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FOREST TREE GROWTH AS A BIOINDICATOR OF POLLUTION ABATEMENT SYS--ETC(U)  
JAN 82 J W SKELLY, L W KRESS DAA029-76-8-0043

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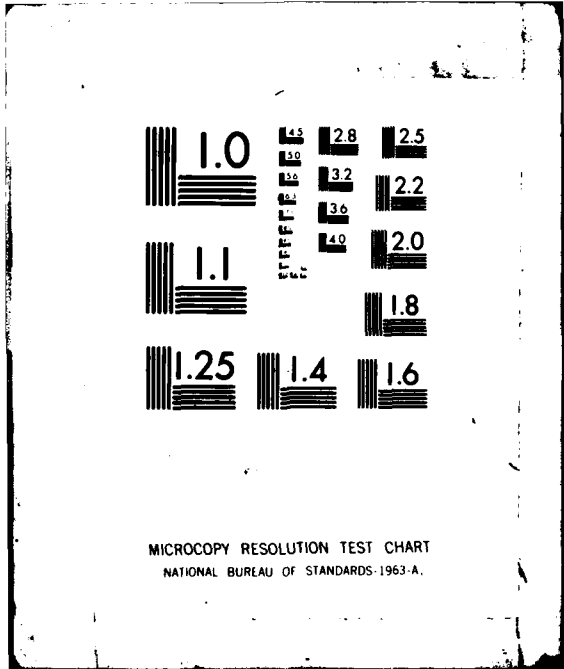
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DRXR0-1P-L-13314-L	2. GOVT ACCESSION NO. AD A110802	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Forest tree growth as a <sup>bio</sup> indicator of pollution abatement system at the Radford Army Ammunition Plant	5. TYPE OF REPORT & PERIOD COVERED Final Report July 1, 1976-June 30, 1978	
6. PERFORMING ORG. REPORT NUMBER		7. AUTHOR(s) John M. Skelly Lance W. Kress
8. CONTRACT OR GRANT NUMBER(s) DAAG29-76-G-0043 VPI&SU 353915-1		9. PERFORMING ORGANIZATION NAME AND ADDRESS Reserach Division Dept. of Plant Pathology and Physiology - VPI & SU, Blacksburg, VA
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS		11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office Post Office Box 12211 Research Triangle Park, NC 27709
12. REPORT DATE January 14, 1982		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		DTIC ELECT FEB 11 1982
18. SUPPLEMENTARY NOTES The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.		E
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) loblolly pine, sycamore, nitrogen dioxide, sulfur dioxide, ozone, pollutant combinations, open top chambers, ammunitions manufacture		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (See attached report.)		

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FOREST TREE GROWTH AS A BIOINDICATOR OF POLLUTION ABATEMENT  
SYSTEMS AT THE RADFORD ARMY AMMUNITION PLANT

FINAL REPORT

Dr. John M. Skelly  
Dr. Lance W. Kress

January 14, 1982

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### Statement of the Problem Studies

The U. S. Radford Army Ammunition Plant (RAAP), located in Southwest Virginia, is a large industrial complex situated in a forested topographic bowl. The production of nitrogenous based propellants and fertilizers results in the emission of substantial quantities of oxides of nitrogen ( $\text{NO}_x$ ), the most biologically important being nitrogen dioxide ( $\text{NO}_2$ ). The RAAP produces its own electrical and steam power through coal-fired generators, which results in the emission of  $\text{SO}_2$ . Levels of  $\text{O}_3$  above the National Ambient Air Quality Standards (NAAQS) (8 ppm/1 hour/once per year) have been monitored at RAAP and in the surrounding mountains of Southwestern Virginia. Thus, three of the major air pollutants ( $\text{O}_3$ ,  $\text{SO}_2$ , and  $\text{NO}_x$ ) are present in the ambient atmosphere at RAAP. The facility is located in a topographic bowl within a region of numerous atmospheric thermal inversions, and therefore is isolated from other major pollutant sources. It is an excellent area for determining the growth impact of air pollution on forest trees. It is also an exceptional area in which to test potential bioindicator systems.

➤ The study objectives of this research were:

- (1) To determine if the pollution levels alone were responsible for the observed growth suppressions in trees growing at RAAP. *Radford Army Ammunition Plant (RAAP)*
- (2) To screen several full-sib families of loblolly pine and half-sib families of American sycamore for tolerance or sensitivity to  $\text{O}_3$ ,  $\text{SO}_2$ , and  $\text{NO}_2$ ;
- (3) To identify and quantify the effects to loblolly pine and sycamore of long-term low-level exposures to  $\text{O}_3$ ,  $\text{SO}_2$  and  $\text{NO}_2$  in combination.

- (4) To demonstrate the success or failure of the abatement programs now being initiated at the RAAP, with loblolly pine and/or American sycamore as bioindicators.
- (5) To contribute to the field of air pollution effects on plants an understanding of the growth impact of pollutant interactions.

### Summary of the Most Important Results

Grafts were made using 2-0 rootstock and scion from 12 ortets of eastern white pine (Pinus strobus L.) growing at the Radford Army Ammunition Plant (RAAP). The 12 ortets represented 4 symptom severity classes (3 ortets/class) ranging from trees with 25% of their crowns exhibiting necrotic tipburn (Class I) to those with healthy crowns (Class IV). Grafts were made in spring 1976 and ramets were grown in a greenhouse drawing charcoal filtered air. Each treatment was performed twice, on separate days for a total of 10 ramets/clone/treatment. Five ramets/clone were used in each 6 hour treatment. The current year's growth was 7-10 weeks old when treated. The treatments were as follows: 1) O<sub>3</sub>-10pphm, 2) O<sub>3</sub>-30pphm, 3) NO<sub>2</sub>-10pphm, 4) NO<sub>2</sub>-30pphm, 5) O<sub>3</sub>-10+NO<sub>2</sub>-30pphm, 7) no pollutant. The fumigation chamber was a modified open-top field chamber located indoors. Environmental conditions during the 14 treatments averaged: 26 C, 64% RH, and 16 Klux. The ramets were evaluated prior to fumigation and then 2, 7, and 14 days thereafter for visible symptoms. The overall injury was generally light with only 11% of the clone treatment combinations exhibiting injury on 25% of the needle fascicles. Clones I-1 and I-2 were the most sensitive clones while clones III-1, IV-2 and to a lesser degree clones III-3 and IV-1 were tolerant. These results agree with field ratings of eastern white pine sensitivity at the RAAP and provide the first step in the development of an air pollution bioindicator system at the installation.

Several full-sib families of loblolly pine and half-sib families of American sycamore were screened for sensitivity to O<sub>3</sub>, NO<sub>2</sub>, or SO<sub>2</sub>. Based on the results of the screening experiments, a sensitive and a



tolerant family of each species was selected to study the effects of long-term low-level exposures with  $O_3$ ,  $NO_2$ , and  $SO_2$  singly and in combination. The two families of loblolly pine were also used to determine the effects of ambient Radford Army Ammunition Plant (RAAP) air on forest trees.

One to two week old trees, produced from seed, were exposed to 5pphm  $O_3$ , 10pphm  $NO_2$ , and 14pphm  $SO_2$ . The treatments were control,  $O_3$  alone,  $SO_2$  alone,  $NO_2$  alone,  $O_3 + SO_2$ ,  $O_3 + NO_2$ , and  $O_3 + SO_2 + NO_2$ . The plants were exposed 6 hours per day for 28 or 56 consecutive days. Significant height growth suppressions were noted in the sensitive family of both species in all treatments except  $NO_2$  alone for pine and both the  $NO_2$  alone and the  $O_3 + NO_2$  for sycamore. Ozone +  $SO_2$  had a more significant effect than either one alone, and adding  $NO_2$  further suppressed the height growth of the sensitive family of each species. Significant height growth suppressions were noted for the tolerant family of both species only in the combination treatments. Adding  $NO_2$  to the  $O_3 + SO_2$  further suppressed height growth in tolerant sycamores but not in tolerant pines. Overall, the sensitive sycamores exhibited greater height growth suppressions, 45% versus 34% for the tolerant sycamores. The sensitive pines suffered 30% height growth suppression versus 14% for the tolerant pines. Foliar injury was never evident on the sycamores and it never exceeded 5% on the pines.

The trees exposed to ambient air at RAAP were planted in open-top chambers. At each of three separate sites the treatments were charcoal-filtered air, non-filtered air, and an open plot. The treatments were performed for the entire 1977 growing season (May-October).

The sensitive pine family exhibited up to a 40% height growth suppression in non-filtered versus filtered air, in the complete absence of foliar symptoms. The tolerant pine family exhibited up to a 29% height growth suppression in non-filtered versus filtered air. The sensitive family was taller than the tolerant family in filtered air, but smaller than the tolerant family in non-filtered air.

This research provides strong evidence in support of the occurrence of invisible damage. Significant height growth suppressions were demonstrated for both of these forest tree species in response to pollutants at concentrations below the National Ambient Air Quality Standard for each pollutant. These results demonstrate that air pollutants may be having significant impact on the growth of forests. Also demonstrated by this research was the potential use of selected families of loblolly pine and American sycamore as bioindicators of ambient air pollution.

SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

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Thesis Title: Growth impact of O<sub>3</sub>, SO<sub>2</sub>, and NO<sub>2</sub> singly and in combination on loblolly pine (*Pinus taeda* L.) and American sycamore (*Platanus occidentalis* L.). Ph.D.  
Diss. Virginia Polytechnic Institute and State University.  
220 p.

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Thesis Title: The response of 12 clones of eastern white pine (*Pinus strobus* L.) to ozone and nitrogen dioxide. M.S. Thesis. Virginia Polytechnic Institute and State University. 141 p.

LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES:

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- Skelly, J. M. 1978. Radial increment growth responses of forest trees to fluctuating levels of air pollution. Proc. III International Cong. Plant Pathology, Munchen, Germany. August 16-23, p. 355.
- Kress, L. W., Skelly, J. M. and Hinkelmann, K. H. 1982. Growth impact of O<sub>3</sub>, NO<sub>2</sub>, and/or SO<sub>2</sub> on Platanus occidentalis. Accepted for publication by Agric. and Environ.
- Kress, L. W. and Skelly, J. M. Effect of low dose exposure to O<sub>3</sub> and O<sub>3</sub>+NO<sub>2</sub> on ten forest tree species. Submitted to Plant Disease.
- Kress, L. W., Skelly, J. M. and Hinkelmann, K. H. 1982. Relative sensitivity of eighteen full-sib families of Pinus taeda to O<sub>3</sub>. Accepted for publication by Canadian J. For. Res.

KRESS, L. W. and J. M. SKELLY. 1981. Response of several eastern forest tree species to chronic doses of ozone and nitrogen dioxide. Plant Disease 72:

Two- to four-week-old seedlings of 10 eastern forest species were exposed to 0, 0.5, 0.10 or 0.15 ppm  $O_3$ , and two- to four-week-old seedlings of 7 tree species were exposed to 0.10 ppm  $O_3$  and/or 0.10 ppm  $NO_2$  in 6 hr/day exposures for 28 consecutive days. Loblolly pine and American sycamore exhibited significant growth suppressions, while white ash and yellow poplar exhibited significant growth stimulations when exposed to 0.05 ppm  $O_3$ . Yellow poplar and Virginia pine were the only species that failed to show any significant adverse growth effects in response to the 0.15 ppm  $O_3$  treatment. In several instances, significant growth effects were noted in the absence of foliar injury. Nitrogen dioxide alone significantly suppressed root and total dry weight of sweetgum. The only significant interaction effects noted between  $O_3$  and  $NO_2$  were less than additive. This study suggests the potential for adverse effects at pollutant concentrations below the current National Ambient Air Quality Standards.

KRESS, L. W., J. M. SKELLY and K. H. HINKELMANN. 1981. Relative sensitivity of eighteen full-sib families of Pinus taeda to O<sub>3</sub>. Can. J. For. Res. 11:

Seedlings of 18 full-sib families of loblolly pine were screened for sensitivity to 0.10, 0.15, 0.20, or 0.25 ppm O<sub>3</sub> in 8 hr exposures. Primary needles of newly germinated seedlings and secondary needles of 1-yr-old trees were exposed when the needle ages were 3-4 wk and 8-12 wk, respectively. Significant variation in foliar symptom expression was noted among families, and was nearly identical for both primary and secondary needles. Family 6-13x2-8 was the most sensitive in 8 of 9 treatments, and was significantly more sensitive than the remaining 17 families in 5 of 9 treatments. In all cases, family 6-13x2-8 sustained greater injury than the families involving parent tree 504 (3 families) and the difference was significant in 8 of 9 treatments. The data suggest that it may be feasible to use sensitive and insensitive families of loblolly pine as air pollutant bioindicators, although considerable further development is necessary. The finding that sensitivity and tolerance may be heritable warrants further study.

KRESS, L. W., J. M. SKELLY and K. H. HINKELMANN. 1982. Growth impact of  $O_3$ ,  $NO_2$ , and/or  $SO_2$  on Pinus taeda. Accepted for publication Environ. Monit. Assess.

Seedlings of two full-sib families of loblolly pine expressing different degrees of sensitivity to  $O_3$  were exposed to 0.05 ppm  $O_3$ , 0.10 ppm  $NO_2$ , and/or 0.14 ppm  $SO_2$  for 6 hr/day for 28 consecutive days. The treatments were  $O_3$ ,  $NO_2$ ,  $SO_2$  (each used alone),  $O_3 + SO_2$ ,  $O_3 + NO_2$ , and  $O_3 + NO_2 + SO_2$ . Significant growth suppressions were noted with the relatively sensitive family in all but the  $NO_2$  alone treatments. The  $O_3 + SO_2$  treatment had a more significant effect than  $O_3$  alone, but adding  $NO_2$  had an inconsistent effect. Significant growth suppressions were noted for the relatively non-sensitive family only in the  $O_3 + SO_2$  and  $O_3 + SO_2 + NO_2$  combination treatments. Adding  $NO_2 + O_3 + SO_2$  had a slightly stimulatory effect. The relatively sensitive pine family suffered a 30% height growth suppression versus a 14% height growth suppression for the relatively insensitive family when exposed to the 3 pollutant combination. Symptoms were noted on less than 4% of the foliage in the most severe treatments. The pollutant concentrations used in this study were below the National Ambient Air Quality Standards (NAAQS) for each pollutant.

KRESS, L. W., J. M. SKELLY and K. H. HINKELMANN. 1982. Growth impact of  $O_3$ ,  $NO_2$ , and/or  $SO_2$  on Platanus occidentalis. Agric. and Environ.

Seedlings of two half-sib families of American sycamore were exposed to 0.05 ppm  $O_3$ , 0.10 ppm  $NO_2$ , and/or 0.14 ppm  $SO_2$  for 6 hr/day for 28 consecutive days. The treatments were  $O_3$ ,  $NO_2$ ,  $SO_2$  (each used alone),  $O_3 + SO_2$ ,  $O_3 + NO_2$ , and  $O_3 + NO_2 + SO_2$ . Significant growth suppressions were noted for both families when exposed to  $O_3 + SO_2$  or  $O_3 + SO_2 + NO_2$ . The  $O_3 + SO_2$  treatment had a more significant effect than  $O_3$  alone, and adding  $NO_2$  to the  $O_3 + SO_2$  treatment further suppressed height growth significantly. A 45% and 34% growth suppression was observed for the two families (16-Syc-19 and 16-Syc-23), respectively, in response to the three pollutants in combination. The height growth of both families was significantly suppressed by  $O_3$  alone in some cases. Both families exhibited significant height growth recovery 2 wk after removal of the pollutant stress. Pollution-induced foliar injury was never evident on the seedlings.



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