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The sanitation and fertilizer test plots in aspen stands on Bright Angel Point of the Grand Canyon National Park were examined October 21-23 of this year. The plots were established by the Division of Forest Pathology in 1941 to determine if the removal of dead and diseased trees and the application of fertilizers would slow down the decline and deterioration of aspen stands in which high scenic value was combined with excessive use. Establishment of the plots and annual examinations between 1941 and 1945 have been described in a number of typewritten reports[1/] The plots were not examined between 1945 and 1951.

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1/Andrews, Stuart R. Report on Sanitation and Fertilization Tests in Aspen Stands on Bright Angel Point, Grand Canyon National Park. 1941.

Mielke, James L. Report on Sanitation and Fertilization Tests in Aspen Stands on Bright Angel Point, Grand Canyon National Park. Separate Reports for 1942-1945, incl.

_____ Office Report on Aspen Study, Bright Angel Point, Grand Canyon National Park. 1945.

Larsen, Harold D. Memorandum to Dr. Lake S. Gill, subject: Analysis of Sanitation and Fertilization Tests in Aspen Stands, June 17, 1947.

Mielke[2] reported that as of 1945, growth on the treated sanitation

[2] See Footnote 1, page 1.

plot was somewhat better than on the check plot but that about the same number of trees had new Valsa (Cytospora) cankers on the two plots. He pointed out that there appeared to be a trend toward accelerated mortality among the trees on the check plot which would have been removed in a sanitation cutting but that it was too early to draw any conclusions in this regard. He stated that the aspen borer was more abundant on the treated plot than on the check plot. According to Mielke, the most significant development in the sanitation test was the appearance of sprout reproduction in the treated plot as a result of opening-up the stand. He was unable to detect any significant effect of the fertilizer on tree vigor, disease, or mortality. In general, he concluded that the aspen stands under study were overmature and, therefore, highly susceptible not only to canker diseases and insect attacks but also to attacks by wood-rotting fungi that predisposed them to breakage or windthrow. He expressed the opinion that in time sanitation measures instead of fertilizers will prove to be of greatest value, mainly because they hasten stand regeneration.

A statistical analysis of the data collected during the 4-year period ending in 1945 was made later by Dr. Harold D. Larsen[3], a

[3] See Footnote 1, page 1.

temporary employee of the Division. He concluded that the removal of infective trees had no significant beneficial effect on the remaining living trees with respect to rate of growth, disease, or attacks by wood borers. Inasmuch as no trees had yet died on the treated plot and only one of the theoritically "left" trees had succumbed on the check plot, no conclusions could be drawn on the effect of a sanitation cutting on mortality. Larsen also concluded that the application of fertilizers had not stimulated tree growth. This was based on a comparison of the percentage increase from 1941 to 1945 in average d.b.h. and average basal area on the plot which was treated with 150 pounds of commercial fertilizer with the untreated check plot.

This year the generally healthier appearance of the treated plots than adjacent untreated stands suggested that the results of treatment might now be more apparent than they were in 1945. Inasmuch as the tests were 10 years old, it seemed advisable to make a complete examination as a basis for a final report or restoring the plots, if continuation of the tests was indicated. The plots were examined after many of the trees had lost their leaves, so it was impossible to estimate tree vigor from the appearance of foliage as was done previously.

## Conclusions and Recommendations

Results of the sanitation test after 10 years indicate that the removal of all dead trees and a major proportion of the infective trees:

1. Stimulated the growth of the remaining trees to a limited extent.
2. Reduced mortality in the residual stand and thereby decreased the amount of new infectious material. Stand density, however, was decreased to a greater extent by the sanitation cutting than occurred during the same period under natural conditions.
3. Did not appreciably increase resistance to disease and insect attack or arrest decline.
4. Stimulated sprout reproduction. For reasons now imperfectly understood, survival of the reproduction has been poor but the potentialities for stand regeneration were obviously increased when the stand was opened.

Results of the fertilizer tests indicate that aspen stands may be benefited if the treatment is applied before serious decline is evident.

1. In the normal or healthy aspen stand tested:
   a. Diameter growth was significantly stimulated only on the two plots that were treated with about four cubic yards of stable manure and 150 pounds of commercial fertilizer, respectively. Inasmuch as growth during the last six years of the tests was generally better than that during the first four years, it is natural to assume that there is a considerable delay in the response of trees to fertilizer. It is possible, however, that a comparison of growth for several years

prior to treatment with that for a similar period afterwards would show that the delay was of shorter duration.

b. Susceptibility to disease and the rate of decline and mortality may have been reduced to some extent, but the significance of this effect could not be verified.

c. The activity of aspen borers remained a minor factor and the effect of fertilizer on the resistance of trees to insect attack was not estimated. It is likely, however, that it was increased to the extent that tree vigor was improved.

d. Inasmuch as aspen stands have an extensive network of roots common to many trees, the effect of a particular fertilizer application may have extended across the 20- to 30-foot isolation strips separating the five plots in the normal stand. This would serve to explain the generally better growth on all plots, including the untreated check. Such diffusion might also tend to reduce the amount of fertilizer actually taken-up by the plot trees.

2. In the declining stand tested:

a. Diameter growth rate was not stimulated, but the rate of fertilizer application was less than the maximum amount effective in the normal stand.

b. Susceptibility to disease and rate of mortality probably was not reduced to any extent.

It is impossible to recommend practicable measures that will prolong the life of aspen in heavily used stands, on the basis of these tests that were planned as a preliminary study. It appears, however, that by removing dead and severely diseased or declining trees and spreading stable manure (one-half cubic foot per inch of d.b.h.) or commercial fertilizer (1.5 pounds of 10:8:6 per inch of d.b.h.) around the bases of selected healthy trees, the rate of deterioration might be markedly reduced and scenic values maintained.

It is recommended that the present tests be placed on inactive status, but that observations be made, if possible, five years hence, especially on the sanitation plots.

The Division of Forest Pathology would welcome the opportunity to continue this line of investigation. Additional study on a larger scale might test sanitation cuttings of different intensities, heavier and possibly several applications of fertilizers having different formulas, and more complete observations on the ecology and pathology of aspen stands in this area of the Grand Canyon National Park.

## Analysis of Results

### Sanitation Test

To provide orientation without recourse to the original report Table 1 gives a comparison of the two sanitation plots as they were in 1941 prior to treatment. It shows that the two plots were fairly similar with respect to mortality, disease, and top dieback, but that aspen borer was definitely more abundant on the plot selected for treatment. The two plots differed in another important respect, viz.,

the trees on the treated plot were smaller than those on the check plot (75 percent of those on the treated plot was less than 7 inches d.b.h. as compared to 61 percent on the check plot).

Rate of Growth

In determining the effect of the sanitation cutting on rate of growth the first analyses were limited to a mechanically selected 10 percent sample (every tenth tree) of the remaining living trees on the treated plot and the living trees on the check plot that would have been retained if the plot had received similar treatment. Results of the analyses shown in Tables 2 and 3 may be summarized as follows:

1. During the 1945-1951 period, mean annual growth was somewhat greater on the treated plot than on the check plot, but the difference was not significant (Table 2).
2. On the treated plot, mean annual growth during the 1945-1951 period was somewhat greater than that during the 1941-1945 period, but the difference was not significant (Table 3, first part).
3. On the check plot, mean annual growth during the 1945-1951 period was somewhat less than that during the 1941-1945 period, but the difference was not significant (Table 3, second part).

Inasmuch as the average d.b.h. for the 10 percent sample of the treated plot was 1.6 inches less than that of the check plot, another significance test was made using trees of approximately the same size (6.6-7.5 inches d.b.h.). Under this condition, mean annual growth during the 1945-1951 period was significantly greater on the treated plot than on the check plot, but the mean annual growth rates for the 1941-1945 period were not significantly different (Table 4).

Mortality, disease, top dieback, and wood borers

Table 5 shows the mortality, disease, top dieback, and active aspen borer work in the remaining trees on the treated plot as compared to the trees on the check plot that would have been left if a similar sanitation cutting had been made. It will be noted that as of 1941, or when the test was started, disease and active borer work was twice as abundant on the treated plot than on the check plot.

During the 1945-1951 period an appreciable number of trees died on both plots, but the rate of mortality on the check plot was two and one-half times that on the treated plot. As would be expected, a much higher proportion (42 percent) of the trees that would have been removed in a sanitation cutting have died on the check plot.

Cankers were observed on 33 percent of the trees on the treated plot this year, as compared to 20 percent in 1941. This amounts to a 65 percent increase for the 10-year period. On the check plot cankers were observed on 18 percent of the trees, as compared to 10 percent in 1941. This amounts to an 80 percent increase for the 10-year period.

Top dieback was observed on 7 percent of the trees on the treated plot, as compared to one percent in 1945. On the check plot this condition was observed on only two percent of the trees, as compared to none in 1945.

Aspen borer work was recorded for 43 percent of the trees on the sanitation plot, as compared to 60 percent in 1945. On the check plot borer activity was recorded for only 9 percent of the trees, as compared to 21 percent in 1945. This suggests a rather pronounced decline in insect activity on both plots, even when account is taken of the effect of mortality in decreasing the number of living trees available for

attack. It remains problematical that opening the treated stand resulted in more intense borer activity, especially in view of the initial differences in the abundance of borer work on the two sanitation plots.

Condition of reproduction on the treated plot

Practically all of the aspen sprout reproduction reported by Mielke appeared to be dead in 1951.

## Fertilization Test

Under the heading "1941" in Table 6 appear the percentages of diseased and declining trees when the 6 fertilizer plots were established in 1941. No records were made of dead trees, but mortality probably had been low on all but plot 6. It will be noted that there was considerable variation in the proportion of diseased and declining trees even among the 5 adjacent plots in the normal stand. The sizes of trees varied to a considerable degree also. Such variation is probably due to the small samples involved.

Rate of Growth

Diameter growth should express changes in tree vigor resulting from the application of fertilizers. Larsen found no significant differences in diameter growth (expressed as percentages of d.b.h. and basal area) between the most heavily fertilized plot and the untreated check plot for the 1941-1945 period. Comparison of 1945 and 1951 diameters indicated that a similar analysis of growth for the last six years of the tests would lead to the same conclusion. On the other hand, inspection of the data suggested that on the average growth had been

more rapid between 1945 and 1951 than during the earlier period; a not unexpected situation if there is a lag in the trees' response to fertilizer.

Table 7 shows the mean annual growth for the remaining living trees on the 5 plots in the normal stand. Growth for the 1945-1951 period was more rapid than that for the 1941-1945 period on all 5 plots. The differences, however, were significant on only two plots; plot 1 which was treated with stable manure, and plot 2 which was treated with 150 pounds of commercial fertilizer.

Apparently the significance of the differences was not affected by mortality. For example, whereas 23 percent of the trees on plot 1 were dead in 1951, none had died on plot 2, and 4 percent had died on plot 5, the untreated check.

Mortality

Table 7 shows the variation in mortality on the fertilizer plots. Fifteen percent of the trees on the 5 plots in the normal stand were dead this year, compared to 47 percent of the trees on the single plot in a declining stand. There was considerable variation on the plots in the normal stand that tended to follow the pattern of disease and decline found in 1941 (Table 8). With 73 percent of the trees on the plot in the declining stand diseased in 1941, and 100 percent declining, the high mortality as of 1951 was to be expected.

Disease

Fifteen of the 101 remaining living trees on the 5 plots in the normal stand were diseased in 1951. Disease on the individual plots

is shown in Table 6. Of the 15 trees, 6 were reported diseased in 1941, and one additional tree was reported in 1945. The remaining 8 trees were listed as healthy prior to 1951. Since 17 percent of the trees were diseased in 1941, there has been a net decrease after allowance for mortality of about 12 percent.

All the remaining living trees on the plot in the declining stand were diseased in 1951. Only 4 of the original 15 trees were reported free from disease in 1941, but even at that time signs of decline were marked in these trees.

Top Dieback

Seven trees on the plots in the normal stand had top dieback in 1941, and all of them are now dead. Not more than 3 of the remaining living trees showed this condition in 1951, although it could not be accurately determined because of the advanced stage of leaf shed. Observations on this point were not made on the plot in the declining stand because the trees were generally diseased and completely defoliated.

Wood Borers

Evidence of attacks by wood borers has always been negligible on the fertilization plots in the normal stands and this was again the case in 1951. No observations were made on insect activity on the plot in the declining stand.

Table 1.--Comparison of sanitation plots prior to treatment in 1941

| | 1941 | |
|---|---|---|
| | Treated Plot (Pct.) | Check Plot (Pct.) |
| 1. Mortality | 12 | 15 |
| 2. Disease | 54 | 44 |
| 3. With top dieback | 15 | 15 |
| 4. Attacked by aspen borers | 54 1/ | 25 |
| Basis (no. trees) | (388) | (490) |

1/ Based on trees that were left because observations were incomplete for those that were cut.

Table 2.--Comparison of mean annual growth made during 1945-1951 period by 10 percent sample of trees on the sanitation plots

| Sanitation Plots | No. | D.B.H. (inches) Mean | Mean Annual Growth | |
|---|---|---|---|---|
| Treated | 18 | 6.0 | 0.085 | |
| Checked | 25 | 7.6 | 0.067 | |
| | | Difference = | 0.018 | |
| | | t = | 1.620 | Not signif. |

Table 3.--Comparison of mean annual growth made during the 1941-1945 and the 1945-1951 periods by 10 percent sample of trees on the sanitation plots

| Sanitation Plots | No. | Mean annual growth in D.B.H. (inches) |
|---|---|---|
| Treated | | |
| 1941-1945 | 18 | 0.079 |
| 1945-1951 | 18 | 0.085 |
| | | Difference = 0.006 |
| | | t = 0.7608 Not signif. |
| Check | | |
| 1941-1945 | 25 | 0.073 |
| 1945-1951 | 25 | 0.067 |
| | | Difference = 0.006 |
| | | t = 1.584 Not signif. |

Table 4.--Comparison of mean annual growth made during the 1941-1945 and 1945-1951 periods by 6.6-7.5-inch d.b.h. trees on the sanitation plots

| | No. | | Mean annual growth in D.B.H. (inches) 1941-1945 | | 1945-1951 | |
|---|---|---|---|---|---|---|
| Treated | 27 | | 0.085 | | 0.095 | |
| Check | 23 | | 0.070 | | 0.067 | |
| Difference = | 0.015 | | | Difference = | 0.028 | |
| t = | 1.4592 | Not signif. | | t = | 3.538 | Highly signif. |

Table 5.--Comparison of the sanitation plots omitting trees marked for removal

| | 1941 | | 1945 | | 1951 | |
|---|---|---|---|---|---|---|
| | Treated (Pct.) | Check (Pct.) | Treated (Pct.) | Check (Pct.) | Treated (Pct.) | Check (Pct.) |
| 1. Mortality | 0 | 0 | 0 | 0 | 2 | 5 |
| 2. Disease | 20 | 10 | 28 | 15 | 33 | 18 |
| 3. With top dieback | 0 | 0 | 1 | 0 | 7 | 2 |
| 4. Attacked by aspen borer | 54 | 27 | 60 | 21 | 43 | 9 |
| Basis (no. trees) | (171) | (239) | (171) | (239) | (171) | (239) |

Table 6.--Comparison of fertilizer test plots showing percentage of trees that were diseased or declining in 1941 and 1951

| Plot | No. Trees | Percent of trees living in | | | |
|---|---|---|---|---|---|
| | | 1941 | | 1951 | |
| | | Diseased | Declining | Diseased | Declining |
| 1 | 30 | 17 | 20 | 9 | 0 |
| 2 | 17 | 6 | 6 | 18 | 0 |
| 3 | 31 | 16 | 14 | 17 | 7 |
| 4 | 18 | 11 | 22 | 13 | 6 |
| 5 | 23 | 17 | 17 | 18 | 0 |
| 6 | 15 | 73 | 100 | 100 | 100 |

Table 7.--Comparison of mean annual growth made during the 1941-1945 and the 1945-1951 periods by trees on the fertilizer plots in a normal stand

| Plot: | Fertilizer treatment | No. Trees: | Mean Annual Growth in D.B.H. inches 1941-1945 | 1945-1951 | Diff. | t |
|---|---|---|---|---|---|---|
| F-1 | Stable manure, 4 cu. yds. | 22 | 0.033 | 0.063 | 0.030 | 4.571 1/ |
| 2 | Commercial, 150 lbs. | 17 | 0.035 | 0.063 | 0.028 | 4.045 1/ |
| 3 | Commercial, 100 lbs. | 23 | 0.054 | 0.059 | 0.005 | 0.7828 2/ |
| 4 | Commercial, 49 lbs. | 15 | 0.055 | 0.068 | 0.013 | 0.4445 2/ |
| 5 | Check | 22 | 0.038 | 0.058 | 0.020 | 0.9155 2/ |

1/ Highly significant

2/ Not significant

Table 8.--Comparison of mortality on fertilizer plots in 1945 and 1951

| Plot | No. Trees | Percent dead in | |
|---|---|---|---|
| | | 1945 | 1951 |
| 1 | 30 | 10 | 23 |
| 2 | 17 | 0 | 0 |
| 3 | 31 | 10 | 25 |
| 4 | 18 | 6 | 17 |
| 5 | 23 | 4 | 4 |
| 6 | 15 | 27 | 47 |