

NEW versus OLDER

fungicides for the control of late blight

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Introduction

Late blight of potato and tomato (Phytophthora infestans deBary) is reported from one or more home gardens or fields nearly every year in Ohio, but its average occurrence in epidemic form is about once in every 4 or 5 years. It caused a rather serious loss in the vicinity of Wooster in 1946, 1950, and 1958 and was present in a milder form in 1954 and 1957. Data on comparative fungicide performance was obtained in 1950 (1) and 1957 (2), and then in 1958 its appearance in every experiment where fungicides were being compared on potato and tomato afforded an excellent opportunity to further evaluate several new (experimental) and older (recommended) fungicides on the basis of their ability to check crop losses from this rather difficult to control disease.

Potato

Several fungicides were sprayed on potatoes for the control of early (Alternaria solani, E & M Jones and Grout) and late blight at Marietta (sandy loam), Wooster (silt loam) and Celeryville (muck) in 1958. A comparatively plant-safe mineral oil was also applied alone and with various fungicides in the same experiments. Some of the data on yield, defoliation from disease attack, late blight foliage infection, and tuber rot are given in Table 1.

Table 1. Comparative control of late-blight tuber rot and foliage infection by various fungicides (some old and some new) at three locations in Ohio in 1958.

Treatment	Formula	Yield in Bu./Acre			Average
		Marietta	Wooster	Celeryville	
1. None	- - -	470	532	384	462
2. Manzate	2-100	576	680	525	594
3. Phaltan	2-100	515	633	492	543
4. Dithane Z-78	2-100	539	687	464	562
5. Tribasic	4-100	499	671	447	539
6. ML-100A (Oil)	1-100	520	633	410	521
7. Orthocide 80	1.5-100	---	683	---	---
8. Kepone	2-100	---	629	---	---
LSD at 5% level		30	34	30	

Treatment	Percent defoliation 2 weeks before harvest				Percent Late-blight Tuber rot	
	Marietta	Wooster	Celeryville	Averages	Wooster	Celeryville
1.	54	85	84	74	6.0	12.2
2.	26	40	31	32	2.7	2.9
3.	40	47	47	45	2.9	6.2
4.	34	37	41	37	3.0	7.8
5.	45	45	58	49	2.8	7.8
6.	29	62	73	55	3.8	12.0
7.	--	52	--	--	3.0	----
8.	--	55	--	--	3.2	----

Four fungicides, with only one of those of an experimental nature, and a mineral oil (ML-100A) was included at all three locations. Of the fungicides used, Manzate gave the highest average yield. In doing this, Manzate gave the largest yield at Marietta and Celeryville, and was second of the group at Wooster. Manzate also gave the best control of defoliation (from all causes) at the same two locations, and was again second at Wooster. As a result, it brought about the lowest average defoliation for all three experiments. When the percentage of late-blight tuber rot is considered, this manifestation of the disease was least with Manzate at both Wooster and Celeryville. Little rot was present, even in the untreated check, at Marietta.

When the number of late-blight lesions per 100 feet of row were counted at each location (data not given), Manzate and Tribasic were tied for the fewest at Marietta, and Manzate was lowest at the other two locations.

Phaltan, a fungicide still in the experimental stage, was very similar to zineb (Dithane Z-78) when all four categories, each of which was influenced in the data it represented by the fact that late blight was present in an epidemic or near epidemic form, are considered. Tribasic (a fixed copper) was only slightly less effective against late blight than were the three organic fungicides. However, of the organics, maneb (Manzate) was definitely the most effective against late blight, both on the foliage and in checking tuber rot.

The plots treated with mineral oil (Treatment 6 in Table 1) were better than the untreated check in all four categories (a higher yield, less defoliation, less tuber rot and fewer late-blight lesions), but the oil was less effective in overall disease control than was any one of the four fungicides. The average yield increase over the untreated

check of 13 percent may have been partly due to some small degree of disease control and to some reduction in the water requirement of the potato plant for tuber production. When this oil was used with the fungicides, there was some reduction in fungicidal efficiency in all instances, this being least with Tribasic.

The performance of Orthocide 80 (captan) and Kepone was somewhat below that of the other organic fungicides at Wooster, and Kepone was greatly reduced in its effectiveness against late blight by the addition of the mineral oil.

Tomato - 1957

Although late blight caused little or no yield loss on potatoes at Wooster in 1957, in spite of the fact that it was present late in the season on that crop, it did cause a considerable amount of fruit rot on tomatoes, where it appeared in several different experimental blocks during the last three weeks in September.

In one experiment in 1957 in which a number of fungicides were being compared for their ability to control anthracnose fruit rot (2), late blight caused a loss of 10.6 percent of the fruits on unsprayed plants in the last two harvests of the season. Some of the data relative to this experiment are given in Table 2. Here the best control of late-blight fruit rot was given by a spray tank mixture of Zerlate and Tribasic, a treatment that has been used by some growers for several years. Maneb (Manzate here) did nearly as well, as might be expected from the excellent control it gave of defoliation (a foliage loss due to the combination attack of early and late blight). Phaltan gave the lowest percentage of total cull fruits, with Manzate ranking second lowest. The conventional lack of

Table 2. Comparative control of late blight by a group of treatments selected to study their effectiveness against anthracnose fruit rot of tomato at Wooster in 1957.

Treatments	Formulas	Net yield T/A	Percent Culls (All harvests)	Percent Late blight (Last 2 harvests)	Percent defoliation on Sept. 27
1. None	- - -	20.0	8.2	10.6	85
2. Manzate	2-100	19.5	5.4	1.4	27
3. Zerlate	2-100	18.5	7.3	11.8	69
4. Zerlate + Manzate	1-1-100	18.6	6.8	1.5	37
5. Zerlate + Tribasic	1-2-100	19.4	6.6	1.2	32
6. Phaltan	3-100	20.2	5.2	4.2	37
7. Captan 50-W	3-100	21.4	6.8	4.4	67
8. Dyrene	2-100	18.6	7.5	2.8	47
LSD at 5% level		N.S.			

effectiveness of Zerlate against late blight was well demonstrated in this experiment by the high percentage of late blight on the fruit and the foliage in the plots treated with it. Captan was somewhat less effective than Phaltan in the control of late blight.

The data relative to another 1957 experiment, in which a considerable number of new and "older" fungicides were being compared for their ability to control the tomato-disease complex, are given in Table 3. In this instance late blight also caused a considerable amount of fruit rot during the last half of September. Zerlate plus Tribasic in Table 3 was replaced in the first place it occupied in fruit rot control in Table 2 by a mixture of Zerlate and Manzate in this experiment. Manzate used alone (treatment 2 in Table 3) ranked second in checking fruit rot, followed closely by Kepone. These three treatments ranked in the same order in the reduction of total culls, a value which was largely determined in this experiment by the amount of late-blight fruit rot.

Tribasic ranked next in late blight control, but at a percentage nearly double that for Manzate. Phaltan and Thioneb were slightly less effective than Tribasic, with Zerlate and Dyrene giving very little control.

The comparative effectiveness of three of these fungicides in the control of late blight as well demonstrated in a third experiment conducted in 1957 in which Manzate, Phaltan, and Dyrene were applied to tomatoes at 7, 10 $\frac{1}{2}$, and 14-day intervals. Again the disease was destructive on the fruit of the last two harvests. The data relative to this experiment are shown in Table 4.

Maneb (Manzate) obviously gave the best control of the disease on the fruit when the spray interval was 14 days, indicating that it was either

Table 3. Comparative control of late blight on tomato fruits by several "old" and "new" fungicides at Wooster, in 1957.

Treatments	Formulas	Net yield T/A	Percent culls (All harvests)	Percent Late blight (Last 2 harvests)
1. None	- - -	17.6	17.4	21.1
2. Manzate	2-100	17.8	7.7	6.3
3. Thionex 50-W	2-100	16.1	11.9	12.7
4. Captan 50-W	2-100	15.1	12.8	13.9
5. Phaltan	2-100	15.2	11.2	12.7
6. Dyrene	2-100	18.3	11.9	20.0
7. Zerlate	2-100	16.7	13.8	18.5
8. Tribasic	4-100	15.6	12.4	11.7
9. Zerlate + Tribasic	1-2-100	15.6	13.6	15.9
10. Zerlate + Manzate	1-1-100	18.4	7.1	3.0
11. Kepone	2-100	16.8	8.1	6.5
LSD at 5% level		2.0		

Table 4. The comparative effectiveness of Mansb (Manzate), Phaltan, and Dyrene in the control of tomato diseases (principally fruit rots) at successively long spray intervals.

Treatment	Formulas	Interval	Yield T/A	Culls %	Anthrac- nose %	Rhizoc- tonia %	Early Blight % in last picking	Late Blight % in last 2 pickings	Foliage Dead 9/27/57 %
1. Check	- - -	- - -	20.9	10.6	5.1	3.0	27.2	9.2	73
2. Manzate	2-100	7 da.	19.8	3.7	1.6	1.3	1.8	22.2	23
3. Manzate	2-100	10½ da.	19.7	4.2	1.5	1.1	3.0	2.2	30
4. Manzate	2-100	14 da.	20.1	7.0	3.2	1.9	12.4	2.5	27
5. Phaltan	2-100	7 da.	19.2	5.5	2.0	1.9	4.3	2.9	33
6. Phaltan	2-100	10½ da.	20.9	6.8	1.7	2.0	8.1	6.7	35
7. Phaltan	2-100	14 da.	19.6	8.2	2.7	1.9	19.8	11.2	51
8. Dyrene	2-100	7 da.	22.2	5.2	1.7	0.7	9.9	7.6	28
9. Dyrene	2-100	10½ da.	20.2	8.0	3.5	0.9	9.5	7.9	34
10. Dyrene	2-100	14 da.	21.8	9.8	4.4	2.1	15.8	9.3	37
LSD at 5% level			2.6						

more stable chemically or was more adhesive, or both, than were the other two compounds. The differences in fruit rot, defoliation, and total culls were less definitive with a 7-day interval between spray applications, but Manzate was again the most effective, with Phaltan and Dyrene closely similar. Phaltan gave the better control of the fruit-rot phase at 7 days, with Dyrene seeming to be somewhat the more effective when the interval was 14 days.

1958

As was mentioned previously, late blight was epidemic over most of Ohio in 1958, both on potato and tomato. At Wooster it appeared on potatoes at least one month before it was found to be causing a rotting of the fruit rot in every one of six tomato experiments being conducted in the vicinity of Wooster. Because of its late appearance on that crop, the disease caused an appreciable loss in only the last two or three harvests (3).

In one isolated experiment in which the effect of a mineral oil on fungicide performance was under investigation, the fruit loss from late blight infection was comparatively small, being only 3.8 percent in the last two harvests. The degree of control furnished by the different fungicides included in this experiment is indicated in the data of Table 5.

All of the fungicides used alone gave comparatively good control of fruit rot with the exception of Dyrene, which gave none in this instance. The plots treated with Kepone, Zerlate, and Orthocide 80 (captan) were virtually free of fruit rot, with a few diseased fruits appearing in those treated with Phaltan and Manzate. Dyrene gave no control in this particular experiment, which was as unusual as was the good performance given by Zerlate.

Table 5. The comparative control by various fungicides of a comparatively light infection of late blight in one tomato experiment at Wooster in 1958.

Treatments	Formulas	Net yield T/A	Percent Culls (All harvests)	Percent Late blight (Last 2 harvests)	Percent defoliation on Sept. 14
1. None	- - -	12.85	13.3	3.8	53
2. Manzate	2-100	15.34	3.0	0.5	22
3. Phaltan	2-100	15.94	4.0	0.5	22
4. Kepone	2-100	12.83	10.4	0.1	38
5. Zerlate	2-100	14.04	4.5	0.1	30
6. Dyrene	2-100	12.52	8.3	4.6	26
7. Orthocide 80	1.5-100	13.32	7.2	0.1	34
8. ML-100A	1-100	12.33	8.7	2.6	37
9. Ave. Fungicides only		14.1	6.0	1.2	28
10. Ave. Fungicides + oil		11.6	5.9	2.3	30

The oil (ML-100A) gave a slight reduction in fruit rot when used alone, but when it was added to the different fungicides (detailed data not given) the average control of late blight by the fungicides used alone was reduced by adding the oil (Item 9 versus 10 in Table 5), although the control of early blight seemed to be somewhat improved. The average yield was also lowered considerably, indicating some degree of phytotoxicity for the mixtures of the oil and the different fungicides. The high percentage of total culls with Kepone was due chiefly to an almost complete lack of control of anthracnose fruit rot, even though it (Kepone) gave good results against late blight.

In another experiment very similar to the one just described, but in a different location, where late blight was more severe, over 30 different treatments were compared. The data relative to some of these are given in Table 6. In this experiment 18.2 percent of the fruits picked in the last two harvests were infected by late blight.

Tribasic gave the best control of fruit rot, closely followed in effectiveness against this disease by Phaltan and Kepone. Zerlate assumed more nearly its usual ranking in late blight control in this instance and Dyrene again gave very little control. Manzate gave the lowest percentage of total culls because of the very good control it gave of anthracnose, even though it did rank somewhat below some of the other fungicides in this particular instance. It also gave very good control of defoliation (caused chiefly by early and late blight infection), being tied with Phaltan for second place in this category, and it (Manzate) gave the highest net yield of disease-free fruits of the experiment. The net yield for Dyrene was low because of its lack of control of late-blight fruit rot, whereas Kepone ranked low in net yield because of its lack of control of anthracnose. Phaltan, by virtue of

Table 6. Comparative control of late blight in a late, but heavy, infection of tomatoes at Wooster in 1958.

Treatments	Formulas	Net Yield T/A	Percent culls (All harvests)	Percent Late blight (Last 2 harvests)	Percent of defoliation Sept. 14
1. None	- - -	11.29	20.3	18.2	59
2. Manzate	2-100	15.54	5.5	1.5	26
3. Phaltan	2-100	14.87	6.6	0.8	26
4. Dyrene	2-100	11.75	18.2	11.3	25
5. Tribasic	4-100	12.68	11.6	0.6	31
6. Zerlate	2-100	13.10	9.3	5.3	36
7. Orthocide 80	1.5-100	12.22	8.8	2.5	42
8. Dithane Z-78	2-100	12.21	7.8	3.7	29
9. Kepone	2-100	12.19	12.2	0.9	31
10. ML-100A	1-100	10.27	22.7	16.9	60
11. Fungicides only		14.52	9.2	3.3	31
12. Fungicides + oil		13.85	8.7	3.2	33

the good control it gave of the fruit rots caused by early and late blights and anthracnose, gave the second highest net yield of the experiments.

The oil, ML-100A, which gave no apparent control of defoliation, gave a slight reduction of late-blight fruit rot, but a lower net yield than the untreated check. However, when it was added to each of the various fungicides, the average percentage of late-blight fruit rot and total culls was reduced slightly (Items 11 and 12 in Table 6), even though the net yield and defoliation values were slightly lower.

In a third experiment where various "established" and "experimental" fungicides were being compared, late blight appeared on some of the fruits that had not ripened by September 15 (see Table 7). Fungicide 658 (copper zinc chromate) gave the best control of the fruit rot caused by late blight, although Manzate gave a much lower percentage of total culls because it gave good control of anthracnose, whereas Fungicide 658 gave very little. Kepone again gave good control of late blight but very little of anthracnose fruit rot. Phaltan gave comparatively good control of both diseases, with the result that it ranked next to Manzate in percentage of total culls.

Since there is a recent trend toward the use of larger plant populations in the production of canning tomatoes, it was decided to plant an experimental block in which the plants were spaced 18 inches apart in the row (one-half the usual spacing of 3 feet) to determine the effect of this closer spacing on disease incidence and its subsequent control by the use of fungicides. The data on the control of fruit rot and of defoliation by several (five) different fungicides are given in Table 8.

Tribasic and Kepone again gave the best control of late-blight fruit rot, but obviously failed to control anthracnose and early blight as well as the

Table 7. Comparative control of late blight on tomatoes at Wooster in 1958 by various "established" and "experimental" fungicides.

Treatments	Formulas	Net Yield T/A	Percent culls (All harvests)	Percent Late blight (Last 2 harvests)	Percent defoliation on Sept. 14
1. None	- - -	8.48	22.9	3.4	90
2. Manzate	2-100	10.89	6.8	1.0	54
3. Dyrene	2-100	12.62	10.4	2.0	62
4. Kepone	2-100	10.80	19.2	1.1	71
5. Orthocide 80	1.5-100	13.60	9.8	1.2	56
6. Phaltan	2-100	12.89	8.2	1.4	57
7. Fungicide 658	3-100	10.62	14.9	0.4	56

Table 8. Comparative control of late blight by various fungicides on close-planted tomatoes grown near Wooster in 1958.

Treatments	Formulas	Net Yield T/A	Percent culls (All harvests)	Percent Late blight (Last 2 harvests)	Percent defoliation on Sept. 14
1. None	- - -	9.49	16.5	2.9	72
2. Manzate	2-100	12.68	6.2	1.4	27
3. Zerlate	2-100	11.50	9.0	2.3	44
4. Tribasic	4-100	12.58	9.4	0.7	35
5. Phaltan	2-100	13.55	6.7	2.0	30
6. Kepone	2-100	9.87	18.0	0.8	52

other fungicides used in the experiment, since they showed the highest percent of total culls. Manzate gave the best control of defoliation and the fewest culls, whereas Phaltan gave the highest yield of good fruits. Zerlate gave the poorest control of late blight on the fruit and comparatively poor control of defoliation.

Averages

It is obvious thus far that the various fungicides did not always rank the same in disease control effectiveness in all experiments, and for that reason they are given an average ranking in the control of three different fruit rots and in the checking of defoliation in Table 9, where they are listed in the descending order of their average effectiveness against the disease complex as it existed at Wooster in 1958.

Manzate, which gave the best over-all performance, ranked first only in the control of early blight, defoliation and total culls, fifth in control of late blight fruit rot and third against anthracnose. Phaltan (an analogue of captan), in second place in the averages, ranked first in net yield and in anthracnose control with second place in defoliation, total culls and early blight control, while dropping to sixth place against late-blight fruit rot, although it gave comparatively good results even in that category. Zerlate, a compound which is usually weak against late blight on the foliage placed surprisingly high in average performance against the over-all disease complex in 1958, placing second against anthracnose and third in total culls, early blight and defoliation control, and fourth in yield and against late blight. Orthocide 80 (captan) failed to equal its analogue Phaltan in over-all performance, but did rank fourth in average performance and third in net yield. The item listed as fixed coppers in Table 9,

Table 9. Average control of foliage and fruit diseases of tomato in all experiments conducted at Wooster in 1958. Treatments are listed in the order of decreasing total effectiveness in disease control.

Treatments	Net Yield T/A	Percentages of fruit rot caused by:--				Percent of defoliation on Sept. 14
		Culls	Anthraco- nose	Early Blight	Late Blight	
1. Manzate	13.6	5.4	2.7	1.7	0.9	32
2. Phaltan	14.3	6.5	2.4	2.1	1.1	34
3. Zerlate	12.9	7.6	2.6	3.1	0.8	37
4. Orthocide 80	13.0	8.6	4.1	3.9	0.5	44
5. Fixed Coppers	12.0	12.0	7.7	3.3	0.6	41
6. Dyrene	12.3	12.3	4.0	3.6	3.7	38
7. Kepone	11.4	15.9	12.1	3.9	0.5	48
8. Check	10.5	18.3	6.5	5.4	10.1	69

which was Tribasic in three experiments and copper zinc chromate (Fungicide 658) in the fourth, gave good control of late-blight fruit rot, but did poorly in anthracnose control, as would be expected from past experience. Neither were they the equal of some of the organic fungicides in checking defoliation. Dyrene, as was mentioned previously, gave comparatively poor control of late blight, and its rather indifferent control of early blight and anthracnose fruit rots gave it a low average ranking. Kepone, which gave surprisingly good control of late blight gave a higher percentage of anthracnose than the untreated check, and largely for that reason, the material assumed the poorest average ranking of the seven fungicides listed in Table 9.

Summary

Late blight was severe on both potatoes and tomatoes in the fall of 1958, and this made it possible to evaluate a variety of fungicides on the basis of their ability to control the disease on both crops at various locations in Ohio.

Maneb gave the highest average yield of potatoes in three experiments in widely separated localities. Zineb was second, with Phaltan and Tribasic (copper) nearly equal in third and fourth place. A mineral oil gave a considerable yield increase over the untreated check, without giving very much control of defoliation or tuber rot.

Maneb gave the best control of defoliation due to early, and more particularly late, blight. Zineb was again second, with Phaltan third and Tribasic fourth.

Maneb was definitely superior in the control of late-blight tuber rot, with Phaltan second and zineb and Tribasic tied for third and fourth ranking.

At Wooster Orthocide 80 (captan) ranked second to zineb in yield, with maneb in third place. Kepone, which gave comparatively good control of late blight, was lowest in yield of the six fungicides used.

Late blight infection in 1958 was more common on the fruit than on the foliage of tomato, where it caused serious fruit loss in many fields, including several in which fungicide spray experiments were being conducted.

In an average of four experiments in the vicinity of Wooster, maneb gave the best average control of the disease complex, which included early- and late-blight fruit rots, anthracnose fruit rot, and defoliation from all causes.

In the same averages maneb was lowest in percentage of cull fruits, early-blight fruit rot, and in dead foliage. It was second to Phaltan in yield, third to Phaltan and ziram (Zerlate) in control of anthracnose, and fifth to other fungicides in the control of late-blight fruit rot.

Phaltan was first in yield and anthracnose control, second in percentage of total culls, and in the control of early-blight fruit rot and defoliation.

Ziram was second in anthracnose control, third in checking defoliation and early-blight fruit rot, and in total culls.

Tribasic and Fungicide 658 gave little or no control of anthracnose, but did well against late-blight fruit rot.

Dyrene gave fair control of anthracnose but was weak against late blight, whereas the opposite was true for Kepone.

Thus, in conclusion it seems apparent that maneb is the best of the present-day fungicides for the control of late blight of potato and tomato, and that it may be expected to give good control of the diseases of tomato. Also, Phaltan offers promise as a tomato fungicide, and if it is used at 3 pounds per acre per application, it should give good control of the tomato disease complex.

Zineb probably ranks somewhat below maneb in the control of late blight on potato and tomato and in the control of tomato anthracnose, especially in a

10-day schedule of spray application.

The fixed coppers, including copper zinc chromate, are effective in the control of late blight on both crops but fail in the control of tomato anthracnose.

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