6-1951

Fungicides for Potato Blight Control

C. M. Nagel
South Dakota State University

L. T. Richardson
South Dakota State University

CIRCULAR 89 • JUNE 1951

FUNGICIDES *for Potato Blight* CONTROL

PLANT PATHOLOGY DEPARTMENT
Agricultural Experiment Station
SOUTH DAKOTA STATE COLLEGE
B R O O K I N G S

Table of Contents

Illustration on page 12 courtesy of the North Carolina Experiment Station.

FUNGICIDES
FOR POTATO BLIGHT CONTROL

C. M. Nagel and L. T. Richardson[1]

South Dakota has an important potato-growing area in Clark, Codington, Hamlin and Deuel counties. Production of certified seed has become one of the important phases of the potato industry in South Dakota. In addition to the main commercial seed and table stock production areas indicated above, smaller producing areas are located in various sections of the state, not to mention the familiar potato patch in most home gardens. Likewise, with the coming of irrigation in the James River Valley of South Dakota, potato production will probably increase further.

Losses in yield and quality of potatoes are severe in seasons favorable to the development of foliage diseases. While these diseases do not occur in serious amounts every season in South Dakota, the profits may be wiped out in those years when they are prevalent. When these diseases strike in epidemic proportions, one of the important effects which they have on the crop is the prevention of normal "sizing" of the tubers, thereby resulting in a reduction of U. S. No. 1 potatoes. For this reason, it is important to know what control measures are effective and can be easily and quickly applied when these diseases strike the crop. An effective fungicide, properly applied, can control these foliage diseases, and by removing another crop hazard can thereby add to the stability of commercial and certified seed potato production in South Dakota.

Chemical fungicides, applied as sprays or dusts, differ in their effectiveness in controlling crop diseases. A particular fungicide might be highly effective in combating one type of disease, but may not be very effective against another. Consequently, it becomes necessary to test many chemicals over a period of several years to determine their effectiveness as well as the dosage rate and the proper time of the season to apply them.

The most prevalent fungus diseases affecting potato foliage in the state are early blight, caused by *Alternaria solani*, and late blight, caused by *Phytophthora infestans*. Early blight is present to some extent every season in South Dakota, and causes losses through reduced grade and yield. The disease first appears as small oval or angular brown spots on the leaves with characteristic target-like markings. As the spots increase in size and number the affected leaves die. As a result of this defoliation the yield, especially of U. S. No. 1 grade potatoes, is reduced.

During those seasons when conditions are favorable for the development of late blight, losses through reduced yields and tuber rot become costly to potato growers. Late blight is favored by cool temperatures and rel-

[1]Head, Department of Plant Pathology, and Associate Pathologist, respectively, South Dakota Agricultural Experiment Station. The authors wish to acknowledge the contributions and encouragement given by Dr. W. E. Buchholtz, formerly Head, Department of Plant Pathology during the initial phases of the work on this project.

atively good moisture conditions. This disease first appears on the leaves as pale green, water-soaked, irregular-shaped spots which may enlarge rapidly, turn brown or black, and show a white mildew-like appearance on the lower surface of diseased leaves. The stems can become infected and the entire plant may be killed in a few days.

Under conditions favorable for the disease (moderate temperatures, with high humidity, heavy dews or frequent rains), it can spread rapidly throughout a field. Spores from diseased foliage washed down to the tubers by rain or brought in contact with them during digging operations can expose tubers to infection with late blight. Late blight-infected tubers develop what is known as late blight tuber rot, either in the field or in storage.

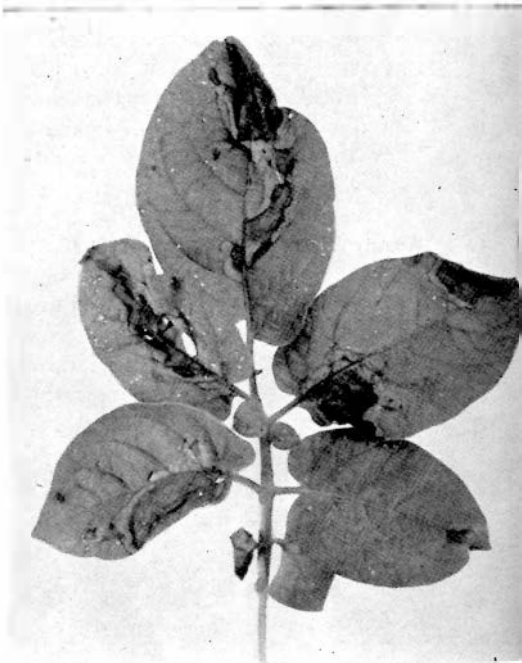
To protect potato plants from these fungus diseases, it is necessary to keep the foliage coated with an effective fungicide. It has been shown experimentally that fungicides applied as sprays provide better coverage and disease control than those applied as dusts.

A series of field experiments were initiated in 1945 at the Experiment Station at Brookings with the object of developing a potato spray program adapted to South Dakota conditions. In 1946, these tests formed a part of a regional potato fungicide trial in which six states in the upper Mississippi Valley participated. From 1947 to 1949 the tests were included in the national cooperative fungicide experiments sponsored by a Special Committee on the Coordination of Field Tests with New Fungicidal Sprays and Dusts, appointed by the American Phytopathological Society.

Materials and Methods

All of the fungicides tested in the course of the spray trials are listed in Table 1 with their chemical names and concentrations. DDT (Deenate 50W) was added to each of these mixtures and was used alone on the check and guard rows. This insecticide was used to eliminate damage to the plants by insects such as flea beetles and leafhoppers, so that the effects of the various fungicides could be compared in the absence of insect damage. Sprays were applied to single rows of plants by means of a motor-driven, tractor-drawn Bean sprayer maintaining 250 pounds pressure. The three nozzles on the boom were so placed as to ensure that each plant was thoroughly covered with fungicide spray.

Potato leaf showing late blight infection.



Each plot contained 50 plants spaced one foot apart in the row. Rows were spaced 42 inches apart. All plots were separated by single untreated rows. The plots were arranged in randomized blocks with at least three replications.

At intervals during the growing season the amount of disease was recorded on all plants in each plot. The method of Barrett and Horsfall was followed in determining the percentage defoliation for each treatment. Yield records were taken at harvest time as pounds per plot and converted to bushels per acre.

Potato leaf showing early blight infection.

Results

1945 Experiments

In 1945 the spray plots were planted May 7 with Early Ohio potatoes, using three replications in a randomized block design. Eight different fungicides were tested, applications being made on July 22, August 1 and 14. Crop was harvested October 10.

Temperatures during the summer months were below normal for the area while the rainfall was above normal. These environmental conditions were favorable for the development of the late blight fungus, and a severe outbreak of the disease occurred this

Table 1. Trade and Chemical Names of Fungicides and Dosages Used on Potatoes as in Experiments at Brookings, 1945–1950

Fungicide	Chemical Name	Dosage/100 Gals. Water
Bordeaux 8-8-100	copper sulfate + hydrated lime	8 lb. + 8 lb.
Bordeaux 8-4-100	copper sulfate + hydrated lime	8 lb. + 4 lb.
Compound A	copper oxychlorides	4 lb.
Cop-O-Zink	tribasic copper sulfate + zinc oxysulfate	4 lb.
COCS	copper oxychloride sulfate	4 lb.
Crag 658	copper zinc chromate	2 lb.
Dithane D-14 (Nabam)*	disodium ethylene bisdithiocarbamate + zinc sulfate + hydrated lime	2 qts. + 1½ lb. + ½ lb.
Dithane Z-78 (Nabam)	zinc ethylene bisdithiocarbamate	2 lb.
Fermate (Ferbam)	ferric dimethyl dithiocarbamate	2 lb.
N 5 E	phenyl mercuric tri-ethanal lactate	½ pt.
Parzate (Zineb)	zinc ethylene	2 lb.
Phygon X L	2, 3-dichloro-1, 4-naphthoquinone	1 lb.
Isothan Q15	lauryl isoquinolinium bromide	1 pt.
Tribasic	copper basic sulfates	4 lb.
Yellow Cuprocide	yellow cuprous oxide	2 lb.
Zerlate (Ziram)	zinc dimethyl dithiocarbamate	2 lb.

*Words in parentheses are new commercial trade names given to these fungicides.

Table 2. Average Percentage Defoliation Caused by Late Blight on Potatoes Treated with Eight Different Fungicides on July 22, August 5 and 22, Brookings, 1945

Treatment	Average Percentage Defoliation On:			
	July 10	July 22	Aug. 5	Aug. 22
Check (No treatment)	0	2.3	93.5	100.0
Q15	0	2.3	95.0	100.0
N 5 E	0	2.3	94.3	100.0
Zerlate	0	2.3	35.0	64.0
Compound A	0	2.3	35.0	45.0
Dithane D14	0	2.3	4.5	23.0
Phygon	0	2.3	8.6	20.1
Yellow Cuprocide	0	2.3	5.1	20.0
Bordeaux 8-8-100	0	2.3	9.0	18.0

Table 3. Average Yield of Ungraded and U. S. No. 1 Early Ohio Potatoes in Plots Sprayed Three Times with Eight Fungicides for the Control of Late Blight, Brookings, 1945

Treatment	Total Yield, Ungraded		Yield U. S. No. 1	
	Bu./A.	% Increase	Bu./A.	% Increase
Phygon	241.5	69.1	201.5	70.3
Yellow Cuprocide	205.6	44.0	170.7	44.2
Bordeaux 8-8-100	172.3	20.7	135.8	14.8
Dithane D14	170.8	19.6	138.0	16.7
Zerlate	163.7	14.6	127.9	8.1
Compound A	157.2	10.1	122.2	3.3
Check	142.8		118.3	
Q15	140.7	-1.5	107.3	-9.3
N 5 E	133.6	-6.4	100.4	-15.4
L. S. D.* (5% level)	43.2	30.2	44.0	30.9

*Least significant difference—Since yielding ability cannot be measured with absolute accuracy, small differences in yields are not important. Unless the difference in yield exceeds the "least significant difference" given in the tables, little emphasis should be placed on the superiority in yield of one treatment over the other.

season. The progress of the disease in the spray plots is indicated by the amount of defoliation presented in Table 2. No evidence of late blight was found on July 10. On July 22 all plants showed uniform light infection. By August 5 there were extreme differences between treatments in the amounts of defoliation resulting from late blight. These differences were still apparent on August 22 when all plants in the check plots were killed. Phygon, Yellow Cuprocide, Dithane, and Bordeaux controlled the disease very well. Zerlate and Compound A moderately so, while Q15 and N5E appeared to be toxic to the plants.

The average plot yields of ungraded and U. S. No. 1 potatoes are presented in Table 3. The highest yields were obtained where Phygon was used, the average increase being 109 bushels per acre or 69 percent over the check plots. Decreased yields resulted from the use of Q15 and N5E, although the difference was not significant.

The effect of late blight on the yield of potatoes is clearly shown in Figure 1. The treatments that provided the best control of late blight produced the highest yields. In a season like 1945 it is important that fungicides be applied regularly and thoroughly in order to ensure a profitable crop.

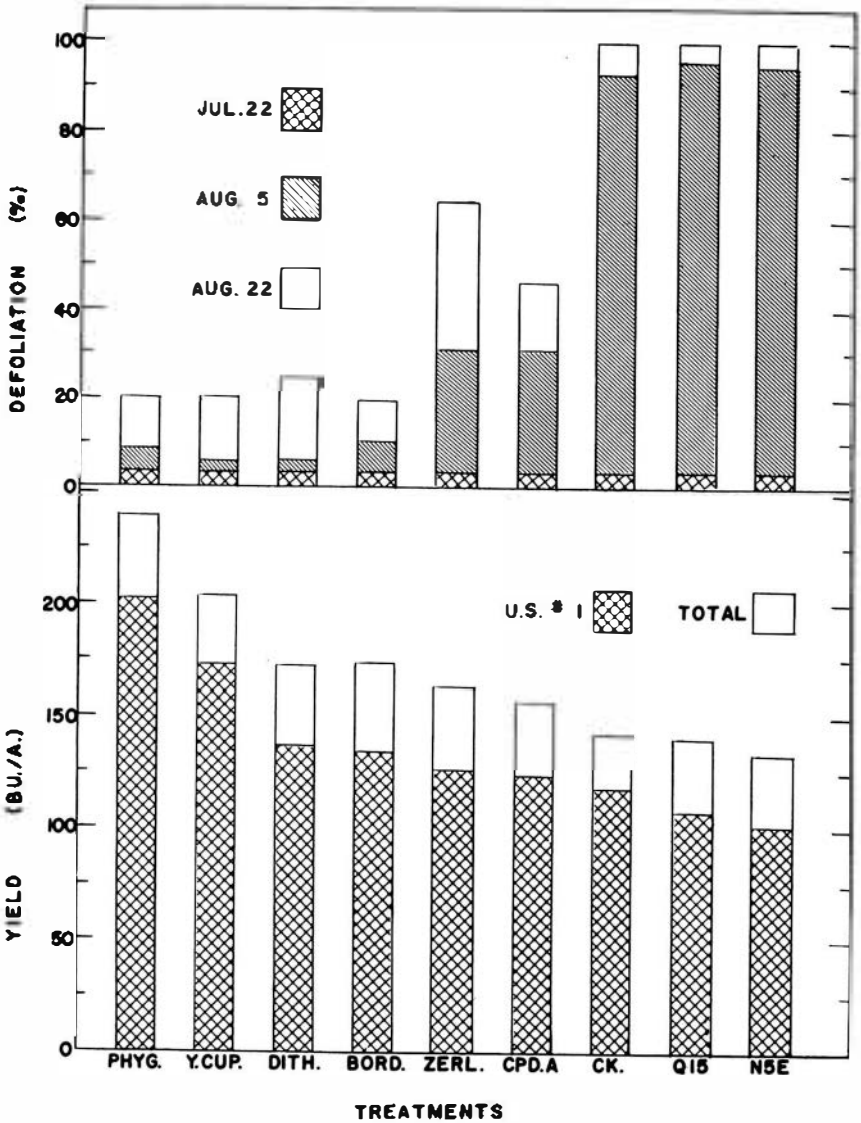


Fig. 1. Effect of three applications of eight different fungicides on defoliation due to late blight and on yield of early Ohio potatoes, Brookings, 1945.

1946 Experiments

In 1946 the Early Ohio variety was again planted in the fungicide test plots. Four replicates were used this year, as was the case in each succeeding year. Three applications were made, on July 27 and August 9 and 20. The average temperatures for July

Table 4. Average Yield, Percentage of Ungraded and U. S. No. 1 Early Ohio Potatoes Harvested from Plots Sprayed with Seven Fungicides on July 27 and August 9 and 20, Brookings, 1946

Treatment	Total Yield, Ungraded		Yield U. S. No. 1	
	Bu./A.	% Increase	Bu./A.	% Increase
Dithane D-1	300.0	28.3	263.8	33.3
Yellow Cuprocide	263.2	12.6	233.7	18.1
Compound A	262.0	12.1	227.1	14.9
Fermate	257.8	10.3	225.7	14.0
Bordeaux 8-8-100	240.1	2.7	210.0	6.1
Phygon	236.1	1.0	204.5	3.3
Check	233.8		197.9	
Zerlate	232.7	-0.5	206.3	4.2
L. S. D.* (5% level)	48.0	20.6	46.5	23.5

*Least significant difference.

and August were normal while the rainfall was below normal. Neither early blight nor late blight was a factor in the plots this season, so any differences in yield (Table 4) may be attributed to the effects of the fungicides on the plants. The Dithane treatment was the only one to show a significant increase in yield over the check.

1947 Experiments

The plots were planted with Bliss Triumph potatoes on May 20, 1947. Sprays were applied on August 12 and 28, and September 12. There was a killing frost on September 22 and the crop was harvested on October 25. Temperatures during the growing season were above normal while the rainfall was below normal. No late blight appeared, but early blight developed near the end of the season. There was little evidence of early blight until September 17 when the plants were severely defoliated (Table 5). While the differences in defoliation between treatments were not great, Parzate and Dithane appeared to provide the most protection, and Bordeaux the least.

The treatments are ranked in Table 5 by total yields. Significant increases over the check resulted from the use of Zerlate, Dithane, Parzate, Yellow Cuprocide, and COCS. The relation

Table 5. Percentage Defoliation and Acre Yields of Ungraded and U. S. No. 1 Bliss Triumph Potatoes Sprayed with Eight Fungicides on August 12 and 28 and September 12, Brookings, 1947

Treatment	Early Blight % Defoliation	Total Yield, Ungraded		Yield U. S. No. 1	
		Bu./A.	% Increase	Bu./A.	% Increase
Zerlate	85.8	371.0	27.0	329.1	35.3
Dithane D14	81.9	365.2	25.0	323.3	32.9
Parzate	81.3	357.3	22.3	313.7	29.0
Yellow Cuprocide	86.6	356.5	22.0	320.8	31.9
COCS	91.7	354.0	21.2	309.6	27.3
Tribasic	83.7	329.5	12.8	290.1	19.3
Phygon	84.8	322.9	10.5	273.9	12.6
Bordeaux 8-8-100	95.0	309.6	6.0	271.0	11.4
Check (No treatment)	95.5	292.2		243.2	
L. S. D.* (5% level)		55.6	19.0	55.4	22.8

*Least significant difference.

between defoliation due to early blight and yield may be seen in Figure 2. The effects would undoubtedly have been more pronounced had the outbreak developed earlier in the season.

1948 Experiments

The variety Irish Cobbler was used in the spray plots in 1948, and four applications of fungicides were made at 10-day intervals throughout the season. The plots were planted on May 8.

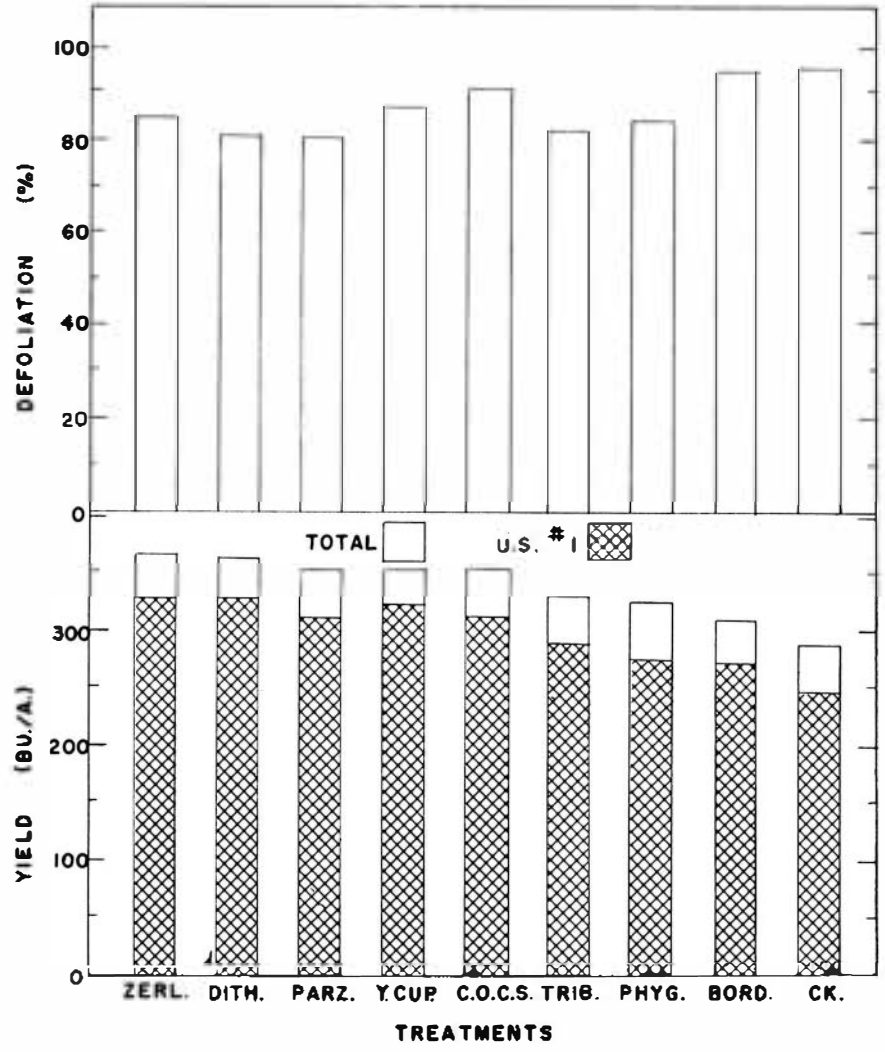
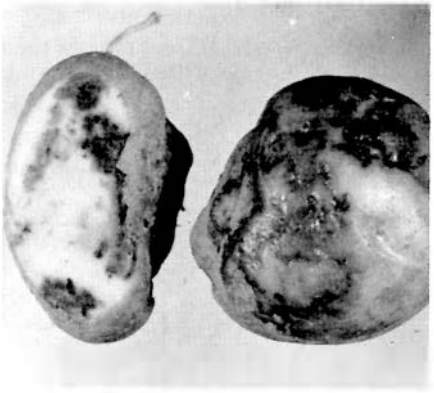


Fig. 2. Effect of eight different fungicides on defoliation and yields of Bliss Triumph potatoes in a season when only early blight was present, Brookings, 1947.



Internal and external symptoms of late blight tuber rot.

and harvested on October 9. The average temperatures were above normal and the rainfall close to normal for this area. Foliage diseases were virtually absent in 1948. However, most of the treatments showed a trend toward higher yields (Table 6) when compared to the untreated plots, although the differences were not statistically significant.

1949 Experiments

The plots were planted with Irish Cobbler potatoes on April 30. Four applications of fungicides were applied on June 24, July 7, 20, and August 1. The crop was harvested on October 3. The average temperatures were well above normal and the rainfall was deficient during the growing season.

Early blight caused about 7 percent defoliation in the plots receiving no fungicide,and was controlled to about the same extent by all treatments (Table 7). Bordeaux mixture appeared to cause some chemical injury to the foliage. The treatments are ranked by yield in Table 7, although the differences between treatments were not significant.

Table 6. Average Yield of Ungraded Irish Cobbler Potatoes Treated with Nine Fungicides on June 24, July 7 and 20, and August 1, Brookings, 1948

Treatment	Total Yield, Ungraded	
	Bu./A.	% Increase
Zerlate	510.9	16.4
Dithane Z 78	474.1	8.0
Parzate	458.1	4.4
Crag 658	453.4	3.3
Tribasic	446.1	1.6
Bordeaux	442.0	0.7
Zerlate alternating with Tribasic	440.9	0.5
Check	438.9	
Phygon	404.6	−7.8
Yellow Cuprocide	396.8	−10.6
L. S. D.* (5% level)	69.8	16.1

*Least significant difference.

Table 7. Average Yields of Ungraded Irish Cobbler Potatoes Obtained in Plots Sprayed Four Times with Eight Fungicides, Including Percentage Increase or Decrease in Yield, Brookings, 1949

Treatment	Early Blight	Total Yield, Ungraded	
	% Defoliation	Bu./A.	% Increase
Zerlate	1.5	185.5	17.3
Cop-O-Zink	1.5	180.1	13.9
Tribasic	1.8	175.5	11.0
Yellow Cuprocide	1.5	168.1	6.3
Crag 658	1.3	166.0	5.0
Dithane Z 78	0.8	163.9	3.7
Check (No treatment)	7.4	158.1	
Bordeaux 8-4-100	1.3	146.1	−7.6
Phygon	2.1	140.7	−11.0
L. S. D. (differences not significant.)			

1950 Experiments

The variety Bliss Triumph was planted in the spray plots on May 17. Sprays were applied on July 12 and 24, and August 3 and 14. The crop was harvested October 13. The average temperatures were considerably below normal for the area. While the total rainfall during the growing season was less than normal, there were prolonged periods favorable for the development of the late blight organism. In spite of this fact, no sign of late blight appeared on the plants. Early blight readings taken August 22 are listed in Table 8. The infection was moderate in the check plots and was controlled adequately by most fungicides, with Phygon providing the least protection.

It was apparent throughout the season that Bordeaux mixture was causing chemical injury to the foliage. When the total defoliation, due to early blight, chemical injury, and maturity, was determined on August 29, Bordeaux-treated plots showed more defoliation than the plots receiving no fungicide. In order to determine the effect of the various treatments on the foliage, five extra plants at the end of each plot were cut off at the ground line on August 21 and weighed. The green weights of these samples are presented in Table 8. It will be noted that the weights are low for both the check and the Bordeaux plots. The lighter weight of Bordeaux-sprayed plants was apparently the result of chemical injury, since these plants showed no more defoliation due to early blight than plants sprayed with other fungicides.

Table 8. Average Green Weight of Tops, Percentage Defoliation from Early Blight Alone, and Defoliation from Early Blight Combined with Chemical Injury and Maturity in Plots of Bliss Triumph Potatoes Sprayed Four Times with Eight Fungicides, Brookings, 1950

Treatment	Average Top Weight Per 5 Plants (lbs.)	Average % Defoliation	
		Due to early blight, Aug. 22	Due to early blight, maturity, and chemical injury, Aug. 29
Zerlate	3.6	0.8	5.6
Cop-O-Zink	3.5	0.8	4.6
Crag 658	3.8	0.4	4.8
Yellow Cuprocide	3.4	0.6	7.9
Dithane Z78	3.4	0.3	5.6
Bordeaux 8-4-100	2.7	0.3	62.6
Tribasic	3.3	0.4	11.2
Phygon	3.4	2.4	7.4
Check	2.5	8.9	41.9
L. S. D.* (5% level)	1.2	0.8	14.5

*Least significant difference.

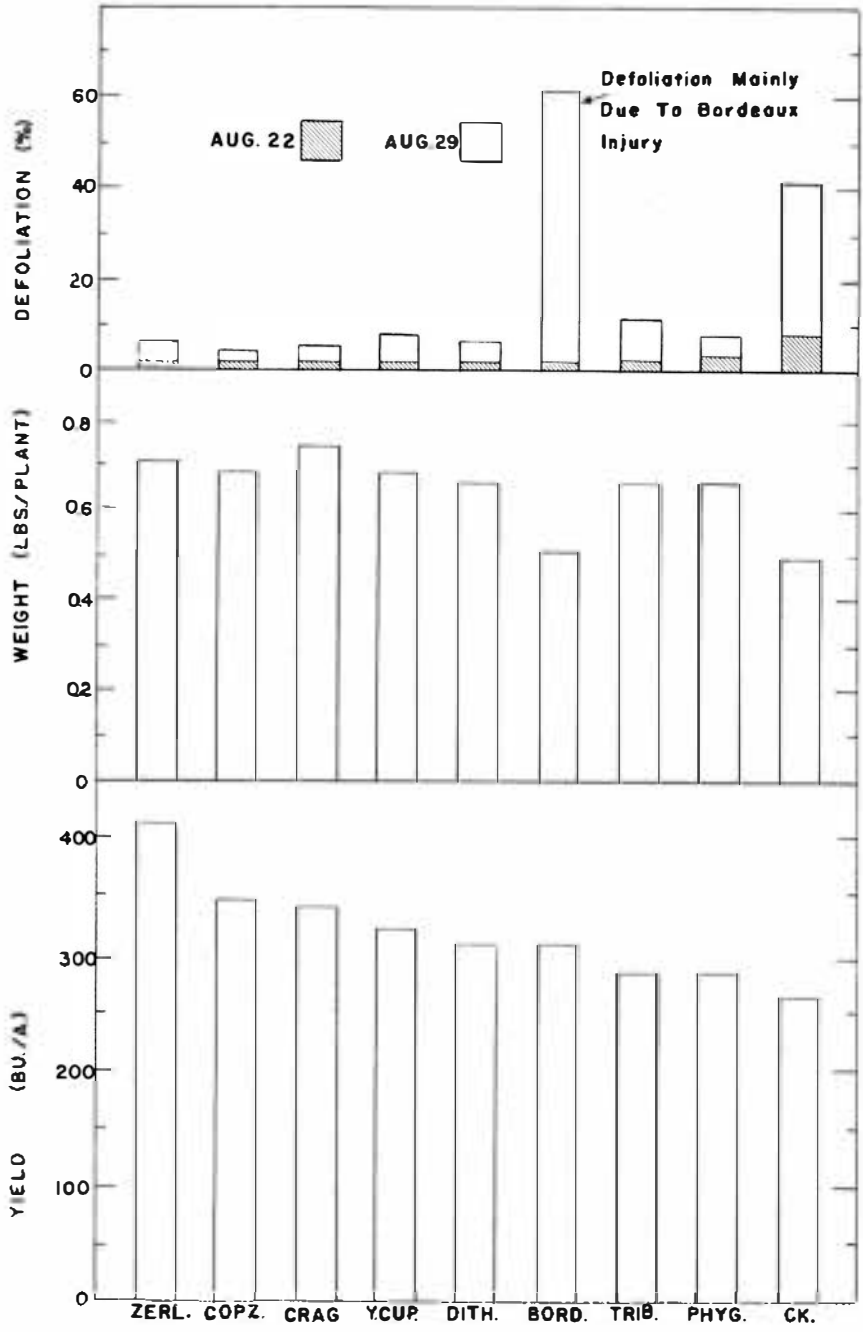


Fig. 3. Percentage defoliation, weight of potato plant tops and yield obtained following four applications of eight different fungicides on Bliss Triumph potatoes, Brookings, 1950.

The yield data for the season are presented in Table 9. Significant increases over the check resulted from the use of Zerlate, Cop-O-Zink, and Crag 658. The fact that these were all fungicides containing zinc is of interest. Since the increases in yield cannot be entirely attributed to disease control, it would appear that zinc had a stimulatory effect on the productivity of the plants in 1950.

A comparison of the weight of tops, percentage defoliation, and yields for each treatment is shown in Figure 3.

Table 9. Average Yield of Ungraded Bliss Triumph Potatoes in Plots Sprayed Four Times with Eight Fungicides, with Percentage Increase in Yield Over Untreated Plots, Brookings, 1950

Treatment	Total Yield, Ungraded	
	Bu./A.	% Increase
Zerlate	422.8	55.8
Cop-O-Zink	357.4	31.7
Crag 658	347.6	28.1
Yellow Cuprocide	334.6	23.3
Dithane Z 78	319.0	17.6
Bordeaux 8-4-100	318.5	17.4
Tribasic	292.1	7.6
Phygon	291.0	7.2
Check (No treatment)	271.3	
L. S. D.* (5% level)	74.2	27.3

*Least significant difference.

Summary and Conclusions

The performance of any fungicide cannot be assessed properly on the basis of the results obtained in a single season. By comparing the results over a period of years it is possible to detect distinct trends even though individual differences may not be significant. It should be noted that a given fungicide will not control all diseases equally; thus certain fungicides are most effective against early blight while others are best suited for late blight control.

From the standpoint of these experiments it was unfortunate that late blight was severe only the first year. Some of the newer fungicides were not available at that time so their effectiveness in controlling late blight under our conditions has not been tested. One positive fact established by the 1945 trials was that the materials Q15 and N5E were not suitable with respect to disease control or yield, as potato fungicides. It was indicated that Yellow Cuprocide, Phygon, Bordeaux mixture, and Dithane were effective in the control of late blight. The results in 1945 also emphasized the importance of thorough spraying or dusting in a season when weather conditions are favorable for late blight infection.

With regard to early blight control, it may be said, in general, that zinc fungicides provided better control in the tests to date than did copper compounds. In a season conducive to late blight, therefore, it would appear advisable to alternate or combine applications of copper and zinc fungicides in order to control both diseases. The newer fungicides, Cop-O-Zink and Crag, which contain both copper and zinc may be effective against both diseases, although they have not been tested in a season when late blight was a factor in the trials to date.

The ultimate value of any potato fungicide depends on obtaining increases in yield of the crop. The average plot yields for the various treatments over the six years of the tests may be compared in Figure 4. While

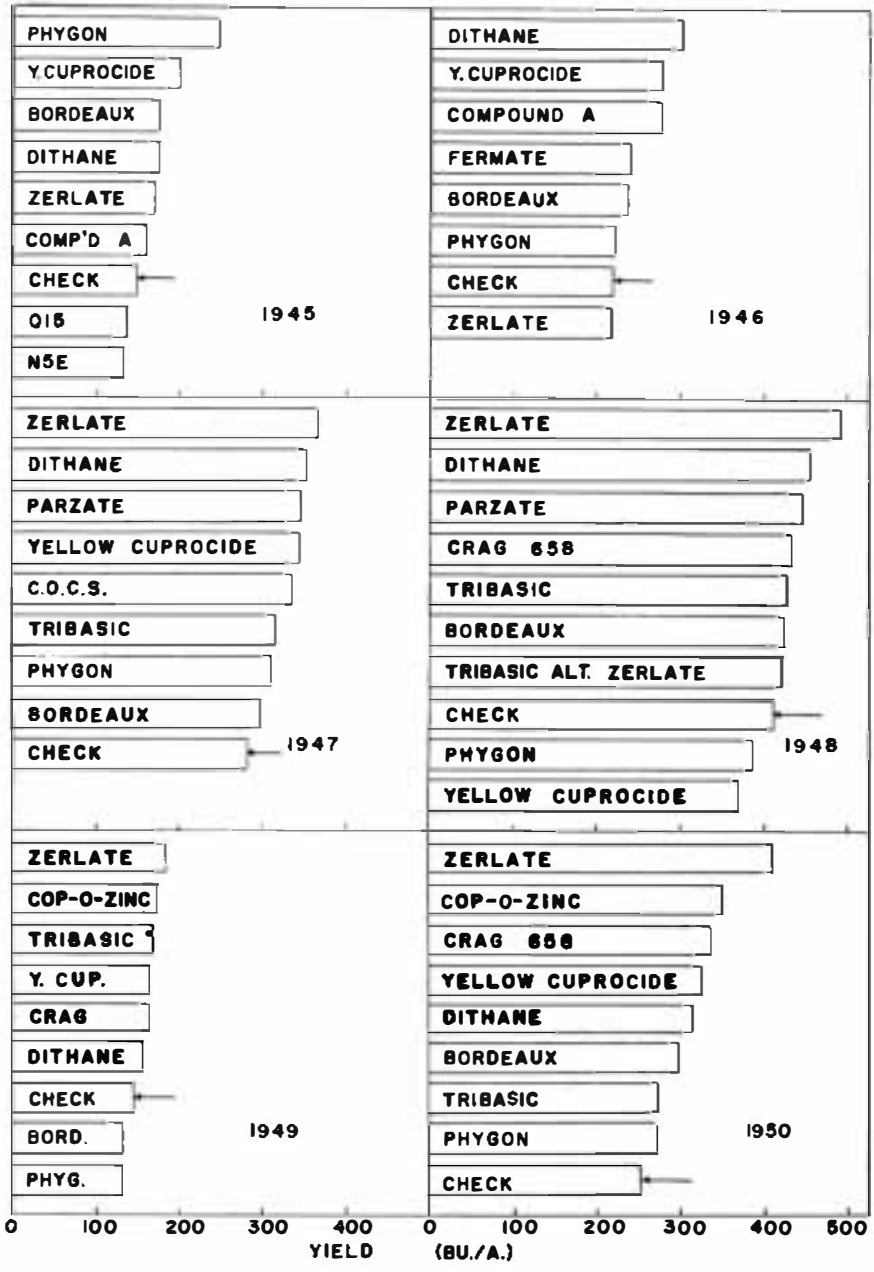


Fig. 4. Average plot yields obtained with various fungicides during the 6-year period, 1944 to 1950, Brookings, 1950.

the yields varied widely from season to season, it is significant that in every season the treated plots outyielded the untreated check plots in practically every case.

It is noted that Zerlate provided the highest yields in each of the last four seasons. Since these high yields can be attributed only partly to disease control it would appear that zinc had a stimulatory effect on the plants under the conditions of these tests. The use of Dithane resulted in consistent increases over the six years. Phygon and Yellow Cuprocide provided big increases in yield in 1945 when late blight was a factor, but their performance was inconsistent in other seasons when late blight was not a problem. Bordeaux mixture controlled foliage diseases well, especially late blight; however, the yield increases were not in proportion because of the chemical injury to the foliage. This damage appeared to be more acute with the lime mixture 8-4-100 than with the 8-8-100 mixture under the conditions of these experiments.

Of those materials tested for shorter periods of time the two zinc fungicides, Cop-●-Zink and Crag, appeared to be the most promising; Parzate was comparable to Dithane in performance, while the fixed coppers, Tribasic, Compound A, and COCS, gave satisfactory results. Further tests with these materials will be necessary in order to evaluate properly their performance under diverse conditions.

The percentage increase in yield obtained with the five fungicides which were used throughout the test period are represented in Figure 5. The increase from each of these treatments amply repaid the cost of the materials and labor involved. At the same time protection was provided against possible outbreaks of the disease which could have ruined the crop.

Regional and National Cooperation

The purpose of the cooperative fungicide trials on a regional and national basis was to evaluate the performance of various fungicides, particularly the newer ones, under a wide range of conditions. By testing the same materials at several locations each season, information was gained that would take many years to obtain from repeated experiments in one location. Because of the variation in weather conditions between regions, there were corresponding differences in the type and degree of foliage diseases prevalent and in the control obtained from the respective fungicides.

On the whole, the results obtained from the fungicide trials in South Dakota over the 6-year period were in line with those obtained from the cooperative trials in other states. The following conclusions may be drawn from the regional trials in 1946 and the national trials in the next three seasons: The zinc organics (Dithane, Parzate, and Zerlate) are, in general, superior to the copper fungicides (Bordeaux, Tribasic, COCS, and Yellow Cuprocide), more so in yield than in disease control, especially where

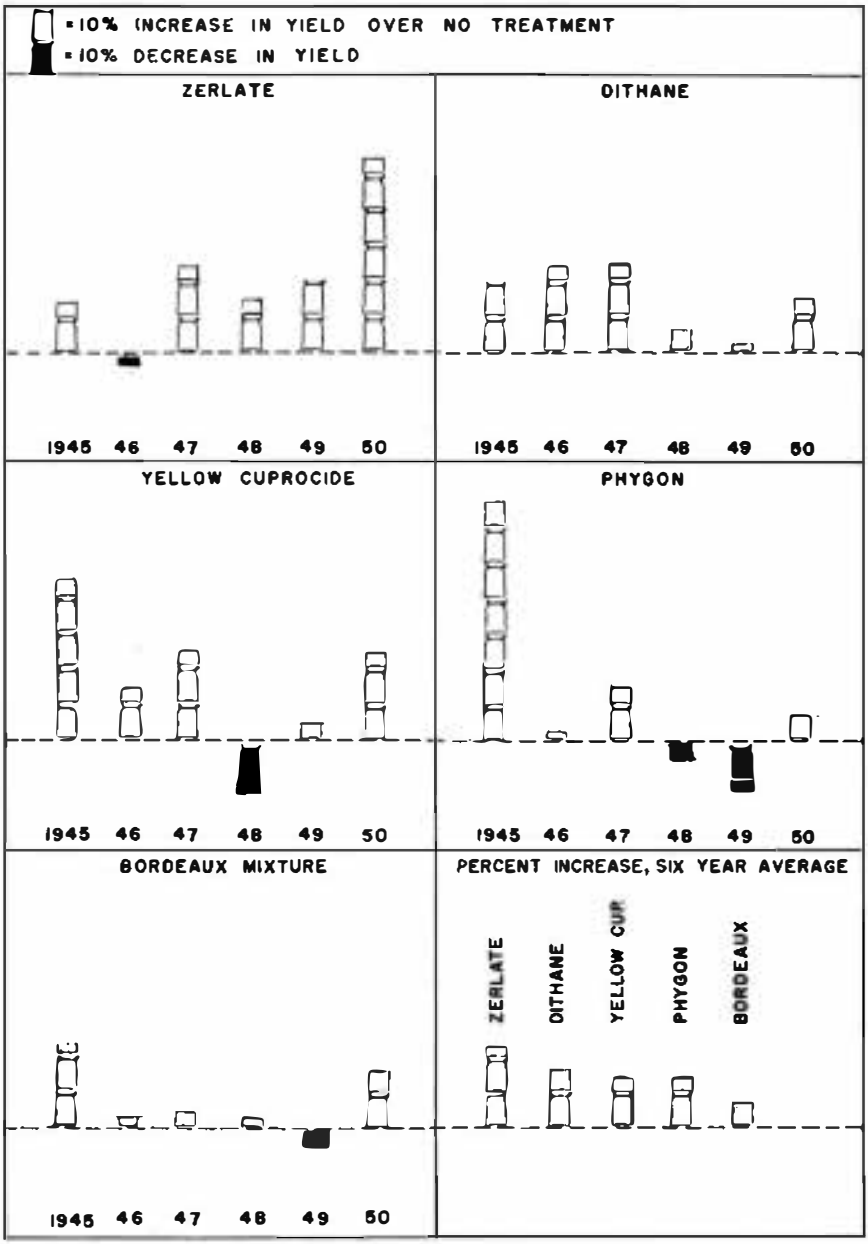


Fig. 5. Percentage increase or decrease in yield of ungraded potatoes, compared with plots which received no treatment (broken line indicates yield of untreated plots) resulting from the use of five fungicides in six consecutive seasons, Brookings, 1945 to 1950.

early blight only is present. Where late blight is present the coppers, especially Bordeaux and Tribasic, most effectively reduce defoliation, although they tend to suppress yield. The coppers, particularly Bordeaux, are toxic to potato foliage, whereas zinc organics are less toxic; in fact, in certain instances they appear to be stimulatory. Copper zinc chromate and Tribasic plus zinc performed well for both early and late blight control and yield. Phygon controlled late blight but not early blight and gave low yields as compared with the zinc organics.