APPARENT PHOTOSYNTHESIS AND TRANSPERSION OF PECAN LEAVES TREATED WITH BORDEAUX MIXTURE AND LEAD ARSENATE

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INTRODUCTION

Two of the most widely used spray materials in the control of insects and diseases of the pecan are lead arsenate and bordeaux mixture. Since it has been clearly demonstrated (6, 8, 12) that certain sprays may have a deleterious effect on the foliage of trees, it seemed advisable to determine to what extent bordeaux mixture and lead arsenate influence the photosynthesis and the transpiration of pecan leaves. Most of the literature relating to the effects of bordeaux mixture on these physiological processes is contradictory and was obtained with species other than the pecan. Lutz and Hardy (10) reported that pecan leaves sprayed with low-lime bordeaux mixture were more efficient in carrying on photosynthesis than unsprayed leaves. Clore (2), Hoffman (8), and others found no significant difference between the carbon dioxide intakes of bordeaux-sprayed and untreated apple leaves, whereas Southwick and Childers (12) found that bordeaux mixture sprayed on apple leaves caused a reduction in apparent photosynthesis. Some workers (3, 13) reported an increase in the rate of transpiration due to the application of bordeaux mixture, while others (1, 4, 11) failed to find very marked effects of this spray material on transpiration rates. Few or no data are available relating to the effects of lead arsenate on carbon dioxide assimilation or transpiration.

In this paper are presented data which show the effects of bordeaux mixture and lead arsenate applications on the rates of apparent photosynthesis and transpiration of mature leaves of the pecan, Carya illinoensis K. Koch (syn. C. pecan), at Brownwood, Tex.

MATERIALS AND METHODS

The apparatus and procedure for measuring the apparent photosynthesis were similar to those used by Heinicke and Hoffman (7). The apparatus consisted of six carbon dioxide absorption towers, of which two were attached to the check leaves, two were attached to the test leaves, and two served as air controls. The assimilation chambers were similar to those described by Heinicke (5) and were adapted for use with pecan leaves by Loustalot and Hamilton (9). A continuous stream of air at the rate of 2 to 2.5 liters per square centimeter of leaf area per hour (7) was drawn through the chambers.
by mercury pumps. The water transpired by the leaves was determined by weighing, after it was absorbed by a dehydrating agent (pumice stone impregnated with sulfuric acid) through which the air was passed before it reached the carbon dioxide absorption towers. The volume of air passing through each absorption tower was accurately measured by a wet-test flowmeter.

All the experiments were conducted during the summer of 1941 with the mature leaves of a 10-year-old pecan tree of the Western variety growing near the laboratory of the United States Department of Agriculture Pecan Field Station, Brownwood, Tex. The tree was in good vigor and was carrying a full crop of nuts. The foliage, which was abundant and dark green, had been sprayed in late spring with zinc sulfate (3-100) to control pecan rosette, but at the time the experiments were started there was no visible residue.

Two pairs of mature, healthy, dark-green leaflets, comparable in position and exposure to sunlight, were selected for each experiment. One pair was designated as check and the other as test leaves before any determinations of transpiration or photosynthesis were begun. Two determinations were made each day in all the experiments—one between 9:00 a.m. and 1:15 p.m. and the other between 1:30 and 4:30 p.m. Weather observations, including temperature (°F.) and relative humidity (percent), were made at the beginning, the middle, and the end of each determination. Owing to lack of facilities for recording solar radiation, the general sky condition prevailing during each determination was estimated.

Apparent photosynthesis was calculated as the average number of milligrams of carbon dioxide assimilated per hour by 100 cm.² of leaf surface. Transpiration was calculated as the average number of grams of water lost per hour by 100 cm.² of leaf area. The relation in the apparent photosynthesis and transpiration was first established between the check and the test leaflets for a period of 4 to 5 days, after which the spray material was applied to the test leaflets.

Three experiments with bordeaux mixture were performed between June 27 and July 28, and two experiments with lead arsenate were conducted between September 2 and October 10. In all instances the spray material was applied to both surfaces of the test leaflets by dipping them twice into a thoroughly agitated, freshly prepared mixture and allowing the material to dry on the leaflets between immersions. The spray material was applied in the morning and had thoroughly dried on the leaves before the determinations were made.

It will be noted that in each of the five experiments the test leaves had lower rates of transpiration and apparent photosynthesis than the check leaves. This was purely accidental and has not particular significance. In setting up each experiment the two pairs of leaflets were selected, numbered, and designated test and check before any determinations were made.

**EXPERIMENTS WITH BORDEAUX MIXTURE**

The data for the three experiments with bordeaux mixture are presented graphically in figures 1 to 3. Since the relation between the two sets of leaflets before the spray application was fairly constant,
as shown in the figures, it was possible to obtain a good estimate of the efficiency of each set of leaves; any appreciable deviation from this established relation after the spray material was applied could be attributed to the treatment.

In experiment 1 (fig. 1) both sets of leaflets were exposed to full sunlight during both the morning and the afternoon period except on cloudy days, when the light varied with the extent of cloudiness. Bordeaux mixture (6–2–100) was applied to the test leaflets at 8 a.m. on July 2. In the succeeding 5 days, inclusive of the day of spraying, the relation in the transpiration and the apparent photosynthetic activity between the two sets of leaflets differed very little from that established during the standardization period from June 27 to July 1. A maximum average temperature of 94° F. occurred on the second afternoon following the spray application but caused no noticeable effect on the transpiration and photosynthetic relations between the check and test leaflets. The variations in the apparent photosynthetic relation between the two pairs of leaflets on June 27 and 28 may have been due to some unbalanced internal conditions in the leaflets or to errors in experimental manipulation or determinations.

In experiment 2 (fig. 2) the procedure was similar to that in experiment 1, except that both sets of leaflets were partially shaded by adjacent foliage during both the morning and the afternoon period. Bordeaux mixture (6–2–100) was applied to the test leaflets on the morning of July 12. During the next 4 days, including the day the spray was applied, there was relatively little change in the relation in the two processes between the two sets of leaflets as compared with
that during the standardization period. The temperature during this period was unusually low for the time of year.

In experiment 3 (fig. 3) the exposure of both sets of leaflets during the morning and the afternoon period was similar to that described for the leaflets used in experiment 1. This experiment differed from experiments 1 and 2 in that the test leaflets received three applications of bordeaux mixture, each on a different day, and the third application was of an 8–8–100 mixture instead of the recommended 6–2–100. The first application was made on July 20, the second on July 23, and the third on July 25. The test leaflets were so well covered with spray residue at the end of the third application that the green color of the leaflets was hardly visible. The results were more or less similar to those obtained in experiments 1 and 2—that is, the relation in the two processes between sprayed and check leaflets remained fairly constant both before and after the application of bordeaux mixture to test leaflets. The fact that the apparent photosynthesis was not affected in the leaflets covered by three spray applications indicates that the absorption of light energy was not sufficiently reduced by the spray residue to influence the rate of carbon dioxide assimilation.
The data show that under the conditions of these experiments bordeaux mixture had little or no effect on the apparent photosynthesis and transpiration of mature pecan leaves. It will be noted from the photosynthesis and transpiration curves that small but inconsistent deviations occurred in the relation between the check and test leaflets, but these deviations fall within the limits of experimental error since they are no greater than differences between duplicate determinations from a single pair of leaflets. The deviations in duplicate determinations were usually less than 5 percent, but in a few instances they were higher, the maximum being about 14 percent. The variations in the ratios between the test and check leaflets, before and after the spray application, were usually less than 5 percent, the maximum being approximately 7 percent.

Lutz and Hardy (10) reported a higher photosynthetic rate for pecan leaves sprayed with low-lime bordeaux than for unsprayed leaves. However, they pointed out that the unsprayed leaves were lighter in color than those sprayed and in addition contained diseased areas. In the same paper these authors presented data indicating...
that dark-green pecan leaves are more efficient in carbon dioxide assimilation than those of a lighter green color, a fact that Heinicke (6) demonstrated with apple leaves. It has also been shown (9) that even a mild infection by the fungus causing the disease known as downy spot [Mycosphaerella caryigena (Demaree and Cole)] markedly reduces the ability of pecan leaves to assimilate carbon dioxide. In view of these facts, it seems reasonable to assume that the beneficial effects of bordeaux mixture on the efficiency of pecan leaves observed by Lutz and Hardy may be attributed to the indirect effect on disease and the intensification of green color rather than to the direct effect of the spray material itself. It should be emphasized in this connection that the leaves used in the experiments reported herein were dark green and free from any visible disease injury, and that, therefore, any direct influence of bordeaux mixture on the two physiological processes could be determined.

EXPERIMENTS WITH LEAD ARSENATE

In the experiments with lead arsenate the same general procedure was followed as in the bordeaux mixture experiments. The first experiment was begun on September 2 and terminated on September 13, and the exposure of the two pairs of leaflets for morning and afternoon periods was similar to that described for the leaflets used in experiment 1 with bordeaux mixture. Lead arsenate (6-100) was applied to the test leaflets on three different dates, September 8, 10, and 12.

In the second experiment, started on September 29 and terminated on October 10, one spray application was made on the morning of October 6. In this case the two pairs of leaflets were located on the east side of the tree and exposed in such a way as to receive full benefit from sunlight, except when cloudy weather obscured the sun, but they were fully shaded by the adjacent foliage during the afternoon periods. No determinations were made on the afternoons of October 4 and 5.

The experimental data for the lead arsenate experiments are presented in figures 4 and 5. These data show no appreciable effect of lead arsenate applications on the rates of transpiration and carbon dioxide assimilation of pecan leaves. There was a wide variation in the average temperature during the experimental periods from September 8 to 13 (fig. 4), the maximum of 93° F. occurring in the afternoon period of September 8 and the minimum of 67° occurring during the morning period of September 9. The average relative humidity varied from a low of 34 percent during the afternoon of September 8 to a high of 96 percent during the morning of September 9. With decreases in temperature and increases in relative humidity the rate of transpiration decreased, but in neither experiment (figs. 4 and 5) was there any appreciable difference in the established ratio between the check and test leaflets. Apparent photosynthesis varied considerably with fluctuations in light intensity and other meteorological factors, but in no instance was there any marked change in the established relation in this process between sprayed and unsprayed leaflets. The minor deviations that occurred in the ratio of both transpiration and apparent photosynthesis rates in test and check leaflets are within the limits of experimental error. Therefore, appli-
The effects of three successive applications of lead arsenate on the apparent photosynthesis and transpiration of mature pecan leaves exposed to full sunlight: A–C, Morning determinations of carbon dioxide assimilated (A), of water transpired (B), and of the accompanying weather conditions (C); D–F, afternoon determinations of carbon dioxide assimilated (D), of water transpired (E), and of the accompanying weather conditions (F).

Cations of lead arsenate to mature pecan leaves had no significant effect on carbon dioxide assimilation or transpiration.

The fluctuations in the apparent photosynthesis from day to day of both test and check leaflets apparently were due to changes in environmental conditions, especially light, while fluctuations in transpiration seemed to follow changes in temperature and relative humidity.
SUMMARY

Studies were made to determine the effects of bordeaux mixture and lead arsenate applications on the rates of the apparent photosynthesis and transpiration of mature pecan leaves on a 10-year-old pecan tree during the 1941 season. Three experiments were conducted with bordeaux mixture during the period from June 27 to July 28, and two similar experiments with lead arsenate were carried on between September 2 and October 10.
No appreciable effects on the apparent photosynthesis or transpiration were obtained by applications of either bordeaux mixture or lead arsenate to mature pecan leaves. The same results were obtained from one or three applications of the spray materials even though the leaves receiving three applications were so well covered that the green color was scarcely visible.

Wide fluctuations occurred in rates of apparent photosynthesis and transpiration from day to day and during the morning and afternoon periods of the same day, but apparently these were due largely to changes in meteorological conditions. The rates of apparent photosynthesis were affected primarily by fluctuations in light intensity, while transpiration rates seemed to follow changes in temperature and relative humidity.

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