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The Etiology of Apricot Scorch in Utah County, Utah

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THE ETIOLOGY OF APRICOT SCORCH IN UTAH COUNTY, UTAH

by

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INTRODUCTION

First Appearance of the Disease

In the summer of 1944 a disease of apricots in Utah County, Utah, was brought to the attention of the staff of the Utah Agricultural Experiment Station. This disease was characterized by a scorched appearance of the edges of the leaves and therefore was called "apricot scorch."

Description of Symptoms

The typical symptoms of apricot scorch are a scorching and curling of the margins of the leaves (Figure 1). The "scorched" area usually turns a characteristic reddish-brown color, but sometimes is quite light brown or gray. The injury starts at the margins of the leaves and works inward in "waves" first scorching the marginal portion of the leaves, then, after a period during which no injury takes place, scorching the outer edges of the formerly uninjured part of the leaves. At the edge of each "wave" of injury a darker brown line is usually left in the scorched portion of the leaf.

Apparently healthy leaves from an apricot tree which shows some scorching will often develop a marginal necrosis if they are picked and are stored for 48 hours in a closed Mason jar. Apricot leaves from orchards in areas where scorch is not common do not exhibit this marginal necrosis when they are given the same treatment.

A tree which has been slightly scorched may later appear to a casual inspection to have never been scorched. This is because the dead

areas at the margins of the leaves may eventually drop off, leaving the tree with a completely green appearance but with the leaf margins gone.

The Chinese type of apricot is apparently more susceptible to apricot scorch than is the Moorpark type. In the work reported in this paper, however, no attempt was made to classify samples or results on a varietal basis.

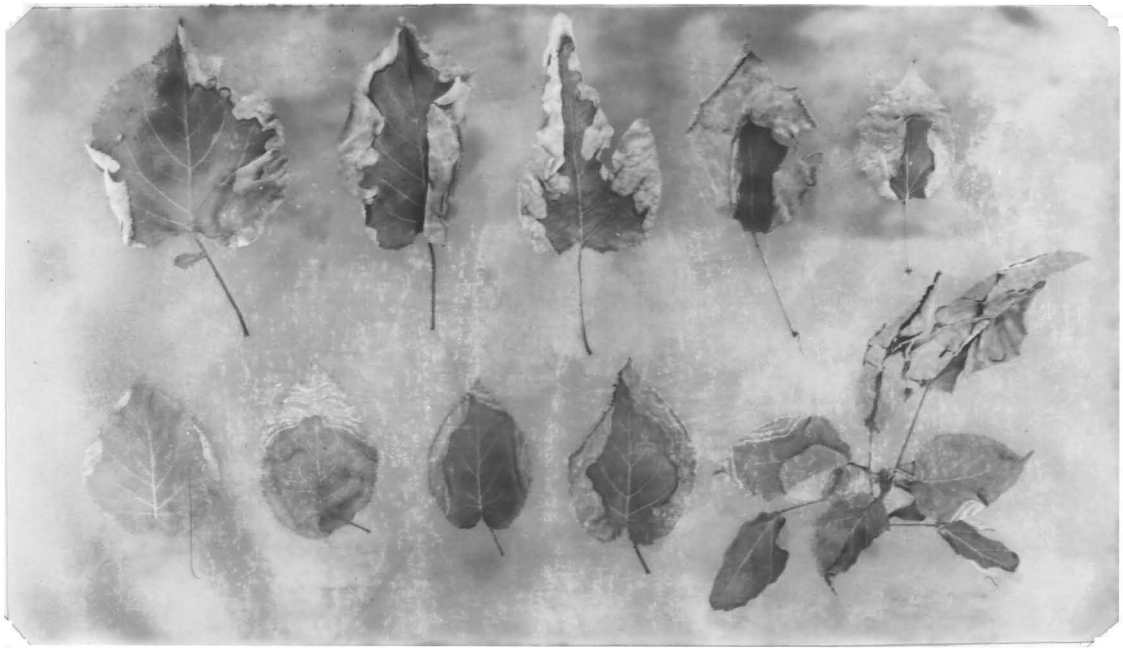

Figure 1. Symptoms of apricot scorch. Leaves collected by F. B. Wann from Peck's orchard in Orem, Utah, September, 1945.

REVIEW OF LITERATURE

Sorauer (5), in his Manual of Plant Diseases, mentioned in 1922 that a marginal scorching of the leaves of birch and other forest trees by hydrofluoric acid sometimes takes place near certain industrial plants. Apricots were not mentioned in this work, but the description of symptoms and the illustration showed that the injury resembled the condition referred to in the present work as apricot scorch.

Fluorine damage to plants has been noticed at various times since 1922 in areas near industrial plants which deliver large amounts of fluorine into the atmosphere. Miller et al.(2) reported a marginal scorch of Italian prune foliage in Washington in the vicinity of an aluminum plant. This prune scorch was accompanied by a high level of fluorine in the leaves of the plants, and was thought to be caused by atmospheric fluorine.

Leone et al. (1) produced a marginal scorching of the leaves of peach, tomato, and buckwheat by growing these plants in nutrient solutions containing high concentrations of fluorine. These leaves were analyzed and were found to contain abnormally high concentrations of fluorine.

Proebsting and Hansen (4) reported a leaf scorch and die-back of apricots in Hollister Valley, California, in 1943. This scorch was found to occur on apricot trees which were on Myrobalam rootstocks. Inarching of apricot roots onto the affected trees caused the plants to recover from the disease.

In 1946, Wann (6) reported experiments which indicated that apricot leaf scorch in Utah County, Utah, was not caused by any common nutrient deficiency or excess. Tomatoes were grown in soil from a severely scorched orchard and were given nutrient solutions containing various nutrient elements. Although some deficiencies were found, nothing was found that could be related to apricot leaf scorch. These tomato plants did not develop the marginal scorch that Leone et al. had produced by growing tomatoes in nutrient solutions containing high amounts of fluorine.

In 1949, when the problem of apricot scorch was given to this writer as a master's thesis problem, Dr. Wann had begun experiments in which scorching was produced on apricots by hydrofluoric acid vapor.

RESEARCH

Preliminary Research

Acid vapors applied to apricot twigs. In an attempt to determine whether the symptoms of apricot scorch could be produced by acids in the atmosphere preliminary experiments were undertaken, starting in June of 1949.

Small cellophane bags were hung on the ends of twigs on apricot trees in two Horticulture Department orchards near Logan. In the closed end of each bag was a vial of 2% solution of acid. The open end of each bag was fastened around the twig with twine so that the bag enclosed several leaves.

The following solutions were used in the vials:

Water
2% phenol in glycerine
2% HF in water
2% HNO_3 in water
2% HCl in water
2% H_2SO_4 in water

Neither the water nor the sulfuric acid produced injury. The phenol produced a blackening of the tips of the serrations of the leaves completely unlike scorch symptoms. The nitric, hydrochloric, and hydrofluoric acids, however, produced symptoms very much like those of apricot scorch. The symptoms began to appear two days after the treatment began in the case of most of the HF treatments, and symptoms were present in almost all bags containing HNO_3, HCl, or HF by the end of the third day.

The scorch produced by these acids was different from what this writer regards as "typical" apricot scorch in only one particular. The

burn produced by the acids left the dead edge of the leaf almost gray in color, while a reddish-brown color is thought to be more typical of apricot scorch.

Thermometers placed in some of the bags showed temperatures within one degree Centigrade of outside temperatures.

Treatment of potted seedlings with HF. Several potted apricot seedlings were placed in a large cellophane box (20 x 30 x 30 inches) which contained a photographic tray full of a 10% solution of HF. Symptoms of leaf injury began to appear on the seedlings after about three hours in the box. These symptoms eventually developed into the typical apricot scorch symptoms.

Some of the plants were removed after only 30 minutes in the box. These seedlings all developed typical apricot scorch symptoms in the greenhouse within five days after the treatment.

After the above treatments had been completed and the box had been well aired for approximately two days, two seedlings were placed in the box for a period of one hour without any acid. Both of these seedlings developed scorch symptoms in the greenhouse within a week after the time of treatment. Two plants which were given the same treatment after the cellophane box had been carefully washed did not show scorch symptoms at the end of four weeks. This scorching of apricots in a box which had been aired indicated that apricots may be scorched by very low concentrations of hydrofluoric acid.

Addition of fluoride to the nutrient solution. As a preliminary investigation of the possibility that apricot scorch might be caused by fluoride in the soil solution, the following experiment was undertaken starting in October, 1949.

Thirty-two apricot seedlings were grown in Vermiculite brand expanded mica in quart Mason jars in the greenhouse in Logan. When the seedlings were about 12 inches tall, the solutions given to the plants were supplemented with the following concentrations of salts in addition to the regular nutrients:

0.20 M NaCl	0.20 M NaF
0.10 M NaCl	0.10 M NaF
0.05 M NaCl	0.05 M NaF
0.02 M NaCl	0.02 M NaF

There were four replications.

Within one week of the time of treatment all of the plants receiving the 0.20 M NaCl and all the plants receiving the 0.20 M NaF showed severe typical scorch symptoms, and one of the plants receiving 0.10 M NaCl showed scorch symptoms. About three weeks after the time of treatment all of the plants receiving the 0.10 M salts showed at least slight scorch symptoms. The severity of the symptoms did not seem to be dependent upon which salt was used.

At the end of this experiment the plants were neglected, and therefore they died. It was noted that all of the plants developed scorch symptoms before their death.

Further small experiments and numerous accidents in the course of other work have all showed that the typical scorch symptoms can

be developed in apricots as a result of insufficient water supply.

It is felt that the symptoms caused by the NaCl and NaF in the nutrient solution were at least partly the result of the osmotic effects of the salts.

No chemical analyses were made of the leaves of these plants.

Scorching of Potted Seedlings in 1949

Materials and methods. Apricot seedlings were grown in # 10 tin cans in Logan greenhouse soil and in soil from Peck's orchard, a very severely scorched orchard in Orem. These seedlings showed no scorch during the entire summer when well cared for in Logan.

Three transparent boxes were built from Sun-Ray brand twine-reinforced cellophane upon a framework of wood. These boxes had slanting transparent tops, transparent walls, and solid 5-ply wooden removable bottoms. The approximate dimensions of these boxes were 36 inches in width by 32 inches from front to rear. Two of the boxes were 45 inches tall, while the third was 37 inches tall. These boxes were provided with facilities for watering plants inside of them without opening the boxes. Blowers were arranged so as to blow air into the boxes at one bottom rear corner, and a hole was provided at the opposite side of the top of the rear of the boxes for the exit of air.

On August 6, 1949, these three boxes were set up in the shade of the production laboratory of the Geneva Steel Company, as is shown in Figure 2. Each box contained one apricot seedling in soil

Figure 2. Experiment set up at Geneva Steel Company plant on August 6, 1949. From left to right the boxes are:

Left: Box #3, receiving air that has been pulled through a gas mask filter.

Center: Box #2, receiving air that has been pulled through wet excelsior. The machine between Box #3 and Box #2 is the blower that pulls the air through the excelsior and blows the cleaned air into Box #2.

Right: Box #1, receiving air that has not been cleaned or filtered.

The blowers connected to Box #1 and Box #3 are behind the boxes and are not visible in this photograph.

from Peck's orchard, one apricot seedling in soil from the greenhouse in Logan, and one peach seedling in soil from the greenhouse in Logan.

The aeration of the boxes was as follows:

Box #1 was provided with no air filter. The rate of flow of air was about 30 cubic feet per minute.

Box #2 was provided with air that had been pulled through wet excelsior. The rate of flow was about 30 cubic feet per minute.

Box #3 was provided with air that had been pulled through gas mask filters (Mine Safety Appliances type GMC, for use against acid gases). Four of these filters were connected in parallel in order to lessen the air resistance. The rate of flow of air was about 3.8 cubic feet per minute. The filters were changed at least once per week, but no tests were made to determine whether or not the capacity of the filters had been exceeded.

Hygrothermographs were left in the boxes to give an indication of whether the direct sunlight falling on the boxes in the mornings and evenings caused high enough temperatures and low enough humidities to be responsible for any scorch which might appear.

The plants were observed at least once per week, and the hygrothermograph records were changed at the times of observation.

Watering of the plants was done daily by personnel of the Geneva Steel Company.

Several apricots and peaches were left outside of the boxes both in greenhouse soil and in soil from Peck's orchard.

Results. The amounts of scorching observed in this experiment are summarized in Table 1.

On August 13 (one week after the experiment was set up) all of the plants outside of the boxes were scorched. One peach was

Table 1. Degree of scorching of potted apricot plants at Geneva Steel Company plant in 1949. Two apricot seedlings were placed in each box on August 6, 1949, and one more was added to each box on September 9

Location of Plants	Degree of scorch injury at various dates		
	August 13	September 9	October 8
Plants not in boxes	severe	severe	severe
Box #1 (uncleaned air)	none	slight	moderate
Box #2 (wet excelsior)	slight on 1 plant	tip burn	tip burn on 2 plants; moderate on 1 plant
Box #3 (filtered air)	none	tip burn	slight

Table 2. Degree of scorching of potted apricot plants at Geneva Steel Company plant in 1950. Three apricot seedlings were placed in each box on June 10, 1950

Location of Plants	Degree of scorch injury at various dates				
	June 24	July 8	mid-July	Aug. 4	Sept. 30
Plants not in boxes	severe	severe	severe	severe	dead
Box #1 (uncovered)	tip burn	severe	severe	severe	almost dead
Box #2 (cheesecloth)	none	none	slight on 1 plant	moderate	severe
Box #3 (filters)	tip burn	tip burn	slight on 2 plants	slight	moderate

only mildly scorched, while the rest of the plants not in boxes were very badly damaged. The apricot in Peck's soil in Box #2 showed very slight scorch symptoms, but all other plants in boxes were unharmed.

On September 9 the peach seedlings were removed from the boxes because they had been severely injured by mites. They were apparently not scorched, but the damage was difficult to evaluate because of the mite injury. At this time new apricots were left in the place of the peaches. The old apricots in Box # 1 had slight scorch symptoms by this time and slight tip burn could be seen on the old apricots in Box #2 and Box #3.

At the end of the experiment on October 8, all three of the plants in Box #1 were moderately scorched. One of the plants in Box #2 was moderately scorched, but the other two plants showed only slight tip burn. The plants in Box #3 showed only slight tip burn with at most one or two definitely scorched leaves on each plant.

The temperatures and relative humidities observed during two representative weeks are summarized in Table 3.

The hygrothermograph records showed that Box #1 had higher temperatures and lower relative humidities than did the other two boxes during the hottest part of the season, but that Box #1 and Box #3 had about the same temperatures during the latter, cooler part of the season. It was during this cooler part of the season that the difference between the scorch in Box #1 and Box #3 became most noticable.

Table 3. Temperatures and relative humidities recorded in boxes at Geneva Steel Company plant during two weeks of 1949

Box No.	Period	Rel. Humidity in %		Temp. in deg. F.	
		Average	Av. Daily Minimum	Average	Av. Daily Maximum
Box #1 (unfiltered air)	Aug. 13-18	20	7	80	102
Box #2 (wet excelsior)	Aug. 13-18	35	21	71	83
Box #3 (filtered air)	Aug. 13-18	33	25	80	96
Box #1 (unfiltered air)	Sept. 23-29	34	20	73	83
Box #2 (wet excelsior)	Sept. 23-29	56	37	56	75
Box #3 (filtered air)	Sept. 23-29	44	31	72	83

The relative humidity in Box #2 was always much higher and the temperature in this box was always lower than were these factors in the other boxes.

Scorching of Potted Seedlings in 1950

Materials and methods. Boxes #1 and #2 were modified for the work done in 1950. Slots four inches wide were made on both sides and on the front of both of these boxes to provide for plenty of ventilation without the use of blowers. These slots were protected from the entrance of rain and of falling particles by overlapping transparent hoods which extended four inches out from the sides of the boxes. The bottom edges of these hoods extended two inches below the bottom edges of the slots. The hoods on the front of the boxes were made so that they could be pulled open for the easy changing of the plants inside of the boxes. The openings in Box #2 were covered with cheesecloth, while the openings in Box #1 were left uncovered.

Neither Box #1 nor Box #2 was provided with a blower. Box #3 had the same blower with the same type of gas mask filters that it had had in 1949.

Three apricots in greenhouse soil were placed in each box and the experiment was set up in the shade of the production laboratory of the Geneva Steel Company on June 10, 1950.

Box #2 was placed on the west (to the right in Figure 2), with Box #1 being placed in the center in 1950. The purpose of this change was to avoid submitting Box #1 (the unprotected box)

to the extremes in temperature caused by the direct exposure of the western box to the evening sun.

Hygrothermographs were not placed in the boxes during 1950.

Several apricot seedlings were left outside of the boxes.

Results. The results of the 1950 experiment are summarized in Table 2.

Bagging of Trees to Prevent Scorch

Bagging in 1950. Peck's orchard is a very badly scorched apricot orchard in Orem. This orchard is neglected, but it has plenty of moisture throughout the entire season. Soil samples taken by Dr. F. B. Wann and field observations by this writer have showed that the soil two feet below the surface remains quite moist.

Late in the summer of 1950 some cloth bags were placed over the ends of twigs in Peck's orchard. It was thought that these bags might prevent the enclosed leaves from becoming scorched.

Upon inspection three weeks after the bags had been put on the trees, it was found that the leaves inside of the bags had had just as much increase in scorch as had those leaves outside of the bags. Inspection six weeks after the bags had been put in place revealed much more scorch than had the inspection after three weeks.

Bagging in 1951. On April 18, 1951, just at the blossoming time of the apricots in Utah County, 25 muslin bags were put over the ends of branches in Peck's orchard. These bags were about 8 inches wide by 30 inches long, and were all carefully washed before being placed on the trees.

The leaves inside and outside of the bags were observed at four different dates, and collections of material for analysis were made at three different dates.

The results of this study are summarized in Table 4. It can be seen that the muslin bags afforded a fair degree of protection to the leaves, but that even the leaves inside of the bags eventually became scorched.

In one case, the end of the twig had made a hole in the end of the bag and had grown through this hole. In this case all the leaves on the part of the twig protruding out of the bag were scorched, while none of the leaves remaining inside of the bag had been damaged on June 8.

On October 8 a fire in the orchard had destroyed many of the bags and had caused additional damage to the leaves. Because of the difficulty in distinguishing fire damage from apricot scorch no observations were recorded.

Analysis of Leaves for Fluorine

Method. Collections of leaves for fluorine analysis were made at several different dates and at several different locations in Utah County. A few samples were collected from apricot trees from the Horticulture Department orchard on the U.S.A.C. campus. The degree of scorch of these samples was recorded as none, slight, moderate, or severe.

The leaves were dried, ground, and kept in paper bags until they were analyzed.

Table 4. Average fluorine content and degree of scorch of leaves and average fluorine content of muslin bags from Peck's orchard in Orem, Utah, in 1951

Material Observed	Date Observed	Average Degree of Scorch	No. of Samples Analyzed	Average PPM F
Leaves from inside of bags	June 8	none	0	
Leaves from next to bags	June 8	moderate	0	
Leaves from inside of bags	July 23	slight	7	85.0
Leaves from next to bags	July 23	moderate	8	108.4
Muslin bags	July 23		5	249.8
Leaves from inside of bags	Sept. 1	moderate	6	110.5
Leaves from next to bags	Sept. 1	severe	7	191.3
Muslin bags	Oct. 8		2	251.5

Analysis for fluorine was made by a modification of the tentative A.O.A.C. method (3). The leaf material was mixed with "fluorine-free" CaO, the mixture was uniformly dampened with water and then dried at 100 degrees Centigrade. The material was then ashed at 600 degrees C., was transferred to perchloric acid with some silver perchlorate, and was carried through a single steam distillation at 135 degrees C., the distillate being kept basic by the addition of KOH solution. An aliquot of the distillate was collected, $NH_2OH \cdot HCl$ and HCl were added, and the aliquot was titrated to a standard colored end point with $Th(NO_3)_4$, with alizarin red being used as an indicator.

Four stills were operated together, and four samples were carried through each determination simultaneously. It was found that occasionally some unknown factor (probably the temperature of ashing) would cause a large error in all four of the samples. Therefore one of the four samples of each run was always from a large quantity of ground leaf material, the fluorine content of which was known. In addition to this precaution, about one-fourth of the samples were run twice.

The results of the analyses were easily reproducible within about plus or minus 4% of the value in question for any well mixed leaf sample.

Results. The range of values of fluorine found in 96 samples of apricot leaves from Utah County was from 34 to 304 parts per million, with an average of 115 ppm. The range of concentrations of fluorine found in apricot leaves in Logan was from 25 to 58 ppm. for ten samples, with an average of 34 ppm.

If values of 1, 2, 3, and 4 are assigned to no scorch, slight scorch, moderate scorch, and severe scorch, respectively, the correlation coefficient between scorch and fluorine content of the apricot leaves from Utah County is 0.63, with fiducial limits at the 5% level of 0.50 and 0.75. (see Figure 3).

The results of analyses of leaves from within the bags and from beside the bags and the analyses of some of the bags themselves are shown in Table 4. The leaves outside of the bags had an average fluorine content of 147 ppm., as compared to an average fluorine content of 96.8 ppm. for the leaves which had been protected by the bags.

The bags themselves had an average fluorine content of 250 ppm. This figure obviously cannot be compared with the values of the fluorine contents of the leaves, but it does show that the bags intercepted considerable quantities of fluorine. Identical bags which had not been placed on trees contained less than 5 ppm. fluorine.

At a given location there was an increase in fluorine content of foliage as the season progressed. This is shown in Tables 4, 5, and 6.

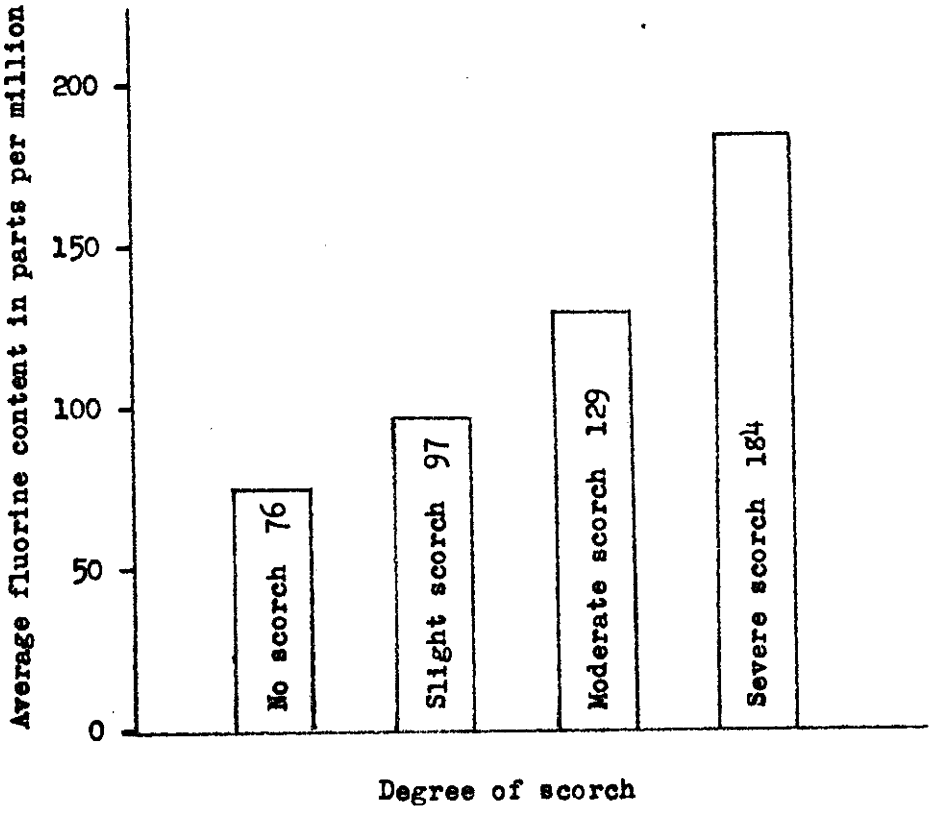

Figure 3. Degree of scorch and average fluorine content of 96 apricot leaf samples collected in Utah County, Utah, in 1950 and 1951.

The correlation coefficient between degree of scorch and fluorine content was 0.63, with fiducial limits at the 5% level of 0.50 and 0.75.

Table 5. Average flourine content of apricot leaves collected at 10th East and 6th North in Orem, Utah, at various dates

Date Collected	Number of Samples	Average PPM Fluorine
Aug. 20, 1950	4	99.8
July 23, 1951	4	80.0
Sept. 1, 1951	3	91.3
Oct. 8, 1951	3	116.7

Table 6. Average fluorine content of apricot leaves collected at orchard 0.3 miles east of intersection of 4th North and Highway 89 in Orem, Utah, at various dates

Date Collected	Number of Samples	Average PPM Fluorine
Aug. 20, 1950	2	88.5
July 23, 1951	2	92.0
Sept. 1, 1951	2	99.0
Oct. 8, 1951	2	133.0

DISCUSSION

That some factor in the atmosphere is responsible for apricot scorch in Utah County is indicated by the following facts:

1. Plants protected from the atmosphere by filters, by cheesecloth, by muslin, by wet excelsior, or by merely being sheltered did not become as badly scorched as did unprotected plants. The plants protected by gas mask filters became only moderately scorched in an atmosphere which killed unprotected plants. Even this moderate scorching may have been because the capacity of the filters had been exceeded.

2. Tomatoes (6) and apricots grown in soil from a severely scorched orchard did not show scorching.

3. One of the most severely scorched orchards is known to have ample moisture for normal growth.

That fluorine is one of the atmospheric factors responsible for apricot scorch in Utah County is indicated by the following facts:

1. Scorched leaves contain high levels of fluorine, with a correlation coefficient of 0.63 between fluorine content and degree of scorch.

2. Fluorine can produce scorch symptoms on apricots.

3. In general, apricot scorch is noticable only near possible industrial sources of fluorine, such as steel plants, brick yards, and refractories plants.

That atmospheric fluorine is probably not the only factor responsible for apricot scorch is indicated by the following facts:

1. Symptoms indistinguishable from those of apricot scorch can be produced solely by a lack of water.

2. Symptoms similar to those of apricot scorch were found to be caused by a stock-scion relationship in California (4).

3. Symptoms similar to those of apricot scorch can be produced by addition of large quantities of fluorides to the nutrient solutions supplied to peach, tomato, and buckwheat (1), and to apricot.

4. The correlation coefficient between the level of fluorine and the degree of scorch is only 0.63.

5. In observing scorched orchards this writer has received the definite impression that neglected orchards suffer much more from apricot scorch than do well cared for orchards in the same environment. This may be because of a lack of water in some cases.

6. Leaves can apparently have sufficient fluorine to cause scorch and yet not exhibit the symptoms until some other (unknown) factors come into play. "Unscorched" leaves may develop a marginal necrosis when stored in Mason jars. Bags put on trees near the end of the season apparently did not affect the degree of subsequent scorching, while bags put on at the beginning of the season modified the amount of scorching over the entire summer.

CONCLUSION

It is the conclusion of this writer that apricot scorch, as encountered in Utah County, Utah, is caused primarily by atmospheric fluorine, but is also influenced by other factors. The exact nature of these other factors is unknown.

SUMMARY

In 1944 a marginal scorching of the leaves of apricots in Utah County, Utah, was noticed. This disease was called "apricot scorch."

Experiments in 1949 indicated that the symptoms of apricot scorch could be produced by the treatment of apricot twigs or seedlings with HF vapor.

In 1949 apricot seedlings were placed in Utah County in three transparent boxes. These three boxes were supplied with filtered air, with air pulled through wet excelsior, and with uncleaned air, respectively. The apricots receiving the uncleaned air became scorched more quickly and more severely than did those receiving cleaned air.

In 1950 apricot seedlings were placed in Utah County in three transparent boxes. Two of these boxes were provided with large ventilating holes, the holes of one of the two boxes being covered with cheesecloth. The third box was provided with filtered air by a blower. The seedlings in the box with uncovered ventilating holes became scorched most quickly and severely. The seedlings receiving the filtered air became scorched most slowly and least severely. The seedlings in the box with cheesecloth were intermediate. Similar apricot seedlings outside of the boxes were killed by repeated scorching.

Before appearance of the leaves in 1951, muslin bags were placed over branches in an orchard where scorch had previously been severe.

The leaves which grew inside of these bags were not so severely scorched as were the outside leaves, and the inside leaves contained considerably less fluorine than did the outside leaves. The bags contained a large amount of fluorine by the end of the season.

In 1950 and 1951 apricot leaves were collected in Utah County and in Logan, with the degree of scorch being recorded on a scale of four. These leaves were analyzed for fluorine by a modification of the tentative A.O.A.C. method.

The average fluorine content of 96 leaf samples from Utah County was 115 ppm., while the average fluorine content of 10 leaf samples from Logan was 34 ppm. The coefficient of correlation between degree of scorch and fluorine content of the leaves from Utah County was 0.63.

It was concluded that atmospheric fluorine is the primary causal factor of apricot scorch in Utah County, Utah.

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