Reducing transpiration to conserve water in soil and plants

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A major pathway of water loss from plants is by transpiration, which accounts for 99 percent of the water taken up by plant roots. This water is lost from the immediate area where the plant is growing, since it passes via the atmosphere to some other point in the hydrologic cycle. Because the water that is transpired is essentially pure, salts in the soil water system become more concentrated.

An antitranspirant (AT) applied to transpiring plant surfaces to reduce transpiration water losses (1) conserves soil water in the root zone, extending its availability to the plant; and (2) conserves water in the plant itself, improving growth by keeping water losses through the leaves in better balance with rate of uptake through the roots—i.e., the plant is kept turgid.

Plant growth depends basically on two factors: (1) accumulating raw materials for cell production, particularly through photosynthesis, and (2) keeping the plant turgid so cells can enlarge. The stomatal pore lets in the carbon dioxide needed for photosynthesis and allows water vapor to escape, influencing both factors. An AT, which either plugs sto-

Both pots of sugar beet were watered on the same day. Three days later, the unsprayed plant had exhausted its soil moisture and wilted, whereas the plant previously sprayed with a film antitranspirant still had sufficient soil moisture available to prevent wilting.

mata ("film forming") or prevents complete opening ("stomatal inhibitor"), also affects both growth factors.

The net effect of applying an AT may be beneficial in some cases and detrimental in others. Crops will use continually available soil moisture at a "luxurious" rate through wide-open stomates, with accompanying rapid photosynthesis. On extremely hot and dry days, however, these plants will tend to close their stomates, because transpiration exceeds uptake of water, and growth factors 1 and 2 will be inhibited. This effect will be less severe in plants sprayed with AT.

In another case—initially moist soil followed by a dry period—photosynthesis and transpiration will be rapid at first but will slow as the soil water becomes depleted, especially if evaporative demand is high. Treatment with AT—preferably after most of the new foliar growth has occurred but while there is still water in the soil profile—will initially retard transpiration and photosynthesis. However, the time at which those functions start to drop off severely because of water stress will be delayed, and, throughout the interim period, the treated plants will be more turgid, will photosynthesize more rapidly, and will have higher growth rates (see photo).

If virtually no soil moisture is available, AT will be of little benefit, because the plant's own protective mechanisms will have come into full operation. Thus, an AT is not a cure for a plant that has already wilted, but it can be a preventive or delaying measure if applied while some soil moisture is still available.

AT usefulness

AT can be used to conserve water. For instance, vast quantities of water are lost by phreatophytes (plants that get most of their water from the water table), such as saltcedar (*Tamarix* sp.) and cottonwood (*Populus* sp.), especially if they grow in riparian areas where ground water is available throughout the summer. Saltcedar can transpire 60 to 70 inches (150 to 180 cm) per year and, in the western United States, it annually uses more than 5 million acre-feet of water. Our experiments have shown that AT spraying can reduce this high rate of water loss by 30 percent without damaging the plants. The accompanying temporary photosynthesis reduction is unimportant for these nonagricultural plants. This approach to improving ground-water storage and increasing the supply of water for agricultural and other demands may be more environmentally acceptable than mechanical or chemical eradication of the plants.

On the farm, much water is wasted by inefficient irrigation—although some of the excess water applied may be needed for leaching. This wastage may be minimized by an AT to slow soil water depletion, reducing the number of irrigations. In Israel, Dr. J. Gale applied a film antitranspirant to field-grown banana plants and reduced soil water extraction by 21 to 44 percent during seven irrigation cycles, without affecting growth or fruit quality. The irrigation intervals were extended from the normal seven days to about ten days. In California, we showed that a film-forming antitranspirant effectively reduced soil water depletion (measured by a neutron moisture-meter) by field-grown ornamental oleander plantings, with the result that irrigation intervals could be extended by at least two weeks, and costly, hazardous irrigations by tanker trucks along highways could be minimized.

In many cases, the primary purpose in using an AT is improvement of plant performance by increasing plant turgidity. Of course, soil water is also conserved in the process, but the grower's main benefit lies in greater monetary returns from the crop by minimizing plant water stress—particularly at sensitive stages of crop growth.

It is unlikely that presently available ATs would increase yield of an annual field crop (which is highly dependent on current photosynthesis for growth and final yield), unless it became stressed from inadequate water and/or a very high evaporative demand. We found in California that a film AT on snap beans reduced leaf expansion, plant height, and yield of green beans when soil moisture was adequate and evaporative demand was moderate. In Israel, however, Dr. Gale showed that periodic AT sprays on beans could increase dry-matter production, and there was only a slight difference in plant dry weights between untreated well-irrigated plots and antitranspirant-treated inadequately irrigated plots. When Dr. Fuehring sprayed AT on sorghum with limited irrigation in New Mexico, grain yield increased 5 to 17 percent.

Established perennial plants normally have more food reserves in storage tissues than do annual plants, so growth is expected to be affected less severely from photosynthetic reduction by an AT. There is some justification for expecting positive yield responses by perennials, especially if the AT is applied at a stage when growth of a particular plant part depends more on maintaining high plant water potential than on photosynthate accumulation.

We observed that daytime shrinkage of fruit tree trunks was significantly reduced by AT treatment, indicating that the lag between water uptake and transpiration had been minimized and that tree water status as a whole had been improved. After spraying AT on the stomatal-bearing leaf surfaces of fruit trees in commercial orchards one or two weeks before harvest (when much of the carbohydrate accumulation in the fruits had already occurred, and fruit sizing depended chiefly on maintaining cell turgidity), fruit volumes were increased by 5 to 15 percent for olives, peaches, and cherries, and more fruit fell into larger size grades. Fruit dry weight was not reduced significantly unless the AT was sprayed too early and at an excessive rate.

We also found that preharvest sprays of ATs on fruit trees curtailed daytime shrinkage of peaches and prevented irreversible olive fruit shrivel. Furthermore, preharvest spray of an acceptable food-grade film AT reduced postharvest fruit desiccation, thereby extending shipping and shelf life.

Dipping seedling tops in an AT solution just before transplanting can help transplants survive the critical moisture-stress period; once the transplant is established, new foliar growth should permit efficient photosynthesis. A pre-transplant AT spray on seven-year-old citrus trees reduced the decline in leaf turgidity after transplanting, thereby reducing transplant shock.

Costs

At present prices, commercially available ATs, usually of the film type (wax-based emulsions or polyterpenes), are not economically feasible to reduce irrigation frequency, unless water is extremely expensive, or to improve crop yield, unless crops are high value, such as cherries and olives. For instance, one of the wax-based ATs, at $4.50 per gallon, diluted to 3 percent (v/v) and sprayed at 300 gallons per acre in a cherry orchard to increase fruit size, would cost $40.50 per acre plus the cost of application. The increased fruit yield, along with the higher returns resulting from more fruit in larger grade sizes, could result in a net gain—depending on current cherry prices.

Most ATs have been produced for the relatively small nursery ornamentals market. It is hoped that when demand develops for an agricultural-scale market, prices will decrease as competition and sales volume increase.

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