THE INFLUENCE OF CERTAIN VARIATIONS IN THE APPLE SPRAYING SCHEDULE IN MICHIGAN ON LEAD AND ARSENIC RESIDUE ON THE FRUIT AND ON CERTAIN TYPES OF SPRAY INJURY

Thesis for the Degree of M. S.

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Thesis

Submitted to the faculty of the Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science

by
Russell George Hill
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Introduction

The history of studies relating to arsenical residues on fruit has been ably described by Herrick (1) who says "Some thirty years ago a severe epidemic of arsenic poisoning took place in England and Wales, when more than 6,000 persons were involved, including 70 deaths, through the consumption of beer containing small amounts of arsenic. The matter was investigated by a Royal Commission headed by Lord Kelvin. The investigations led the commission to recommend that no liquid used as food should contain more than .01 of a grain of arsenic per gallon and that no solid material used as food should contain more than .01 of a grain of soluble arsenic per pound of dry matter. This limit has been generally accepted by food authorities since that time, and it is now known as the "international tolerance" for arsenic in foods. Unfortunately, this is not the whole story. "The lead in the arsenate of arsenate of lead sprays is now considered as dangerous as the arsenic. Both are distinctly cumulative poisons."

Most fruit harvested from apple trees sprayed according to the commonly recommended schedules fail to come under the above tolerance. The problem then resolves itself into two phases: first, to find a substitute for lead arsenate which is its equal as an

insectide without injuring the host plant and which leaves no poisonous residue on the fruit, and second, to find satisfactory means to remove the residue from fruit that has been sprayed with lead arsenate to control all the broods of one of our most destructive apple pests-- the codling moth.

The Food and Drug Administration of the United States Government has set up certain regulations governing the tolerance of residue on food stuffs as follows (2):

Soluble Arsenic	-	.01 grain per pound of fruit
Soluble Fluorine	-	.01 grain per pound of fruit
Soluhle Lead	-	.018 grain per pound of fruit

Wharton (11) voiced the attitude of the Food and Drug Administration towards excessive residue in his speech to the Peninsular Horticulture Society when he said "I can state to you definitely and certainly that it is the serious intention of the Food and Drug Administration to effect seizures on lots of fruit in commerce which contain an excess of spray residue, and to prosecute the shippers thereof".

Historical

In reviewing the literature available on spray residue it becomes very apparent that [redacted] has been placed on the removal of spray residue than upon finding satisfactory substitutes for the sprays that produce the excess residue.

Bregger (3) states that "Probably the outstanding phase of the spray problem of today is the question of using lead arsenate. From the standpoint of pest control, this chemical is superior to all others now known. Because lead arsenate sticks well to the fruit and is a good insecticide it is also somewhate difficult to remove from the fruit when applied late and in large quanities. Increased pest problems requiring longer spray programs and meeting the federal regulations of a low arsenic and a new lead tolerance are presenting to the fruit grower a new situation."

Haller, Beaumont, and Cassil (4) state that "With the establishment of regulatory tolerance for lead many fruit growers throughout the East turned to substitute sprays for lead arsenate or to restricted programs. These efforts to avoid washing usually resulted in increased worm infestation and were found by experience to be uneconomic. This has caused a return to a more adequate program of lead arsenate sprays and the necessity of washing to remove excess residue." They concluded from their work that "fish oil or mineral oil might be added to the first two lead arsenate cover sprays without influencing the amount of residue at harvest. The results indicate that the addition of mineral oils, fish oil or casein-lime spreader increases the residue at harvest, particularly so in the case of mineral oil." Sherman (5) showed that "apples from plots sprayed with lead arsenate are well above the tolerance for both lead and arsenic, while apples from plots sprayed with zinc and calcium arsenates were well below in lead and near the tolerance in arsenic. The summer oil nicotine-sulphate, nicotine-sulphate-bentonite, cuprous cyanide, and Kalo oil schedules were below tolerance in both lead and arsenic." Yet he concludes that "Lead arsenate remains our most dependable weapon against codling moth. Because of its low cost, availability, stability, compatibility with necessary proven fungicides, and record of effectiveness over a long series of seasons with every diversity of climate, lead arsenate retains its prominence." In the question of moth control his experiments indicated that "Lead, zinc, and calcium arsenate rate in effectiveness in the order named". Rasmussen, Hutson, and Cation (8) state that "generally speaking lead arsenate may be used on winter varieties in petal-fall and first cover applications and zinc or calcium arsenate in the calyx, first and second cover applications without resulting in resulting in residues beyond present tolerances. The only effective material that can be recommended for the remainder of the season without causing excessive residue is summer oil emulsion and nicotine sulphate." According to Webster and Marshall (9) "the addition of mineral oil or fish oil increases deposit and improves coverage. Calcium arsenate with mineral oil resulted in high deposit and good control with practically no injury to foliage and no residue difficulty when acid washed".

Overly and Overholser (10) state that "the presence of moisture is probably the main contributing factor associated with arsenical injury on fruit. Many instances have been noted during the last six years and especially during the last season (1933) in both Yakima and Wenatchee districts where considerable fruit of different varieties, showed calyx end injury before the fruit was washed."

McLean (12) says "In view of our experience, I would make the following suggestions as a profitable solution of the spray residue problem. 1. For early varieties the use of lead arsenate up to and including the 17 day spray and the adoption of a suitable substitute for lead arsenate in all subsequent sprays. 2. For late varieties the use of lead arsenate in all sprays and washing of the fruit when necessary". Brinton (13) sums up the work done in Delaware by saying "I believe the experience of these growers in Delaware are typical of what must be expected by the apple growers in the near future. The tolerance is going to be lowered; more lead arsenate must be put on to get marketable fruit; and residue remaining at harvest time must be removed before the fruit reaches the consumer".

The residue situation in Ohio is summarized by Holland (14) who compiled the following data showing the effect of certain spray schedules on the amount of arsenical residue on two varieties of apples.

	Residue - Gr. Per Lb.	
	Grimes	Jonathan
Standard Schedule	.01 - .008	.011 - .009
" " + lime	.007	.006 - .01
" " + lime-fish oil	.007	
" " + fish oil	.001	
" " + fluxit	.02	
" " 3 sprays+2dusts	.011	.009

Standard Schedule:

Pre blossom sprays - No arsenate of lead

Petal fall spray - Lime-Sulphur 1 to 50; Arsenate of lead 3 lbs. to 100 gal. water;

Two weeks - Lime-Sulphur 1 to 50, Ars. of lead 3 to 100

Five weeks - " " " " " " " " 3 to 100

Seven " " " " " " " " " 2 to 100

Results - "Lime tends to reduce residue although further research is necessary". In New York, however, there existed in 1929 a somewhat different opinion. This is summed up by Streeter and Harman (15) who say "In conclusion, it may be said that apples grown in New York state are relatively free from arsenic. The results indicate that, except in unusual cases, the washing of apples grown under present conditions is unnecessary." Vinson (16) in Missouri has reported "as one would expect, the increase of lead and arsenic in the spray residue with and increase in the number of cover sprays. The great capacity of certain oils to cause lead to be retained on the surface of the fruit is brought out in these tables. Kolofog seems only a little less effective in causing retention of lead. On the other hand, the use of lime with lead arsenate even when Kolofog was also applied, is shown to generally reduce the residue of lead and arsenic and when used with calcium arsenate reduced the residue of arsenic." One fact brought out by Vinson which I have noted in my work is that "Inspection of the data discloses the fact that in some cases it was possible to reduce the arsenic content of the residue to, or near zero, at the same time the lead content remained appreciable."

Marshall and Ford (17) from their work in Indiana on Lead Arsenate versus Oil Sprays conclude "The plots with a lead arsenate schedule throughout the season showed a much higher residue at harvest and consistently poorer control than either of the plots with summer oil or summer oil and oleic acid to replace lead arsenate in the second and third brood sprays." Marshall also stated that "No fixed ratio exists in the weathering off of lead and arsenic on fruit". Diehl (18) believes that at the present time lead arsenate is the only material which can be used for adequate moth control. He says "Control of the codling moth has become essential in the production of marketable apples and pears in practically all deciduous-fruit districts of the United States, and thorough spraying with lead arsenate has been for many years the only accepted control method. Apples sprayed with lead arsenate bear at harvest time an arsenical residue, and this residue must be removed in the interest of public health".

In the matter of secondary interest Hartman, Robinson, and Zeller (19) say that "It now appears that arsenic injury may occur whenever apples that are coated with arsenical residue become wet either before or after picking".

In connection with this work an interesting statement is made by Percival and Potter (20) who say "It is shown definitely that the arsenic residue on the bottom one-third of the tree is approximately three times that found on fruits from the top third, and that the middle section is about the average. This fact would be of significance in case inspection of the crop was made from apples sampled from the trees". Weber and McLean (21) have shown that dusts substituted for late spray applications have proven very unsatisfactory.

In concluding this historical resume I believe that even though the literature herein discussed indicates that at the present there is no adequate substitute for lead arsenate in the spraying program to reduce residue and injury, additional research is likely to result in the discovery of such substitutes. Encouraging is the statement made by Headlee (22) of New Jersey who says "In general, it may be said that while washing of heavily sprayed fruit is a practicable matter there are many cases in which it would be much better to use some material other than arsenate which would destroy the codling moth and leave the fruit suitable for marketing. Two materials of this kind have been developed, one known as Pyrethrum White Oil and the other as Nicotine Tannate".

Objects of Experiments

The primary purpose of this study was to compare a series of spray combinations from the standpoint of the amount of residue remaining on the fruit after a schedule to control late broods of codling moth had been practiced. It was also planned to ascertain the effects, if any, of each of these combinations upon the fruit and upon the foliage.

Location of Experiments

The orchard in which the spray residue studies were made is located in Tuscola County, about thirty miles east of Saginaw and owned by R. L. Hill of Caro, Michigan.

Time of Experiments

This study was made during the spraying season for codling moth in 1935 and 1936.

Description of Orchard and Outline of Spray Plots

Approximately one-hundred trees from this orchard were divided into twelve plots, each one of which was treated with a different spray combination. The plots were located on the east side of a six-acre orchard, the trees of which are principally of the Red Delicious variety. The trees were twenty-one years old and in excellent growing condition. They have been lightly pruned each winter and scraped to remove loose bark under which the codling moth might complete its resting stage. The orchard is grown in sod and fertilized with commercial fertilizer in early spring and a straw mulch in early fall each year. Prior to these experiments they have been sprayed each spring with dormant strength oil emulsion to control the scale insects, given pre-blossom applications of lime-sulphur for scab, and lead arsenate plus lime for the control of codling moth. Insects and diseases have not been prevalent in the orchard for a number of years and the spray schedule has been one of prevention rather than one of cure.

Table 1 shows the arrangement of the plots in relation to each other and the varieties found in each plot.

x = Delicious

o = King David

* = Wilson Red June

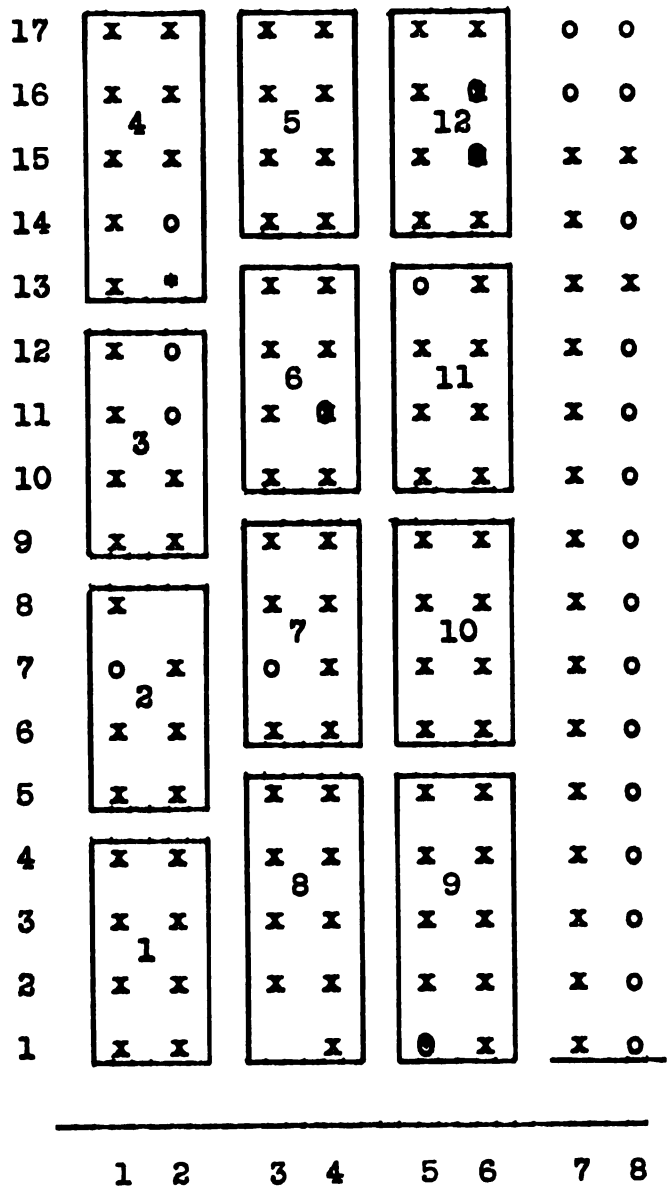
● = Early Raspberry

● = Winesap

Varieties and

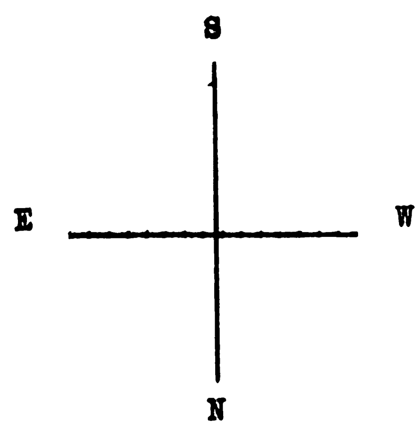
Plots

TABLE 1



Orchard Hills

Caro, Michigan



By R. G. Hill

Application of Spray Materials

Since the trees were not exceedingly large the sprays were applied with a four-nozzle broom gun. This was done from the ground in order to secure adequate coverage, especially on the inside of the trees. A pressure of between 400 and 450 pounds at the sprayer was maintained at all times. The average application per tree amounted to approximately 7½ gallons of solution.

At the beginning of these experiments the following order of mixing the spray ingredients was used: 1. Sulphate 2. Lime 3. Arsenate 4. Lime-Sulphur. The spray tank was filled with water and while the agitators were in motion the materials were added. The Sulphate, Lime, and Arsenate were mixed with water and put into a suspension before adding to the spray solution. Some difficulty was experienced at first in getting the Zinc Sulphate into solution and preventing heavy precipitates which followed. However, when the agitation in the tank was increased and the order of mixing changed to 1. Arsenate 2. Lime 3. Sulphate 4. Lime-Sulphur this difficulty was overcome.

Table 2 shows the spray schedule used on each plot both in 1935 and 1936.

SPRAY SCHEDULE USED ON PLOTS IN 1935 & 1936

TABLE 2

Plot	Spray	
1.	Lead Arsenate 3 lbs. to 100 gals. water	
2.	Lead Arsenate 3 - 100 Hydrated Lime 4 - 100	
3.	Calcium Arsenate 3 - 100 Hydrated Lime 4 - 100	
4.	Calcium Arsenate 3 - 100 Zinc Sulphate 4 - 100 Hydrated Lime 4 - 100	
5.	Calcium Arsenate 3 - 100 Iron Sulphate 4 - 100 Hydrated Lime 4 - 100	
6.	"Rex" Zinc Arsenate 3 - 100	
7.	Zinc Arsenate 3 - 100	
8.	Zinc Arsenate 3 - 100 Hydrated Lime 4 - 100	
9.	Zinc Arsenate 3 - 100 Zinc Sulphate 4 - 100 Hydrated Lime 4 - 100	
10.	Zinc Arsenate 3 - 100 Iron Sulphate 4 - 100 Hydrated Lime 4 - 100	
11.	Petal Fall@	
	First Cover	Lead Arsenate 3 - 100
	Second Cover	Calcium Arsenate 3 - 100 Zinc Sulphate 4 - 100 Lime 4 - 100
	Third Cover Fourth Cover Fifth Cover	Oil-Nicotine Oil 3/4 gallon Nicotine 3/4 pint
12.	Petal Fall@	
	First Cover	Lead Arsenate 3 - 100
	Second Cover	Kalo 3 - 100
	Third Cover	Oil Emulsion ½ gallon
	Fourth Cover	Kalo 3 - 100
	Fifth Cover	Kalo 3 - 100

TABLE 3

Lime Sulphur In Sprays

1935

Petal Fall— Added to all plots

First Cover— Added to plots 1-11-12 only

Second Cover— Added to all plots

Third Cover— Added two days prior to this spray

Fourth Cover— None

Fifth Cover— None

1936

Petal Fall— Added to all plots

First Cover— Added to all plots

None after first cover

Table 3 shows the Lime-Sulphur applications added to the regular spray schedule used in these experiments. The Lime-Sulphur was not put on as a separate application but was added to the rest of the spray materials being applied. In 1935, due to warm rainy weather after petal fall, the scab infections were exceedingly heavy, necessitating additional applications. Owing to its presence in the third cover I had to continue the Calcium Arsenate, Zinc Sulphate, Lime combination in Plot 11 instead of the Oil-Nicotine, as serious foliage injury has been known to occur when Oil-Nicotine was applied too soon after Lime-Sulphur.

TABLE 4

Dates of Applications

1935

Petal Fall-- June 4

First Cover-- June 13

Second Cover-- June 28

Third Cover-- July 13

Fourth Cover-- August 1

Fifth Cover-- August 18

1936

Petal Fall-- May 28

First Cover-- June 7

Second Cover-- June 19

Third Cover-- July 3

Fourth Cover-- July 20

Fifth Cover-- August 4

Sixth Cover-- August 17

In 1936 a sixth cover spray was necessary due to an extremely late brood of codling moth which threatened to damage the fruit. Shortly after this application heavy and continuous rains fell until picking time, causing considerable spray material to be washed off the apples.

Climatic Conditions At Time Of Application

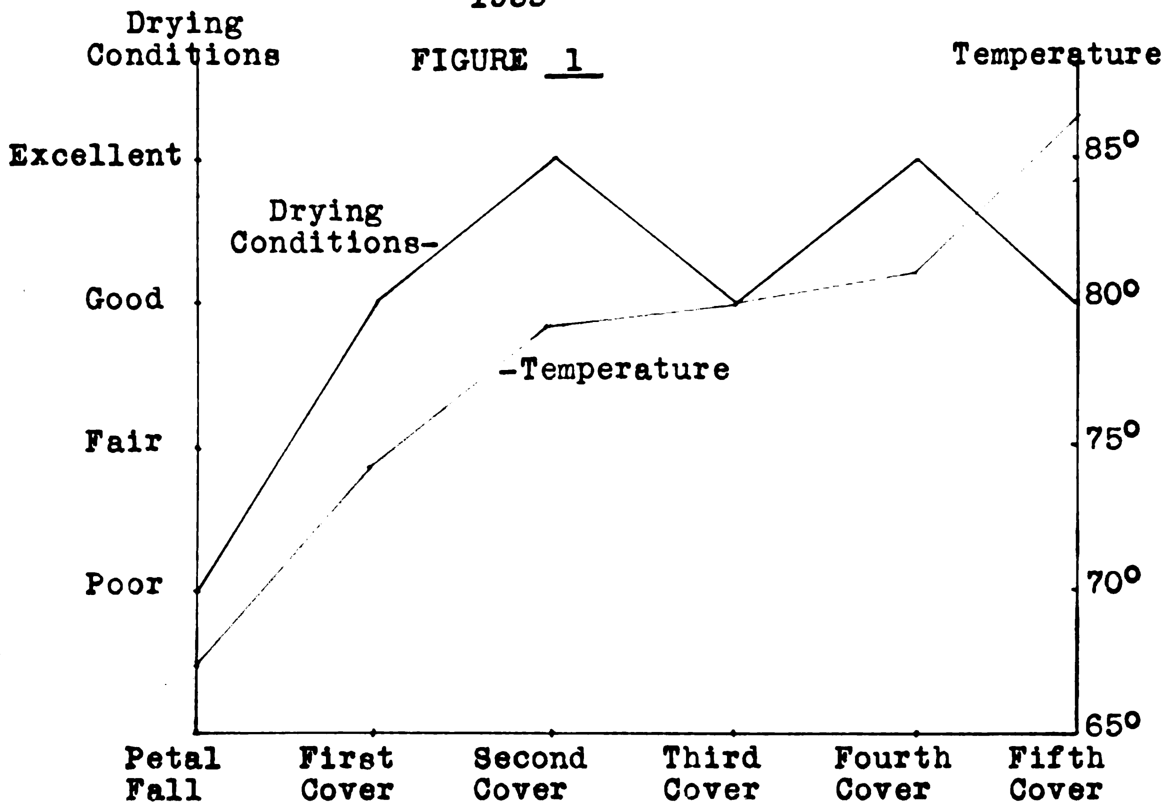
Figures 1 and 2 show the temperature and the drying conditions during the time the applications were made in 1935 and 1936, respectively.

By "Excellent" drying conditions is meant weather which causes rapid drying of the spray materials on the foliage, namely, high temperature, low humidity, and air movement. These situations considered as the ideal ranged down to "good", "fair" and finally to "poor" when atmospheric conditions were detrimental to good drying.

CLIMATIC CONDITIONS AT TIME OF APPLICATIONS

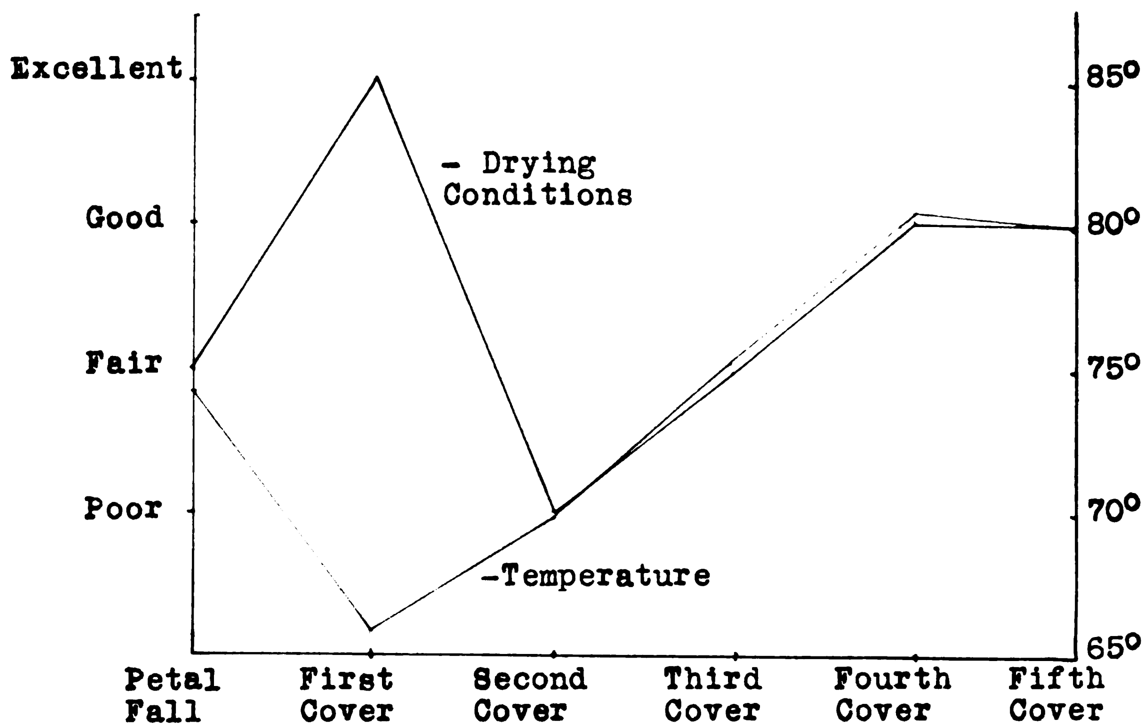
1935

FIGURE 1



1936

FIGURE 2



Amount of Residue

In selecting the fruit for residue determination uniform apples of from 2½ to 2¼ inches in diameter were collected at random from around the lower part of the trees where residue appeared to be the heaviest. Apples so hung that they rubbed against each other or against leaves or stems were avoided. Samples of 14 to 16 apples were collected from each plot in triplicate and put into ten pound paper bags. These samples were selected just prior to picking time. The average residue of the three samples was used as the final record.

TABLE 5 shows the soluble lead and arsenic residues remaining on the fruit when the determinations were made.

TABLE 5

AMOUNT OF ARSENICAL AND LEAD RESIDUE*

TREATMENTS		1935 gr./lb. Arsenic	1936 gr./lb. Arsenic	1935 gr./lb. Lead	1936 gr./lb. Lead
Lead Arsenate	3-100	.008	.004	.025	.035
Lead Arsenate	3-100	.006	.004	.025	.010
Hydrated Lime	4-100				
Calcium Arsenate	3-100	.007	.003	.001	.001
Hydrated Lime	4-100				
Calcium Arsenate	3-100	.006	.003	000	000
Zinc Sulphate	4-100				
Hydrated Lime	4-100				
Calcium Arsenate	3-100	.008	.002	000	000
Iron Sulphate	4-100				
Hydrated Lime	4-100				
"Rex"					
Zinc Arsenate	3-100	.008	.006	000	.001
Zinc Arsenate	3-100	.008	.007	000	.001
Zinc Arsenate	3-100	.009	.006	000	000
Hydrated Lime	4-100				
Zinc Arsenate	3-100	.007	.005	000	000
Zinc Sulphate	4-100				
Hydrated Lime	4-100				
Zinc Arsenate	3-100	.009	.007	.001	000
Iron Sulphate	4-100				
Hydrated Lime	4-100				
Cover Sprays					
1.Lead Arsenate	3-100	.007	.004	.002	.012
2.Calcium Arsenate	3-100				
Zinc Sulphate	4-100				
Lime	4-100				
3.Oil-Nicotine					
4. " "					
5. " "					
1.Lead Arsenate	3-100	.005	.004	.009	.015
2.Kalo	3-100				
3.Oil Emulsion					
4.Kalo	3-100				
5.Kalo	3-100				
Limits		.01		.018	

*Courtesy of Michigan State College Experiment Station Chemistry Staff

The residue results are quite obvious. Where the regular lead arsenate spray was applied during the entire season,in plots 1 and 2, it will be noted that, especially in 1935, the soluble lead remaining on the fruit far exceeded the tolerance limit set up by the government. The 1936 results were similar. Though the arsenic residue was not excessive in these experiments, it was too close to the limit to be passed by unnoticed. This was true of every spray combination, especially in 1935, where an arsenate was included in the spray. In both years the oil-nicotine and the oil-emulsion plots in the late brood applications showed a low arsenic residue in comparison to the other plots. One observation apparent in these data is the fact that while these plots show a lower arsenic residue there is very little difference in the lead remaining on the fruit. Whether this indicates that the lead is less soluble and thus is harder to remove from the apples is questionable. One reason for the lower residue on the fruit in 1936 was the extremely heavy rainfall occuring during September and October of that year. Yet here again there was an extremely heavy lead residue in those plots where lead arsenate alone formed either the entire spray or where it was used alone in the first brood sprays.

These results seem to indicate that if lead arsenate is to be used to control all the broods of codling moth then washing the fruit will be necessary. In each case the ~~fruit from~~ the calcium arsenate plots seemed to have about the least amount of arsenic residue. There was no codling moth damage in any part of the orchard either year regardless of spray treatment. This made it impossible to determine effectiveness of moth control.

LEAF INJURY

The following data (TABLE 6) show the injury to leaves caused by the indicated treatments. These leaf counts were made on four to five trees in each plot and branches were selected from all sides of the trees. Between 750 and 900 spurs were counted per plot. Spurs were selected for counting from two, three and four year old wood in each case.

TABLE 6 LEAVES PER SPUR

TREATMENTS	1935 Aug. 10	Sept. 15	Oct. 5	1936 Aug. 12	Sept. 15	Oct. 10
Lead Arsenate	4.5	4.3	3.5	4.8	3.9	3.4
Lead Arsenate Hydrated Lime	4.6	4.1	3.9	4.75	4.6	3.8
Calcium Arsenate Hydrated Lime	4.6	4.6	4.3	4.8	4.5	3.9
Calcium Arsenate Zinc Sulphate Hydrated Lime	4.3	4.3	3.9	4.6	4.58	3.9
Calcium Arsenate Iron Sulphate Hydrated Lime	4.6	4.3	4.3	4.2	3.6	3.1
"Rex" Zinc Arsenate	4.3	4.1	3.9	4.5	4.4	3.7
Zinc Arsenate	4.3	4.3	3.7	4.7	4.3	3.9
Zinc Arsenate Hydrated Lime	4.7	4.1	3.8	4.9	4.4	3.8
Zinc Arsenate Zinc Sulphate Hydrated Lime	3.75	3.73	3.5	3.9	3.7	3.35
Zinc Arsenate Iron Sulphate Hydrated Lime	4.1	4.0	3.9	4.0	3.0	2.45
Cover Sprays 1.Lead Arsenate 2.Calcium Arsenate Zinc Sulphate Lime 3.Oil-Nicotine 4. " " 5. " "	4.4	4.35	4.1	4.6	4.5	4.0
1.Lead Arsenate 2.Kalo 3.Oil Emulsion 4.Kalo 5.Kalo	4.4	4.4	4.1	4.59	4.3	4.1

Upon looking over these data there is an indication that in the plots where lead arsenate was used continuously for moth control there was the greatest amount of leaf injury. This condition appeared in both the 1935 and 1936 leaf counts, although there was not sufficient difference to warrant reaching a definite conclusion. The foliage of the trees on which zinc sulphate was used maintained the best color. This was indicated by deep dark green leaves and little or no arsenical injury. One significant condition which manifested itself was the extreme defoliation in 1936 of the plot on which zinc arsenate, iron sulphate and lime was used. This condition became noticeable around September 1st. The foliage looked and felt dry, the edges turned up and finally the leaves dropped off. This continued to the point where by the time the other trees in the orchard started normal defoliation the trees in this plot had scarcely a leaf remaining. This condition resulted in dwarfing the fruit. Two hundred apples were picked at random from this plot and two hundred apples from a similar plot where zinc sulphate was substituted for the iron sulphate. The average diameter of the apples in the iron sulphate plots was 1 15/16 inches while the diameter of the apples in plot 9 was 2 3/16 inches. I believe that this condition showed up more prominently in 1936 due to the fact that the apples made a major part of their growth after the heavy September rains. The plots on which oil was used in the late brood applications showed very little injury and maintained excellent color and appearance until normal leaf fall.

Dutton (7) states in his Spray Injury studies that "the size of the fruit may be affected unfavorably by serious foliage injury."

Blossom End Injury and Russeting

An effort was made to determine the effect, if any, these spray combinations had upon blossom end injury and upon russeting. In observing fruit injury three bushel samples from each plot were picked at random from the outside of the trees. These apples were sorted and classified as to russet or as to blossom end injury. The apples were considered as russeted if they showed enough lesions to be readily detected, since the chief disadvantage of such a condition is its influence on the salability of that fruit. The effects of these sprays upon the fruit are shown in the following figures:

FIGURE 3

PERCENT OF RUSSETING

1935

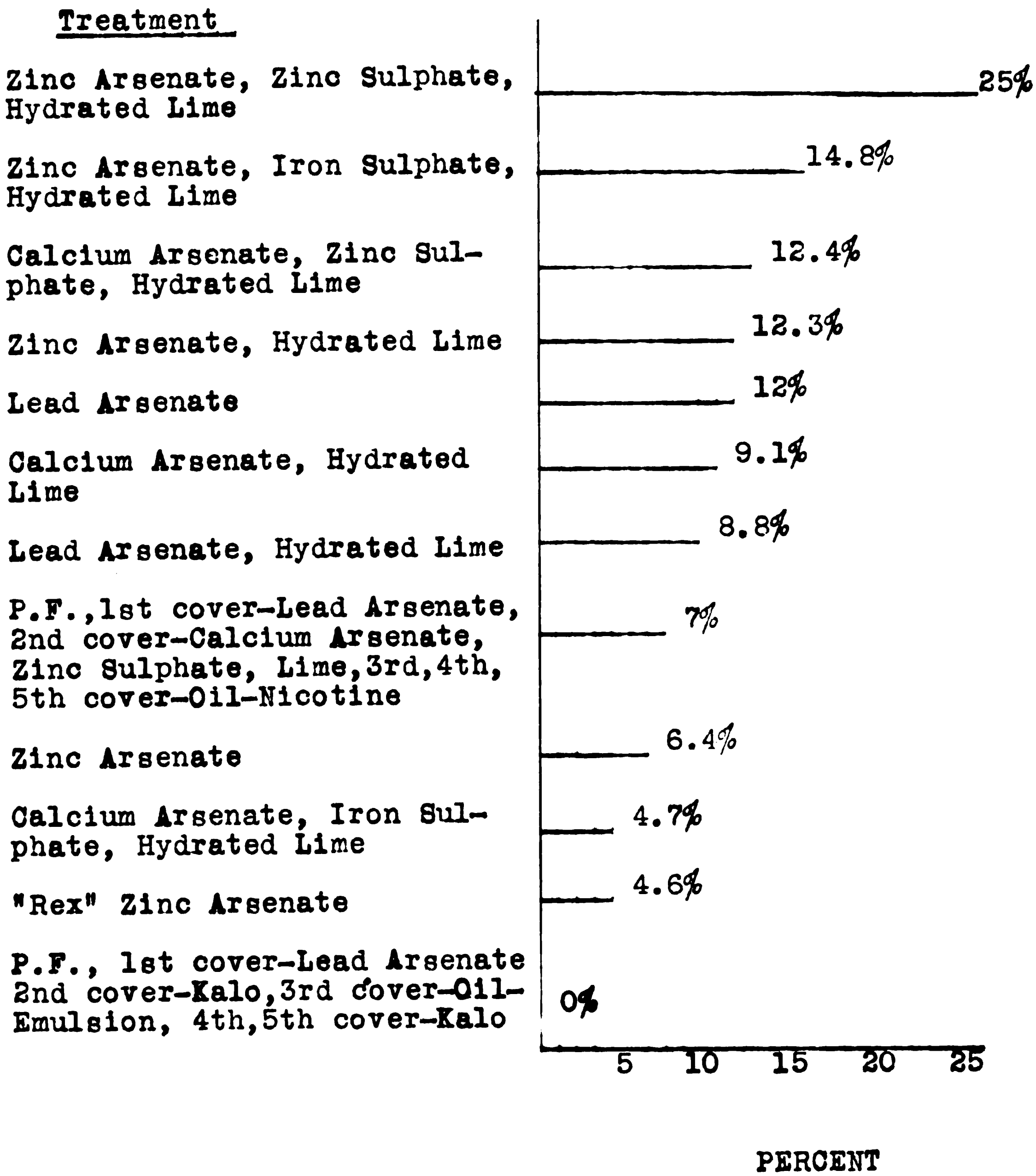


FIGURE 4

PERCENT OF RUSSETING

1936

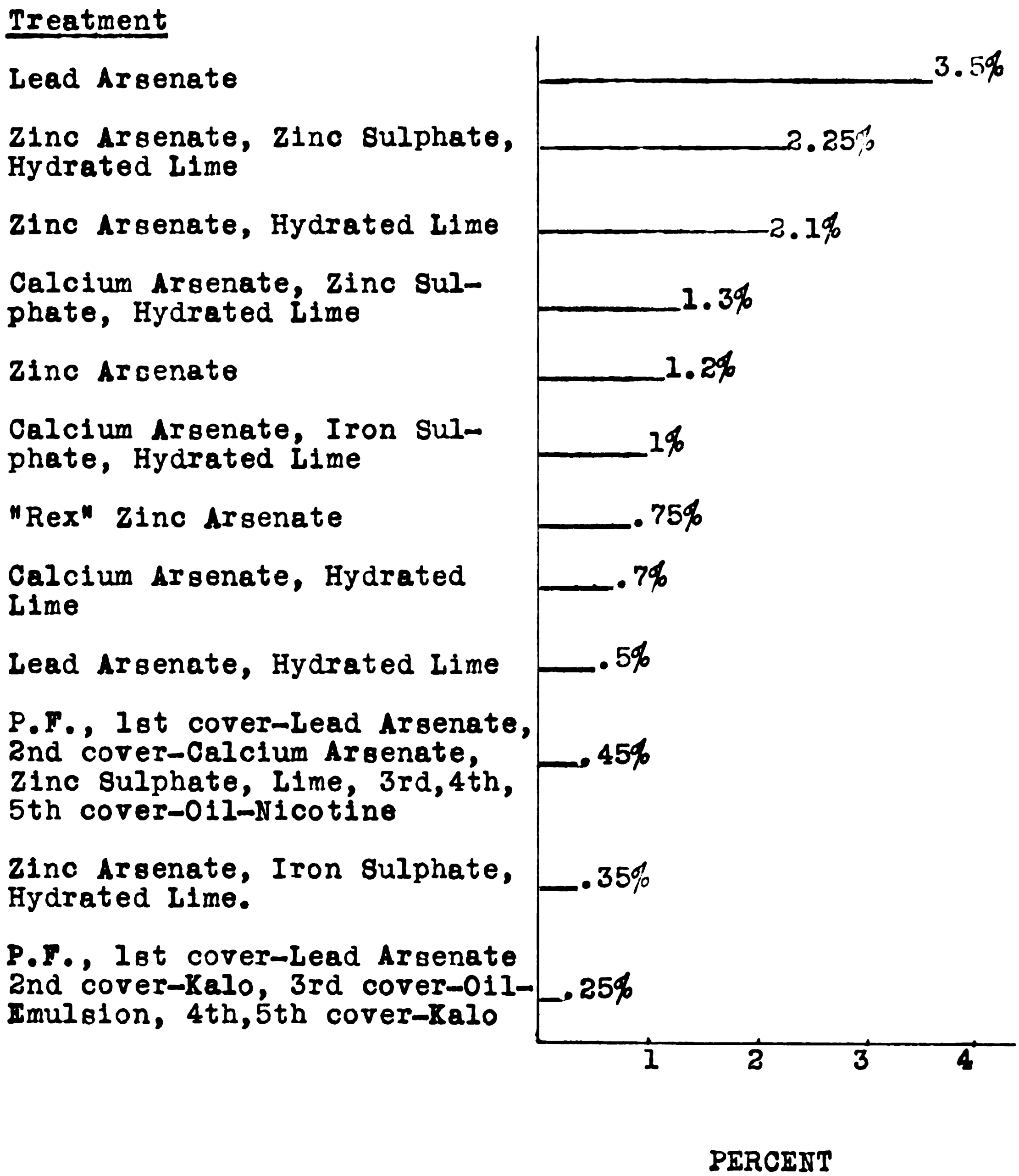


FIGURE 5

PERCENT OF BLOSSOM END INJURY

1935

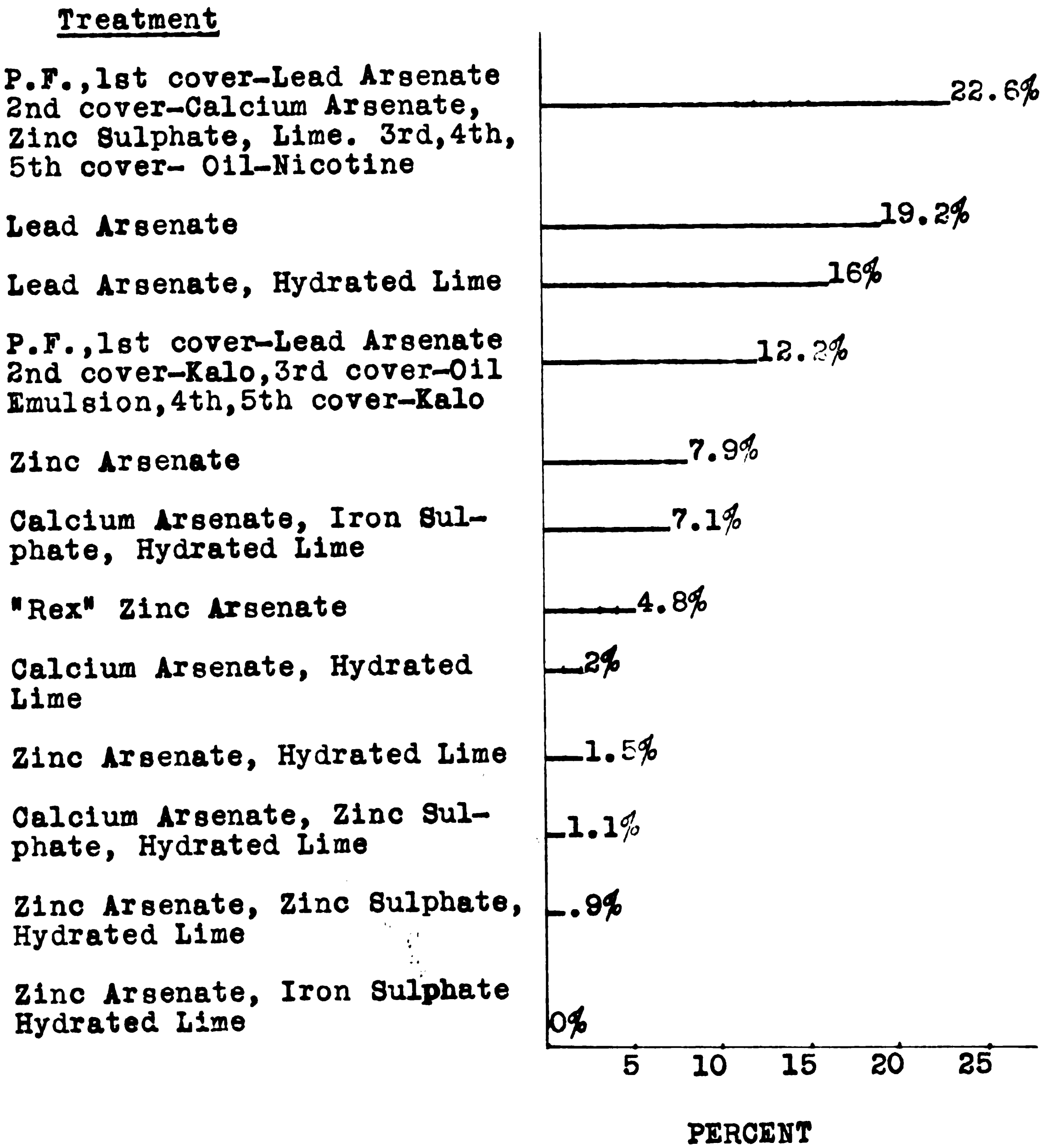
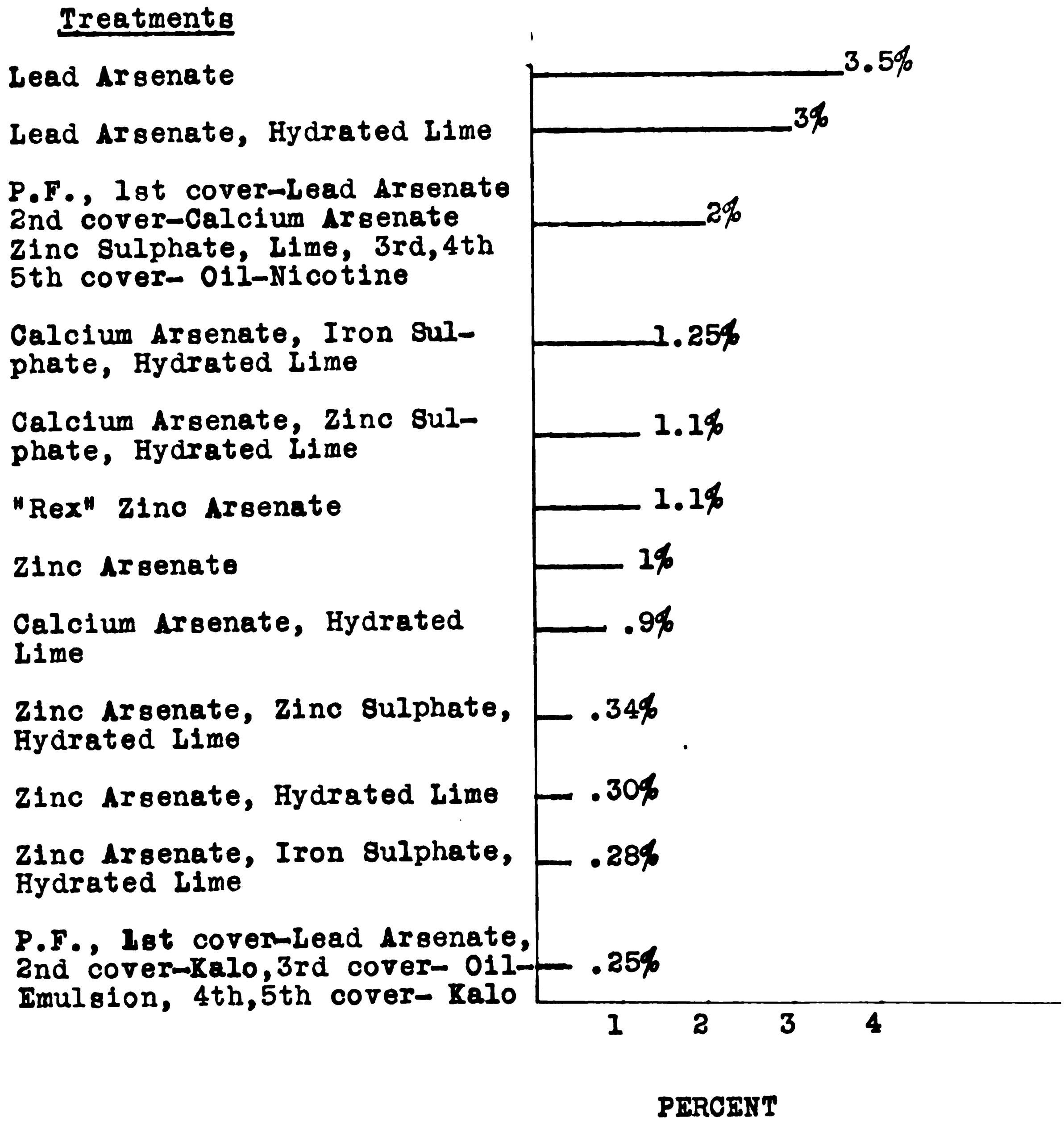


FIGURE 6

PERCENT OF BLOSSOM-END INJURY

1936



Both the percentage of blossom end injury and the percentage of russeting was greater in 1935 than in 1936. It is reasonable for one to believe that these types of injuries have some relationship to weather conditions as well as to spray materials.

Dutton (7) concludes that "the use of lime-sulphur and lead arsenate in mid-and late-summer often causes considerable russeting of the fruit and on susceptible varieties, blossom end injury. The applications most responsible for russeting of the fruit have not been determined but the petal-fall and other early season applications are probably important." He further states that "Russeting is probably reduced to a certain extent and blossom-end injury is practically prevented where iron sulphate is used in the so called standard lime-sulphur lead arsenate spray." Dutton summarizes his work on russeting by saying "Much of the russeting of the fruit following the use of lime-sulphur and lead arsenate is probably the result of injury from water soluble arsenic. Frost injury often causes russeting that is indistinguishable from that caused by spraying materials."

In respect to blossom end injury it is stated by Dutton that "Arsenicals are responsible for another form of injury to fruit. This occurs around the calyx and is called blossom end injury. The cause of this injury has not been definitely established but recent work, especially by Hartman (6) had indicated definitely that soluble arsenic is responsible."

Since calyx-end injury provides a place where fungi and bacteria may enter the apple, usually resulting in the rotting of the fruit, this condition is extremely undesirable, especially where the fruit is to be stored for any considerable length of time. This study corroborates the work of Dutton and Hartman in that the fruit on which applications of lead arsenate were made show the greatest amount of calyx end injury. The possible influence of lime-sulphur on this condition, as mentioned by Dutton, was borne out, since it was found that a greater amount of calyx-end injury occured in 1935 when lime-sulphur was applied until late summer than in 1936 when no lime-sulphur was applied after the first cover.

Though russeting may not have any pathogenic results on the fruit it reduces the market value and therefore is important to the grower. In this study the spray combinations containing zinc, especially zinc sulphate, showed the greatest amount of russeting on the apples. In 1935 the zinc arsenate, zinc sulphate, lime applications caused approximately one-fourth of the apples to have such a quanity of lesions that the fruit would have to be classified as culls.

DISCUSSION

This study of the effects of certain apple spray combinations on arsenic residue on the fruit and on certain types of spray injury adds very little to the present knowledge on the subject. However, on the whole, the results obtained corroborate the findings of Dutton, Sherman, Cation and Rasmussen in Michigan, Haller, Beaumont and Cassil for the United States Department of Agriculture, McLean in New Jersey, Marshall and Ford in Indiana and others reported in the Review of Literature. It is the opinion of the author that none of the present known spray materials can be safely used in quantities or concentrations adequate for the control of the fruit pests without danger of excess residue on the fruit.

SUMMARY

In this work it was definitely shown that where lead arsenate was used in the second-brood spray application an excess residue remains. The lead arsenate-oil nicotine combination has possibilities in cutting down the amount of residue, although the efficiency with which the oil-nicotine combination will control late broods of moth was not ascertained. Calcium arsenate and zinc arsenate looked good, especially from the standpoint of limited fruit and foliage injury. There seemed to be no relationship between the effect of weathering on the amount of lead and the amount of arsenic remaining on the fruit. Lead arsenate plus lime-sulphur applications caused a large amount of calyx-end injury. Extreme defoliation occured where zinc arsenate, iron sulphate and lime was used in 1936. This resulted in dwarfing the fruit. In 1935 considerable russeting of the fruit occured in plots where zinc arsenate in combination with either zinc or iron sulphate was used in the spray schedule. The results obtained warrant no change in general recommendations. A standard spray schedule should be followed and where late broods of moth are prevalent, necessitating late sprays, some provision be made for residue removal.

BIBLIOGRAPHY

1. Herrick, Glenn W. Rural New Yorker, editorial August 5, 1933

2. Lincoln, Burr Michigan State Agriculture Commission, Personal communication May 25, 1937

3. Bregger, John American Fruit Grower, The Apple Spray Residue Situation, July, 1933

4. Haller, Beaumont, J. H., Cassil, C. C. U.S.D.A. Investigations 1934, Effect of Certain Spray Combinations on Residue

5. Sherman, Franklin III Insecticide Experiments on Codling Moth in Michigan 1929-1935. Michigan Agricultural Experiment Station Bulletin No. 277, 1936

6. Hartman, Henry; Robinson, R. H.; Childs, LeRoy The Occurence and Prevention of Calyx Injury in Apples from the Hood River Valley, Oregon Agricultural Experiment Station Bulletin No. 242, 1929

7. Dutton, W. C. Spray Injury Studies I, Michigan Agricultural Experiment Station Special Bulletin 218, 1932

8. Rasmussen, E. J.; Hutson, Ray; Cation, Donald Spray Calendar, Michigan Agricultural Experiment Station Extension Bulletin 154, 1937

9. Webster, R. L.; Marshall, James
Arsenic Deposit and Codling Moth Control. Washington Agricultural Experiment Station Bulletin 293, 1934

10. Overley, F. L., Overholser, E. L.
Arsenic Injury of Apples, Washington Agricultural Experiment Station Popular Bulletin No. 149, April, 1934

11. Wharton, W. R. M. Food and Drug Administration U. S. Department of Agriculture, The Arsenic Spray Residue Problem Transactions of Peninsula Horticulture Society 1931

12. McLean, Harry C. New Jersey Experiment Station Experiences with the Spray Residue Problem Transactions of the Peninsula Horticulture Society, 1930

13. Brinton, C. S. The Spray Residue Problem in Delaware. Transactions of the Peninsula Horticulture Society, 1930

14. Holland, C. S. Spray Residue Situation as it Exists in Ohio, Ohio State University Agricultural Experiment Station Bulletin

15. Streeter, L. R.; Harman, S. W.
Spray Residues, New York Agricultural Experiment Station Bulletin No. 579, 1929

16. Vinson, C. G. Spray Residue Work in Missouri, Missouri Agricultural Experiment Station Bulletin 382, 1937

17. Marshall, Edw. G.; Ford, O. W. The Relation of Apple Spray Schedules to the Arsenious oxide and Lead Residues. Purdue Agricultural Experiment Station Bulletin No. 381, 1933

18. Drehl, H. C.; Lutz, J. M.; Ryall, A. L. Removing Spray Residue from Apples and Pears. U. S. Department of Agriculture Bulletin No. 1687

19. Hartman, Henry; Robinson, R. H.; Zeller, S. M. The Removal of Spray Residue from Apples and Pears. Oregon State Agricultural College Bulletin 234

20. Percival, G. P.; Potter, G. F. Amount and Variability of Spray Residue on New Hampshire Baldwins. University of New Hampshire Agricul ture Experiment Station Technical Bulletin 49, 1932

21. Weber, A. L.; McLean, Harry C. Modern Methods of Removing Spray Residues from Apples and Pears. New Jersey Agriculture Experiment Station Extension Bulletin 87, 1931

22. Headlee, Thomas A Five-Year Cooperative Campaign against the Codling Moth. Peninsula Horticulture Society Transactions 1930

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