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Evaluation of Fungicides for Control of Fruit Diseases

University of Tennessee Agricultural Experiment Station

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Many new fungicides and changed formulas became available to fruit growers within recent years. Because of this fact, plant pathologists of the Agricultural Experiment Station gave increased emphasis to testing of fungicides during the period 1950-1955. The objective of the testing project was to determine the economy and effectiveness of new materials in comparison with older and commonly-used fungicides. The tests were conducted in the vicinity of Jackson, Tennessee, utilizing blocks of trees available in commercial plantings. The data obtained from these disease control investigations, for the period specified, are reported herein.

These studies made it necessary to evaluate scores of chemicals and combinations not in general use. Obviously, several of the materials were found to be of little value in disease control. Others, however, showed varying degrees of value; and investigations will be continued with the materials showing most promise. Recommendations for growers are given in the Tennessee spray schedules published annually by a committee representing the Departments of Entomology, Horticulture, and Plant Pathology (3).

APPLE FUNGICIDE TESTS

The timing of spray applications has been published for Tennessee and the schedule has been generally accepted by commercial growers for several years (2, 7, 9, 10). Materials formerly used have not been entirely satisfactory but some new compounds offer promise of better fruit finish, more effective disease control, and greater economy. Tests initiated in 1952 included fungicides already on the market but which required careful testing under local conditions, with particular attention to control of scab, cedar rusts, blossom blight, frog eye, and bitter rot. Considerable exploratory work has been done in addition to the work herein reported, as well as studies in conference with the workers of the Mid-West. These findings are embodied in Table 1, modified to Tennessee conditions.

Tests in 1952

Five combinations were used in the pre-bloom and early cover sprays, with 1-3-50 Bordeaux applied to all treatments in the bloom. Modifications were made beginning with the second cover.

Materials with Rates per 100 Gallons

Through first cover		Beginning second cover	
1. Crag 341	1½ lbs.	Ferbam (76%)	2 lbs.
2. Orthocide 406	2 lbs.	Orthocide 406	2 lbs.
3. Velsicol 46	1½ pts.	Phygon	2 lbs.
4. Ferbam (76%)	½ lb.	Ferbam (76%)	2 lbs.
Sulfur	6 lbs.		
5. Kolofog	8 lbs.	Kolofog	2 lbs.
		Ferbam (76%)	1½ lbs.

Applications were made: Pre-pink, April 3; pink, April 11; full bloom, Golden Delicious, April 20; Red Delicious, April 23; Stayman, April 27; petal fall, May 1; first cover, May 8; second cover, May 17; third cover, May 30; fourth cover, June 13; fifth cover, June 28.

Data were obtained by picking 500 to 600 leaves per tree—5 Red Delicious and 5 Golden Delicious per plot. These were then divided into classes based on lesions per leaf, and calculations were based upon the different classes. Unsprayed checks were not available in the commercial orchard used in this test. Some variation was noted in disease incidence among varieties, but differences were not significant. The data represent total counts of both.

Results. Scab on fruit was negligible, bitter rot was not present, nor was fire blight of any consequence. No records were made of these diseases.

Foliage diseases were of moderate severity and a relative comparison of control by the different fungicides was possible as reflected in the data. The differences for scab were not significant. Cedar rust and frog-eye showed significant variation among treatments.

Finish of fruit was superior following the use of sulfur and Orthocide 406. Phygon was phytotoxic. Although the other materials did not cause serious damage, they did not provide good finish.

TABLE 1—*Disease Attacking Apple and Fungicides Suggested for Control.*
(Not in order of effectiveness).

Disease	Fungicide, rate per 100 gal.	Remarks
Bitter rot (*Glomerella cingulata*)	Captan (50%) 2 lbs. Ferbam (76%) 1½ to 2 lbs. Bordeaux 4-8-100	Prompt removal of diseased fruits essential.
Black rot and frog eye leafspot (*Physalospora obtusa*)	Ferbam (76%) 1 to 1½ lbs. Captan (50%) 2 lbs. Zineb (75%) 2 lbs.	Removal of dead twigs and sanitation as important as chemical treatment.
Black pox (*Helminthosporium papulosum*)	Captan (50%) 1½ to 2 lbs.	Bark cankers difficult to control.
Blotch (*Phyllosticta solitaria*)	Ferbam (76%) 1½ lbs. Captan (50%) 2 lbs.	
Botryosphaeria fruit rot (*Botryosphaeria ribis*)	Captan (50%) 1 to 1½ lbs.	No completely satisfactory control. Removal of dead twigs and prunings is very important.
Brooks spot (*Mycosphaerella pomi*)	Ferbam (76%) 1 lb. Zineb (75%) 1½ lbs. Captan (50%) 1½ lbs.	Not common in all orchards.
Rusts: cedar-apple, quince, and hawthorn (*Gymnosporangium juniperi-virginianae, G. clavipes,* and *G. globosum*)	Ferbam (76%) 1 to 1½ lbs. Ferbam (76%) ½ lb. plus other fungicide ½ strength Zineb (75%) ½ lb. plus other fungicide ½ strength Zineb (75%) 1½ lbs.	Actidione 100 p.p.m. reported to control rust on red cedar.
Fire blight (*Erwinia Amylovora*)	Bordeaux ½-2-100 Zineb (65%) 2 lbs. Streptomycin 50 to 100 p.p.m.	Remove cankers on young trees.
Fly speck (*Microthyriella pomi*) and (*Glocodes pomigena*) Sooty blotch	Captan (50%) 1 to 2 lbs. Ferbam (76%) 1 to 1½ lbs. Glyodin (34%) 1 qt. Zineb (75%) 1½ lbs.	
Scab (*Venturia inaequalis*)	1. Wettable sulfur 6 to 8 lbs. 2. Captan (50%) 2 lbs. 3. Phenyl mercury at manufacturer's recommendation. 4. Glyodin (34%) 1 qt. 5. Liquid lime-sulfur 2 gal. 6. Dichlone (50%) ½ lb. 7. Zineb (75%) 2 lbs.	1. May cause scorch in hot weather 3. May be combined at half-strength with 2, 4, or 7. 4. Excellent eradicant. Do not use after 1st cover. 6. Do not use in post-bloom sprays.

Disease	Fungicide, rate per 100 gal.	Remarks
Bitter pit or stippen	None applicable	Balanced fertilizers may reduce injury. More severe on large fruit.
Jonathan spot	None applicable	Avoid long storage period.
Apple measles		Maintain soil near pH 6.5.

TABLE 2—*Incidence of Disease on Leaves*, 1952.

Materials	Percentage lesions			
	None	Cedar Rusts	Scab	Frog eye
Ferbam + sulfur	68.9	3.1	5.3	23.2
Ferbam + glyodin	79.7	4.0	2.2	15.6
Sulfur (Kolofog)	65.8	5.4	10.6	18.5
Phygon + Velsicol	52.7	21.4	6.2	24.9
Orthocide 406	47.3	10.3	11.8	32.7
L.S.D. (5%)	7.0	Not Sign't	Not Sign't	11.8

Tests in 1953

For this experiment a solid block of Golden Delicious apples was obtained. The orchard had not been sprayed for several years, was adjacent to cedars, and afforded good opportunity for studying cedar rust and fire blight. The plan of the experiment provided for several fungicides to be used in the pre-bloom, calyx, and first cover sprays, followed by a single material for the later cover sprays. Special treatments were made for bloom applications, including zineb as a substitute for Bordeaux since it would control blight (5); and, being a carbamate, it probably would afford control of cedar rust.

Materials With Rates Per 100 Gallons

(Through First Cover Except Bloom)

1. Sulfur 6 lbs. + ferbam (76%) ½ lb.
2. Crag 341, 2 lbs.
3. Captan (50%) 2 lbs.
4. Zineb (65%) 2 lbs.

(bloom sprays)

Bordeaux 1-3-100

Zineb (65%) 2 lbs. per 100 gallons.

Due to difficulties in application of the pre-bloom sprays only the pink was applied.

Data for the 1953 tests pertained only to cedar rust and scab, the incidence of other diseases being very low with no significant differences among treatments. Counts were taken in August on foliage only, by taking 10 samples per tree with approximately 60 leaves in each sample. Since the lesions per leaf were uniformly 3 to 5, presence or absence alone was recorded and expressed in percentage. Four replicates were used per treatment, consisting of single trees each.

TABLE 3—*Disease Incidence on Leaves*, 1953

Materials—except bloom where zineb was used	Percentage diseased leaves	
	Cedar rusts	Scab
Ferbam + sulfur	4.2	2.2
Crag 341	6.0	1.9
Zineb	3.7	2.4
Captan	8.9	2.0
Unsprayed check	44.6	9.8
L.S.D. (5%)	10.7	5.2

Results—There were no significant differences among materials, all showing marked reduction in cedar rust, and, to a lesser extent, scab. This is attributed in large measure to the zineb employed during the bloom period since the principal discharge of spores occurred during this period of some 2 to 3 weeks. Observational records showed trees sprayed with Bordeaux for another experiment had a much heavier infection of cedar rust. It should be noted that only the pre-pink could be applied this year prior to bloom and the two zineb bloom sprays probably masked any differences in control by the other materials.

Differences were noted in condition of foliage and finish of fruit this season. Captan and zineb held damage to the minimum, and gave the best finish, with Crag 341 next best. Ferbam gave the poorest finish.

Tests in 1954

The same block of Golden Delicious apples used previously served for the experiments this season, and the same schedule and plan again were followed. Materials were slightly changed to include some fungicides that had just appeared, particularly a streptomycin formulation that had shown promies for fire blight control. Randomized plots consisted of two trees for each treatment with the different fungicides except the bloom sprays. Four replications were made. The bloom spray was imposed on

the main test to determine (a) relative control of blossom blight by Agrimycin and zineb, (b) scab control by a fungicide during the bloom period, (c) cedar rust control during this period. All treatments were split—one-half using Agrimycin at 100 p.p.m., and one-half with zineb, 2 lbs. per 100 gallons. All spraying was done with 1X concentration, using hydraulic equipment.

Applications were made: Pink bud, March 19; blossom 1, April 5; blossom 2, April 10; petal fall, April 19; first cover, May 4; second cover, May 17; third cover, May 31; fourth cover, June 12; fifth cover, June 23.

Seasonal conditions: On the whole, dry weather was more severe in West Tennessee than in the eastern part of the state, although the early season was similar in both areas.

Conditions were favorable for apple scab, frog eye, cedar rust, and blossom blight. They were unfavorable for the fruit rots of mid-to-late summer, hence no data are available on these diseases for this period.

Materials and Rates per 100 Gallons:

Glyodin, 1 pt. + TAG, ¼ pt.
Sulfur, 6 lbs.; ferbam (76%), ½ lb.
Captan, 2 lbs.
Panogen, ¼ pt.
Vancide, 2 lbs.
Zineb, 2 lbs.
Agrimycin 100, 265 grams.

In determining the intensity of blossom blight the total clusters per tree were estimated by counting tree segments, after which the diseased clusters were counted on the entire tree. This method was necessitated by the great number of clusters per tree which was in excess of 5,000. Leaf counts for rust were made from samples of 100 to 200 leaves per tree, picked at random. The samples were then classed and percentages determined on the basis of lesions per leaf. Fruit was classed according to scab lesions per fruit.

Incidence of Blossom Blight, 1954

Treatment	Percentage of diseased clusters
Zineb	0.6
Agrimycin	0.2
Check (no treatment)	3.8
L.S.D. (1%)	1.7

Per Cent Cedar Rust Lesions Per Leaf, 1954

Pink, calyx, first cover	Bloom sprays	
	Zineb	Agrimycin
Glyodin	1.1	1.8
Sulfur - ferbam	.6	1.5
Captan	.6	1.5
Panogen	1.5	4.0
Vancide	.3	.7
Check - none	1.4	3.3
L.S.D. (5%)	0.8	1.0

Results—During this season the most serious diseases of apples were cedar rust and scab. While not an epidemic, fire blight was of some consequence. Of the materials tested, the carbamates were conspicuous in rust control, captan and glyodin for scab, and streptomycin for fire blight. The season was somewhat atypical in that the pre-bloom period came on so rapidly that only one application was made; whereas, the blooming period, which prevented the application of customary sprays for scab, was nearly three weeks. Accordingly, the zineb applied during bloom for fire blight played an important role at the same time for rust control and gave some scab protection. Although not as effective as the antibiotic, it afforded a measureable control of fire blight. It, therefore, offers a practical means of reducing the incidence where blight is not in epidemic proportions. The incidence of frog-eye was reduced by all fungicides, despite the fact that fungicide effectiveness is reduced in an orchard with a great deal of dead wood, such as this one. Following the first cover, the unprecendented drought of 1954 began and fruit rots and midsummer diseases were of no consequence.

Conclusions From the Three Seasons' Tests With Apples

All results confirmed previous findings: That the timing of spray applications as now given in current recommendations is satisfactory. However, modifications can be made for greater economy where advantage is taken of varietal resistance especially in seasons when climatic conditions do not favor certain diseases. This requires a comprehensive understanding of the likelihood of disease attack, based on anticipated weather and previous history of the orchard. The use of eradicant fungicides has enabled post infection sprays to be effective in some cases, particularly apple scab.

Of the older fungicides, lime-sulfur and Bordeaux have very limited usefulness when their phytotoxicity is considered. Ferbam

is very effective for cedar rust and bitter rot, but does not give good control of scab, and it causes russeting on Golden Delicious. It can be utilized at a reduced concentration in the early sprays for rust where other compatible fungicides are employed for scab control.

Captan was the one fungicide giving best control of most diseases, but it is ineffective for rust and sooty blotch. Where these diseases are prevalent other materials must be used. Zineb was the best supplementary fungicide for this purpose. When employed during the blooming period no damage was observed and the incidence of rust was greatly reduced. Significant reduction in blight was obtained at the same time, although the best blight control was provided by streptomycin. Where blight is a serious factor, streptomycin has a definite place in the spray program.

The mercury-glyodin combination was quite satisfactory for early season sprays but the finish was not good. Its low cost, however, lends itself to the production of fruit for processing, where highest finish is not required. Under most local conditions it would not be first preference.

Diclone was phytotoxic. It was discarded in the course of the experiments. Panogen was so injurious to fruit that it was dropped. Vancide gave good control but it was not of sufficient superiority to justify further confusing an already complicated schedule. Recapitulating, the following materials should give good performance in Tennessee: Captan, zineb, organic mercury-glyodin, ferbam, sulfur, and, to a limited extent, liquid lime-sulfur; and Bordeaux mixture.

PEACH FUNGICIDE TESTS

The time of application of fungicides for peach diseases, as with apples, has been fairly well established (8). Therefore, the object of these tests was the determination of advantageous use of new chemicals. A succession of late freezes invalidated the test program by restricting the data to 1953, but the information obtained coincided with that of other states and previous work here. Practically all the effort was toward brown rot and scab control, the latter having become comparatively serious in recent years.

Recent work by Dunegan (4) and other workers has shown the value of early applications for brown rot control. Scab appears

from 4 to 6 weeks after initial fruit infection, according to studies by Keitt (6) in 1917. Twig lesions were examined on the March 1, 1956, with the peach scab fungus well advanced. Notwithstanding the trend toward early fungicide applications practiced in recent years, scab has become of considerable importance, indicating the conceivable need for post harvest applications to reduce the incidence of twig cankers—the means whereby the organism is carried over to another season. This point needs further study as a practical measure under conditions faced by fruit growers in Tennessee.

Three peach varieties were used with a slight variation in harvest date, the data being taken at ripening. Three materials were tested—glyodin 1 qt.; captan 2 lbs.; sulfur 8 lbs., per 100 gallons. Applications were made: Pre-pink, March 5; full bloom, March 13; petal fall, March 19; shuck split, March 29; and 6 cover sprays.

Results—For grading, the peaches were sorted into five classes: No spots per fruit; 1 to 5 spots per fruit; 6 to 10 spots per fruit; and 11 to 20 spots per fruit. The results from replicated plots are given in Table 4.

TABLE 4—*Average Percentage Peach Scab by Classes.*

Materials for 100 gallons	Percentage of scab classes				
	None	1-5 spots	6-10 spots	11-20 spots	Over 20
Captan 2 lbs.	17.7	24.1	47.1	6.6	5.1
Glyodin 1 qt.	1.1	6.9	36.1	30.0	25.7
Sulfur 8 lbs.	69.0	16.3	9.6	2.8	2.6

From these tests it was found that glyodin gave insufficient control, captan gave good commercial control, and sulfur gave the most clean fruit. There was so little brown rot in the orchard that no data were obtainable.

ALL-PURPOSE SPRAY SCHEDULE

There is considerable interest in spraying mixed plantings of a few trees or vines without consideration of efficiency, cost, or finish. Such plantings may be found in home orchards, or city lots, and a few gallons of spray will suffice. Usually in such instances there are several varieties of each kind of fruit and the blooming dates extend over a wide range. Hence, there is no way to time spray applications effectively except in a general

way. This problem has been studied for many years with only fair success. However, the advent of newer fungicides and insecticides that may be effectively applied to several kinds of fruits without injury has made a satisfactory combination appear more promising. Preliminary studies had been made prior to 1954. In that year an experiment was set up specifically to test three combinations. After reviewing blooming dates for several years it was decided that the following was the most likely sequence and correlation among the fruits selected for test:

Timing

Apples	Peaches Plums Cherries	Grapes
Pre-pink	Pre-bloom	Shoots 4" - 6" long
Pink bud	Petal fall	Pre-bloom
Calyx or petal fall	Shuck split	After bloom
First cover	Two weeks later	Pea size grapes

Mixtures

	For 100 gallons
1. Fermate	2 lbs.
Wettable sulfur	6 lbs.
Lead arsenate	3 lbs.
DDT (50%)	2 lbs.
2. Methoxychlor	2 lbs.
Malathion (25%)	2½ lbs.
Captan (50%)	2 lbs.
3. Zineb	2 lbs.
Malathion	2½ lbs.
Methoxychlor	2 lbs.
4. Check	None

Results—The cherries and plums were injured by freeze, hence no records were made. Grapes were not satisfactory for data but apples and peaches provided some information. Data are from 2-tree plots.

It has been found that zineb and malathion have a short shelf-life when stored, hence a mixture containing these materials is not desirable if not used shortly after preparing. Later tests have shown that captan is a very good fungicide for grapes,

TABLE 5—*Incidence of Peach Scab and Brown Rot Under All-Purpose Spray Schedule.*

Class	Scab—percentage			Brown rot—percentage		
	Mix. 1	Mix. 2	Mix. 3	Mix. 1	Mix. 2	Mix. 3
Clean	33.5	32.6	0.7	89.2	93.2	94.8
Useable	66.4	67.0	72.4			
Culls	0	0.3	26.7	10.8	6.7	5.1

Unsprayed trees were virtually a total loss.

TABLE 6—*Incidence of Apple Scab Under All-Purpose Schedule.*

Variety and Class	Fruit scab—percentage			Leaf scab—percentage		
	Mix. 1	Mix. 2	Mix. 3	Mix. 1	Mix. 2	Mix. 3
Red Delicious						
Clean	52.1	42.3	52.0	63.1	62.7	79.0
Trace	43.4	40.5	40.8	13.7	19.2	10.2
Severe	4.3	17.1	7.1	23.0	18.0	10.7
Winesap						
Clean	80.6	76.0	66.0	64.2	71.0	69.0
Trace	17.7	23.0	30.0	15.7	12.2	9.8
Severe	1.6	0.8	4.0	20.0	16.9	21.1
Golden Delicious						
Clean	95.0	97.3	93.5	97.4	96.8	96.9
Trace	4.9	2.6	6.4	2.5	2.5	2.4
Severe	0	0	0	0	0.6	0.6

whereas mixtures including sulfur cause serious injury. Where an all-purpose fruit mixture is required, either Mixture 1 or 2 will serve with the exceptions noted. The information obtained by these experiments is published for general use in a recent Agricultural Extension Service circular (1).

RESIDUES

No attempt was made to analyze fruit for residual chemicals. Henceforth this must be carefully considered in any spray program. A brief consideration of Federal legislation is apropos since it has a direct bearing on the application of any fungicide data to practical problems.

A Federal law became effective in June, 1954, regulating the amount of certain chemicals that would be permitted on any raw fruit or vegetables offered for sale. The bill, popularly known as the "Miller Bill", required all manufacturers or formulators first to show the necessity for their product, then to prove what pests it would control and at what rates, before they could obtain a label and sell the product. Tolerances were then established and experiments made to determine, on the average, the necessary

time prior to harvest for natural attrition to reduce the amount of residue to an allowable margin. Furthermore, insecticides and fungicides are additive when both are applied; and on chemical analysis they appear as a total. It is imperative, therefore, to have a selection among fungicides and insecticides so that if a high residue is approached some material may be selected that will not add to the amounts already present. For example, there are no restrictions on sulfur, hence, it could be used where practicable late in the season without being counted in the tolerance limit.

SUMMARY

The inorganic fungicides such as liquid lime sulfur, elemental sulfur, and copper compounds have been replaced in large measure by newer materials. The adaptability of these fungicides to local conditions must take into consideration the seasonal variation, finish of fruit desired, and prevalence of certain diseases.

Among the apple varieties grown in localized areas in Tennessee, blossom blight and cedar rust are of major importance. Also, scab, frog eye, and occasionally bitter rot are of varying importance. Sooty mold can become important. No single fungicide provided adequate protection against all diseases.

The best control of scab and frog-eye leafspot was obtained by use of captan, organic mercury, and glyodin. Zineb, and sulfur-ferbam, while not as reliable, afforded a significant reduction in disease. Captan provided the best finish.

Cedar rusts were not satisfactorily controlled by captan—ferbam and zineb being distinctly superior. Applications of zineb during the blossoming period when other fungicides were restricted gave marked reduction in rust.

Blossom blight incidence was greatly reduced by the use of streptomycin, 1-3-50 Bordeaux, and to a lesser extent by zineb.

It is recommended that a fungicide be selected that will most effectively and economically control the most serious disease in a given orchard, and that other fungicides be fitted into the schedule to supplement the weak spots left by the major fungicide selected.

Common peach diseases were controlled by both captan and elemental sulfur. For small plantings of fruit an all-purpose mixture provided fruit that could be utilized for home consumption although not of market quality.

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