temperature of 8° C (46°F) could be maintained.

4) Temperature of the growing medium in containers sitting on the floor remained the same as the floor temperature.

5) The water injected between the 2 layers of polyethylene is not heated directly by the suns rays, but rather by the warm air. For example, with 43.2 klx (4000 ft-c) and 10°C (50°F) outside temperature and 21°C (70°F) in the collection chamber the water could be heated to about 18°C (65°F). On a colder day with 43.2 klx (4000 ft-c) and −7°C (20°F) outside temperature and 10°C (50°F) in the collection chamber the water could be heated only to about 4.5°C (45°F).

6) The third layer of plastic over the structure provided the same insulation capacity to the collection chamber as would be provided to the inside air of a standard double poly greenhouse. This third poly layer increased the heat collection apacity by about 10-12°C (20-25°F).

7) The 2.5 cm (1 inch) layer of styrofoam beneath the entire greenhouse greatly reduces the downward loss of heat. This would be of even greater importance in more northern climates. In addition, the styrofoam provides a smooth base for the polyethylene sheeting and reduces the chance of puncture and subsequent leakage and reduced efficiency.

8) The sand used in the storage system must be packed in order to prevent shifting of the work floor. However, sand size must be sufficiently uniform to allow water to circulate at a reasonable rate. Precise specifications are not currently available.

9) Of 3 cultivars of chrysanthemums potted January 25, 1977 and grown in the present structure, 'Garland' and 'Bright Golden Ann' set buds and flowered on schedule, with good flower quality and uniformity. 'Deep Crystal', however, did not set buds in the solar house with night temperatures at 5-6°C (40-43°F) with day maximum 30°C (85°F), while flowering proceeded normally in an adjacent gas-heated house. Thermostat controlled cooling fans drew in outside air, preventing higher air temperatures.

10) 'Better Boy' tomatoes grew well and flowered and fruited normally when grown in large containers sitting on the floor.

11) Petunia, ageratum, periwinkle and dahlias were grown as bedding plants in 6.3 × 6.3 × 6.3 cm plastic containers sitting on the floor. Plant growth and quality were equal to or better than plants grown in gas heated greenhouses.

12) Construction cost (materials only) was about \$19.40/m^2 (\$1.80/ft^2).

Literature Cited

1. Roberts, W. J. and D. R. Mears, 1969, Double-covering a film greenhouse using air to separate film layers, *Transactions of the* ASAE 12(1):32, 33 and 38.

HortScience. 13(1):32–33. 1978.

Chemical Defoliation of Pin Oak in the Expanding Leaf Stage[1]

J. P. Sterrett and R. A. Creager[2]

Agricultural Research Service, U.S. Department of Agriculture, Frederick, MD 21701

Additional index words. abscission, *Quercus palustris*

Abstract. **Low levels of 7-oxabicyclo(2,2,1)heptane-2,3-dicarboxylic acid (endothall), ranging from 37.5 to 300 ppm, combined with 1000 ppm of (2-chloroethyl)phosphonic acid (ethephon) and sprayed on pin oak (*Quercus palustris* Muenchh.) seedling sprouts in the greenhouse caused temporary defoliation during the initial stages of leaf development. Defoliation was 75 to 86% with a 75 ppm endothall/1000 ppm ethephon combination applied during the first 27 days of leaf expansion. In field trials a 75 ppm/1000 ppm, endothall/ethephon combination defoliated 85% of 17 year-old pin oak trees in the expanding leaf stage. Shoot damage was negligible and foliar density of field trees reached 90% of control 10 weeks after defoliation.**

It has been suggested that the gypsy moth (*Lymantria dispar* L.), a serious pest of trees in northeastern U.S., could be controlled by temporarily removing tree foliage during the expanding leaf stage when the larvae are feeding. Since little information is available regarding defoliation during the expanding leaf stage, a study was designed to determine whether a combination of endothall and ethephon, which has successfully defoliated mature foliage of deciduous woody species (5), would temporarily defoliate pin oak during the initial stages of leaf development. Pin oak was selected because oaks are defoliated more severely by the gypsy moth than any other trees (3).

Preliminary studies with expanding foliage of pin oak branches in the field, determined that the effective range of defoliant activity for endothall was between 37.5 and 300 ppm, and that 1000 ppm of ethephon was an optimum concentration in combination with endothall.

Two-year-old container grown pin oak seedlings were used in a greenhouse experiment to determine effective rates for defoliation throughout the expanding leaf stage of development. Seedlings were induced to sprout by decapitation in June 1975 and the sprouts were pruned to one per stump. Sprouts were sprayed to runoff in a spray chamber at 13, 20, 27, and 41 days after decapitation. Four levels of endothall (ranging from 37.5 to 300 ppm) combined with 1000 ppm ethephon and 1% surfactant (AL-1161) were used. The foliage expanded through 27 days after decapitation and appeared fully developed at 41 days.

Percent defoliation was evaluated at 2 weeks by counts of attached leaves before and after treatment. Percent foliage density at 5 weeks after treatment was used as an index of recovery from defoliation. Recovery index was the ratio of the no. of leaves at 5 weeks to the no. at the time of treatment. The average no. of leaves per sprout at treatment time ranged from 9 to 12. Treatments (1 plant per treatment) were replicated 4 times in a randomized block design.

At least 75% defoliation occurred on plants treated up to the 20th day after

---

[1]Received for publication July 27, 1977.

[2]Plant Physiologist and Horticulturist, Weed Physiology and Growth Regulator Research Laboratory. The authors thank Dr. C. L. Graham, Entomologist, ARS, Plant Disease Research Laboratory, Frederick, MD for his assistance with insect defoliators. We also thank the Pennwalt Corporation for the endothall acid, Amchem Products, Inc. for the ethephon (Amchem 68-240), and ICI America, Inc., Atlas Chemicals Division, for the AL-1161.

Table 1. Defoliation in 2 weeks of pin oak sprouts treated with endothall/ethephon at several time periods after decapitation of seedlings.

Endothall[z] (ppm)	Defoliation (%)[y] Treatment time after decapitation (days) 13	20	27	41
0 (untreated)	0h (176)[x]	0h (167)	0h (166)	0h (141)
37.5	52bcde (201)	49cdef (161)	23fgh (149)	2h (148)
75	85a (127)	75abc (125)	86a (102)	10h (170)
150	79ab (165)	89a (129)	45defg (58)	20gh (98)
300	44defg (103)	65abcd (95)	25efgh (61)	65abcd (79)

[z]All levels of endothall were combined with 1000 ppm ethephon and 1% surfactant.

[y]Mean separation by Duncan's multiple range test, 5% level.

[x]Values in parentheses are % foliage densities 5 weeks after treatment.

Table 2. Percent foliage density of field grown pin oak trees throughout the growing season following 87.5 ± 2.5% defoliation of expanding leaves sprayed with a 75 ppm/1000 ppm, endothall/ethephon combination.

Time	Foliage density (%)[z]
May 28	27.5 ± 2.5
June 11	75.0 ± 6.4
July 23	90.0 ± 0
August 26	90.0 ± 0
September 27	90.0 ± 0

[z]Mean ± SE ratings were determined on a scale of 0 (none) to 10 (100%).

decapitation with either 75 ppm/1000 ppm or 150 ppm/1000 ppm of the endothall/ethephon combination (Table 1). At the 27-day treatment period, only the 75 ppm/1000 ppm combination of endothall/ethephon was effective (without injury) and, at 41 days when most of the foliage had stopped expanding. The 300 ppm/1000 ppm, endothall/ethephon combination caused the greatest defoliation. Five weeks after treatment foliage densities of the 75 ppm/1000 ppm level of endothall/ethephon, although not as high as the untreated controls, were higher than at treatment time (over 100%).

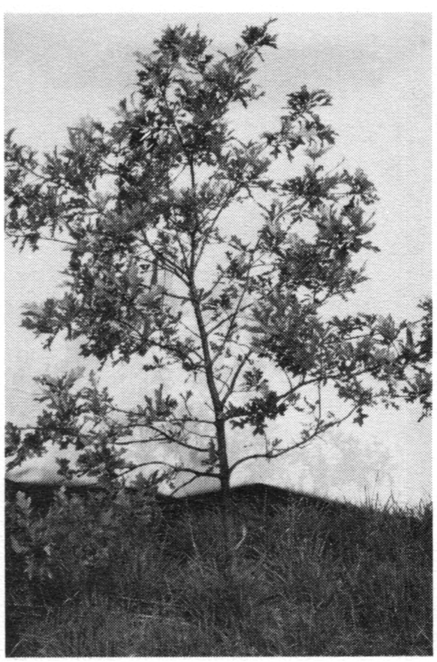
In field trials based on the results of the greenhouse seedling experiment, 17 year-old pin oak trees were sprayed to runoff with a 75 ppm/1000 ppm, endothall/ethephon combination, plus 1% AL-1161. Application was made when the foliage was expanding on April 30, about 15 days after bud break. Defoliation 13 days after treatment and foliage density throughout the growing season were estimated visually by at least 2 persons on a scale of 0 (none) to 10 (100%). The treatment (1 tree per treatment) was replicated 4 times and compared with untreated control trees.

By May 13th, 13 days after treatment, 87.5% of the leaves had dropped (Table 2). New expanding leaves increased the foliage density from 27.5% on May 28th to 75% by June 11th. In late July the foliage density reached 90% and remained there until late Sept. before natural leaf fall. Foliage density was normal during the following growing season.

Induction of abscission by the endothall/ethephon combination is attributed to mild leaf desiccation caused by endothall, which is thought to inhibit the transport of ethephon and thus increase the availability of ethylene for the abscission process (1, 2, 4). Only part of the defoliation of both seedling sprouts and trees appeared to occur from abscission. The other portion of the defoliation occurred from badly desiccated leaves that dropped as a result of dead, weakened petioles.

Even though abscission did not account for all of the leaf drop in both greenhouse seedlings and field trees, the total amount of defoliation appeared great enough to discourage insect defoliators. Some shoot-tip dieback occurred, but was virtually undetectable when the new foliage appeared (Fig. 1). Slight desiccation of the grass beneath the field trees was evident in May, but was undetectable by mid-July.

C. L. Graham (Entomologist, Plant Disease Research Laboratory, Frederick, MD 21701, 1976) has suggested that the feasibility of controlling insect defoliators with endothall/ethephon combinations could be determined by infesting pin oak seedlings with gypsy moth larvae at various stages during the expanding leaf stage and spraying with 75 ppm/1000 ppm endothall/ethephon to determine the stage at which the larvae would be least likely to survive if denied food for a period of time. Since thorough foliar coverage with endothall/ethephon sprays is essential for effective defoliation, treatment of large wooded areas as a control measure for defoliating insects, such as the gypsy moth, would be impractical. However, the technique could be an effective tool for use on individual trees of high value.



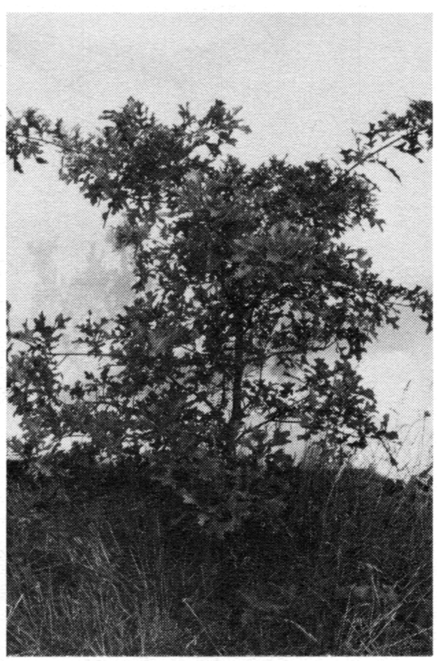


Fig. 1. Left: Foliar density of field grown pin oak in July after 85% defoliation in early May. Right: Foliage density of untreated control in July.

Literature Cited

1. Hall, W. C. 1952. Evidence on the auxin-ethylene balance hypothesis of foliar abscission. *Bot. Gaz.* 113:310-321.
2. Jackson, J. M. 1952. Physiology of leaf abscission. *Ark. Acad. Sci.* 5:73-76.
3. Nichols, J. O. 1961. The gypsy moth in Pennsylvania. *Pa. Dept. Agr. Misc. Bul.* 4404.
4. Sterrett, J. P., G. R. Leather, and W. E. Tozer. 1974. An explanation for the synergistic interaction of endothall and ethephon on foliar abscission. *J. Amer. Soc. Hort. Sci.* 99:395-397.
5. ________, G. R. Leather, W. E. Tozer, W. D. Foster, and D. T. Webb. 1974. Foliar abscission of woody plants with combination of endothall and ethephon. *Weed Sci.* 22:608-614.