MEASURING EARLY BLIGHT, ITS PROGRESS AND INFLUENCE ON FRUIT LOSSES IN NINE TOMATO CULTIVARS[1]

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Abstract

In field tests conducted for 3 years, the severity of early blight [Alternaria porri f. sp. solani] in nine tomato cultivars was reliably measured by counting the leaves having 75% to 100% necrotic area. The small lesioned areas on the remaining leaves rarely exceeded 6% of the total foliage surface of a plant exposed to either natural infection or artifical inoculation. Disease progress curves based on both leaf and fruit infection indicated that, on average, 60% defoliation would be necessary to obtain 10% infected fruits in all cultivars tested except Mini-Rose. Fruits of Mini-Rose were free from early blight lesions. Under conditions of moderate natural infection, the total number of fruits of marketable size was not significantly reduced but the loss due to visibly infected fruits ranged from 0% to 13%. Under conditions of severe disease created by artificial inoculation, yield reductions of 10% to 34% occurred in some cultivars in addition to a 13% to 37% loss in quality due to blemished fruit.

Resume

Au cours de 3 ans d'essais de plein champ, on a determine avec precision la virulence de la brûlure alternarienne (Alternaria porri f. sp. solani) sur neuf cultivars de tomates, en comptant les feuilles dont les zones nécrosées dépassaient 75%. Les plages légèrement atteintes du reste des feuilles dépassaient rarement 6% de la surface totale du feuillage des plants exposes soit à l'infestation naturelle soit à l'inoculation artificielle. D'après les courbes de progression de l'infection, calculées d'après les infestations des feuilles et du fruit, il faut en moyenne une defoliation de 60% pour que 10% des fruits de tous les cultivars analyses, à l'exception de Mini-rose, soient infestés. Les fruits de Mini-rose étaient exemptés de lesions de la brûlure alternarienne. En conditions d'infestation naturelle modérée, la quantité de fruits commercialisable n'a pas subi de baisse significative cependant, les pertes provenant de fruits visiblement infestés variaient de 0 à 13%. En conditions de forte infestation provoquées par inoculation artificielle, on a observe des baisses de xendement de 10 à 34% chez certains cultivars en plus de pertes de qualité de 13 à 37% dues à l'altération des fruits.

Tomato early blight incited by Alternaria porri f. sp. solani has caused serious losses (7, 16). Although this disease can be controlled by fungicides (5, 6, 7, 13), highly resistant tomato cultivars are still being sought (1). In the process of evaluation of fungicides and disease resistance, attempts have been made to determine blight severity by visually estimating damaged leaf area or by counting dead leaves, or both (6), by counting leaf spots (5), and by measuring the size of leaf spots (1). The effect of the disease on fruit yield, however, has remained uncertain for several reasons as discussed by Horsfall and Heuberger, although they reported a linear relationship between the numbers of killed leaves and infected fruits up to a limit of 65% defoliation (6, 7).

The present work was initiated to assess the severity of early blight and its effects on yield in several tomato cultivars of commercial type.

Materials and methods

A pathogenic isolate of Alternaria porri (Ellis) Cif. f. sp. solani (Ell. & Mart.) Neerg. and the following tomato (Lycopersicon esculentum Mill.) cultivars and lines were used in field plot experiments during 1969-71: Geneva John Baer was tested for 3 years; Fireball VR, New Yorker, Mini-Rose, Trent, Ottawa 78, Heinz 1350, Campbell 19, and Jet Star were tested for 2 years. For each cultivar a randomized block design with four replications and three treatments

[1] Contribution No. 384, Ottawa Research Station, Agriculture Canada, Ottawa, Ontario K1A 0C6.

corresponding to low, moderate, and severe disease levels was used. In early June, 5- to 6-week-old tomato seedlings were transplanted to the field in rows 4.5 ft apart with 3 ft spacing between plants in a row. Three adjacent rows constituted a plot for each treatment. Plots were separated by untreated buffer rows. The number of plants per row was 22 for John Baer in 1969 and 12 for all cultivars in 1970-71. After the first or second fruit trusses had formed, the plants were staked and pruned to develop only two main branches. Plants in treatment 1 (T1, low disease level) were protected by weekly sprays of maneb which is recommended for the control of early blight in Ontario (13) and is not known to affect tomato yield. Plants in treatment 2 (T2, moderate disease level) received no application of maneb and were exposed to natural infection (2, 7, 14). Plants in treatment 3 (T3, severe disease level) were spray-inoculated once in late July with a heavy suspension of conidia of the pathogen in water (4 x 10. conidia/ml) and received no fungicide sprays.

Tomato yield and disease data were recorded only from the center rows of each plot, discarding one plant at each end of the row. All fruits of marketable size (diam. 2 inches or more) were picked weekly as they ripened. Green fruits were harvested at the end of the growing season (last week of September), Fruits from each plot were sorted into infected and healthy groups and counted. The number of infected fruits at each harvest was expressed as a percentage of the total number of fruits produced during the season. The severity of the disease on tomato foliage was recorded every 2-3 weeks by counting the killed leaves on each plant and by estimating the area of necrotic spots on one branch from each of 4 (1969) or 2 (1970) pre-determined, labelled plants, usually every 5th one, in a row. The area of the leaves and of the necrotic spots was estimated by comparing them with tomato leaflet diagrams prepared by standard methods (8). The average amount of necrotic area at each date of recording was expressed as a percentage of the total leaf area produced by a labelled plant during the season (i.e. potential leaf area). A record of necrotic areas on the top 10 leaves of one branch of each of these plants was maintained separately. A leaf with 75% or more damage was considered killed; the area of such a leaf was estimated from the average area of a random sample of 100 previously tagged leaves, from the lower half of the plants.

Table 1. Percentage of necrotic area* on leaves of naturally infected and spray-inoculated John Baer tomatoes at four dates in 1969

Treatment and leaves assessed	Dates of recording disease			
	Aug 12	Aug 26	Sept 9	Sept 22
Naturally infected				
1. killed leaves	21.75	40.11	58.97	67.25
2. all remaining leaves	6.10	2.74	2.52	5.97
3. top 10 leaves	1.46	0.43	0.85	1.71
4. total (1 + 2)	27.85	42.85	61.49	73.22
Spray-inoculated				
1. killed leaves	64.32	76.99	*100.00*	
2. all remaining leaves	0.85	3.33		
3. top 10 leaves	0.48	1.51		
4. total (1 t 2)	65.17	80.32	*100.00*	

* Percentage based on the total foliage area produced by a plant during the season (i.e. potential leaf area); each entry represents an average of 16 plants.

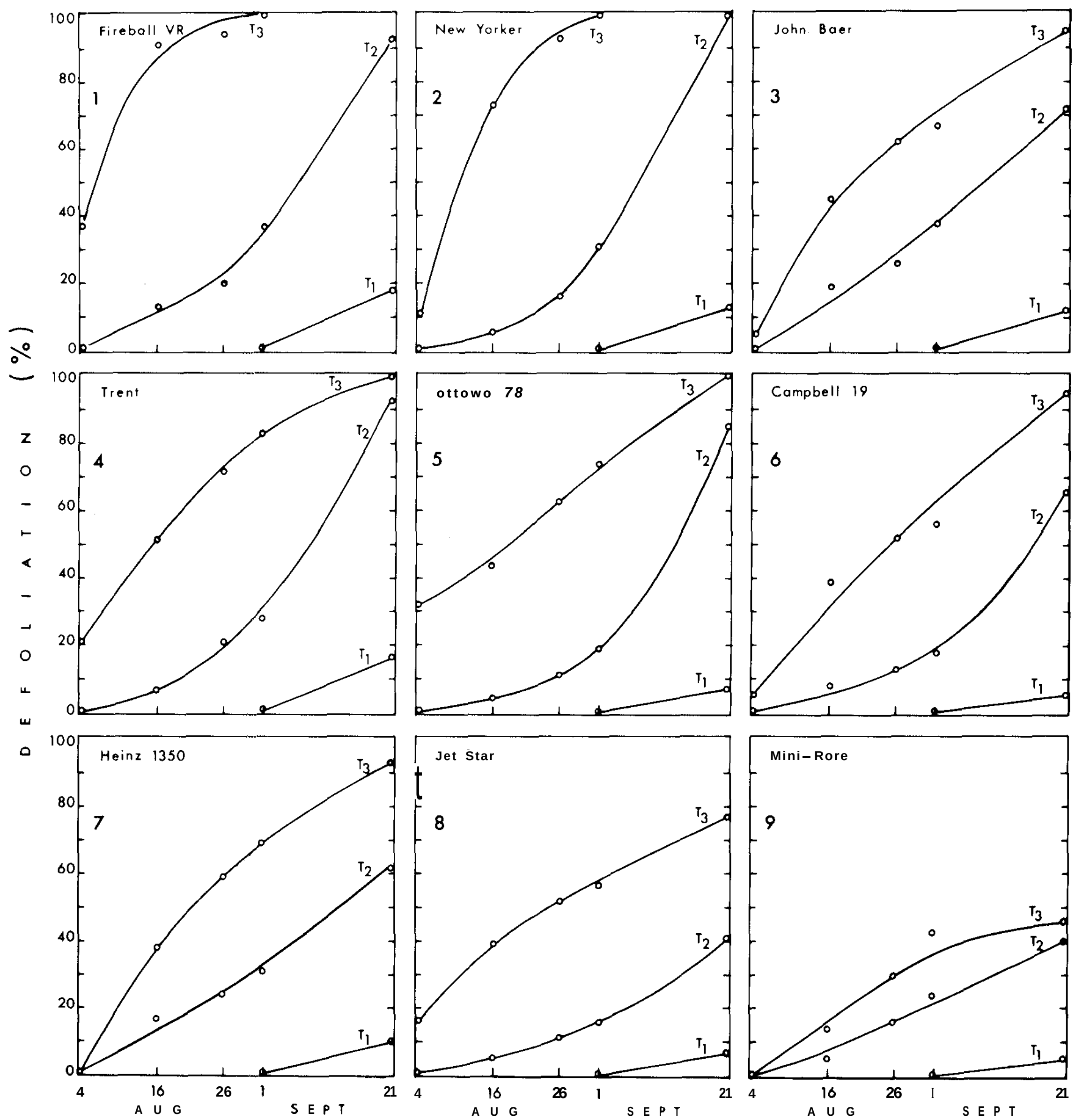
Results

Measurement of foliage blight

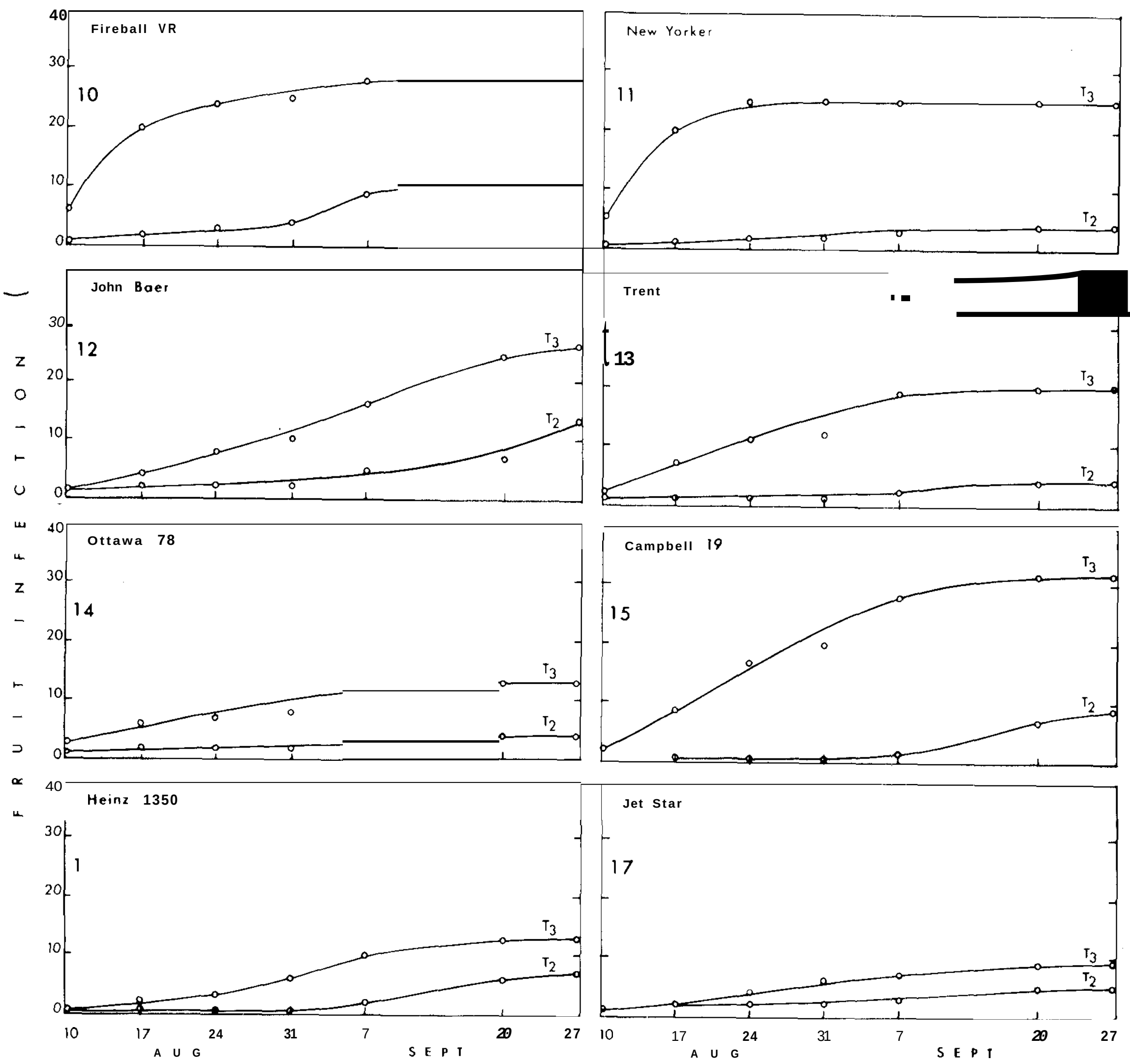
The percentage of necrotic area, based on potential leaf area, produced on naturally infected and spray-inoculated John Baer tomatoes during 1969 is shown in Table 1. The killed leaves, which averaged 90 cm^2 in size, accounted for the major portion of damage on a plant. The total necrotic area on the remaining leaves rarely exceeded 6%, and on the top 10 leaves it was less than 2% at all times during the season. It should be noted that a gradual increase in disease was reflected both by the percentage of killed leaves and by the total damage, but not by the area of small necrotic spots on the living leaves alone (Table 1). Consequently, the percent defoliation, based on the number of killed leaves, was sufficiently accurate to express the magnitude of the disease. Similar conclusions were arrived at from the 1970 results. In 1971 the progress of disease on the foliage was determined only by the percentage of killed leaves (% defoliation).

Disease progress on foliage and fruits

Foliage - Disease progress curves based on percent defoliation of nine tomato cultivars in the three treatments are presented in Figures 1-9. On spray-inoculated (T3) plants of most cultivars, early blight progressed rapidly; Fireball VR and New Yorker were completely defoliated by September 1, 1971. At that time natural infection (T2) had resulted in less than 40% defoliation in Fireball VR, New Yorker, John Baer, Trent, and Ottawa 78. Three weeks later, these cultivars suffered 70% to 100% defoliation, Campbell 19 and Heinz 1350 about 60%, and Jet Star and Mini-Rose less than 40% defoliation. In fungicide protected (TI) plants very few blight lesions were found and, in these plants, defoliation due to natural senescence ranged from 5% to 20% in the nine cultivars tested.



Figures 1 to 9. Progress of defoliation caused by early blight in nine tomato cultivars in 1971 under conditions of fungicide protection (T_1), natural infection (T_2), and artificial inoculation (T_3).



Figures 10 to 17. Progress of early blight infection on fruits of eight tomato cultivars in 1971 under conditions of natural infection (T_2) and artificial inoculation (T_3).

Fruit - Fungicide-protected (T1) plants of all cultivars showed less than 1% fruit infection. The cultivar Mini-Rose had no infected fruits even when plants were spray-inoculated (T3). Disease progress curves based on the percentage of infected fruits under conditions of natural (T2) and artificial (T3) infection for 8 of the 9 cultivars are shown (Figs. 10-17). Inoculated (T3) Jet Star, Heinz 1350, and Ottawa 78 showed lower levels of fruit infection than the other five cultivars. The rapid rise and subsequent flattening of the T3 curves of Fireball VR and New Yorker were due to their early maturity. The percentage of naturally infected (T2) fruits increased qradually in most cultivars. Overall, fruit infection rarely exceeded *30%* in the spray-inoculated and 13% in the naturally infected plants.

Relationship between foliaqe and fruit infection

The data on the percentage of defoliation and fruit infection from the progress curves of eight cultivars were plotted to determfne if a relationship between foliage and fruit infection could be established, irrespective of the conditions of infection (treatments) and of the relative susceptibility of the cultivars. The composite curve (Fig. 18) showed that more than 60% defoliation would be needed to produce 10% infected fruits; however, large variations existed especially in the higher ranges of infection.

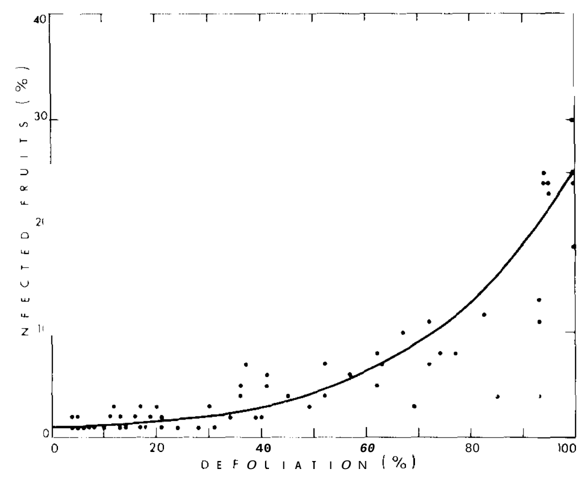


Figure 18. Composite curve showing approximate relationship between defoliation (%) and infected fruits (%) of eight tomato cultivars, irrespective of the conditions of early blight infection.

Losses due to yield reduction and fruit infection

Tomato losses may be of two kinds, quantitative and qualitative. In this study, it is assumed that a visibly infected fruit is unsalable in markets for fresh vegetables, although it could be used by processing firms depending upon the amount of fruit rot caused by the disease. These two aspects of loss are considered here.

Under conditions of natural infection, the mean yields (average number of both healthy and infected fruits from four qroups of 10 plants) of nine cultivars were not significantly less than the yield of fungicide protected plants (Table 2, cols. 1-3). Artificial inoculation caused statistically significant yield reductions in five cultivars (Table 2, cols. 1, 4 and 5). The overall loss due to reduction in yield ranged from 0% in Mini-Rose to 10-34% in other cultivars.

Losses from infection of fruits were significant in three of nine naturally infected cultivars (Table 2, col. 9), and in all artificially inoculated ones (Table 2, col. 11). The average percentage of infected fruits of the cultivars tested during 1969-71 is presented in Table 3. Fruit infection ranqed from 13% to 36.9% on artificially inoculated plants and 3.9% to 12.7% on naturally infected plants of most cultivars except Mini-Rose which had no fruit infection. Very few (0.5-3.5%) fruits of the plants protected by fungicide showed symptoms of early blight.

Discussion

The measurement of early blight on tomato foliage by counting the number of leaves killed (75% or more damage) was less time consuming and more objective than by estimating the area of the lesions with the aid of standard area diagrams (8, 11). Results (Table 1) indicate that in order to obtain typical disease progress curves (12, 15), the percentage of killed leaves alone could be used satisfactorily. It would appear that the small amount of necrotic area (leaf spots) on the remaining green leaves can be disregarded as far as yield loss is concerned. Tomato plants tolerated more than 60% defoliation from natural infection without showing significant reduction in yield (cf. Figs. 1-9 and Table 2). Although Khan & Sagar (9, 10) reported that all leaves contribute to fruit production, it is interesting to note that in de-leafing experiments (3,4), the loss of up to 32 leaves per plant caused no yield loss in tomato. Based on our results, it appears that yield reductions of 10-34% may occur only from early epiphytotics, comparable to those created by deliberate inoculation. Therefore, when the disease is not in epiphytotic proportions, the loss would be only from the number of visibly infected

Table 2. Effects of early blight on yield and fruit infection of 9 field-grown tomato cultivars under conditions of fungicide protection (control), natural infection, and artificial inoculation with *A. porri* f. sp. solani in 1971

Tomato cultivar	Mean yield[a] and percent reduction[b] of fruits						Average number and percentage of infected fruits						
	Control	Natural infection		Artificial inoculation			Control		Natural infection		Artificial inoculation		
	Yield	Yield	% reduction	Yield	% reduction	S.E.[c]	No.	%	No.	%	No.	%	S.E.
Campbell 19	357.8	313.7	12.32	268.5*[d]	24.95	24.30	1.0	<1	27.0* **	8.6	84.8** **	31.58	3.30
Fireball VR	324.0	291.0	10.18	258.3	20.27	15.46	3.0	<1	31.8	10.02	76.8	29.73	3.15
H 1350	352.8	289.5	17.94	239.8	32.02	26.44	0.8	<1	15.8	5.45	31.8	13.26	7.53
Jet Star	365.3	317.5	13.08	327.0	10.48	21.94	3.0	<1	17.3	5.44	30.3 **	9.26	5.40
John Baer	381.3	395.8	- 3.80	342.3 **	10.22	15.32	1.5	<1	50.8	12.83	88.3 **	25.79	9.14
New Yorker	367.5	323.0	12.10	241.5	34.28	13.98	0.5	<1	12.5	3.86	61.0	25.25	6.55
Ottawa 78	322.8	273.3	15.33	230.5	28.93	19.74	2.5	<1	9.5	3.47	31.0**	13.44	2.64
Trent	391.0	330.5	15.47	283.8*	27.41	16.91	1.3	<1	13.3	4.03	56.5**	19.90	6.80
Mini-Rose[e]	621.7	622.0	0.00	693.0	0.00		0.0		0.0	0.00	0.0	0.00	

[a] Mean number of fruits from 4 replications, each containing 10 tomato plants.

[b] Based on yield of control plants (col. 1).

[c] standard error of the grand mean as obtained from analysis of variance with actual number of fruits.

[d] Level of significance, * at 5% and ** at 1% by L.S.D. values from the mean of control (fungicide protected) plants.

[e] Mini-Rose produced large numbers of small fruits (avg diameter 1") with no **loss** due to early blight.

Table 3. Percentage* of infected fruits of nine tomato cultivars under conditions of fungicide protection, natural infection, and artificial inoculation with A. *porri* f. sp. solani

Tomato cultivar	Fungicide protection	Natural infection	Artificial inoculation
Campbell 19	1.6	12.7	31.2
Fireball VR	1.0	8.1	34.4
Heinz 1350	2.3	6.2	18.9
Jet Star	1.4	6.8	13.1
John Baer	2.4	12.2	36.9
Mini-Rose	0.0	0.0	0.0
New Yorker	1.1	6.4	20.9
Ottawa 78	1.3	7.2	13.0
Trent	2.1	3.9	21.3

* Based on the average of 3 years for John Baer (1969-71) and 2 years (1970-71) for the remaining tomato cultivars.

fruits. This loss, however, may not be considered too serious to the tomato processing industries except for the possible increase in mold count.

An attempt was made to correlate percent defoliation and fruit infection, as was done by Horsfall and Heuberger (6), in order to estimate the amount of fruit infection from defoliation data. The composite curve (Fig. 18) for the cultivars tested shows only an approximate relationship between defoliation and fruit infection. It indicates that the amount of infected fruits can be expected to be less than 10% unless defoliation exceeds 60% and that the upper limit of fruit infection would be near 30% even in severe disease outbreaks.

It may be concluded that a reliable estimate of loss can be made directly from the percentage of infected fruits and that the percent defoliation bears only an approximate relationship to fruit infection. The measurement of necrotic areas on leaves that are not killed seems unnecessary in relation to estimation of loss.

Acknowledgments

The author wishes to thank C.S. Shih, Statistical Research Service, Agriculture Canada, Ottawa, for helpful suggestions, and S.I. Wong for technical assistance.

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