Temperature Control and Water Conservation in Above-Ground Containers©

Carl E. Whitcomb and Andy C. Whitcomb
Lacebark Inc. 2104 N. Cottonwood Road, Stillwater, Oklahoma 74075
Email: Carl@lacebarkinc.com

INTRODUCTION

Excess heat in above-ground containers has long been recognized as a major problem. The challenge has been to find a practical way to moderate temperature. Harris (1967) measured temperatures in California 8 cm (3 inch) below the surface and 2.5 cm (1 inch) from the exposed edge of metal containers painted black or white, covered by aluminum foil, or shaded by wood. Exposed sides of black containers reached 46° C (115 °F) and remained at or above 38 °C (100 °F). There were no roots in about 33% of the container volume due to excessive heat. Painting the container white reduced temperature only 3 to 4 °C (5 to 7 °F), while aluminum foil reduced temperature about 5.5 °C (10 °F), but temperatures were still above the lethal point for roots. Shading containers with wood was the most effective treatment; none of these treatments were commercially feasible.

Whitcomb (1980) compared injection molded containers made of white or black plastic and found the white container only about 3 °C (5 °F) cooler. Temperature reduction was minimal because white containers were translucent. The light penetration not only increased temperature, but also produced a thick algal slime on the inside. Whitcomb (1983) and Whitcomb and Mahoney (1984) reported that white on black co-extruded plastic containers were 4 to 7 °C (7 to 12 °F) cooler than black containers, which reached a maximum of 56 °C (132 °F) on the sun-exposed side in Oklahoma. Temperature reduction was insufficient to allow roots to survive.

As temperature in container growth medium increases, so does the rate of evaporation and transpiration, while root function and the portion of container volume suitable for root growth declines. Under summer conditions in Oklahoma, plant water uptake for a 24-h period ranges from 16% to 32%, while the remaining 84% to 68% is lost to evaporation.

All irrigation waters contain low to high salt levels. Salts are all compounds soluble in water. Some salts used for fertilization are desirable, such as potassium sulfate and ammonium nitrate, since potassium, sulfate, ammonium, and nitrate are all essential for plant growth and beneficial unless applied in excess. On the other hand, salts like sodium chloride (non-essential element), and excess amounts of calcium bicarbonate and calcium chloride are undesirable and can be detrimental to plant growth. When water evaporates, residual salts are left behind.

The RootTrapper® (patent pending) container is made of an insulating black fabric with a bonded coating of white polyethylene on the outside. The container sidewall is impervious to water loss and root penetration. The RootTrapper has vertical sides and a flat bottom which aids stability and reduces blow over (Fig. 1). In addition, the RootTrapper stops roots from circling by trapping root tips in the fabric inner wall and stimulates root branching. Root tip trapping was discovered to be the factor that stimulated additional branching in polyethylene bags with

Figure 1. White RootTrapper® containers are cooler and conserve water.

gusset-folded bottoms (Whitcomb 1979, 1983, 1988, 2003). Root-tip trapping was later used to reduce root circling and stimulate root branching in stair-step pots (Whitcomb and Williams, 1983). By reducing root zone temperatures by 11 to 14 °C (20 to 25 °F), the RootTrapper containers reduce water loss by evaporation. Unlike conventional containers, drainage is through thousands of small holes around the bottom. By having very small drain holes, more water is retained and nutrient loss by leaching is minimized (Fare, 1998). Greater water retention in the container also reduces potential non-point-source pollution and simplifies water recycling (Fare, 1998 and 1999).

Containers made of porous fabric have previously been studied and found to have water loss rates two to three times greater than conventional plastic pots in Oklahoma (Whitcomb, 2003). The increased evaporation is due to the pervious nature of the fabric. In addition, the porous fabric containers turned green with algae near the bottom and white with salts above. The soluble salts come from fertilizers used in the growth medium and irrigation water. Pruning of roots on the sidewall may be due to high salt concentrations, causing root death as well as dehydration pruning (Whitcomb, 2003). The RootMaker® air-root-pruning container openings make up less than 2% of the sidewall, while RootBuilder air-root-pruning openings make up about 5% of the sidewall.

Water availability is of increasing concern, as well as taking steps to minimize nutrient runoff from nurseries (Fare, 1999). Several states, including Florida, California, and Texas, have begun water-monitoring programs and are likely to restrict water use by nurseries in the future. Likewise, water runoff, fertilizer leaching, and effects on recycling water systems are important considerations when selecting

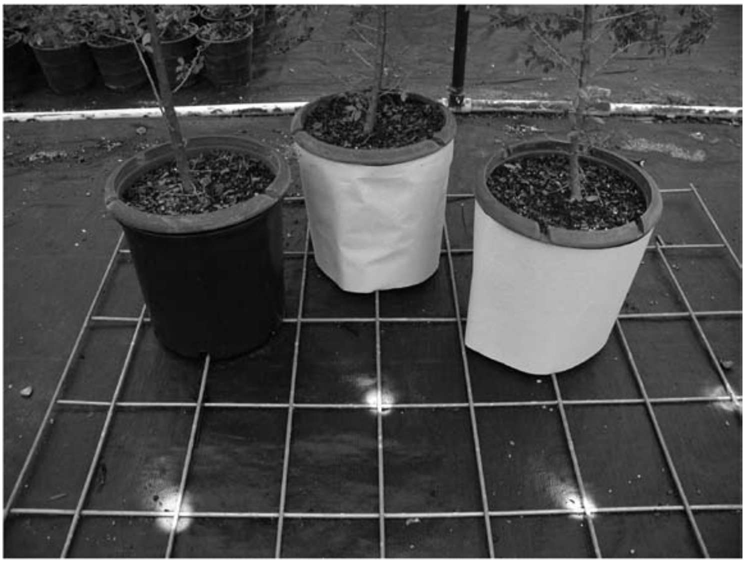

Figure 2. RootSkirts® made of the same white-on-black insulating fabric as the RootTrapper® container can be installed directly on production containers or on permanent support pots into which production containers are inserted.

the most suitable container. One study found 86% less nitrate leaching when the drainage hole in a conventional container was reduced from 2 to 0.5 cm (0.8 to 0.2 inches), with no adverse effect on plant growth (Fare, 1998).

MATERIALS AND METHODS

Four studies were conducted dealing with temperature control and water conservation in above-ground containers.

Experiment 1. Containers (32-L, 7-gal) with different sidewall composition were compared for rate of water loss. The container sidewalls were: (1) conventional black plastic, (2) a porous fabric that readily allows water evaporation through the sidewall, (3) a white laminated fabric impervious to water (RootTrapper) with exposed mix surface, and (4) a white laminated fabric impervious to water (RootTrapper) with surface protected by a fabric disc of the same material.

The containers were filled with an air-dry pine bark, peat, sand growth medium (3 : 1 : 1, by volume) to the same depth and weight. The containers were then watered repeatedly by hand to thoroughly wet and settle the mix. Weight of the containers was then determined every hour for 8 h. Wetting and water loss measurements were repeated five times. All water loss was due to evaporation since there were no plants in the containers.

Experiment 2. In order to determine the composition of the accumulated salts and effects of the high rate of water lost on movement of nutrient elements, a comparison of 57- and 114-L (15- and 30-gal) containers made of black porous fabric versus white, impervious fabric (RootTrapper) were studied. The containers were filled with a mix of pine bark, peat and sand (3 : 1 : 1 by volume) and planted to several species of trees. Watering was by overhead irrigation.

Experiment 3. Temperatures were compared between 26-L (7-gal) white RootTrapper containers versus conventional black plastic containers. All container temperatures were measured between 13:00 and 15:00 along the inside wall exposed to full sun and at 8 cm (3 inches) below the surface. Species tested were shumard oak (*Quercus shumardii*) and catalpa (*Catalpa bignonioides*). Growth medium was pine bark, peat, and sand (3 : 1 : 1, by volume). Watering was by overhead sprinklers.

Experiment 4. Temperatures were monitored on 11-L (3-gal) containers, as reported in Experiment 3. Treatments were: (1) conventional black plastic container, (2) conventional black plastic container inserted snugly in a support pot to prevent blow over, (3) conventional black plastic container setting inside a larger container with a space between the container walls, (4) RootMaker #3 air-root-pruning container alone, (5) RootMaker #3 containers fitted with insulating RootSkirt® made from white, laminated RootTrapper fabric (Fig. 2), and (6) RootMaker #3 container in a support pot fitted with RootSkirt.

RESULTS

Experiment 1. The conventional black plastic 27-L (7-gal) containers held 11.2 pounds of water 1 h after the last thorough watering. The water held by the standard 27-L (7-gal) plastic container was assigned 100%. Water held initially and rate of loss from other containers was plotted relative to the standard black plastic pot.

Water loss from the container with porous fabric sidewall was greatest. One hour after watering, the porous fabric container lost 11% more water than the standard plastic pot. On the other hand, after 1 h containers made of white laminated fabric impervious to water (RootTrapper) held 12% more water that the standard plastic pot with surface exposed and 16% more with surface covered. After 8 h the container with porous fabric sidewall had lost 32% of the total water held, whereas the standard black plastic pot had lost 15%, while the white laminated fabric container had lost only 10% with its surface exposed, and 5% with surface covered. Saving 22% to 27% of irrigation water applied after 8 h is a significant reduction in water use.

To put these findings in perspective, a nursery with 5000 plants in #7 containers made of porous fabric would lose by evaporation 2,162 gal or 2.1 times more water every 8 h under the conditions of this study, compared to loss from a standard black plastic pot (1,021 gal), and 3.2 times more water compared to containers made of white impervious sidewall (RootTrapper) with a loss of only 660 gal. In 8 h, conventional black plastic containers lost 1.5 times more water compared to white RootTrapper containers.

Experiment 2. Containers with porous fabric sidewalls quickly turned from black to grayish-white due to evaporation and accumulation of salts. At the end of the growing season samples of salts washed from the fabric sidewall revealed that the main components were calcium, sulfur, and bicarbonates, with lesser quantities of potassium, ammonium, and other elements (Table 1). Because the trees were watered by overhead sprinklers, the more soluble nitrate, potassium, and magnesium were likely washed off, through the porous ground cover cloth and into the soil below.

Table 1. Analysis of salts accumulated on outside of porous uncoated black fabric bag after four months with overhead irrigation. A 0.3 m^2 (1 ft^2) section of fabric was removed from the container, soaked in distilled water (approx. two parts water to one part sidewall material by weight), then the solution analyzed.

NH_4-N	NO_3-N	P	K	Ca	Mg	Na	S	Fe	Zn	Mn	Cu	Bicarb	Cl-
Black fabric outer surface													
19.1	0.6	14.5	66.3	583.9	30.3	11.6	480.1	0.1	0	0.8	0	242	11.3

Note: Values are in parts per million (ppm)

Table 2. Analysis of growth media in two types of containers after 5 months. A 0.1 N HCl was used as the extracting agent for nutrients. Soluble salts were determined using 2:1 water to media and expressed as mmho·cm^{-1}.

NH_4-N	NO_3-N	P	K	Ca	Mg	Na	S	Fe	Zn	Mn	Cu	Salt level	pH
Black fabric 1 inch inside wall													
358	293	302	1205	6321	584	151	448	312	116	164	49	2.1	4.8
Black fabric, 6 inches													
124	53	278	786	2370	486	101	412	156	79	100	38	0.69	4.4
RootTrapper® 1 inch inside wall													
99	62	205	522	2548	485	84	138	229	72	94	31	0.95	4.6
RootTrapper 6 inches													
114	53	196	509	2526	503	87	101	210	79	88	29	0.89	4.6

Table 3. Root-zone temperatures in black versus white RootTrapper containers monitored on 5 summer days. All container temperatures were measured against the inside wall exposed to full sun and 7.6 cm (3-inches) below the surface during times from 13:00 to 15:00.

Date	Air temperature (°F)	Black container temperature (°F)	White RootTrapper temperature (°F)
26 May	84	107	88
22 July	104	127	109
16 Aug.	98	124	101
31 Aug.	92	119	96
12 Sept.	94	125	96

To better understand the effect of a high rate of water evaporation from a container sidewall, samples of growth medium 1-inch in diameter were removed just inside the fabric wall and 15 cm (6 inches) inside on containers with porous and white nonporous sidewalls. Water movement from inner areas of the growth medium to the sidewall of the porous fabric container transported from high to modest quantities of nutrient elements (Table 2). Nitrate-N was 5.5 times and ammonium-N 2.9 times higher near the sidewall versus at 15 cm (6 inches). Potassium, calcium, and iron were 1.5, 2.6, and 2.0 times higher, respectively, near the sidewall versus the internal 5 cm (6 inches) of the container medium. Soluble salts were three times higher near the sidewall and reached toxicity levels (Ann., 1997 and Whitcomb, 2003) compared to the internal 5 cm (6 inches) of the container medium (Table 2). White containers with impervious sidewalls had similar nutrient and soluble salts levels.

Experiment 3. Temperatures against the sidewall were reduced from 10 °C (18 °F) during May and July and 13 to 16 °C (23 to 29 °F) during Aug. and Sept. (Table 3). When the sun was directly overhead, temperature moderation was less (May and July readings). As the sun moved southward during the later part of summer, and contacted container sidewall more directly, the temperature reduction was greater.

When root development was evaluated on 18 Sept., there were no roots on the exposed side of the black container. Approximately 30% of the container volume was wasted. By contrast, there were many roots with white root tips on the exposed side of the white RootTrapper container.

Experiment 4. When RootSkirts were installed either directly on production containers or on support pots in which production containers were located in order to prevent blow over, temperature reductions were similar to those observed in Expt. 3 (Table 3). When production containers fit snugly against the inside wall of the support pots and no RootSkirts were used, the support pot provided little or no temperature moderation. On the other hand, if there was a space of 1 to 2.5 cm (0.5 to 1 inch) between the side of the support pot and the production container and no RootSkirt was used, a temperature reduction of 3 to 5 °C (5 to 9 °F) was measured. This difference is due to direct transfer of heat through the two plastic containers when touching compared to the "chimney effect'" between the two containers when some space occurred. The chimney effect resulted from the air between the containers being heated and rising, which drew in cooler air, lowering the container temperature.

DISCUSSION

Benefits of containers made of white on black laminated and insulating fabric include:

- White, laminated fabric (RootTrapper) containers used 1.5 times less water than conventional black plastic containers and 3.2 times less water than porous fabric containers.
- White laminated onto black fabric blocks out light and stops internal algae growth.
- Conserves water by reducing temperature.
- Conserves water and nutrients by slowing exit of water.
- Trapping of root tips stimulates root branching.
- Additional root branching back in the growth medium increases absorption of water and nutrients.
- No root circling was observed.
- Tough and durable, RootTrapper can be dropped, shifted, lifted, or dragged.
- Broad, flat bottom reduces blow over problem.
- Broad, flat bottom increases heat dissipation to the earth in summer and heat absorption in winter.
- Accelerates growth of some species.
- Accelerates establishment into the next size container or into the landscape.
- Containers are easily removed and may be reused.
- Easy to fill and handle.
- Lightweight and easy to ship.
- There are no sharp edges to damage other plants during shipping.
- No toxic copper or other chemicals.
- Economical, particularly in sizes of 10 gal or larger.

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