fungicide-cultivar combinations and fungicide timing procedures affected final disease ratings. At the end of the 1975 season, plots of Seb-0.75 had significantly less late blight than did plots of RR-1.0 or RR-0.75 (Table 3). When methods for timing fungicide applications were compared, there was significantly less late blight in plots that received fungicide every 7 days than in plots that received fungicide according to "Blitecast" or the 1.27 cm of rain method (Table 3).

Effect of different fungicide-cultivar combinations and timing techniques on proportion of tubers blighted and on total yield.—Only 2% of the tubers from plots of Seb-0.75 were blighted (Table 4). This was significantly less than the 4.9% of tubers blighted from plots of RR-1.0 which was significantly less than the 7.8% from plots of RR-0.75. There were no statistically significant differences in total yields attributable to fungicide-cultivar combinations. Plots sprayed with fungicide according to the 1.27 cm rainfall technique produced a lower total yield and a higher proportion of blighted tubers than did plots sprayed every 7 days or according to "Blitecast".

Efficiency of fungicide use.—If efficiency is defined as the ratio of return/investment, the program which maximizes this ratio is most efficient. Because of market fluctuations, it is not feasible to evaluate the ratio in monetary units. However, one can evaluate the ratio in terms of the degree of control achieved. The maximum amount of fungicide used in 1975 was 15.89 kg (a. i.)/ha, which was applied to plots of RR-1.0 in sprays every 7 days, whereas the minimum amount was 7.59 kg (a. i.)/ha applied to plots of Seb-0.75 according to "Blitecast". The final amount of foliage blight and r in plots of Seb-0.75 sprayed according to "Blitecast" tended to be equivalent or lower than they did in plots of RR-1.0 sprayed every 7 days.

Efficiency also can be evaluated in terms of the amount of blight-free tubers per unit of fungicide. The comparision is valid only for cultivars of comparable yielding ability and one must assume that foliage blight is correlated to tuber blight. Experiments reported here support this assumption for plants which survive to the end of the season. Plots of Seb-0.75 sprayed according to "Blitecast" produced 4,730 kg of blight-free potato tubers/kg of fungicide, wheras plots of RR-1.0 sprayed every 7 days produced only 2,240 kg of blight-free tubers per kg fungicide. Based on these comparisons, the most efficient use of fungicide was to apply it at a reduced dosage to Sebago according to "Blitecast".

Comparison of final disease ratings with apparent infection rates.—Results obtained by analysis of final percent disease differed from results obtained by analysis of apparent infection rates (r) in at least three respects. First, there were significant differences among replications when final percent disease was analyzed, but not when r-values were analyzed (Table 3). The average final percent disease decreased with increasing distance from the inoculum source. Replication 1 (with 39.9% disease) was located nearest the inoculum source, whereas replication 3 (with 21.8% disease) was located furthest from the inoculum source. Second, the final disease ratings of RR-0.75 were not significantly different from those of RR-1.0, whereas r for RR-0.75 was significantly greater than r for RR-1.0 ($P = 0.1$). [The final disease ratings of RR-0.75 plots were relatively lower in replicate 1 than the same treatments in replicates 2 and 3 ($P = 0.005$). This comparison contributed more than half of the variance associated with the residual in the analysis of variance.] Third, there were no significant differences among timing techniques when apparent infection rates

TABLE 4. Effects of three fungicide-cultivar combinations and fungicide timing techniques on yield and proportion of tubers blighted during 1975

Timing method	RR-0.75[a]		RR-1.00		Seb-0.75[b]		Means	
	kg/ha	(%)[c]	kg/ha	(%)	kg/ha	(%)	kg/ha	(%)
7-day	37,800	(5.8)	40,100	(4.3)	37,900	(1.7)	38,800 A[d]	(3.9) X
1.27 cm (0.5 in) of rain	32,300	(11.3)	31,100	(6.7)	32,500	(2.7)	32,000 B	(6.9) Y
"Blitecast"	36,900	(6.2)	35,600	(3.7)	36,500	(1.7)	36,300 A	(3.8) X
Means	36,700 A	(7.8) X	35,600 A	(4.9) Y	35,600 A	(2.0) Z		

[a]Plots of Russet Rural potatoes receiving no fungicide yielded 18,700 kg tubers/ha and 34% of these were blighted.
[b]Plots of Sebago potatoes receiving no fungicide yielded 25,800 kg/ha and 9.1% were blighted.
[c]Proportion of tubers (by weight) with late blight lesions.
[d]Values of means followed by the same letter are not significantly different, as determined by orthogonal comparisons ($P=0.05$). No transformation was applied to the values for proportions of tubers blighted.

were analyzed, but the final disease rating of plots sprayed every 7 days was significantly lower than that of plots sprayed according to "Blitecast" or the 1.27 cm of rainfall technique (Table 3). Before 3 August, all plots had less than 0.01% disease. Between 3 August and 17 August 1975, weather was very conducive to late blight, but plots sprayed weekly were the only ones which received fungicide between 3 and 9 August 1975 (Table 2). Because mancozeb does not persist long on leaves (14), plots sprayed according to the 1.27 cm of rain technique or "Blitecast" were unprotected during this initial period when the environment was especially conducive to blight. By 23 August, plots sprayed every 7 days had 0.4% disease, whereas plots sprayed according to the 1.27 cm of rainfall or "Blitecast" techniques had about 3% disease. Subsequently, the rate at which blight increased, was similar in all plots (Table 3).

DISCUSSION

Equivalence of polygenic resistance and fungicide.—The difference in polygenic resistance of Sebago vs. Russet Rural provided control equivalent to at least one quarter of the recommended dosage of fungicide. This difference in PR was maintained despite the use of three techniques of timing the applications. Thus, growers should be able to increase fungicide efficiency by adjusting the dosage of fungicide to complement the polygenic resistance of various cultivars. Preliminary assessments of the fungicide equivalency of several potato cultivars have been reported (6) and experiments are continuing to define these and others more precisely.

Comparison of final disease levels with rates of epidemic development as parameters to assess fungicide efficacy or polygenic resistance. —In the experiments reported here, final disease levels did not always provide the same information as did apparent infection rates. I believe that a major reason for the differences is interexperiment interference (12). Final disease levels seemed to be more sensitive to this interference than were apparent infection rates. The final disease level in the replicate closest to the inoculum source was greater than that in the replicate furthest from the inoculum source, but no such relation existed for apparent infection rates. The greater final disease ratings associated with the 1.27 cm of rainfall technique and "Blitecast" are attributable to a higher level of infection during the first part of August. This large increase occurred because of the adjacent experiment which provided much inoculum. The differences were maintained to the end of the season, because apparent infection rates for the three methods during that time were equivalent.

In replication 1, plots of RR-0.75 had relatively lower final disease ratings than did these treatments in the other replications. However, the apparent infection rates were not affected differentially. I believe this discrepancy also is due to interexperiment interference. Random positioning of plots in replicate 1 resulted in plots of RR-0.75 being grouped together not directly downwind from the inoculum source. I believe that during the early part of August plots of RR-0.75 in replication 1 did not receive as much inoculum as did other plots in replication 1.

Thus, it appears that the discrepancies between results obtained by analysis of final disease levels and results obtained by analysis of apparent infection rates are due primarily to interexperiment interference. Apparent infection rates were not demonstrably affected by such interferences. Therefore, the apparent infection rate is apparently a more reliable measurement than is the final disease level in studies designed to determine efficacy of polygenic resistance or fungicides.

Potential application of fungicide timing techniques and fungicide-cultivar combinations.—In commercial potato production, fungicide timing techniques should be used with caution if a large inoculum source is near production fields. Such sources might be cull piles or fields in which late blight is allowed to increase without restraint. If such inoculum sources are not present, use of timing techniques should enhance fungicide efficiency. The fungicide efficiency may in fact be maximized by adjusting the amount of fungicide to complement the PR of the cultivar.

LITERATURE CITED

1. ANDRILENAS, P. A. 1975. Farmers' use of pesticides in 1971–Extent of crop use. Agric. Economics Rep. 268, Econ. Res. Serv., U. S. Dept. Agric., Washington, D. C. 25 p.
2. ANONYMOUS. 1947. The measurement of potato blight. Trans. Br. Mycol. Soc. 31:140-141.
3. BARRIGA, R. O., H. D. THURSTON, and L. E. HEIDRICK. 1961. Ciclos de aspersión para el control de la "gota" de la papa. Agricultura Tropical. 17:617-622.
4. DAY, P. R. 1974. Genetics of host-parasite interaction. W. H. Freeman, San Francisco. 238 p.
5. EIDE, C. J., and F. I. LAUER. 1967. Testing potatoes for field resistance to late blight. Am. Potato J. 44:9-16.
6. FRY, W. E. 1975. Integrated effects of polygenic resistance and a protective fungicide on development of potato late blight. Phytopathology 65:908-911.
7. GRAINGER, J. 1953. Potato blight forecasting and its mechanization. Nature 171:1012-1014.
8. HODGSON, W. A. 1963. The eradicant effect of some fungicides on potato late blight. Am. Potato J. 40:143-148.
9. HYRE, R. A. 1954. Progress in forecasting late blight of potato and tomato. Plant Dis. Rep. 38:245-253.
10. JAMES, W. C. 1971. An illustrated series of assessment keys for plant diseases, their preparation and usage. Can. Plant Dis. Surv. 51:39-65.
11. JAMES, W. C., C. S. SHIH, and L. C. CALLBECK. 1973. Survey of fungicide spraying practice for potato late blight in Prince Edward Island. 1972. Can. Plant Dis. Surv. 53:161-166.
12. JAMES, W. C., C. S. SHIH, L. C. CALLBECK, and W. A. HODGSON. 1973. Interplot interference in field experiments with late blight of potato (Phytophthora infestans). Phytopathology 63:1269-1275.
13. KRAUSE, R. A., L. B. MASSIE, and R. A. HYRE. 1975. Blitecast; a computerized forecast of potato late blight. Plant Dis. Rep. 59:95-98.
14. NEELY, D. 1970. Persistence of foliar protective fungicides. Phytopathology 60:1583-1586.
15. SNEDECOR, G. W., and G. W. COCHRAN. 1967. Statistical methods. 6th ed. Iowa State Univ. Press. Ames, Iowa. 593 p.
16. THURSTON, H. D. 1971. Relationship of general resistance: Late blight of potato. Phytopathology 61:620-626.
17. VAN DER PLANK, J. E. 1963. Plant diseases: epidemics

and control. Academic Press, New York. 349 p.

18. VAN DER PLANK, J. E. 1967. Epidemiology of fungicidal action. Pages 63-92. *in* D. C. Torgeson, ed. Fungicides: an advanced treatise, Vol. I. Academic Press, New York. 697 p.
19. VAN DER PLANK, J. E. 1968. Disease resistance in plants. Academic Press, New York. 206 p.
20. WALLIN, J. R. 1962. Summary of recent progress in predicting late blight epidemics in United States and Canada. Am. Potato J. 39:306-312.