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PROGRESS IN THE CONTROL OF ELM DISEASES IN NURSERIES

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An investigation of the effectiveness of fungicidal materials in controlling the elm diseases commonly known as "wilts"* has been underway since 1931. Reports of the results obtained have been made periodically, and this report brings up to date the information the investigation has yielded, particularly for experiments not completely reported on previously. A special point has been made, in two sets of experiments, of observing the effect of treatment on tree growth and on the sale value of the treated trees.

All of the tests have been conducted in commercial nurseries, in cooperation with the nurseries, and have been performed on trees receiving the cultivation usual in commercial production. The trees have been sprayed or dusted with fungicidal preparations containing either sulfur or copper. All of the dusts were sulfur dusts, and some of the sprays were sulfur sprays. All of the copper treatments were sprays.

The following specific materials were used: Koloform, Kolodust, dry wettable flotation sulfur, flotation sulfur dust, "Mike" sulfur, lime sulfur, a commercial Bordeaux, instant Bordeaux and Z-O. The characteristics of these materials are stated later.

Two of the experiments reported here have been in progress for several years and furnish data on the effectiveness of a commercial Bordeaux and two wettable sulfurs as summer sprays. Two other experiments, under way for four years, furnish data on the effectiveness of two copper sprays, instant Bordeaux and Z-O, used both as dormant and as summer sprays. The fifth experiment, also in progress for four years, furnishes data on the effectiveness of two wettable sulfurs as summer sprays with lime sulfur as a dormant spray. A sixth experiment only two years old gives preliminary indications of the value of "Mike" sulfur as a summer spray. The last experiment, under way for four years, gives data on the effectiveness of two summer sulfur dust treatments.

In these seven experiments over 6,500 trees have been used. The smallest number of trees used in any experiment was 400 and the largest number was 1,659.

MATERIALS

The sprays and dusts named above have the characteristics given below and each was used in the strength stated.

KOLOFORM is a wettable sulfur dust distributed by the Niagara Sprayer and Chemical Co., Inc. It contains not less than 54 per cent of sulfur, as the active ingredient, and not more than 46 per cent of inert ingredients. A portion of the sulfur is colloidal sulfur produced by the adsorption of molten sulfur by bentonite clay. It was used as a spray, at the rate of 15 pounds to 100 gallons of water.

KOLODUST is a sulfur dust also distributed by the Niagara Sprayer and Chemical Co., Inc. It is similar to Koloform but is adapted for direct use as a dust rather than as a spray ingredient. It contains not less than 87 per cent of sulfur, as its active ingredient, and not more than 13 per cent of inert ingredients.

* The terms "wilt" and "elm wilt" have been in general use by nurserymen for years to designate any disease of elms that results in the wilting of any small or large part of a tree. It is used in this sense in this paper, rather than in the technically limited sense of the plant pathologist. The fungi most frequently associated with "wilting" of elms in the experimental plots belong to the fungus genera *Coniothyrium*, *Cytosporina*, *Phoma* and *Vermicularia* (see page 5).

DRY WETTABLE FLOTATION SULFUR is an exceedingly fine, wettable sulfur dust formerly manufactured by the White Tar Company of New Jersey, Inc. It contains not less than 80 per cent of sulfur, the active ingredient, and not more than 20 per cent of inert ingredients. It was used as a spray, at the rate of 8 pounds to 100 gallons of water.

Dry wettable flotation sulfur has not been obtainable since 1936; and in the experiment in which it was in use (plot XII) "Mike" sulfur was used in 1937 and 1938.

FLOTATION SULFUR DUST is a sulfur dust formerly manufactured by the White Tar Company of New Jersey, Inc., for use as a dust rather than as a spray ingredient. It is otherwise similar to dry wettable flotation sulfur.

"MIKE" sulfur is a wettable sulfur dust manufactured by the Dow Chemical Company. It contains more than 95 per cent of sulfur as an active ingredient and less than 5 per cent of inert ingredients. It is composed of very minute particles, mixes readily with water for use as a spray ingredient and can be used also as a dust. As a spray, it was used at the rate of 8 pounds to 100 gallons of water.

LIME SULFUR, a standard fruit-tree fungicide, was used at a strength of 1 in 10. A liquid lime sulfur manufactured by the Grasselli Chemicals Department, E. I. duPont de Nemours and Co., Inc., was used as basic material.

COMMERCIAL BORDEAUX is a premixed preparation of lime and copper sulfate, which forms a Bordeaux spray mixture when added to water. The preparation used in our experiment was the Corona Bordeaux manufactured by the Corona Chemical Division of the Pittsburgh Plate Glass Company; this preparation contains not less than 13 per cent of copper as an active ingredient; and throughout the tests the spray used has been equivalent to 4-4-50 Bordeaux mixture.

INSTANT BORDEAUX is a homemade spray made with blue vitriol (copper sulfate) powder and dehydrated lime. It is prepared in the sprayer tank as it is needed and has the two practical advantages of being more quickly and easily prepared than regular Bordeaux mixture and of giving a more uniform and stable suspension of materials. In our experiment, instant Bordeaux was used at a strength equivalent to 4-4-50 Bordeaux mixture.

Z-0 is a proprietary material sold in powdered form by the Niagara Sprayer and Chemical Co., Inc. It contains copper as an active ingredient in an amount equivalent, as metallic copper, to 25 per cent. It was developed as a material more convenient to use than Bordeaux mixture. Because of the gradual release of copper and the absence of lime, it is claimed that Z-0 is less harmful to plants than any other copper-containing spray. It has proved effective for general spraying of ornamentals and for dusting truck crops. For both summer and dormant sprays, we used Z-0 at the rate of 3 pounds to 100 gallons of water.

METHODS

From 1931 until the fall of 1935, liquid fungicides were applied in one plot with a 50-gallon, hand-operated spray outfit and in another plot with a 50-gallon power outfit. But since early in the spring of 1936 all spraying has been done with a 100-gallon Bean Little Giant Duplex outfit, operated at a pressure of approximately 275 pounds, thus eliminating lack of uniformity in spray applications. Dusting has been done with a Niagara blower dust gun that sends a good cloud of dust to a height of 8 to 10 feet, and dust applications have been made mostly in early morning when dew was on the foliage and before the wind became so strong as to prevent uniform dusting.

Summer applications of fungicides have been started in late April, May or early June, according to the season, and have been terminated in the latter part of August each year. In general, applications have been made at two-week intervals until the beginning of the dry weather period, usually about the middle of July, and then at three-week intervals during the remainder of the season.

SOME DISEASES OF NURSERY ELMS

- A. *Cytosporina* infection in an advanced cankerous stage.
- B. *Phoma* infection with the fungus sporulating through the bark.
- C. *Vermicularia* discoloration in the wood.
- D. Young *Coniothyrium* infection, typical of the first appearance of most wilts.
- E and F. Advanced stages of *Coniothyrium* infection ready to produce spores.

TABLE 1.--Disease control obtained from seven years of summer spraying and pruning.

Plot Number and Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease							Difference in Favor of (+) or Against (-) Treatment*	Percentage of Control (+) or Lack of Control (-)**
		1932	1933	1934	1935	1936	1937	1938		
Plot VII										
Check	711	15	62	23	16	39	31	12	198	
Dry wettable flotation sulfur	474	16	23	26	16	37	....	....	118	- 22 trees -14.2
Commercial Bordeaux . .	474	18	21	29	20	28	17	11	144	- 18 trees - 9.1
Plot IXS										
Check	254	5	14	50	51	23	20	6	169	
Pruning	282	....	....	....	31	31	20	13	95	+ 16 trees +14.4
Koloform.	236	3	16	51	33	14	20	7	144	+ 16 trees + 8.5
Koloform and pruning***	230	2	13	49	31	13	20	10	138	+ 19 trees +10.1

* Calculated on bases of 711 trees in plot VII and 282 trees in plot IXS.

** Percentage of control obtained as follows: $\frac{\text{Treatment difference}}{\text{Cases of disease in check}} \times 100$.

*** Sprayed seven seasons; pruned only the last four seasons.

Dormant sprays have been applied in March or early April, before the buds opened, and in October or November.

At regular intervals observations have been made and data recorded relative to the effectiveness of each of the fungicides used and to the prevalence of disease.

SEVEN-YEAR RESULTS FROM SUMMER SPRAYING

In two experiments dealing with over 2,600 trees, the relative effectiveness of summer spraying with commercial Bordeaux, Koloform and dry wettable flotation sulfur has been tested through periods of seven years for the first two sprays, and five years for the last named spray. In one experiment commercial Bordeaux and dry wettable flotation sulfur have been compared directly with each other, each on 474 trees, and with an untreated check group of 711 trees. In the other experiment Koloform alone and in combination with pruning (236 and 230 trees, respectively) has been compared with pruning (282 trees) and with an untreated check group (254 trees).

In these groups the majority of the trees that became diseased had been attacked by one of the *Phoma* wilts, but occasional trees were infected with *Cytosporina* and *Verticillium*.

The results obtained year by year and for the entire period of experimentation are shown in table 1. Five years of summer spraying with dry wettable flotation sulfur permitted the development of a greater number of infections than occurred, proportionally, among the check trees in the same period. Seven years of summer spraying with commercial Bordeaux also permitted a greater proportional development of disease than occurred among the check trees. Spraying with these two materials appears, in other words, to have favored development of disease to the extent of 14.2 per cent and 9.1 per cent, respectively, as indicated in the last column of the table.

Seven years of summer spraying with Koloform resulted in the occurrence of fewer cases of disease than among the untreated check trees. Similar spraying with the same material through seven years, with pruning added in each of the last four years, permitted development of fewer cases of disease, proportionally, than occurred among either the check trees or those only sprayed. The degree of control for spraying alone is indicated as 8.5 per cent and for the combination of spraying and pruning as 10.1 per cent. It is significant that a group of trees in the same block, given no treatment other than pruning and that for only the last four of the seven years, developed fewer new cases of disease during those four years than occurred in the check.

FOUR-YEAR RESULTS FROM SUMMER DUSTING

In an experiment involving nearly 1,400 trees the relative effectiveness of the sulfur dusts as summer applications, alone and in combination with pruning, has been under test for four years. Six applications of the dusts have been made each summer except 1937, when seven applications were made. Kolodust has been applied to the same groups of trees throughout the period. Flotation sulfur dust was applied to other groups of trees in 1935 and 1936; but, after this sulfur was not available, "Mike" sulfur was applied to these groups.

The prevalent infection in the plot was a species of *Phoma*, to which is attributable about 70 per cent of the total number of cases of disease. Most of the remainder of the infections were due to *Cytosporina*.

The results obtained year by year, and the degree of disease control for the entire period, are given in table 2. In the untreated, or check, group 171 trees, about 72 per cent, have become infected. But in the group in which pruning alone has been practiced, only 84 trees, about 39 per cent, have contracted disease. Summer dusting with Kolodust has permitted 149 trees, or about 64 per cent, to become infected; but the Kolodust treatment combined with pruning has permitted only 93 trees, about 47 per cent, to become infected. In the tree groups dusted first with flotation sulfur dust

TABLE 2.--Disease control obtained from four years of pruning, of summer dusting with sulfur and of summer dusting supplemented by pruning. (Plot XIV).

Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease				Difference in Favor of Treatment	Percentage of Control *
		1935	1936	1937	1938	Total	
Check	236	47	37	69	18	171	
Pruning	218	29	17	11	27	84	47.0
Kolodust.	235	40	41	40	28	149	12.6
Kolodust and pruning.	201	32	21	15	25	93	35.5
Flotation sulfur dust and "Mike" sulfur**	253	36	50	22	19	127	30.6
Flotation sulfur dust, "Mike" sulfur and pruning**	222	18	10	33	26	87	45.9

* Calculated on the basis of 253 trees in each treatment.

** Flotation sulfur dust was applied in 1935 and 1936, "Mike" sulfur dust in 1937 and 1938.

and later with "Mike" sulfur, 127 trees, about 50 per cent, have become diseased; but in the group so dusted and also pruned only 87 trees, or 39 per cent, have become diseased.

Both dusting alone and dusting in combination with pruning appear in this experiment to have proved less effective than merely pruning out diseased material. This result is in accord with results reported previously for the early years of treatment in some of the first plots established. Although it may seem that the use of sulfur dusts is detrimental rather than useful, there are other considerations, such as the eventual disease control obtained over the growth-period of a block of trees and the extra growth resulting from the control of leaf spots and a great variety of minor pests.

FOUR-YEAR RESULTS FROM DORMANT AND SUMMER COPPER SPRAYS

The relative effectiveness of two copper sprays, applied as dormant and summer sprays alone and in combination with pruning, has been tested for four years in two experiments involving nearly 1,300 trees. In one of these experiments Z-0 was applied alone to 143 trees and in combination with pruning to 133 trees, in comparison with 145 trees receiving pruning only and 136 untreated check trees. In the other experiment instant Bordeaux was applied to 178 trees and in combination with pruning to 186 trees, in comparison with 181 pruned trees and 186 check trees.

Most of the disease among these trees was the result of *Phoma* and *Coniothyrium* infections. A few cases were caused also by *Cytosporina* and by *Verticillium*.

The degree of disease control for the duration of these experiments and the results obtained each year are shown in table 3. In both sets of trees treated with Z-0, approximately 23 per cent of the trees became diseased during the four years, while about 35 per cent of the pruned group and 21 per cent of the check group became diseased. There were more cases of disease in the treated groups than in the untreated group of trees. In the pruned group 75 per cent more trees showed disease than in the untreated group, while the sprayed group and the sprayed and pruned group each had 13 per cent more trees that showed disease than had the untreated group.

In the experiment with instant Bordeaux, approximately 33 per cent of the trees sprayed with instant Bordeaux became diseased during the four years of the experiment, and about 14 per cent of the trees that were sprayed and pruned became diseased. In the check group about 26 per cent of the trees became diseased, and in the pruned group about 25 per cent became diseased.

These results indicate that the use of instant Bordeaux alone as both a dormant and summer spray tends to favor the development of disease, but that this treatment in combination with pruning gives a marked degree of control. The degree of control obtained with the combination of treatments, shown as 46.9 per cent in table 3, is actually 11 times greater than that given by pruning alone.

FOUR-YEAR RESULTS FROM DORMANT AND SUMMER SULFUR SPRAYS

A series of experiments to test the relative effectiveness of dormant and summer sulfur sprays has been in progress on approximately 850 trees for four years. Dormant applications of lime sulfur were made in the fall and in the spring on all sprayed trees and summer applications of two sets of sulfur sprays were made on definite groups of trees. The following sulfurs were used as sprays: Koloform, dry wettable flotation sulfur and "Mike" sulfur.

Koloform was applied alone to 136 trees and in combination with pruning to 141 trees. Dry wettable flotation sulfur was applied alone to 142 trees in 1935 and 1936 and was followed with "Mike" sulfur in 1937 and 1938. This same treatment in combination with pruning was given also to another group of 142 trees. For comparison a group of 145 trees were pruned and a group of 136 trees were left untreated, as checks.

Disease in these groups of trees was caused mainly by a *Phoma* and by a *Coniothyrium*; however, a few trees were infected with *Cytosporina* and a few with *Verticillium*.

TABLE 3.--Disease control obtained from four years of spraying with dormant and summer copper sprays.

Plot Number and Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease				Difference in Favor of (+) or Against (-) Treatment*	Percentage of Control (+) or Lack of Control (-)
		1935	1936	1937	1938	Total	
Plot XII							
Check.	136	12	9	3	3	27	
Pruning.	145	21	14	10	6	51	- 22 trees
Z-0.	143	18	12	2	1	33	- 4 trees
Z-0 and pruning.	133	15	8	3	4	30	- 4 trees
Plot XIII							
Check.	186	26	11	9	3	49	
Pruning.	181	37	3	6	0	46	+ 2 trees
Instant Bordeaux	178	40	14	2	0	56	- 10 trees
Instant Bordeaux and pruning	186	23	2	1	0	26	+ 23 trees

* Calculated on the basis of 145 trees per block in plot XII and of 186 trees per block in plot XIII.

TABLE 4.--Disease control obtained from four years of treatment with lime sulfur as a dormant spray and with different sulfur summer sprays. (Plot XII).

Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease				Difference Against Treatment*	Percentage Showing Lack of Control
		1935	1936	1937	1938	Total	
Check.	136	12	9	3	3	27	
Pruning.	145	21	14	10	6	51	75.9
Dormant and Koloform summer spray	136	13	14	10	1	38	41.4
Dormant, Koloform and pruning. . .	141	21	5	8	2	36	27.6
Dormant, dry wettable flotation sulfur and "Mike" sulfur summer spray**	142	13	15	8	1	37	30.0
Dormant, dry wettable flotation sulfur, "Mike" sulfur and pruning**	142	36	8	5	0	49	72.4

* Calculated on the basis of 145 trees in each treatment.

** Dry wettable flotation sulfur used in 1935 and 1936, "Mike" sulfur in 1937 and 1938.

The year by year results that have been obtained and the degree of disease control for the four-year period are given in table 4.

All of these treatments permitted the occurrence of a greater number of cases of disease than occurred proportionally in the check block, but the variations in cases of disease shown by the several treatments are not otherwise consistent. In the check group 20 per cent of the trees became diseased and in the pruned group 35 per cent became diseased. Of the trees given the Koloform summer spray 28 per cent contracted disease, and of those sprayed with Koloform and pruned 25 per cent contracted disease. Of those sprayed with dry wettable flotation sulfur and "Mike" sulfur 26 per cent became diseased, and of those so treated and also pruned 34 per cent became diseased. The group of trees that were pruned had 76 per cent more trees that showed disease than did the untreated group. In comparison with the per cent of disease in the untreated group of trees there was 41 per cent more disease in the group of trees that was treated with dormant and Koloform summer sprays. But there was only 27 per cent more disease in the group of trees that received this same spray treatment in combination with pruning.

In most of the treatments that were tested we have found that sprays in combination with pruning have given a greater degree of disease control than have applications of sprays alone. However, in this experiment the group of trees treated for two years with dormant and dry wettable flotation sulfur and then treated for two years with dormant and "Mike" sulfur had 42 per cent less disease than did the group of trees that received the same spray treatment but was tested in combination with pruning.

TWO-YEAR RESULTS FROM SPRAYING WITH "MIKE" SULFUR

In one experiment involving 400 trees the effectiveness of summer spraying with "Mike" sulfur has been tested for two years. "Mike" sulfur alone and in combination with pruning, each treatment on 100 trees, was compared with pruning (100 trees) and with an untreated check group (100 trees). Six applications of the spray were made each summer.

Most of the disease that has occurred in this plot has been caused by a *Phoma*, but a few *Coniothyrium* infections have also been found.

The results that were obtained each year and the degree of disease control for the two-year period of the experiment are given in table 5.

Two years of summer spraying with "Mike" sulfur resulted in 92 per cent less disease than was present in the untreated check group of trees. There was 46 per cent less disease in the group of trees that was sprayed with "Mike" sulfur in combination with pruning than in the untreated check group of trees. The group of trees that was pruned had 38 per cent more disease than did the untreated check group.

TABLE 5.--Disease control obtained from two years of spraying with "Mike" sulfur and from pruning. (Plot XV).

Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease			Difference in Favor of (+) or Against (-) Treatment	Percentage of Control (+) or Lack of Control (-)
		1937	1938	Total		
Check	100	12	1	13		
Pruning	100	13	5	18	- 5 trees	- 38.5
"Mike" sulfur	100	1	0	1	+12 trees	+ 92.3
"Mike" sulfur and pruning.	100	6	1	7	+ 5 trees	+ 46.2

TABLE 6.--An estimate, on the basis of increase in trunk diameter, of the gain in sale value resulting from the spraying and pruning of trees for four years.

Plot Number and Treatment	Number of Trees Measured	Estimated Sale Value		Total Increase In Sale Value	Average Increase Per Tree in Sale Value	Calculated Gain in Sale Value per 1,000 Trees From Treatment
		Fall and Spring of 1934-35	Fall of 1938			
Plot VII (estimated in the fall of 1934)						
Check	258	\$175.25	\$590.45	\$415.20	\$ 1.61	\$370.00
Dry wettable flotation sulfur spray	175	128.35	475.30	346.95	1.98	
Commercial Bordeaux spray	184	126.65	477.25	350.60	1.91	300.00
Plot XII (estimated in the spring of 1935)						
Check	101	63.70	203.45	139.75	1.39	
Pruning	120	80.15	252.85	172.70	1.44	50.00
Dormant, dry wettable flotation sulfur, "Mike" sulfur and pruning	101	67.35	243.80	176.45	1.75	360.00
Dormant, Koloform summer spray and pruning. . .	99	58.70	222.25	163.55	1.65	260.00

In this experiment, "Mike" sulfur appears outstanding in its ability to control disease. However, the results of this experiment are parallel with the early results obtained in other previously reported experiments, in which combinations of pruning and spraying, as well as pruning alone, proved over a period of years to be the more effective treatments. Continuation of this experiment is necessary for a better evaluation of the effectiveness of this sulfur.

EFFECT OF TREATMENT ON TREE GROWTH

Two kinds of data have been kept which throw light on the effect of sprays on tree growth as a consideration separate from disease control. Measurements of tree diameters, made in connection with two of the spray experiments, give definite evidence that treated trees have grown better than untreated trees. Less definite, but perhaps equally indicative of the value of treatment, is the record of the number of trees selected and sold from one of the experimental plots.

DIAMETER MEASUREMENTS.--In the fall of 1934 diameter measurements were taken of the trees in the plot reported above as having received seven years of summer spraying with dry wettable flotation sulfur and commercial Bordeaux (see table 1, plot VII), and in the following spring similar measurements were made of trees in the plot reported as having received dormant and summer sulfur sprays for four years (see table 4). In the fall of 1938 diameter measurements were taken again of all of the trees then standing in these plots.

The individual trees measured in 1938 were selected from among those measured in 1934 and 1935, arranged in diameter classes differing by one-half inch, and valued according to wholesale prices of that date, to give their total sale value as of the winter of 1934-35. After measurement in 1938, they were again valued at wholesale prices, as of the winter of 1938-39, on the basis of one-half inch diameter classes. The increase in the sale value of check groups and of treated groups, after four years of growth, was determined by subtracting the 1934-35 valuation from the 1938-39 valuation. The results of this estimation are given in table 6.

For all treatments represented by an adequately indicative number of trees, there is definite indication that growth occurred more rapidly and that sale values increased more quickly in the treated than in the untreated trees. The increase in valuation averaged 30 cents per tree as a result of summer spraying with commercial Bordeaux and 37 cents per tree with dry wettable flotation sulfur. For pruning alone this increase amounted to 5 cents per tree, but with dormant and summer sprays combined with pruning this increase was respectively 26 cents and 36 cents per tree for the two types of summer sulfur sprays.

Although small per tree, these increases in value amount to considerable sums, as indicated in table 6, when considered as applicable to a thousand salable trees, and represent possible additional sale values of from \$50 to \$370 per thousand over trees receiving no treatment.

NUMBERS OF TREES SOLD.--During the winters of 1936-37 and 1937-38 the larger and better trees were selected by the nursery owner from one of the experimental plots, in order to fill purchase orders for trees of specified large diameters and high quality. The exact numbers of suitable trees found in the check group and in each of the treated groups are shown in table 7.

The advantage of treatment for disease control as a stimulant to more rapid growth is indicated by the fact that from 3 to 9 per cent more trees were selected from groups receiving some kind of treatment than from the untreated check group. These figures are the more significant, because the diameter specifications on which the selections were made were above the average run of the plot.

TABLE 7.--Number of trees sold from one experimental plot during the two winters, 1936-37 and 1937-38. (Plot IXS)

Treatment	Number of Trees Originally Present	Trees Sold		Total	Percentage of Trees Sold
		1936-37	1937-38		
Untreated	226	10	14	24	10.6
Pruning (four years). . . .	250	22	26	48	19.2
Koloform.	217	3	30	33	15.2
Koloform and pruning* . . .	200	3	24	27	13.5

* Sprayed for seven seasons; pruned only the last four seasons.

RESULTS

A recapitulation of the data presented in preceding pages is given in table 8, for direct comparison of the results obtained with the various treatments and combination of treatments.

These data indicate, as have the data in previous reports, that more than half of the different treatments tested have some value. The effective treatments, indicated by "+" signs in the table, range from .2 per cent to 92 per cent in their degree of effectiveness, and several--those effective to 30 per cent or more--are of practical value. As has been pointed out in previous reports, both ineffective and effective treatments for wilt control leaf diseases and stimulate tree growth.

The average percentages of control or lack of control shown in the last column of Table 8 are compared diagrammatically in fig. 1. The bars reaching to the right of the vertical line represent effective treatments, those to the left represent ineffective treatments and the bar-lengths indicate degrees of effectiveness or ineffectiveness.

From fig. 1 and from table 8, it may be seen that the treatments that have been effective in the control of disease are (1) pruning, (2) instant Bordeaux in combination with pruning, (3) Koloform, (4) Koloform in combination with pruning, (5) "Mike" sulfur spray, (6) "Mike" sulfur spray in combination with pruning, (7) Kolodust, (8) Kolodust in combination with pruning, (9) flotation sulfur dust and "Mike" sulfur and (10) flotation sulfur dust and "Mike" sulfur in combination with pruning. The ineffective treatments are (1) commercial Bordeaux, (2) instant Bordeaux, (3) Z-0, (4) Z-0 in combination with pruning, (5) dry wettable flotation sulfur, (6) dormant and summer sulfur sprays and (7) dormant and summer sulfur sprays in combination with pruning.

It is shown in this report, as in previous reports, that most of the effective treatments involve either pruning or sulfur dusting. In addition, this report shows that two other treatments are effective, namely, spraying with Koloform and spraying with "Mike" sulfur.

Pruning, in most experiments, has shown a beneficial effect. But our experimental work has demonstrated that pruning does not always prevent the further development of disease. When, however, all diseased and discolored wood was removed, further progress of disease did not become evident for two or more years. In the trees in which disease recurred, it appeared that reinfection had taken place and that the disease was not a continuation of the original infection. In most of the pruned trees from which all of the discolored wood was not removed, disease continued to develop year after year. Pruning, when used in combination with instant Bordeaux, Koloform and the sulfur dusts, consistently increased the effectiveness of these treatments.

Fig.1.--Comparative degrees of disease control (+) and lack of control (-) obtained with various treatments of elms in nursery plots.

TABLE 8.--Recapitulation of the data to show the effectiveness of treatment on the occurrence of disease in nursery elms.

Treatment	Number of Groups of Test Trees Used	Total Number of Trees in Test Groups	Percentage of Control (+) or Lack of Control (-)		
			Least	Greatest	Average
<u>Pruning</u>	5	926	- 75.9	+ 47.0	+ 0.2*
<u>Sulfur Dusts</u>					
Kolodust.	1	235	....	+ 12.6	+ 12.6
Kolodust and pruning.	1	201	....	+ 35.5	+ 35.5
"Mike" sulfur (2 years), flotation sulfur (2 years).	1	253	....	+ 30.6	+ 30.6
"Mike" sulfur (2 years), flotation sulfur (2 years) and pruning	1	222	....	+ 45.9	+ 45.9
<u>Sulfur Sprays</u>					
Dry wettable flotation sulfur	1	474	- 14.2	....	- 14.2
Koloform.	1	236	....	+ 8.5	+ 8.5
Koloform and pruning.	1	230	....	+ 10.1	+ 10.1
"Mike" sulfur	1	100	....	+ 92.3	+ 92.3
"Mike" sulfur and pruning . .	1	100	....	+ 46.2	+ 46.2
Lime sulfur dormant and sulfur sprays	2	278	- 41.4	- 30.0	- 35.6*
Lime sulfur dormant, sulfur sprays (summer) and pruning	2	283	- 72.4	- 27.6	- 50.0*
<u>Copper Sprays</u>					
Commercial Bordeaux	1	474	- 9.1	....	- 9.1
Instant Bordeaux.	1	178	- 20.4	....	- 20.4
Instant Bordeaux and pruning.	1	186	....	+ 46.9	+ 46.9
Z-0	1	143	- 13.8	....	- 13.8
Z-0 and pruning	1	133	- 13.8	....	- 13.8

* These averages were obtained by weighting data from individual groups in proportion to the number of trees in the groups.

Although the results given in this report have not been consistent in every respect with those given in previous reports, they agree in attributing to sulfur dusts the most uniform effectiveness in preventing new infections. The effectiveness of these dusts was greatly increased when they were applied in combination with pruning.

The use of copper and sulfur fungicides on nursery elms stimulates growth and especially the rate of diameter enlargement. These fungicides, when they are properly applied, also will control foliage diseases.

RECOMMENDATIONS

The growing of American elms involves two distinct problems in disease control. One is prevention of the leafspot and anthracnose diseases which recur annually and injure leaves and new growth more or less severely according to weather. The other is prevention and treatment of the group of destructive diseases known as wilts, which invade the interior of the tree and eventually result in the death of the tree.

CONTROL OF LEAF DISEASES.--Since elms are only retarded in growth by the attack of leaf diseases, control of those diseases has not generally been attempted. But the estimates given in this report, as well as those given in a previous one, indicate that considerable increases in growth and sale value can be obtained if spraying or dusting programs are followed which bring the leaf diseases under control.

For this purpose any of the sprays or dusts named herein are effective. Where this type of disease constitutes the chief problem, it is necessary to make only summer applications of fungicides. Dormant applications are likely to have little direct beneficial effect. It is important that spraying or dusting be done at relatively frequent intervals, so as to furnish protection continuously to the growing shoots and new leaves.

CONTROL OF WILT DISEASES.--Several of the treatments reported upon above have given control of wilt diseases to the extent of 30 per cent or more in comparison with lack of treatment in check groups of trees. These treatments, we believe, have practical value and may be used where the control of wilt diseases is the major problem. They are as follows:

1. Summer dusting with Kolodust, and pruning.
2. Summer dusting with sulfurs such as flotation sulfur dust and "Mike" sulfur, with or without pruning.
3. Dormant and summer spraying with instant Bordeaux, and pruning.
4. Summer spraying with "Mike" sulfur, and pruning.

In general, it appears advisable to rely on sulfur dusts, since they have given the most consistent results over a period of years of experimental tests.

The use of sprays for wilt should be avoided, generally, as for some reason most of them appear to favor development of greater numbers of wilt infections or, at best, give only a small degree of control. An exception is Bordeaux when combined with pruning, and a possible exception is "Mike" sulfur with or without pruning. Bordeaux combined with pruning is likely to be as effective as any of the sulfur dust treatments. Although "Mike" sulfur spray seems to have exceptional possibilities, the two years through which it has been tested are not sufficient to prove its full value.

Pruning, although not uniformly dependable as an individual means of disease control, is essential if best results are to be obtained from the use of most of the effective fungicides. Pruning in connection with disease control, it should be understood, is more than the usual shaping of the growth habit of the tree. Its purpose is to remove completely all infected material, even to the extent of the destruction of an entire tree when needful.

In order to obtain satisfactory results with the treatments recommended above, it is necessary to follow a consistent schedule in the application of the fungicides, to use them in effective concentrations and, in pruning to carry out the operation faithfully.

SCHEDULES FOR TREATMENT.--Dormant sprays may be applied at the grower's convenience. It is desirable that two such sprays be used. The first application should be made shortly after the beginning of the dormant period and the second should be made near the close of the dormant period. Since these are in the nature of "clean-up" treatments, their effectiveness is probably increased by the higher fall and early spring temperatures.

During the summer, the sprays or dusts used should be applied at regular intervals. The first application should be made as soon as the first leaves are well grown. The time of this first application will of course vary from season to season. Applications should then be made at two-week intervals through June or, if the weather continues moist, until mid-July. During July and August the period between applications may ordinarily be lengthened to three weeks.

Pruning for disease control is best done just before each of the periodic applications of fungicides. If pruning is done immediately preceding each spraying, a regular schedule is maintained and trees are freed of infection before being treated. Naturally, better results follow.

SULFUR DUSTS.--Sulfur dusts are used in the form in which they are received. No diluting or mixing with other materials is required. Dusts can be applied with either hand- or power-driven dusters, depending on the size of the trees to be cared for. Hand-power dusters send a satisfactory dust cloud to a height of only about 10 feet beyond the duster nozzle. Trees over 15 feet tall should be dusted with a power duster.

Preferably, dusting should be done in early morning while there still is dew on the foliage and before the wind becomes strong, but it may also be done after a light rain, while the foliage is still damp.

SULFUR SPRAYS.--In the preparation of sulfur sprays fine wettable sulfur dusts are mixed directly with water in the spray tank. Directions as to the amount of dust needed for an effective spray usually are given on the manufacturer's package or label. Kolofom, which is recommended above, should be mixed with water at the rate of 15 pounds per 100 gallons. "Mike" sulfur, also recommended, should be used at the rate of 8 pounds per 100 gallons. A good, even distribution of the dust in the water results from a few minutes' operation of the agitator in the spray tank before spraying is begun.

INSTANT BORDEAUX.--Instant Bordeaux equivalent to the usual 4-4-50 Bordeaux mixture is desirable. For this strength 8 pounds of powdered blue vitriol (copper sulfate) and 8 pounds of superfine hydrated lime are required for each 100 gallons of water. In the preparation of the mixture, about one-fourth the required amount of water is run into the spray tank and then the blue vitriol powder, and afterwards the lime, are washed through the intake strainer as the tank is filled. A minute's operation of the agitator in the spray tank before spraying is begun gives all the mixing that is necessary.

PRUNING.--The effectiveness of pruning, whether used alone or in conjunction with other treatments, is dependent on the thoroughness with which it is done. In pruning for disease control, it is absolutely necessary that all wood containing discolorations be removed, and it is best to continue cutting back until a foot or more of clean, healthy wood has been removed below the part which is diseased. Sterility of the pruning instruments is essential to prevent spread of disease during the operation. It is better to cut out too much than too little.