ENGINEERING AND ECOLOGICAL EVALUATION OF ANTITRANSPIRANTS FOR INCREASING RUNOFF IN COLORADO WATERSHEDS

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Table of Contents

INTRODUCTION

The potential for water conservation and reallocation through reductions in transpiration is great because ninety-nine percent of the water absorbed from the soil by a plant is transpired into the atmosphere. In arid and semi-arid regions, actively growing plants with an adequate water supply (e.g. phreatophytes) will transpire a weight of water equal to their fresh leaf weight each hour. Phreatophytic vegetation in the Western United States covers about 16 million acres and transpires about 25 million acre feet of water each year. Salt cedar (*Tamarix sp.*) plants are estimated to cover over 1.3 million acres and to consume over 5 million acre feet of water per year (Robinson, 1965).

Transpiration reductions can be achieved in two general ways: (1) reduction of the transpiring surface by mechanical or chemical harvesting or eradication of the plants, and (2) reduction of the amount of water lost per unit leaf surface by treating the plants with chemical anti-transpirants.

Mechanical and chemical destruction of vegetation along irrigation canals and on watersheds has been widely used. However, permanent eradication of phreatophytis is seldom achieved, and these methods often also cause undesireable side effects, such as soil erosion, leaching of nutrients from the soil, increased silting of the waterway, loss of wild-life habitat, and decreased aesthetic value.

Chemical antitranspirants offer the potential for achieving significant water savings without seriously altering the ecosystem. Experiments conducted over the past decade and a half have demonstrated that antitranspirants can appreciably reduce water consumption by plants (see e.g. Gale and Hagan, 1966; Davenport, et al. 1969; Poljakoff-Mayber and Gale, 1972; Davies and Kozlowski, 1974). However, the results have varied widely depending on the chemicals and amounts used, the plant species, and the environmental conditions.

Metabolic antitranspirants, which reduce stomatal aperture, have been found to reduce water consumption appreciable for periods of a week or more. But some of them have proved toxic to a variety of herbaceous and woody plants (Davenport, et al., 1971; Mishra and Pradham, 1972; Kreith, et al., 1975). However, recent studies indicate that naturally-occurring antitranspirant compounds such as abscisic acid and all-trans-farnesol may have promise as commercial metabolic antitranspirants without causing undesireable side effects (Ogunkanmi, et al., 1974; Wellburn, et al., 1974).

Film-forming antitranspirants, which reduce transpiration by coating the leaf with thin, water-impervious film, have been found to be less toxic and to have a longer period of effectiveness than metabolic antitranspirants (Davies and Kozlowski, 1974; Kreith, et al., 1975). Again, however, reported results vary aprreciably, depending upon (1) the plant species, (2) the antitranspirants and methods of application, and (3) the environmental conditions under which the plants were grown and the ambient environmental conditions at the time of antitranspirant application.

PURPOSE AND SCOPE

The objective of this study was to evaluate the potential of using chemical antitranspirants on phreatophyte communities to increase watershed runoff and streamflow. More specifically, the research included (1) laboratory evaluation of the effects of the most promising antitranspirants currently available on transpiration and photosynthesis of *Tamarix* sp. (2) phytotoxicity trials in the laboratory and in the field, and (3) field evaluation of one antitranspirant on *Tamarix* at the U.S. Bureau of Reclamation Evapotrnaspirometer Site at Bernardo, New Mexico.

In the summer of 1974 the original work plan was modified to include antitranspirant screening studies for the U.S. Bureau of Land Management (BLM). The BLM is interested in the potential of using antitrnaspirants along roadsides in the intermountain west to conserve soil moisture, which could, in turn, maintain the vegetation in a green state for longer periods and reduce fire hazard during the latter part of the growing season. The immediate objective of our studies for the BLM was to evaluate in the laboratory the effects of two antitranspirants on transpiration and photosynthesis of several species representative of roadside vegetation.

For convenience, the "Results and Discussion" section of this report is divided into "BLM Studies" and "Phreatophyte Studies".

METHODS

Plant Culture

The sources of plant materials for both the BLM and phreatophyte studies are shown in Table I. Stock cultures were maintained in a greenhouse at ambient temperatures ranging from 15° to 35°C. Photoperiod was extended to 16 hours during the winter months. Experimental plants were grown in a Warren/Sherer model CEL 36-10 controlled environment chamber programmed for a 16 hour photoperiod and a 25°C day/15°C night thermal regime. Plants in the growth chamber were watered daily, alternating between Hoagland's solution and tap water.

Table I. Sources of Plant Material

Species	Common Name	Source
Achillea millifolium L.	Yarrow	Vegetative clones collected at 5800' near Deer Lodge, Powell County, Montana
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass	Seed collected from roadside, Interstate 80, Elk Mountain, Wyoming
Elymus Canadensis L.	Canada wild rye	Seeds collected from roadside, Deer Lodge, Montana
Melilotus officinalis (L.) Lam.	Yellow sweetclover	Seed purchased from Farmers Marketing Association, Denver Lot 14-305
Tamarix pentandra Pall.	Salt cedar	Cuttings obtained from U.S. Bureau of Reclamation Site, Bernardo, New Mexico

Transpiration and Photosynthesis Measurements

Transpiration and net photosynthesis were measured with an open, gas exchange system similar to that described by Anderson and McNaughton (1973), but utilizing the plant cuvette described by Mooney, et al. (1971). Briefly, the plant top was sealed into the plexiglass cuvette through which air was circulated at a known flow rate. The net photosynthetic rate was determined by measuring the carbon dioxide concentrations of the air entering and leaving the cuvette with a Beckman 865 infrared gas analyzer. The infrared gas analyzer was calibrated daily against standard gases containing zero and 320 ppm carbon dioxide. The system was sensitive to carbon dioxide concentration changes of 1 - 2 parts per million.

The transpiration rate was determined by measuring the relative humidity of the air entering and leaving the chamber and calculating the amount of water added to the air stream. The relative humidity was determined with narrow range lithium chloride hydro-sensors (American Instrument Company, Silver Spring, Maryland) sensitive to relative humidity changes of 0.1 percent.

The accuracy of the transpiration measuring system was determined using a modification of the technique suggested by Tranquiliny and Caldwell (1972). The amount of water evaporating from an open plastic Petri dish base was measured gravimetrically and simultaneously with the gas exchange system. Paired results of ten trials at different cuvette temperatures and relative humidities agreed within 2%.

Cuvette temperature was maintained within 0.1°C by circulating an ethylene glycol solution through the cuvette heat exchanger from a constant temperature water bath. A fan within the cuvette provided for efficient heat exchange as well as excellent temperature control and prevented gradients in carbon dioxide or water vapor concentration. The cuvette temperature was measured with a thermistor and/or a copper-constantan thermocouple.

In the laboratory the plant was illuminated by one 500 watt quartz lamp (GE Q500 PAR56MFL) placed at a distance of 34 cm from the cuvette and one 150 watt tungston shaded spotlamp placed 15 cm from the side of the cuvette. Light in the cuvette (approximately 1/3 full sunlight) was near saturation for photosynthesis and above saturation for maximal stomatal opening for all species studies.

For the field studies, the cuvette was mounted on a heavy duty, TV tripot (Elevator Hi-Boy IV, Quick Set Inc., Northbrook, Illinois), which can be adjusted to heights of up to 2.7 meters for use on shrub and tree branches. For measurements on salt cedar branches in the top of the canopy, each tripod leg was further extended with two one meter lengths 3.8 cm diameter plastic pipe telescoping on a wooden dowel. With this extension, the cuvette could be raised as high as 4.5 meters. The other components of the gas exchange system used in the field were housed in a small utility trailer. A nine meter umbilical cord containing water and air lines and thermocouple and thermistor wires coupled the cuvette to the measuring and recording components in the trailer. Cuvette illumination in the field was provided by full sunlight.

Laboratory Antitranspirant Experiments

A plant was removed from the controlled environment chamber, sealed into the cuvette, and illuminated until transpiration and net photosynthesis reached steady state values. The plant was then removed from the cuvette and sprayed to run off with antitranspirant, using a Binks Model 15 paint spray gun. The plant was then returned to the growth chamber to allow the antitranspirant to dry, and then was returned to the cuvette periodically for transpiration and photosynthetic determinations. Control plants were treated identically, except that they were sprayed with distilled water. All laboratory experiments were conducted at 25°C air temperature and a relative humidity of from 35 to 42% inside the cuvette.

Field Studies

Field studies were conducted at the United States Bureau of Reclamation Evapotranspirometer Installation at Bernardo, New Mexico, approximately 55 miles south of Albuquerque near the Rio Grande River.

At this site nine evapotranspirometer tansk, each 12 feet deep with a 1000 square foot surface, had been constructed in 1961-62. Each tank was lined with 1/16-inch butyl rubber and after construction, native soil was returned to each tank in as near the original profile as possible. Presently, four tanks are planted with Tamarix, two with Russian olive, two with salt grass, and one measures evaporation from bare ground. The surrounding area, which was originally cleared to facilitate construction of the tanks, was planted with Tamarix to eliminate any oasis effect. Evapotranspiration from each tank is determined by measuring the amount of water which must be added to maintain a constant water level. The water supply to each tank is regulated by a solenoid valve controlled by a suspended probe assembly and relay. As the water level falls below the lower probe, the relay is de-energized, completing the electrical circuit opening the solenoid valve. As the water table reaches the upper probe, the relay is energized and the valve closes. The amount of water added is measured by standard water meter to the nearest one-tenth.

Tamarix plants were planted on the tanks and surrounding area at a density of 1 plant per square foot, or 100 plants per evapotranspirometer, which was typical of the undisturbed Tamarix in the area. Our studies were confined to tanks 4, 5, and 6 which have similar Tamarix stands. Water consumption on the fourth Tamarix tank (Number 3) was too low to serve as a valid control.

Evapotranspirometer Number 6 served as a control for all studies. Number 4 was sprayed with 15 liters of 10% Mobileaf on 16 June 1975 and 17 liters of 15% Mobileaf on 24 June 1975. Tank number 5 was sprayed with 18.5 liters of 15% Mobileaf on 18 June 1975. The results of the second spraying of tank 4 were not available for inclusion in this report.

Antitranspirant was applied in the field with a KWH 66 Power Knapsack Mist Blower. In the first application on tank 4, the antitranspirant was applied primarily by spraying from the top of a 14-foot ladder which was moved around the periphery. In subsequent sprayings, individual plants were sprayed from top to bottom at close range with the operator standing on the ground, then the canopy was sprayed from the ladder top on the tank periphery.

Spray coverage was evaluated by two methods. Thirty-two paper tags, each with a microscope cover slip glued to it, were hung by strings at approximately 0.5, 1.5, 2.7, and 4 meters height on eight plants on each evapotranspirometer that was sprayed with antitranspirant. After spraying when the droplets had dried, the tags were collected for later evaluation of spray spattered density. Coverage was also evaluated on a random sample of twigs that were air freighted to the University of California, Davis, for scanning electron microscope cathode illuminescence studies. These studies are being completed by co-workers at the University of California, Davis, and are not available for inclusion in this report.

Field gas exchange studies were conducted on evapotranspirometers 5 and 6. The end of an intact branch 10 to 15 cm in length was sealed into the cuvette and steady state transpiration and net photosynthetic rates in full sunlight measured. Prior to spraying, steady state values were measured on 8 brnaches of plants on evapotranspirometer 5 and 7 branches on number 6, the latter serving as controls. During spraying, two of the eight branches on tank 5 were covered with plastic bags, to also serve as controls. When first measured, each branch was carefully tagged so that the same amount of plant material would be present when the branch was returned to the cuvette for periodic measurements after spraying. Green leaf material was harvested after the last measurement had been taken on a branch, and also fresh and dry weight were determined so that rates could be compared on a unit plant material basis.

Antitranspirants

The antitranspirants included in the study are shown in Table II. A literature review, and discussions with co-workers at the University of California, Davis, indicated that these were the most promising film type antitranspirants currently commercially available. They are also representative of the different types of chemicals used as film-forming antitranspirants.

Table II. Antitranspirants Included in the Study

Antitranspirant	Type of Material	Concentrations Used	Manufacturer
Mobileaf*	Wax emulsion in water	5-16.5% v/v, (stock solution diluted in water)	Mobil Chemical Company P.O. Box 26683 Richmond, VA 23261
Wilt Pruf*	Beta pinene emulsion in water	16.5% v/v, (1:5 dilution of stock solution in water)	Nursery Specialty Products 410 Greenwich Ave. Greenwich, CT 06830
XEF-4-3561	Siloxane emulsion in water	5% siloxanes (1:9 dilution of stock solution in water)	Dow Corning Corporation Midland, MI 48640

*FDA approved for direct application to edible crops.

Phytotoxicity Trials

On 27 May 1975, 5, 10, and 15% concentrations of Mobileaf were sprayed on *Tamarix* branches at the Bernardo evapotranspirometer site. Two branches received a heavy application (thorough drenching) and two received a light or application at each concentration. The branches selected were exposed to full sunlight. Periodic observations revealed no apparent discoloration within a month after treatment. Studies conducted out of doors on growth chamber-reared *Tamarix* plants at Boulder, Colorado, during late May and early June similarly showed no apparent phytotoxicity at similar spray concentrations, but ambient temperatures at Boulder were cool and rains were frequent during the tests.

RESULTS AND DISCUSSION

BLM Studies

XEF (5% solution) reduced transpiration and photosynthesis of *Achillea Millefolium* 40-60% within a few hours after spraying; however, both rates returned nearly to their original values within two days (Figure 1). Mobileaf (10% v/v solution) produced only a 10-30% reduction in transpiration and photosynthesis of *A. millefolium*, but at that concentration the Mobileaf did not appear to cover the surface well. A mixture (50:50 v/v) of 5% XEF and 10% Mobileaf produced about an 80% reduction of both transpiration and photosynthesis of *A. millefolium*, but also its effectiveness decayed within two days. Coverage of the finely dissected, pubescent Yarrow leaves appeared to be enhanced when using the mixture of antitranspirant compared to Mobileaf alone.

Because the XEF seemed to achieve larger initial reductions while Mobileaf appeared more persistent, we decided to conduct further experiments with both antitranspirants and a mixture of the two. The concentration of Mobileaf in subsequent experiments was increased to 16.5% (1:5 v/v dilution in distilled water), the concentration recommended by the manufacturer for treating tobacco transplants. The antitranspirant mixture in subsequent experiments was prepared by diluting stock Mobileaf 1:5 v/v in the 5% XEF solution.