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

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 three inches below the surface and one inch from the exposed edge of metal containers painted black, painted white, covered by aluminum foil or shaded by wood. Exposed side of black containers reached 115 F (45 C) and remained at or above 100 F (38C) for five hours each day. There were no roots in about 1/3 of the container volume due to excessive heat. Painting the container white reduced temperature only 5 to 7 F, while aluminum foil reduced temperature about 10 F but temperatures were still above the lethal point for roots. Shading containers with wood was the most effective treatment. But none of these treatments were practical.

Whitcomb, 1980, compared injection molded containers made of white or black plastic and found the white container only about five degrees 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, found that white on black co-extruded plastic containers were 7 to 12 F (4 to 7 C) cooler than black containers which reached a maximum of 132 F (55 C) on the exposed side in Oklahoma. Still, temperature reduction was insufficient to allow roots to survive on the exposed side of the container.

As temperature in container growth medium increases so does the rate of evaporation while root functions and the portion of container volume suitable for root growth declines. Under conditions of Oklahoma in summer, plant water use for a 24 hour period ranges from about 16 to 32%, while the remaining 86 to 68% is lost to evaporation.

All irrigation waters contain salts and levels range from low to very high. Salts are all compounds soluble in water. Some salts are desirable such as potassium sulfate and ammonium nitrate where potassium, sulfate, ammonium and nitrate are all essential for plant growth and beneficial unless applied in large excesses. On the other hand, salts like sodium chloride, calcium bicarbonate and calcium chloride are undesirable salts where the sodium, chloride, bicarbonate and calcium (when in excess) are non-essential and detrimental to plant growth. When water evaporates, salts are left behind. This is what causes the coating inside a tea kettle and white stain on your shirt after a hot day and lots of sweat.

A new container entered the market in 2001. 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 (Figure 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 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) sold briefly by Imperial Plastics, Evansville, IN. White RootTrapper® containers also have the water conserving advantage of reducing root zone temperatures by 20 to 25 degrees F. which reduces water loss by evaporation. In addition, unlike conventional containers, drainage is through thousands of small holes around the bottom. By having very small drain holes, water absorption by components of the growth medium is more complete, more water is retained and nutrient loss by leaching is minimized (Fare, 1998). Greater water retention in the container also reduces pollution and simplifies water recycling (Fare, 1998 and 1999).

Figure 1. White, RootTrapper® containers are cooler, conserve water and provide many other benefits.

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). This is due to 100% of the circumference evaporating water and not just the surface. 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). [For comparison, 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, particularly water of good quality and nurseries should take steps to minimize nutrient runoff (Fare, 1999). Several states such as Florida, California, Texas and others 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 the most suitable container. One study found 86% less nitrate leaching when the drainage hole in a conventional container was reduced from ¾ inch to 3/16 inch, with no adverse effect on plant growth (Fare, 1998).

Materials and Methods

We conducted four studies dealing with temperature control and water conservation in above ground containers.

Experiment 1. Seven gallon containers with different sidewall composition were compared for rate of water loss. The container sidewalls were:

A. conventional black plastic
B. porous fabric that readily allows water evaporation through the sidewall
C. white laminated fabric impervious to water (RootTrapper®) with exposed mix surface and
D. white laminated fabric impervious to water (Root Trapper®) 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 were then determined every hour for eight hours. Wetting and water loss measurements were repeated five times. All water loss was due to evaporation as 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 15 and 30 gallon containers made of black porous fabric versus white, impervious fabric (RootTrapper®) was 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 #7 white RootTrapper® containers versus conventional black plastic containers. All container temperatures were measured between 1:00 and 3:00 p.m. against the inside wall exposed to full sun and three inches below the surface. Species present were shumard oak, Quercus shumardi or 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 #3 containers similar to experiment 3. Treatments were:
Conventional black plastic container.
Conventional black plastic container inserted snugly in a support pot to prevent blow over.
Conventional black plastic container setting inside a larger container with a space between the container walls.
RootMaker #3 air-root-pruning container alone.
RootMaker #3 containers fitted with insulating RootSkirt® made from white, laminated RootTrapper® fabric (Figure 2).
RootMaker #3 container in a support pot fitted with RootSkirts®

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.

Results

Experiment 1. The conventional black plastic #7 containers held 11.2 pounds of water one hour after the last thorough watering. The water held by the standard #7 plastic container was assigned 100%. Water held initially and rate of loss from other containers was plotted relative to the standard black plastic pot (Figure 3).

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 one hour 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 eight hours the container with porous fabric sidewall had lost 32% of the total water held (7.6 pounds of water remained), whereas the standard black plastic pot had lost 15% (9.5 pounds of water remained) while the white laminated fabric container had lost only 10% with surface exposed (10.1 pounds of water remained) and 5% with surface covered (10.6 pounds of water remained).

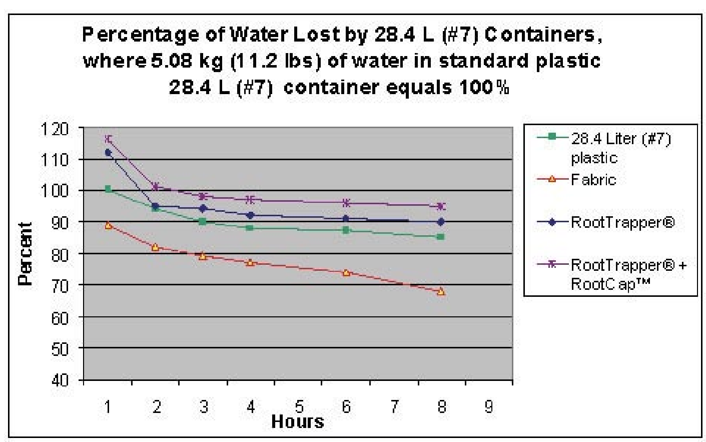

Figure 3. Percentage of water lost by #7 (28.4 L) containers where 11.2 pounds (5.08 kg) of water in conventional black plastic containers equals 100%.

Saving 22 to 27% of irrigation water applied after eight hours is a significant reduction in water use. In 8 hours the containers with porous fabric sidewalls had lost 3.6 pounds of water compared to the white impervious sidewall that had lost only 1.1 pounds. The standard black plastic pot held 11.2 pounds of water after being thoroughly watered and allowed one hour to drain to reach container capacity. Of the 11.2 pounds, approximately 4.0 lbs was bound to the growth medium and relatively unavailable (the approx. wilt point) leaving about 7.2 pounds available for plant growth. By contrast, the container made with porous fabric sidewalls had lost 1.2 pounds of water at the end of one hour and 3.6 pounds after eight hours, leaving approx. 3.6 pounds for plant use before reaching the wilt point. White containers with impervious sidewall and no top cover had retained 1.2 pounds more water than the black plastic pot after one hour and 0.6 pounds more after eight hours. White RootTrapper® containers with surface protection retained 1.2 pounds more water that the black plastic pot after one hour and 1.1 pounds after eight hours.

To put these findings in perspective, a nursery with 5000 plants in #7 containers made of porous fabric would lose by evaporation 2,162 gallons or 2.1 times more water every eight hours under the conditions of this study, compared to loss from a standard black plastic pot (1,021 gallons) and 3.2 times more water compared to containers made of white impervious sidewall (RootTrapper®) with a loss of only 660 gallons. In eight hours, 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 most soluble materials such as nitrate, potassium and magnesium were likely washed off, through the porous ground cover cloth and into the soil below.

To better understand the effect of a high rate of water evaporation from a container sidewall, samples of growth media one inch diameter were removed just inside the fabric wall and six 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 in six inches. Potassium, calcium and iron were 1.5, 2.6 and 2.0 times higher respectively near the sidewall versus in six inches. Soluble salts were three times higher near the sidewall and well into the salt toxicity level (Ann. 1997 and Whitcomb 2003) compared to a level six inches into the mix (Table 2). White containers with impervious sidewalls had similar nutrient and soluble salts levels near the sidewall versus in six inches and showed no trends suggesting influence of the sidewall.

Experiment 3. Temperatures against the sidewall were reduced from 18 degrees F during May and July and 23 to 29 degrees F during August and September (Table 3).
When the sun was near direct overhead temperature moderation was less (May and July readings). As the sun moved southward and contacted container sidewall more directly, the temperature reduction was greater.

When root development was evaluated on September 18, 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 experiment 3 (table 3) and are not presented. One distinct difference deserves mention. 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 0.5 to 1.0 inch between the side of the support pot and the production container and no RootSkirt® was used, a temperature reduction of 5 to 9 degrees was measured. This difference is due to direct transfer of heat through the two plastic containers when touching compared to a 'chimney effect' being created between the two containers when some space occurred. The chimney effect results from the air between the containers being heated and rising, which in turn draws in cooler air through the drain holes of the support pot.

Table 3. Root zone temperatures in black versus white RootTrapper® containers monitored on five summer days. All container temperatures were measured against the inside wall exposed to full sun and three inches below the surface during times from 1:00 to 3:00 pm.

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

Discussion.
Containers made of white on black laminated and insulating fabric provide many benefits benefits:
• 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 algae growth inside.

• Conserves water by reducing temperatures 20 to 25 degrees F.
• Conserves water and nutrients by slowing exit of water.
• Trapping of root tips simulates root branching.
• Additional root branching back in the growth medium increases absorption of water and nutrients.
• No root circling has been observed.
• Tough and durable, can be dropped, shifted, lifted or dragged.
• Broad, flat bottom reduces blow over problem.
• Broad, flat bottom increases heat dissipation to the earth in sum mer 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 ship ping.
• No toxic copper or other chemicals.
• Economical, particularly in sizes of 10 gallons or larger.

Increased use and refinement of slow release fertilizer has reduced accumulation of unusable fertilizer components and the incidence of fertilizer salt root tip death in conventional containers. Containers made with porous fabric sidewalls and used above ground were water guzzlers. When water evaporation is allowed to occur from the entire circumferential sidewall of a container as well as the surface of the growth medium, the problem of salt accumulation and root tip death has returned.

Consider a #30 container that is 24 inches in diameter and 14 inches tall. The surface area of the growth medium is 452 square inches. However, the sidewall surface area is 1055 square inches or 2.3 times that of the surface. In addition, water loss from the surface of a container proceeds more slowly compared to the sidewall. As the surface of the growth medium dries, even modestly, water loss rapidly declines. This happens because with rainfall or irrigation the smaller particles in the growth medium segregate from the larger particles and move slightly downward, leaving the more coarse particles on the surface to act as mulch.

On the other hand, when the entire container sidewall is porous, there is no opportunity for the natural mulch effect to occur and slow water loss. Further, if a container is 14 inches deep, approximately the lower ¼ of the growth medium holds more water than the top ¾ because of the perched water table at the bottom (Whitcomb 1988 and 2003, Bilderback and Fonteno 1987). Exposing this zone of concentrated moisture to evaporation increases water loss dramatically. This is the zone that turned green with algae in the study. This phenomenon can be observed even with conventional containers. Any nursery or greenhouse that has marginal quality water will observe salts accumulated around the drain holes of conventional containers long before any salts are observed on the surface of the growth medium. Bilderback and Fonteno state that “The air and water holding capacities of a medium are dependent upon the container depth and width and not solely to the medium”, they should now add extreme sidewall porosity as well. They also note “When water restrictions become necessary, these procedures are basic to calculating and planning irrigation requirements”.

White insulating RootSkirts® either on production container or on support pots also reduce root zone temperature 20 to 25 degrees F and allow roots to function on the side exposed to sun. For example, when 10 to 30% of the volume of a #3 black conventional container is void of roots, plant response is similar to a #2 container. By avoiding heat root death, root diseases are also minimized. Finally, there are practical ways to avoid excess heat and conserve water.

Table 1. Analysis of salts accumulated on outside of porous uncoated black fabric bag after four months with overhead irrigation. A one square foot 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. Values are in parts per million.

	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

Table 2. Analysis of growth media in two types of containers after five months.
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.

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

Literature Cited

Annonymous. 1997. Best management practices guide for producing container grown plants. So. Nursery. Assoc. Marietta, Ga. 69 pages.

Bilderback, T.E. and W.C. Fonteno. 1987. Effects of container geometry and media physical properties on air and water volumes in containers. J. Environ. Hort. 5:180-182.

Brown, E.F. and F.A. Pokorny. 1982. Physical and chemical properties of media composed of milled bark and sand. Jour. Amer. Soc. Hort. Sci. 100:119-121.

Fare, Donna C. 1998. Does Container Drainage hole size affect your water quality? Proc. Int. Plant Prop. Soc. 48:608-610.

Fare, Donna C. 1999. Let's think out of the pot. Proc. Int. Plant Prop. Soc. 49:480-482.

Whitcomb, Carl E. 1979. Growing plants in poly bags. American Nurseryman 149:10,97,98.

Whitcomb, Carl E. 1980. Effects of containers and production bed color on root temperatures. Amer. Nurseryman 136 (11): 11, 65-67.

Whitcomb, Carl E. 1983. Containers vs. poly bags – which are better? American Nurseryman 157:101-103.

Whitcomb, Carl E. and J.D. Williams. 1983. A stair-step container for improved root growth. HortScience 20:66-67.

Whitcomb, Carl E. and G.W.A. Mahoney. 1984. Effects of temperature in containers on plant root growth. Okla. Agri. Exp. Sta Res. Rept P-855: 46-49.

Whitcomb, Carl E. 1988. Plant Production in Containers. Lacebark Inc. Stillwater, Ok. 633 pages.

Whitcomb, Carl E. 2003. Plant Production in Containers II. Lacebark Inc. Stillwater, Ok. 1,150 pages.

Whitcomb, Carl E. 1975. Plants, Pots and drainage. Horticulutre horizons 9:12-13.

White, J.W. and J.W. Mastalerz. 1966. Soil moisture as related to container capacity. Proc. Amer. Soc. Hort. Sci. 89:758-765.