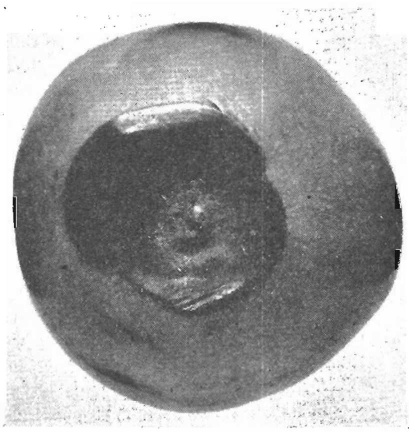
STATION BULLETIN 242 CORVALLIS, OREGON MAY, 1929

The Occurrence and Prevention of Calyx Injury in Apples from the Hood River Valley



Agricultural Experiment Station
Oregon State Agricultural College
CORVALLIS

The Occurrence and Prevention of Calyx Injury in Apples from the Hood River Valley

By

HENRY HARTMAN, LEROY CHILDS, and R. H. ROBINSON

INTRODUCTION

For a number of years the apples from the Hood River Valley and other sections of the Pacific Northwest have been subject to a peculiar form of calyx injury. This injury is known in various localities by such names as "calyx burn," "calyx scald," "black end," "blossom end rot," "water scald," "arsenic injury," or "calyx decay." It is a distinct trouble and must not be confused with such forms of calyx injury as are sometimes caused by apple scab fungus, certain oil sprays, or sunburn. Although it may occur in apples attached to the tree, it is most severe in fruit that has been exposed to prolonged wet weather after picking. At times it has occurred following the washing process for the removal of spray residues.

When visible from the outside this form of calyx injury appears as a dark-colored area (Fig. 1) usually involving the calyx lobes and not infrequently the surrounding epidermis and outer layers of the underlying flesh. Sometimes it is confined to the calyx tube beneath the sepals, and can not be detected from outward appearances. Calyx injury as such does not detract a great deal from the value of the fruit and would not be especially serious were it not for the fact that the injured portions often become infected with rot-producing fungi, which may cause decay of the entire fruit.

While the trouble occurs in many varieties of apples it is probably most severe in Jonathan and Delicious and to a less extent in Newtown, Winesap, and Spitzenburg. So far as known, the trouble does not occur in pears.

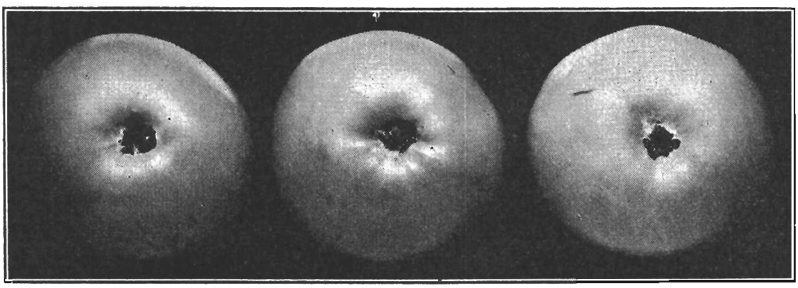


Fig. 1. Typical calyx injury in Newtown apples.

Review of literature. Late in 1927, Fisher and Reeves[2] announced results showing that calyx injury whether in washed or unwashed apples is due, in a large measure, to arsenic in soluble form, the source of the arsenic being the spray materials applied during the growing season. This explanation was confirmed by Hartman, Robinson, and Zeller,[3] Heald, Overly, and Neller,[6] Magness,[5] and others.

Scope of work. Studies relating to calyx injury were carried on by the Oregon Agricultural Experiment Station during the seasons of 1927 and 1928, when an attempt was made (1) to segregate the factors that may contribute to calyx injury in both washed and unwashed fruit and (2) to develop methods for its prevention. While the work has not been completed in all details, this bulletin is published in order that the industry may profit by the results thus far obtained. The report deals primarily with the data and observations as they relate particularly to the Hood River Valley, where calyx injury in apples is of special significance owing to the varieties grown, to the climatic conditions and to the prevalence of certain decay organisms.

EXPERIMENTAL: GENERAL METHODS

In the effort to segregate the factors that may contribute to calyx injury, a number of tests were carried on with apples that had received no applications of spray materials during the season. These were divided into representative lots and the calyces were treated with various combinations of water, of washing compounds, of arsenicals, and of spores of various decay-producing organisms. In addition apples which had received varying amounts and kinds of arsenicals in straight applications, or in combination with lime and bordeaux mixture, were subjected to various treatments at harvest time. Some were packed wet without removal of the spray residue, while some were packed dry without the removal of the spray residue; others were cleaned by different methods, followed by various rinsing and drying treatments.

Laboratory experiments were also conducted to determine, if possible, the conditions under which arsenate of lead may become soluble in the calyces of apples.

The control or prevention phase of the problem was attacked by means of modifications of the spray program as well as by modifications of handling and cleaning practices. Considerable attention was given to neutralizing agents such as might be used in the sprays or along with the washing process.

DISCUSSION OF RESULTS

CALYX INJURY IN UNWASHED APPLES

Relation to arsenical sprays. The results of these experiments show that typical calyx injury is definitely associated with certain arsenical sprays applied during the season. As shown in Table I, unsprayed apples have remained free from the trouble while those given regular applications of acid arsenate of lead ($PbHAsO_4$), calcium arsenate, and magnesium arsenate have consistently developed it under certain conditions. Apples sprayed with such non-arsenicals as bordeaux mixture and lime-sulfur or with basic arsenate of lead have not developed the common form of calyx injury.

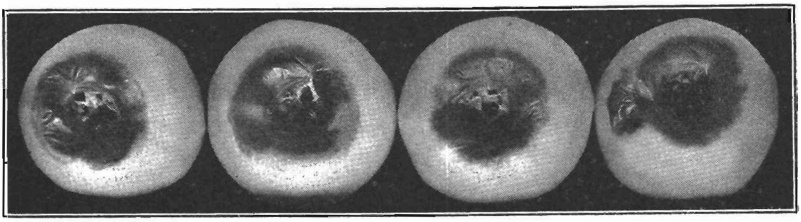


Fig. 2. Calyx injury produced by sodium arsenate ($Na_3AsO_4 . 12 H_2O$).

While calyx injury has been most severe in fruit that has been heavily sprayed it has frequently occurred in cases where only light or moderate spray schedules had been followed. In 1927, for example, a commercial lot of Newtown apples which had received only two applications of single-strength arsenate of lead (2 pounds per 100 gallons of water) developed 34.4 percent calyx injury in common storage.

TABLE I. THE RELATION OF ARSENICAL SPRAYS TO CALYX INJURY IN JONATHAN APPLES

Packed wet. Stored at 65° F.

Lot No.	Spray treatment	Date of picking and storing	Date of examination	Calyx injury	Calyx decay
				%	%
1	Unsprayed	9/12/28	10/2/28	0.0	0.0
2	Calyx spray + 4 cover sprays of *basic arsenate of lead,* 2 lbs. per 100 gals.	9/12/28	10/2/28	0.0	0.0
3	Calyx spray + 4 cover sprays of *acid arsenate of lead,* 2 lbs. per 100 gals.	9/12/28	10/2/28	36.1	14.2
4	Calyx spray + 4 cover sprays of *calcium arsenate,* 2 lbs. per 100 gals.	9/12/28	10/2/28	39.4	6.3
5	Calyx spray + 4 cover sprays of *magnesium arsenate,* 2 lbs. per 100 gals.	9/12/28	10/2/28	42.7	10.1

Relation to moisture. The results show further that there is a close relationship between the occurrence of calyx injury and the moisture conditions to which the fruit is subjected. In unwashed apples the trouble has rarely occurred when the fruit has been dry before and after harvest, but has been common in apples that have been wet for some time from rain, snow, heavy dews or fog. Fruit left uncovered in the orchard during protracted spells of wet weather has frequently developed calyx injury. Table II shows the relation of moisture to the occurrence of calyx injury in apples held in common storage.

TABLE II. THE RELATION OF MOISTURE TO THE OCCURRENCE OF CALYX INJURY IN APPLES

Lot No.	Variety	Spray program	Treatment	Date of treatment	Date of examination	Calyx injury	Calyx decay
						%	%
1	Newtown	Calyx spray + one cover spray of arsenate of lead (Pb H As O_4), 2 lbs. per 100 gals.	Packed dry	1/25/28	3/4/28	0.0	0.0
			Packed wet	1/25/28	3/4/28	33.4	9.6
2	Newtown	Calyx spray + 5 cover sprays of arsenate of lead (Pb H As O_4), 2 lbs. per 100 gals.	Packed dry	10/8/27	12/3/27	0.0	0.0
			Packed wet	10/8/27	12/3/27	34.7	14.5
3	Jonathan	Calyx spray + 4 cover sprays of arsenate of lead (Pb H As O_4), 2 lbs. per 100 gals.	Packed dry	9/10/28	10/4/28	0.0	0.0
			Packed wet	9/10/28	10/4/28	26.1	9.4
4	Newtown	Calyx spray + 5 cover sprays of arsenate of lead (Pb H As O_4), 6 lbs. per 100 gals.	Packed dry	9/30/28	11/4/28	3.0	0.0
			Packed wet	9/30/28	11/4/28	25.6	2.1
5	Jonathan	Calyx spray + 5 cover sprays of arsenate of lead (Pb H As O_4), 2 lbs. per 100 gals.	Packed dry	9/17/28	10/20/28	0.0	0.0
			Packed wet	9/17/28	10/20/28	44.0	2.1
6	Spitzenburg	Calyx spray + 5 cover sprays of arsenate of lead (Pb H As O_4), 2 lbs. per 100 gals.	Packed dry	10/8/27	11/17/27	2.1	0.0
			Packed wet	10/8/27	11/17/27	16.8	10.6

Calyx injury produced by soluble arsenic. In the series of laboratory experiments carried on in 1928, typical calyx injury was again produced artificially by introducing a weak solution of arsenic pentoxide (As_2O_5) or sodium arsenate ($Na_3AsO_4.12\,H_2O$) into the calyces of unsprayed apples. Arsenic pentoxide definitely produced calyx injury when used in amounts ranging from one part in 500 to one part in 15,000 of water. The trouble was not produced by water alone or by non-arsenicals such as are used in the spraying of apples. This confirms the results of 1927, and those of other investigators to the effect that arsenic in soluble form is largely responsible for calyx injury in unwashed apples.

As already indicated, the question as to why arsenate of lead should become soluble in unwashed apples received attention in the course of these studies. This phase of the work, however, is incomplete at this time and only a brief summary is given here. No attempt is made to interpret the results obtained.

The work of such investigators as McDonnell and Graham,[7] Bradley and Tartar,[1] Haywood and McDonnel,[4] Headden,[5] Stewart,[10] and Mogendorff,[9] shows that acid arsenate of lead ($PbHAsO_4$) may be broken down by prolonged exposure to water, especially in the presence of certain alkaline or saline substances. While decomposition from this cause may account for the presence of soluble arsenic in the calyces of apples, the authors have suspected that other factors are involved, especially since arsenate of lead, washed free of soluble arsenic, has produced calyx injury in a very short time in apples known to be free of alkaline or saline agents.

The laboratory tests carried on here have demonstrated that water in the calyces of apples may become acid and as such will react with arsenate of lead. Water which had stood in the calyces of Grimes apples 48 hours and was then removed to test tubes, dissolved .011 grams of As_2O_3 per 100 c.c. in 12 hours. Distilled water failed to produce soluble arsenic that could be tested qualitatively during this time. The amount of arsenic rendered soluble in the foregoing manner is sufficient to produce calyx injury, especially with the increased concentration that comes with evaporation of the water.

Relation to temperature. It has been observed that apples held in cold storage develop less calyx injury than those held in common storage at fairly high temperatures. Table III, for example, shows that Newtown apples, heavily sprayed with arsenate of lead and packed wet, developed 34.7 percent calyx injury and 14.5 percent calyx decay at 65° F., while apples of the same lot, also packed wet, but held at 32° F., developed only 5.4 percent injury and 2.1 percent calyx decay during the storage season.

TABLE III. THE RELATION OF TEMPERATURE TO THE OCCURRENCE OF CALYX INJURY IN APPLES

Calyx spray + 5 cover sprays of arsenate of lead ($PbHAsO_4$) 2 lbs. per 100 gals. Fruit packed wet.

Lot No.	Variety	Date of treatment	Date of examination	Storage temperature	Calyx injury	Calyx decay
					%	%
1	Newtown	10/8/27	12/3/27	65° F.	34.7	14.5
			5/29/28	32° F.	5.4	2.1
2	Spitzenburg	10/8/27	11/17/27	65° F.	16.8	10.6
			2/10/28	32° F.	3.4	1.2

Spitzenburg held in common storage developed 16.8 percent calyx injury and 10.6 percent calyx decay while those held in cold storage developed 3.4 percent injury and 1.2 percent calyx decay.

Decay following calyx injury. Data from storage tests and from field observations show that decay due to fungi may follow in a large percentage of the cases of calyx injury. Tables I, II, and III, for example, show that under the conditions of these experiments decay has followed in from 13.7 to 37.0 percent of the cases where the injury has occurred. Commercial lots have frequently shown decay in from 10 to 30 percent of the cases of calyx injury. The amount of infection that may occur varies considerably with such factors as (1) the amount of contamination present, (2) the extent of the injury, and (3) the storage treatment given. Usually it

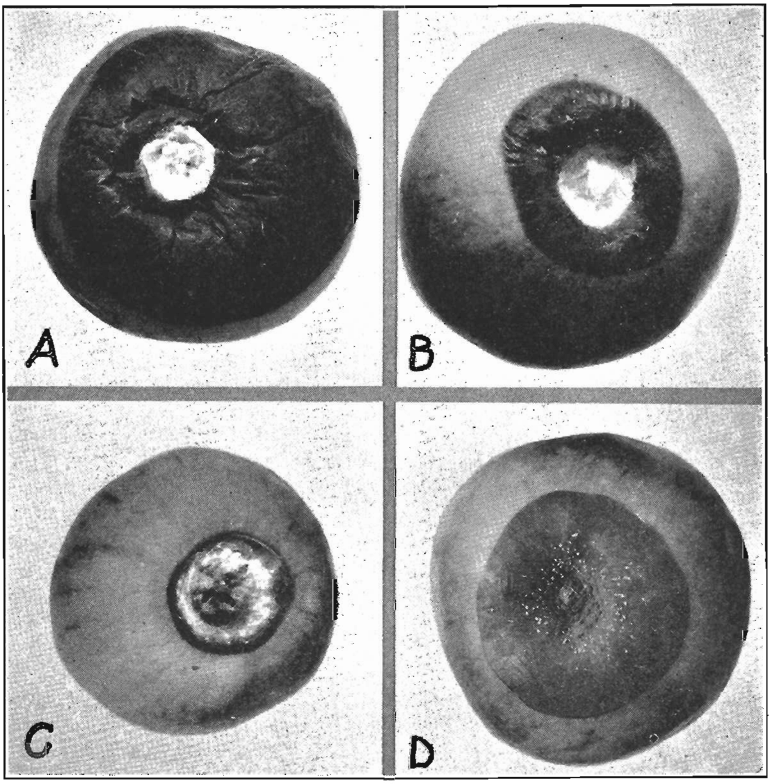


Fig. 3. Calyx injury followed by various decay organisms.
(A) Glutinitum, (B) Alternaria, (C) Fusarium, and (D) Penicillium.

is most severe in warm, moist rooms where the spores of decay organisms are present in abundance.

At least seven forms of organisms are known to produce decay following calyx injury under Hood River conditions.* Of these, Penicillium (blue

*Organisms identified by H. P. Barss and S. M. Zeller.

TABLE IV. THE RELATION OF LIME IN THE SPRAYS TO THE OCCURRENCE OF CALYX INJURY IN UNWASHED APPLES

Fruit packed wet

Lot No.	Variety	Kind of storage	Spray program	Date of storage	Date of examination	Calyx injury	Calyx decay
						%	%
1	Newtown	Common (65° F.)	Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals	10/8/27	12/3/27	32.0	14.5
			Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals. + *August bordeaux, 4-4-50*	10/8/27	12/3/27	5.0	1.1
2	Newtown	Cold (32° F.)	Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals	10/8/27	5/29/28	5.4	2.1
			Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals. + *August bordeaux, 4-4-50*	10/8/27	5/29/28	0.2	0.9
3	Jonathan	Common (65° F.)	Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals	10/4/28	10/24/28	39.5	7.2
			Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals. + *lime in last cover spray, 2 lbs. per 100 gals*	10/4/28	10/24/28	9.5	0.0
4	Newtown	Common (65° F.)	Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 4 lbs. per 100 gals	10/3/28	11/4/28	15.4	3.0
			Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 4 lbs. per 100 gals. + *4 lbs. hydrated lime in August spray*	10/3/28	11/4/28	2.6	2.1
5	Newtown	Common (65° F.)	Calyx spray + 5 cover sprays of arsenate of lead $Pb\ H\ As\ O_4$), 2 lbs. per 100 gals	10/16/28	11/3/28	10.1	15.3
			Calyx spray + 5 cover sprays of arsenate of lead ($Pb\ H\ As\ O_4$), 2 lbs. per 100 gals. + *August bordeaux, 4-4-50*	10/16/28	11/3/28	0.0	0.0

mold) and Gloeosporium (perennial canker) are the most common. Other organisms at times associated with the trouble are Botrytis (gray mold), Alternaria (black mold), Neofabraea (anthracnose), Glutinium, and Fusarium.

TABLE V. THE RELATION OF CERTAIN CALCIUM COMPOUNDS TO THE OCCURRENCE OF CALYX INJURY IN UNSPRAYED NEWTOWN APPLES

Stored at 65° F.

Lot No.	Treatment	Date of treatment	Date of examination	Calyx injury	Calyx decay
				%	%
1	Calyces treated with water + arsenate of lead ($PbHAsO_4$) + blue mold spores	10/23/28	11/2/28	Severe	44.0
2	Calyces treated with water + arsenate of lead ($PbHAsO_4$) + *calcium carbonate* ($CaCO_3$) + blue mold spores	10/23/28	11/2/28	Practically none	0.0
3	Calyces treated with water + arsenate of lead ($PbHAsO_4$) + *hydrated lime* ($Ca(OH)_2$) + blue mold spores	10/23/28	11/2/28	None	0.0

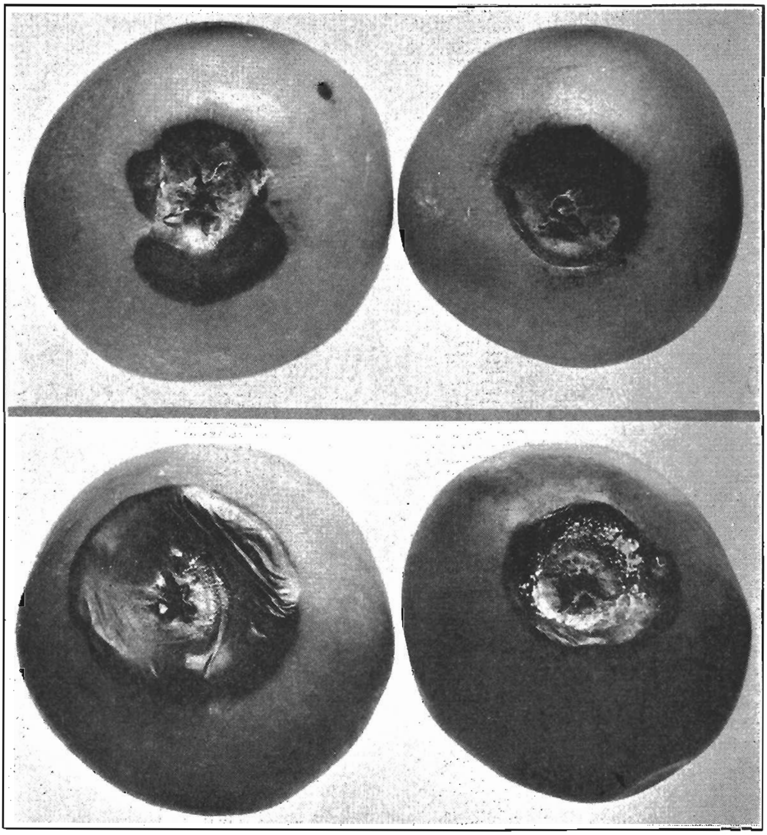


Fig. 4. *Upper:* Calyx injury followed by anthracnose (Neofabraea malicorticis). *Lower:* Calyx injury followed by Gloeosporium perennans.

Effect of lime with arsenical sprays. The series of experiments relating to neutralizing agents have shown that hydrated lime when combined with arsenical sprays has more or less influence on calyx injury. Under laboratory conditions calyx injury has not occurred in the presence of an excess of this compound and as shown in Tables IV and V a reduction in the amount of injury has been noted following the use of lime in the spray schedule. This has been true when the lime has been applied as a combination of arsenate of lead and hydrated lime or as a combination of arsenate of lead and home-made bordeaux mixture, which contains excess lime.

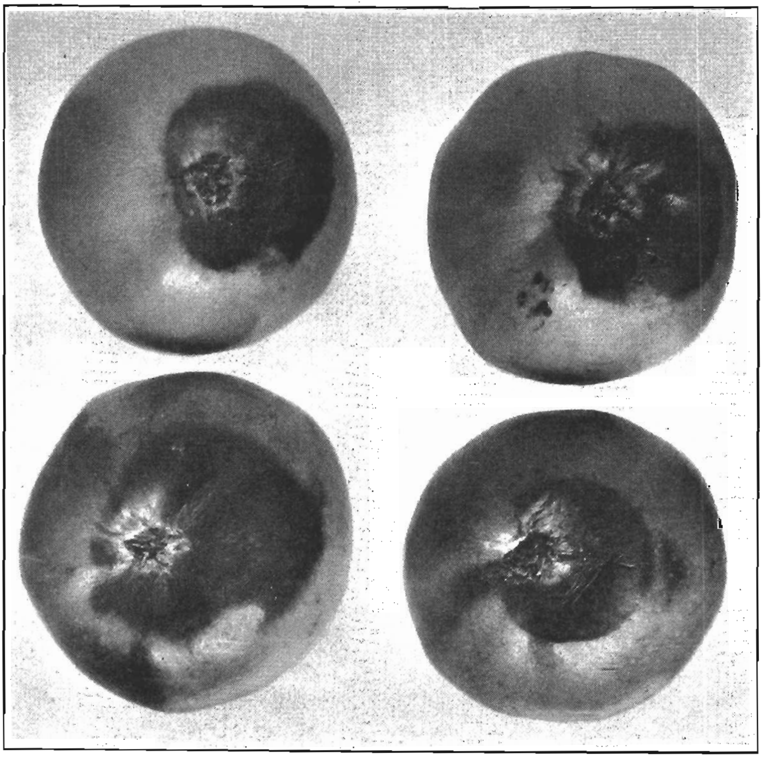


Fig. 5. Calyx injury followed by perennial canker in Newtown apples which had received only the calyx spray and one cover spray of arsenate of lead.

It appears that hydrated lime may perform several beneficial functions in reducing calyx injury. It neutralizes such acids as may be liberated by the apple itself, as well as any water-soluble arsenic acid or other forms of soluble arsenic. It also changes the surface tension of water, making possible a more rapid evaporation of the moisture in case the fruit becomes wet. In addition, it seems to possess fungicidal properties against certain decay organisms. It at least tends to create an unfavorable field for the germination and growth of spores following injury from soluble arsenic.

It is plain from these tests, however, that lime offers protection only when present in excess amounts. The clear solution of lime water did not prevent calyx injury under laboratory conditions, and field tests have shown that lime applied with the sprays will not prevent injury in case the calyces remain wet for extended periods of time. While lime seems to be effective during short periods of wetness, it is apparently neutralized by the acids exuded from the apple after continued exposure to moisture in the calyces of the fruit. Injury may then recur.

Relation of hydrated lime and bordeaux mixture in arsenate of lead sprays to codling-moth control. Hydrated lime and bordeaux mixture apparently do not materially affect the effectiveness of arsenate of lead in codling-moth control under Hood River conditions. Satisfactory control has been obtained when bordeaux mixture (4-4-50) has been used with the August codling-moth spray and worm injury has been no greater in cases where hydrated lime used with calcium caseinate spreader was applied with the arsenate of lead throughout the season. Table VI shows comparative results obtained during 1928 when hydrated lime was used at strengths of one pound and four pounds to each 100 gallons of double-strength arsenate of lead. It will be noted that control was obtained with all the lime combinations, worminess varying from 3.37 percent to 0.85 percent with an average of 1.94 percent for the lime plots. Differences in results can be attributed largely to experimental error. The comparatively high percentage of wormy apples in the straight lead block is accounted for, in part at least, by the light crop of fruit which developed in these trees. It is interesting to note that 56.9 percent of the fruit in the unsprayed checks became wormy.

TABLE VI. THE RELATION OF LIME IN ARSENATE OF LEAD TO CODLING-MOTH CONTROL

Lot No.	Materials used	Spray program: Calyx	1st cover	2d cover	3d cover	4th cover	5th cover	Amount of arsenic on unwashed fruit at picking time (Grains of As_2O_3 per lb.)	Worminess
								gr.	%
1	4-100 Arsenate of Lead 1-100 Hydrated Lime	*	†	†	†	†	†	.053	2.61
2	4-100 Arsenate of Lead 1-100 Hydrated Lime	*	*	†	†	†	†	.044	1.40
3	4-100 Arsenate of Lead 1-100 Hydrated Lime	*	*	*	†	†	†	.054	1.63
4	4-100 Arsenate of Lead 1-100 Hydrated Lime	*	*	*	*	†	†	.045	1.95
5	4-100 Arsenate of Lead 4-100 Hydrated Lime	*	†	†	†	†	†	.048	1.48
6	4-100 Arsenate of Lead 4-100 Hydrated Lime	*	*	†	†	†	†	.044	2.28
7	4-100 Arsenate of Lead 4-100 Hydrated Lime	*	*	*	†	†	†	.052	.85
8	4-100 Arsenate of Lead 4-100 Hydrated Lime	*	*	*	*	†	†	.043	3.37
9	Check	No spray						-----	56.90
10	4-100 Arsenate of Lead	*	*	*	*	*	*	.061	8.66

*Indicates sprays in which arsenate of lead was used alone.
†Indicates sprays in which arsenate of lead was used with lime.

Fig. 6. The influence of hydrated lime on calyx injury.
Above: Calyces treated with water + arsenate of lead + blue mold spores.
Below: Calyces treated with water + arsenate of lead + hydrated lime + blue mold spores.

Relation of bordeaux mixture to perennial canker rot on fruit. Aside from its beneficial effects on calyx injury, bordeaux mixture appears to be of value in reducing perennial canker or "Bull's-eye rot" on the fruit, a storage trouble of considerable importance in Hood River apples. At times the reduction in this form of rot has been of definite significance. During years of heavy infection, Newtown apples sprayed with arsenate of lead alone have developed as much as 50 percent decay during the storage period, while apples from adjacent trees which had received an August application of bordeaux mixture developed approximately 5 percent decay. The extent of fruit infection appears to be a decidedly variable factor one year with another. This variation, doubtless, is owing to differences in the weather conditions prevailing during the harvest season.

CALYX INJURY IN WASHED APPLES

Relation to soluble arsenic. It is now fairly certain that arsenic in soluble form is the chief causal agent of calyx injury when such injury follows the washing process. The series of experiments carried on in 1928 have given further credence in this view. As shown in Table VII and Fig. 7, water and blue mold spores introduced into the calyces of unsprayed apples produced neither physiological injury nor calyx decay. Washing compounds such as hydrochloric acid (HCl), sodium hydroxide ($NaOH$), sodium carbonate (Na_2CO_3), and trisodium phosphate (Na_3PO_4) all produced some physiological injury when left in the calyces of unsprayed apples with blue mold spores, but this seldom resulted in decay and was not typical of the common form of calyx injury. When these compounds were left in the calyces with arsenate of lead ($PbHAsO_4$), however, or when a weak solution of arsenic pentoxide (As_2O_5) was introduced by itself, a great deal of calyx injury occurred, which was followed by considerable decay in case spores of rot-producing fungi were present. Lead chloride ($PbCl_2$) and other non-arsenical compounds formed from the reaction of washing solutions and arsenate of lead did not produce calyx injury.

TABLE VII. THE RELATION OF CERTAIN ARSENICALS AND NON-ARSENICAL COMPOUNDS TO CALYX INJURY IN UNSPRAYED JONATHAN APPLES

Stored at 65° F.

Lot No.	Treatment	Date of treatment	Date of examination	Calyx injury	Calyx decay
					%
1	Calyces treated with water + blue mold spores	9/12/28	10/2/28	None	0.0
2	Calyces treated with .3% hydrochloric acid (HCl) + blue mold spores	9/12/28	10/2/28	Slight (not typical)	0.0
3	Calyces treated with .3% hydrochloric acid (HCl) + arsenate of lead ($PbHAsO_4$) + blue mold spores	9/12/28	10/2/28	Severe	52.8
4	Calyces treated with water + arsenic pentoxide (As_2O_5) + blue mold spores	9/12/28	10/2/28	Severe	70.1
5	Calyces treated with water + lead chloride ($PbCl_2$) + blue mold spores	9/12/28	10/2/28	None	0.0

Washing compounds apparently may contribute to calyx injury only in a secondary capacity. They may aid in breaking down arsenate of lead but do not produce typical calyx injury of themselves.

TABLE VIII. THE RELATION OF HYDROCHLORIC ACID AND CERTAIN SODIUM COMPOUNDS TO CALYX INJURY IN JONATHAN APPLES SPRAYED WITH ARSENATE OF LEAD

Stored at 65° F. Calyx + 4 cover sprays of arsenate of lead, 2 lbs. per 100

Lot No.	Treatment	Date of treatment	Date of examination	Calyx injury	Calyx decay
					%
1	Unwashed, calyces treated with water + blue mold spores	10/2/28	10/11/28	Slight	6.6
2	Unwashed, calyces treated with .3% hydrochloric acid (H Cl) + blue mold spores	10/2/28	10/11/28	Severe	46.6
3	Unwashed, calyces treated with 1/10 normal solution of sodium hydroxide (Na OH) + blue mold spores	10/2/28	10/11/28	Severe	40.0
4	Unwashed, calyces treated with 1/10 normal solution of sodium carbonate (Na_2CO_3) + blue mold spores	10/2/28	10/11/28	Severe	52.1
5	Unwashed, calyces treated with 1/10 normal solution of tri-sodium phosphate (Na_3PO_4) + blue mold spores	10/2/28	10/11/28	Severe	66.6
6	Unwashed, calyces treated with ½ normal solution of sodium bi-carbonate (Na HCO_3) + blue mold spores	10/2/28	10/11/28	Slight	21.8

TABLE IX. THE RELATION OF ARSENATE OF LEAD, HYDROCHLORIC ACID, AND CERTAIN SODIUM COMPOUNDS TO CALYX INJURY IN UNSPRAYED JONATHAN APPLES

Stored at 65° F.

Lot No.	Treatment	Date of treatment	Date of examination	Calyx injury	Calyx decay
					%
1	Calyces treated with water + blue mold spores	10/3/28	10/12/28	None	0.0
2	Calyces treated with water + arsenate of lead (Pb H As O_4) + blue mold spores	10/3/28	10/12/28	Quite severe	44.1
3	Calyces treated with arsenate of lead (Pb H As O_4) + .3% hydrochloric acid (H Cl) + blue mold spores	10/3/28	10/12/28	Severe	76.8
4	Calyces treated with arsenate of lead (Pb H As O_4) + 1/10 normal solution of sodium hydroxide (Na OH) + blue mold spores	10/3/28	10/12/28	Severe	63.0
5	Calyces treated with arsenate of lead (Pb H As O_4) + 1/10 normal solution of sodium carbonate (Na_2CO_3) + blue mold spores	10/3/28	10/12/28	Severe	66.6
6	Calyces treated with arsenate of lead (Pb H As O_4) + 1/10 normal solution of tri-sodium phosphate (Na_3PO_4) + blue mold spores	10/3/28	10/12/28	Severe	100.0
7	Calyces treated with arsenate of lead (Pb H As O_4) + ½ normal solution of sodium bicarbonate (Na H CO_3) + blue mold spores	10/3/28	10/12/28	Severe	54.1

In the various tests carried on, less calyx injury has occurred with hydrochloric acid than with the alkaline solvents. This is probably owing to the fact that alkaline solvents are not effectively removed by rinsing with water alone, and hence remain to act upon such arsenate of lead as may be

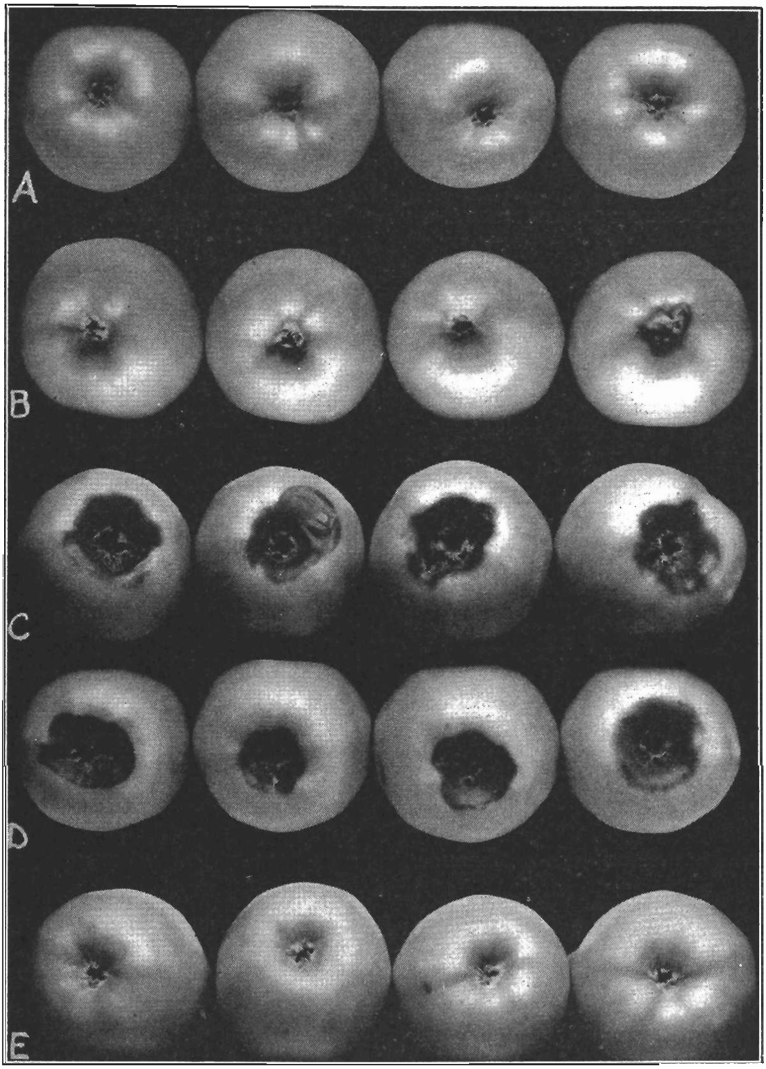


Fig. 7. The relation of arsenic to calyx injury.

(A) Calyces treated with water + blue mold spores. (B) Calyces treated with water + hydrochloric acid + blue mold spores. (C) Calyces treated with water + arsenate of lead + hydrochloric acid + blue mold spores. (D) Calyces treated with water + soluble arsenic + blue mold spores. (E) Calyces treated with water + lead chloride + blue mold spores.

left in the calyces. Hydrochloric acid, on the other hand, is quite easily removed by water.

Relation to types of washing machines. The nature of the washing equipment used has considerable bearing on the occurrence of calyx injury. Most of the calyx injury that can be attributed to washing has occurred following the use of machines that tend to force the washing solutions past the sepals and into the calyx tube. The trouble has usually come from machines of the deep-submersion type or those employing strong, direct-pressure jets. Machines of the diffused-spray, flood-wash or flotation type when properly operated have caused but little calyx injury.

Injury from accumulation of soluble arsenic in washing solutions. Soluble arsenic accumulating from repeated use of washing solutions may be a factor in producing calyx injury in apples. This appears to be the case, however, only when arsenic-charged solution is forced into the calyx and is not removed by rinsing. In the tests with various types of washing equipment, calyx injury was not materially increased with repeated use of the solution, provided the fruit was washed in machines of the diffused-spray, flood-wash or flotation types, with efficient rinsing. It was increased, however, when the fruit was washed by submersion.

It now appears that arsenate of lead not removed by the washing treatment is a far more common cause of calyx injury in washed apples than is soluble arsenic in the washing solution. As a precaution against possible contamination from blue mold and other organisms, however, frequent change of both the washing solution and the rinse bath is desirable.

Lime in rinse bath. The use of hydrated lime in the rinse bath seems to be of considerable value in preventing calyx injury when the acid process is used. Hydrated lime apparently is beneficial in several ways when used in this connection. It neutralizes hydrochloric acid as well as arsenic acid and other forms of soluble arsenic. When left on the fruit it may neutralize such acids as are liberated by the apple itself and seems to be of some value in preventing decay.

Baking soda ($NaHCO_3$) and calcium carbonate ($CaCO_3$) have proved to be less effective than hydrated lime. It has been shown, in fact, that baking soda may actually increase calyx injury in that it may react with any arsenate of lead that may remain in the calyces following the washing treatment. This would be true particularly in case the fruit remained wet for some time.

TABLE X. THE INFLUENCE OF LIME IN THE RINSE BATH ON CALYX INJURY IN NEWTOWN APPLES WASHED BY THE ACID PROCESS

Stored at 65° F.

Lot No.	Rinsing treatment	Acid concentration	Length of acid treatment	Calyx injury	Calyx decay
		%	*min.*	%	%
1	Clear water	1.5	5	5.2	8.5
2	2 pounds hydrated lime per 100 gallons of water	1.5	5	0.0	0.0

Influence of lime in sprays on calyx injury following washing. Lime used with the arsenical sprays may have a beneficial effect on calyx injury following the acid washing process. This seems to be true especially in case of incomplete removal of the spray residue and in cases where rinsing has not been thoroughly done. As shown in Table XI, apples which had received the combination spray of lime and arsenate of lead developed less calyx injury with incomplete rinsing than the apples which had received only the straight applications of arsenicals. Apparently the lime left in the calyces after washing neutralizes the hydrochloric acid in part at least.

TABLE XI. THE INFLUENCE OF LIME IN THE SPRAYS ON CALYX INJURY IN WASHED NEWTOWN APPLES

Stored at 65° F. Treated 10/24/28. Examined 11/9/28.

Lot No.	Washing treatment	Rinsing treatment	Spray program	Calyx injury	Calyx decay
				%	%
1	Flotation 1.5% acid	Water containing 1/10% hydrochloric acid	Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals.	8.4	13.6
			Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals. + *2 lbs. hydrated lime in each spray*	1.1	0.9
2	Submersion 1.5% acid	Clear water	Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals.	10.2	11.4
			Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals. + *2 lbs. hydrated lime in each spray*	2.4	3.7

Observations from practical experience. It is now clear from the experiences of the past two years that washing when properly done has tended to reduce calyx injury in Hood River apples. Thorough removal of the arsenical spray residue is undoubtedly a safeguard against this trouble. Fruit properly washed has remained comparatively free from calyx injury (Table XII and Fig. 8) even when wetted several times during the storage period. Unwashed fruit, on the other hand, has been subject to it even when only small amounts of moisture were present. This is especially significant since changes of temperature during handling operations often result in condensation or "sweating."

Much of the calyx injury attributed during the past two years to washing is now known to have been caused by the presence of excess moisture prior to the washing treatment. With the moisture or water as media, water-soluble arsenic is formed which penetrates the apple tissue and causes injury.

PRACTICAL APPLICATION

Calyx injury in past years has been a serious menace to the apples from the Hood River Valley. By following a few simple precautions, however, it is now possible to eliminate or at least greatly reduce the trouble. While final recommendations are not made at this time, the following precautions are advised.

TABLE XII. THE INFLUENCE OF WASHING ON CALYX INJURY IN APPLES PACKED WET

Lot No.	Variety	Kind of storage	Spray program	Treatment	Calyx injury	Calyx decay
					%	%
1	Newtown	Common (65° F.)	Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals.	Not washed, packed wet	37.7	14.5
				Washed with .3% hydrochloric acid. Packed wet	0.0	0.0
2	Newtown	Cold (32° F.)	Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals.	Not washed, packed wet	5.5	2.2
				Washed with .3% hydrochloric acid. Packed wet	0.2	0.3
3	Spitzenburg	Common (65° F.)	Calyx + 5 cover sprays of arsenate of lead, 2 lbs. per 100 gals.	Not washed, packed wet	7.5	5.1
				Washed with .3% hydrochloric acid. Packed wet	1.2	0.0

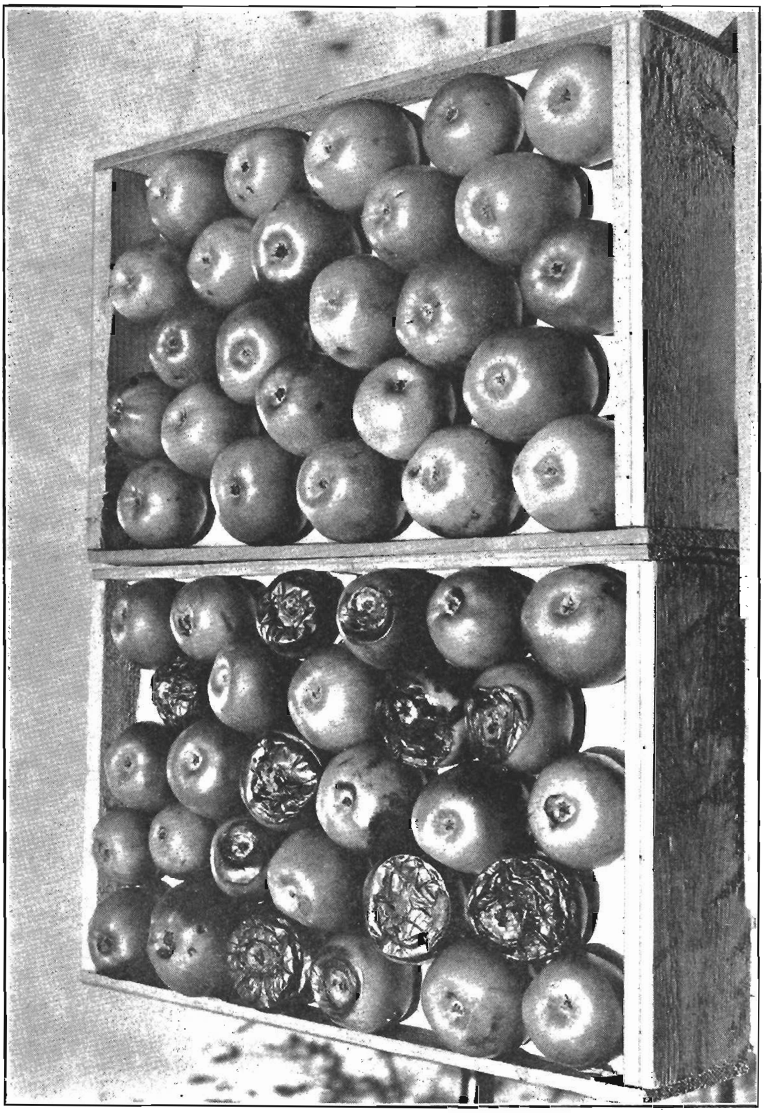


Fig. 8. Relation of washing to calyx injury in apples packed wet.
Left: Unwashed, packed wet. *Right:* Washed with .33 percent hydrochloric acid, packed wet.
Calyx injury followed by perennial canker decay.
(Gloeosporium perennans).

Keep fruit dry after picking. Since calyx injury is definitely associated with arsenical sprays and moisture, it is highly essential that unwashed apples be kept dry after picking. So long as the fruit is attached to the tree, the calyces remain fairly free from moisture even during protracted wet spells. Most of the water drains from the rims of the basins and does not enter the calyces. After picking, however, a large percentage of the calyces are turned upward and retain moisture if the fruit is exposed to rain. Most of the calyx injury in unwashed apples comes from this condition.

Rush harvesting operations. Owing to the climatic conditions of the Hood River Valley, apples should be harvested as soon as they are sufficiently matured. This is desirable since apples exposed to rain and wet weather are not only subject to calyx injury but also to contamination from perennial canker and other decay-producing organisms.

Use lime or bordeaux mixture with sprays. Hydrated lime and bordeax mixture tend to reduce calyx injury when applied with the arsenical sprays. Aside from this they are beneficial in that they facilitate spray residue removal by the acid process and are of value in reducing fungous diseases. Bordeaux mixture to be effective, however, must contain excess lime and should be applied only with the last codling-moth spray. Hydrated lime can be applied with any of the codling-moth sprays but is probably most effective in the later applications. Only a good grade of hydrated lime should be used. Lime which has been exposed to the air for some time is unsatisfactory. Two pounds of hydrated lime to each 100 gallons of arsenate of lead mixture should be sufficient.

Certain precautions must be considered when bordeaux mixture is used with the last codling-moth spray. The trouble known as "Red spot," a discoloration which appears around the lenticels, especially in green or yellow varieties, has been found to develop a little more readily on fruit sprayed with bordeaux mixture. In order to overcome this trouble the fruit should be harvested as soon as it is matured, since the discoloration increases rapidly after the middle of October. "Red spot" occurs only in apples exposed to the sun. It does not develop in apples that are harvested and under cover.

Wash as soon as possible. Since arsenical sprays are the chief cause of calyx injury, fruit should be cleaned as soon after picking as possible. Apples that have been properly washed are far less susceptible to calyx injury than are unwashed apples under Hood River conditions. Wiping or other forms of mechanical cleaning are ineffective in reducing calyx injury. Machines of the diffused-spray, flood-wash, or flotation types should be used. Those of the deep-submersion type tend to augment calyx injury.

Change washing solutions frequently. Arsenic accumulating from the repeated use of washing solutions may cause calyx injury when not thoroughly removed by rinsing. To overcome this possibility and to guard against contamination from blue mold and other organisms it is wise to change the washing bath at frequent intervals. With tanks of 150- to 250-gallon capacity the solution should be changed after each day's run or after 800 to 1,200 boxes of fruit have been washed.

Use lime in rinse bath. Hydrated lime in the rinse bath is effective in reducing calyx injury when the acid washing process is used. To be efficient, however, lime must be used in liberal quantities. The rinsing solution should be white with the lime at all times. One and one-half to two pounds of hydrated lime per 100 gallons of water are not excessive amounts. Lime in the rinse bath is especially valuable when water for rinsing purposes is not available in abundance.

Keep fruit dry after washing. Even when washing has been properly done, some of the arsenicals may still remain in the calyces. This can cause calyx injury if the fruit is kept wet for some time after washing. A few such cases have come to attention especially in unpacked fruit that had been stored in wet basements or cellars. At ordinary humidities, however, fruit dries out quickly and practically no trouble has been experienced even when the fruit was not thoroughly dried by the washing machine.

ACKNOWLEDGMENTS

The authors have received assistance in the course of these investigations from other members of the Station staff and from commercial organizations. Among those who have rendered valuable aid are: H. P. Barss, S. M. Zeller, W. S. Brown, and D. E. Bullis. The Hood River Apple Growers' Association donated storage space and the use of cleaning equipment.

LITERATURE CITED

[1]Bradley, C.E., and Tartar, H.V. 1910.
Further studies of the reactions of lime sulfur solution and alkali waters on lead arsenates.
Jour. Indus. Chem. pt. 2, pp. 328-329.

[2]Fisher, D.F. 1927.
Some effects of cleaning treatments on the keeping quality of apples and pears.
Pro. 23d Ann. Meeting, Wash. State Hort. Assoc., pp. 163-175.

[3]Hartman, H., Robinson, R.H., and Zeller, S.M. 1928.
The removal of spray residue from apples and pears.
Ore. Exp. Sta. Bul. 234.

[4]Haywood, J.K., and McDonnell, C.C. 1910.
Lead arsenate.
U. S. Dept. Agr. Bur. Chem. Bul. 131.

[5]Headden, W.P. 1908, 1910.
Arsenical poisoning of fruit trees.
Colo. Agr. Exp. Sta. Buls. 131, 157.

[6]Heald, F.D., Overly, F.L., and Neller, J.R. 1928.
Arsenical residue and its removal from apples and pears.
Wash. Exp. Sta. Bul. 226.

[7]McDonnel, C.C., and Graham, J.J.T. 1917.
The decomposition of dilead arsenate by water.
Jour. Amer. Chem. Soc. V. 39 pt. 2 pp. 1912-1918.

[8]Magness, J.R. 1928.
The removal of spray residue from fruit.
Better Fruit, 12:12. June, 1928.

[9]Mogendorff, N. 1925.
Some chemical factors involved in arsenical injury of fruit trees.
N. J. Agr. Sta. Bul. 419.

[10]Stewart, J.P. 1912.
Sulfur arsenical spray injury and its prevention.
Ann. Rpt. State Coll. Pa., 1911-1912, pp. 571-578.

SUMMARY

(1) Calyx injury in unwashed apples is primarily an arsenical trouble. It is found only in apples that have been sprayed with arsenical compounds and can be produced by introducing soluble arsenic into the calyces of unsprayed apples.

(2) It occurs only when apples sprayed with arsenicals become wet either before or after harvest.

(3) While it is most severe in heavily sprayed fruit, it may occur in apples that have received only moderate or small amounts of spray.

(4) Calyx injury under Hood River conditions is often followed by decay from Penicillium (blue mold) or Gloeosporium (perennial canker). Occasionally it is followed by such organisms as Alternaria (black mold), Botrytis (gray mold), Neofabraea (anthracnose), Glutinium and Fusarium.

(5) The present studies have shown that acid liberated by the apple itself may contribute to the solubility of arsenic compounds in the calyces of apples.

(6) Calyx injury is usually more severe in fruit held in common storage than in that held in cold storage.

(7) When applied with the arsenical sprays, hydrated lime and bordeaux mixture containing excess lime tend to reduce calyx injury in both washed and unwashed apples.

(8) The effectiveness of arsenate of lead in codling-moth control is apparently not impaired by the addition of hydrated lime or bordeaux mixture.

(9) Calyx injury attributable to the washing process is due primarily to arsenic rendered soluble by the washing compounds or by prolonged exposure to moisture.

(10) Much of the calyx injury attributed in past years to washing now appears to have occurred in the field prior to the washing treatment.

(11) Washing compounds such as hydrochloric acid, sodium carbonate, sodium hydroxide, and tri-sodium phosphate, when left in the calyces by themselves, all produce some physiological injury, but this is not typical of the common form of calyx injury and seldom results in decay.

(12) Arsenicals remaining in the calyces appear to be a more common cause of calyx injury in washed apples than arsenic accumulating with repeated use of the washing solution.

(13) Hydrated lime used in the rinse bath is effective in reducing calyx injury when the acid process is used.

(14) When properly done, washing tends to reduce calyx injury under Hood River conditions.

(15) Precautions for the prevention of calyx injury are given.