EFFECTS OF SIMULATED ACID RAIN, OZONE AND SULFUR DIOXIDE ON SUITABILITY OF ELMS FOR ELM LEAF BEETLE

by Richard W. Hall, Jack H. Barger and Alden M. Townsend

Abstract. Cuttings from two clonally propagated elm hybrids ('Pioneer' and 'Homestead') were treated with ozone (O_3), sulfur dioxide (SO_2), simulated acid rain or left untreated. Fumigants were applied 7 hours per day, 5 days per week for 9 weeks in open-top chambers. Fumigation treatments were: 0.1 ppm O_3, 0.2 ppm SO_2, 0.1 ppm O_3 plus 0.2 ppm SO_2 and charcoal filtered air. An acid rain treatment (pH 4.0) of ca. 1.27 cm was made weekly in rain simulation chambers. Elm leaf beetle, *Xanthogaleruca luteola* (Muller), were fed foliage harvested from trees subjected to the treatment combinations. Oviposition and mortality of beetles were examined. Significantly fewer eggs were laid on 'Pioneer' elm than on 'Homestead' elm. Fumigation treatments had little direct effect on preoviposition period and fecundity. However, beetles fed acid rain treated foliage laid significantly fewer eggs than beetles fed foliage not treated with acid rain. Beetle mortality was not affected by any of the treatment combinations tested.

Résumé. Des boutures de deux ormes hybrides propagés par clones ('Pioneer' et 'Homestead') furent traitées avec de l'ozone (O2), du dioxide de soufre (SO2), des pluies acides simulées, ou laissées non traitées. Des fumigants furent appliqués sept heures par jour, cinq jours par semaine, pendant neuf semaines en chambres ouvertes. Les traitements de fumigation furent: 0.1 ppm d'O2, 0.2 ppm de SO2, 0.1 ppm d'O2 avec 0.2 ppm de SO2 et de l'air filtré au charbon. Un traitement avec des pluies acides (pH 4.0) de 1.27 cm fut réalisé à chaque semaine dans des chambres de simulation de pluies. Des galéruques de l'orme, *Xanthogaleruca luteola* (Muller), furent nourris du feuillage récolté sur les arbres ayant subi les différents traitements. L' oviposition et la mortalité des insectes furent examinés. Une quantité moindre d'oeufs furent déposés sur l'orme 'Pioneer" que sur l'orme 'Homestead'. La fumigation a eu peu d'effets directs sur la période de pré-ovipostion et de fécondité. Cependant, les insectes nourris avec du feuillage traité aux pluies acides ont déposé moins d'oeufs que les insectes nourris avec de feuillage non traité aux pluies acides. La mortalité des insectes ne fut pas affectée par aucune des combinaisons de traitements.

Atmospheric deposition may influence trees by impairing photosynthetic capacity, and by reducing carbohydrate production and nutrient retention (11). Repeated exposures to acidic precipitation may lead to acidification of leaf surfaces or may alter leaf surfaces by eroding the cuticle (5, 15). These effects may directly or indirectly impact phytophagous insects by altering host-plant nutritional quality (7). Such evidence is beginning to surface linking direct and indirect influences of atmospheric deposition with effects on insect herbivores feeding on treated plants.

Elm leaf beetle, *Xanthogaleruca luteola*(Muller), was introduced into Eastern United States early in the nineteenth century (13) and has since spread across North America. In nature, elm leaf beetle (ELB) feeds on *Ulmus* spp. Many municipalities have planted elm hybrids as replacement trees for American elms that were lost to Dutch elm disease. But most of these hybrid elms are susceptible to extensive feeding by the ELB. As a result, the ELB is now cited by urban foresters as an important tree pest in most regions of the U.S. (8, 12). Hall (2), and Young and Hall (19) have found that significant differences in ELB fecundity occurs among clonally propagated elms and that fecundity is also a good indicator of host quality. Because populations of ELB are more common on stands of elm in urban areas than on similar stands of elm in surrounding environs, and because atmospheric deposition may be one factor that influences host quality of elm for ELB, we chose to use ELB to assay for subtle differences in the host quality of elms fumigated with air pollutants and treated with acid rain.

Materials and Methods

One-year-old potted elm cuttings were subjected to a combination of atmospheric pollutants and acid rain treatments for 9 weeks. The elms used, 'Homestead' and 'Pioneer', are clonally propagated hybrids developed by the USDA Agricultural Research Service (16, 17). The growing medium used was Terra-Lite 500. Elms were fumigated for 7 hours per day, 5 days per

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week in 4 open-top chambers that were 10 feet (3 m) in diameter and 8 feet (2.5 m) in height (4) (Figure 1). Four fumigation treatments were used: 0.1 ppm ozone (O_3); 0.2 ppm sulfur dioxide (SO_2); 0.1 ppm ozone + 0.2 ppm sulfur dioxide (O_3 + SO_2); and charcoal filtered air. Acid rain solutions, pH 4.0, were made by adjusting the pH of deionized water with 2 parts H_2SO_4 and 1 part HNO_3. Half of the elms were removed from fumigation chambers once each week, subjected to simulated acid rain treatments, and allowed to air dry before continuing fumigation treatments. Acid rain treatments were 45 minutes in duration (ca. 1.27 cm) applied through beta fog nozzles at 10 psi (69 kPa) in rain simulation chambers equipped with platforms, 4 feet (1.2m) in diameter, revolving at 4 rpm (Figure 2). The other half of the hybrids remained in the fumigation chambers and were not subjected to a simulated rain treatment. All hybrids were randomly assigned to the fumigation and acid rain treatment combinations. Only those leaves produced by the elms after onset of the treatments (i.e., leaves less than 9 weeks old) were collected from each hybrid (8 replicates each). After 9 weeks of treatments, leaves were removed from the hybrids once each week for 2 weeks and held under refrigeration until used. Pooling of foliage by treatment was necessary because many hybrids did not produce an adequate number of leaves to permit bioassays of individual replicates.

ELB were field collected from *Ulmus procera* Salisbury as wandering third instars and were held in the laboratory at 25°C at 15:9 (1:d) for pupation and adult emergence. Pairs (male plus female) of newly enclosed, unfed, adult ELB were randomly assigned to plastic petri dishes containing foliage subjected to a given treatment combination (Figure 3). Fifteen pairs of beetles were used with each treatment. Leaves in petri dishes were replaced every 2 to 3 days. Dishes were examined daily to determine mortality, onset of oviposi-

Figure 1. Open-top chambers used to fumigate elms.

tion and fecundity (Figure 4). All bioassays were run at 25°C 15:9 (1:d) for 2 weeks. Data were subjected to a 3-factor ANOVA (14).

Results and Discussion

ANOVA showed significant differences between elm hybrids in preoviposition period, number of eggs per female and number of eggs per oviposition female (Table 1). Differences due to hybrid were consistent among all measures of host suitability. In general, 'Pioneer' elm appeared to be more suitable for ELB than 'Homestead' elm (Figure 5). Mortality of males and females did not differ greatly between hybrids or among treatments.

The effects of fumigation on elm suitability were subtle. Statistically significant differences occurred only for number of eggs per ovipositing female. However, acid rain treatments significantly altered suitability of the foliage (Table 1). In general, there were fewer eggs per female and

Figure 2. Elms being treated with simulated acid rain.

fewer eggs per ovipositing female on acid rain treated foliage (Figure 5). This difference was quite evident under charcoal filtered conditions alone. However, there were no differences in preoviposition period. Significant interactions among hybrids, fumigants, and acid rain

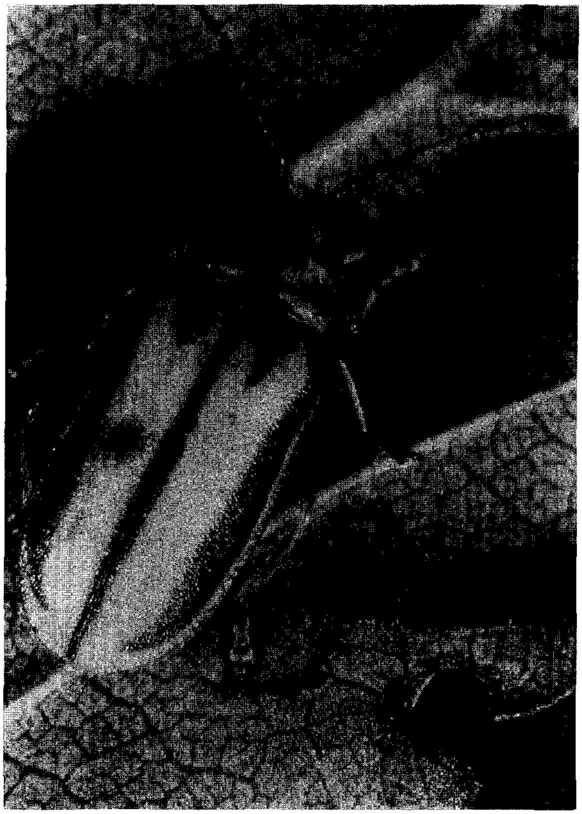

Figure 3. Adult elm leaf beetle used to bioassay for effects of atmospheric deposition on elm suitability.

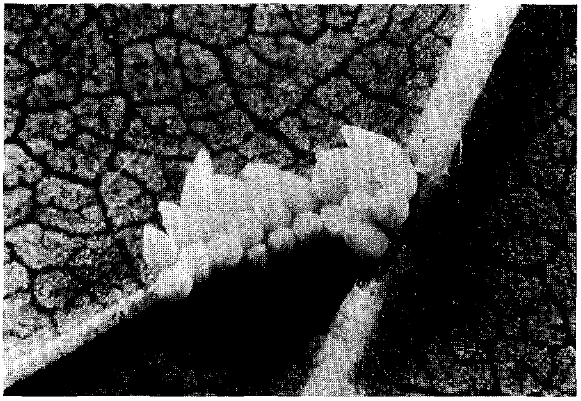

Figure 4. Elm leaf beetle eggs used to determine host suitability after atmospheric deposition treatments.

treatments were present (Table 1). Effects of the interactions are best illustrated in 'Pioneer' elm treated with simulated acid rain and fumigated with ozone (Figure 5). Here, beetles fed foliage from acid rain treated trees laid substantially more eggs than those fed foliage from trees with no acid rain treatments.

Decreased host nutritional quality may be due to a variety of factors (1, 6). Interruption of water and/or nutrient uptake and nutrient leaching from leaves provide possible mechanisms for observed changes in suitability for the acid rain treated trees (9, 18). Young and Hall (2) showed that fertilization and watering can modify the suitability of elms

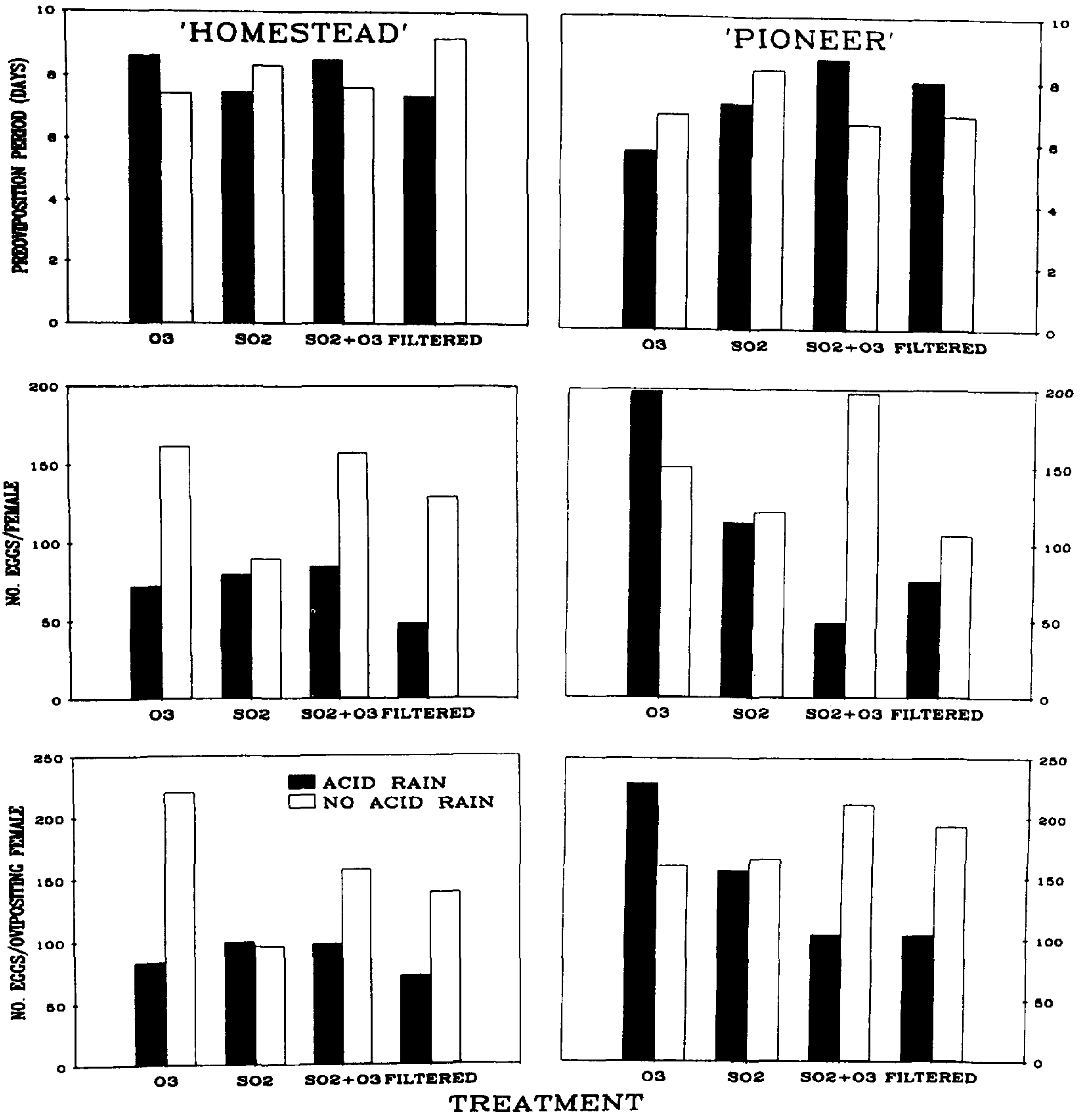

Figure 5. Oviposition during a 2-week period by elm leaf beetles fed leaves harvested from elms exposed for 9 weeks to simulated acid rain, and ozone and sulfur dioxide fumigation treatments.

Table 1. Results of a 3-factor analysis of variance of oviposition during a 2 week period by elm leaf beetles fed leaves harvested from elms exposed for 9 weeks to simulated acid rain, ozone and sulfur dioxide treatment combinations.

Source	*Preoviposition period*	*Eggs/female*	*Eggs/ovipositing female*
Elm hybrid (H)	F(1,181) = 8.0**[a]	F(1,224) = 7.0**	F(1,181) = 12.2**
Acid rain (AR)	F(1,181) = 0.0	F(1,224) = 21.9**	F(1,181) = 15.0**
Fumigation (F)	F(3,181) = 1.5	F(3,224) = 2.5	F(3,181) = 2.8*
HxAR	F(1,181) = 0.4	F(1,224) = 0.2	F(1,181) = 1.4
HxF	F(3,181) = 1.6	F(3,224) = 0.9	F(3,181) = 0.3
ARxF	F(3,181) = 3.6*	F(3,224) = 4.3**	F(3,181) = 2.2
HxARxF	F(3,181) = 4.2**	F(3, 224) = 3.4*	F(3,181) = 5.3*

[a]* = Significant at the 0.05 level.
** = Significant at the 0.01 level.

for ELB. In their studies, leaf protein content and leaf water content were low in unfertilized, water-stressed trees. Such trees were less suitable for ELB than were fertilized, well-watered trees with high leaf protein and leaf water content. Thus, if nitrogen and/or water uptake were reduced in acid rain treated trees, we would expect a reduction in leaf protein content and a reduction in host suitability. Similar results may occur if nitrogen or water content of leaves were modified by cuticular or epidermal damage and/or foliar leaching. Other factors such as altered leaf carbohydrate content, modification of secondary plant chemistry, or changes in leaf surfaces may be responsible for our observed differences. And the basic cations normally found in natural precipitation were lacking in our acid rain solutions. Absence of these cations may have increased the leaching capacity of the acid rain events.

Several studies have documented differences in suitability of different elm species and hybrids for ELB (2, 3, 10, 19). In this study, 'Pioneer' elm generally was found to be more susceptible to ELB than 'Homestead' elm. Additional field experiments are needed before we can make recommendations to arborists that one hybrid be chosen over another because of differences in ELB suitability that may be even further complicated by urban pollutants.

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