Elvenia J. Slosson Endowment Fund for Ornamental Horticulture

Annual Report
30 June 2005

Investigation of water stress-induced bedding plant establishment problems and their solution

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Cell-pack-grown bedding plants often fail to become established following transplanting into landscape soil. These plants are healthy and vigorous at the time of transplanting, but either decline or die in the landscape. The most striking feature of this problem is the failure of roots to grow out of the rootball into the surrounding soil. This transplanting problem is prevalent during spring and summer, but less common in autumn.

We hypothesize that the lack of root growth and plant establishment is due to severe water stress of the plant despite normal irrigation. The reasons are twofold:

1) Drainage of water out of the rootball into the surrounding soil following irrigation. The container media normally used are very high in organic amendment. Their moisture retention while in the container is high, but when in contact with landscape soil the media readily lose water into the surrounding soil, which has finer pores. This loss, which can occur within hours of transplanting or irrigation, can amount to 50% or more of the available water in the medium (Costello and Paul, 1975).
2) Most commercially grown bedding plants have a high transpiring leaf area relative to the volume of the container medium.

When added together, these factors may impose a severe water stress on the plants within hours of irrigation. We frequently have observed that root balls become powder dry, even when the surrounding soil is moist. Root growth ceases under these conditions (Kratky et al., 1980).

In addition to the work cited above, there is some published research on the water relations of container-grown ornamental plants following transplanting into landscape soil, but it has not addressed the problems peculiar to bedding plants. For example, both shoot and root growth of Norway spruce seedlings were reduced by exposure to either preplanting or postplanting drought periods (Helenius et al., 2002). In another experiment, conifer seedlings transplanted from peat-based media had higher survival if they were irrigated immediately prior to planting, but survival of birch seedlings was not affected by preplanting irrigation (Heiskanen and Rikala, 2000). Landscape soil texture and water content affected root emergence from the root ball of Scots pine (Heiskanen and Rikala, 1998). In a study of large container-grown ornamental nursery stock (11 liter soil volume), Havis (1980) found that stomatal resistance of plants increased dramatically at soil moisture tensions between 0.25-0.4 bar. For most container media these tensions would occur soon after plants extract all easily available water. In fact, a 4-inch pot of medium transplanted (with no plant) into ground bed soil can lose up to 85% of its available water within a few hours (Nelms and Spomer 1983).

The problems peculiar to bedding plants, mentioned in the preceding paragraph, occur because of their exceedingly small root ball volumes and relatively large transpiring leaf area at planting time. These factors, coupled with the effects of landscape soil on water relations of transplanted root balls cited above, can lead to extremely rapid changes in moisture content of the root ball. Transplanted bedding plants may be exposed to stresses quite different from those faced by larger transplants: It is known that the rapid imposition of water stress induces responses in plants that differ from those in plants exposed to water stress that develops gradually (Garcia-Navarro et al., 2004).

This progress report presents the results of the initial phase of our project, which was devoted to developing methods for use of specialized tensiometers for continuous measurement of water potential in the rootballs of bedding plants. Several experiments were conducted in late July, September, and October 2004. Three representative experiments are described here.

Methods

Specialized tensiometers, made for use in small soil volumes, were purchased from Soilmoisture Equipment Corp. These tensiometers have several important features (Fig. 1). The porous ceramic cup has a diameter of 0.25 inches and a length of about 1 inch, so it is small enough to fit in the rootball of a bedding plant transplant without distorting results. The cup is attached to the tensiometer body by a 6-foot-long flexible tube, so the rootball need not be disturbed while the tensiometer is serviced. The standard pressure gauge has been replaced with a pressure transducer, which can be connected to a datalogger for continuous monitoring of soil moisture tension. The pressure transducer can register tensions between 0-500 mbar. The tensiometers were tested and calibrated before use.

The field plots were on a Yolo Silt Loam soil at the Department of Environmental Horticulture. Plot dimensions were 1 m X 1 m. The plots were leveled and enclosed on all sides by a berm. One or two days prior to planting, the plots were irrigated with 4-6 inches of water. Bedding plants were obtained from a retail nursery in Davis. A sufficient number of plants was purchased so that uniform plants could be used in the experiments. For each experiment, eight plants were transplanted on 6-8 inch centers in the plot, with the surface of the rootball flush with the soil surface. The shoots were removed at the soil line from four of the plants, so that only the rootball remained. A tensiometer was placed in the center of the rootball of each plant. Four additional tensiometers were placed at a similar depth in the field soil. After planting, the plot was irrigated with 1-2 inches of water.

Figure 1. Soilmoisture tensiometer, showing porous cup, flexible tubing, tensiometer barrel, and pressure transducer.

Soil moisture tension and water loss from unplanted bedding plants were monitored and the data were used to determine available water and to construct moisture release curves for the container medium. For this, individual cells containing plants were detached from a cell-pack. Tensiometers were placed in the center of each rootball, after which the medium was irrigated to container capacity. Pot weight and soil moisture tension were recorded hourly until visible wilting occurred. The tensiometer was then removed and the shoot was detached at the soil line. The bulk volume of the container mix was calculated from the dimensions of the rootball, which was then weighed, oven-dried, and reweighed. The volumetric moisture content and available water were calculated and a moisture release curve was plotted.

Results and Discussion

Experiment 1

The first experiment was conducted with zinnias planted on July 27, when the maximum air temperature reached 32°C. The equipment for continuous recording of tensions had not yet arrived, so values were recorded manually every 1-1.5 hr during the day. Tension values followed a clear pattern (Fig. 2). Within an hour after irrigation, the tension in rootballs and in the field soil was about 50 mbar. In rootballs with intact shoots, the tension rose rapidly during the next 3 hr. When the tension reached about 300 mbar, the plants wilted and were irrigated again. The tension in the soil and in the rootball without a shoot appeared to be in equilibrium, reaching a maximum of about 100 mbar at the time of re-irrigation. The moisture release curve for the container medium was used to estimate the amount of water lost to drainage. At the tension of 50 mbar, which was reached soon after planting, about 65% of the readily available water in the rootball had already been lost to drainage. Most of the remaining available water in the rootball was lost to drainage within the next 3 hr. In rootballs with intact shoots, the additional water loss to transpiration removed all available water and caused wilting within 3 hr. A

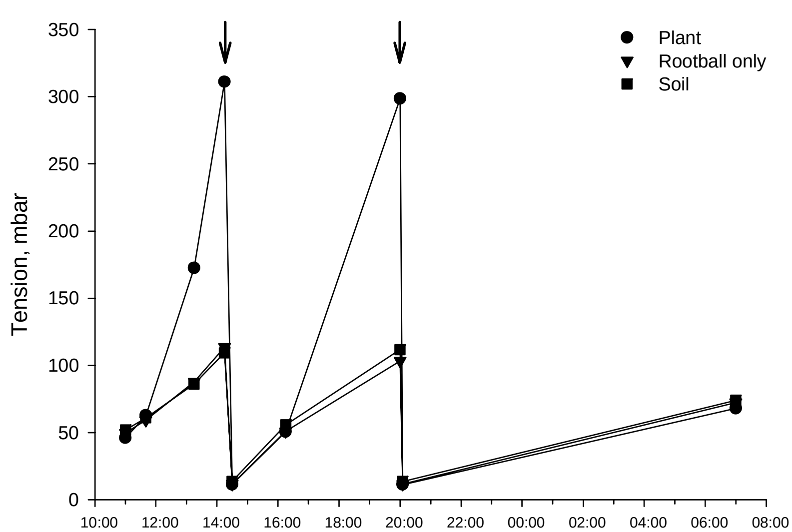

Figure 2. Changes in soil moisture tension in rootballs of zinnia and in Yolo Silt Loam soil. Experiment was conducted on July 27-28. Arrows indicate irrigation following plant wilting.

similar pattern occurred during the late afternoon, following re-irrigation. Wilting of the plants occurred again near the end of the day, so the plot was irrigated for the third time that day. Thus there was marked water stress of the zinnia plants twice during the day. During the night, all tensions rose slowly to about 70 mbar, with soil and rootballs again apparently in equilibrium. It is noteworthy that more than 70% of the available water in the rootzone was lost to drainage overnight, even when plants were irrigated at the end of the day.

Experiment 2

A subsequent experiment using manual recording of soil moisture tensions on transplanted celosia yielded similar results. Finally, in September, we received the equipment for continuous monitoring. We conducted the first full experiment with that equipment on September 29. Maximum air temperature ranged from 23°C on September 29 to 30°C on October 3. Pansy transplants were planted as described above. The general pattern of changes in soil moisture tension was similar to that found in previous experiments. Soil moisture tensions exceeded 60 mbar within an hour after planting and irrigation (Fig. 3). The tension in the rootball with an intact shoot climbed to 350 mbar during the afternoon. Most of the available water was consumed within 6 hr, and the plants were water-stressed but did not wilt. The tensions in the soil and the rootball without a shoot rose to about 170 mbar in the afternoon and appeared to be in equilibrium with each other. This increase in tension appeared to be due mainly to evaporation, since tension did not increase substantially at night. In fact, all tensions decreased gradually about 40 mbar during the first night and early the next morning, then rose rapidly as midday approached. This decrease in tension, which had not been noted in previous experiments, when values were recorded manually, probably was caused by upward movement of water from moister soil below the root zone. However, the increase in soil moisture content in the rootball at night was small, amounting to about 5 ml.

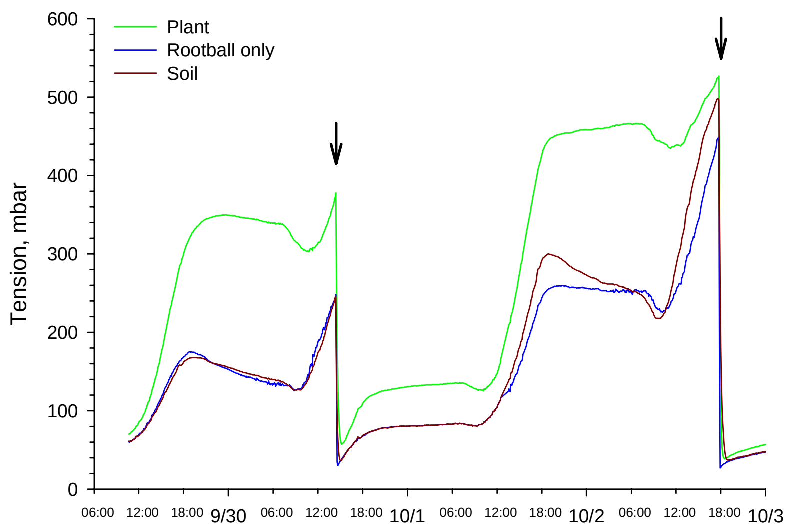

Figure 3. Changes in soil moisture tension in rootballs of pansy and in Yolo Silt Loam soil. Experiment was conducted on September 29-October 3. Arrows indicate irrigation following plant wilting.

On the second day, tensions began to rise rapidly in late morning. The tensions in the field soil and in the rootballs without shoots rose to about 240 mbar in early afternoon. The tensions of rootballs of intact plants reached about 375 mbar by 2 PM, when the shoots wilted. The plot was then irrigated heavily, after which tensions rose rapidly during the remainder of the afternoon to values of 120 mbar in rootballs of intact plants and 70 mbar in the soil and in rootballs without shoots. In all cases, tensions rose slightly overnight. In the rootballs of intact plants, over 80% of available water was lost by morning, and over 70% of available water was lost from the rootballs without shoots.

By late morning on the third day, tensions rose rapidly as the remaining available water was quickly lost to evapotranspiration. Values reached 440 mbar in rootballs with intact plants and 260-300 mbar in soil and rootballs without shoots. Even at the high tensions, the plants did not wilt. The ability of the plants to avoid wilting was surprising to us, but a careful inspection of the rootballs of intact plants at the conclusion of the experiment showed that roots had already begun to grow into the field soil. Such growth would increase the volume of water available to plants, partly because the volume explored by the roots would be greater and partly because more water is available in the field soil at the moisture tensions that occurred. We speculate that detectable root extension into the soil occurred in this experiment, but not in previous ones, for two reasons. First, the milder weather conditions reduced the rate of onset of water stress. Second, soil was packed more firmly around the rootballs in this experiment, resulting in better contact between the field soil and the container medium. This improved contact may have allowed for more rapid root growth, as well as for better transfer of water to the rootball when its soil moisture tension exceeded that of the field soil.

During the following night, tensions in the soil and rootball without shoots decreased as they did the first night, but tension in the rootball of the intact plants continued to increase slightly overnight. This departure from the pattern seen before probably indicates that no significant water transfer occurred from below the root zone of the intact plants because both the rootball and the surrounding soil were drier than before. The tensions of all rootballs and soil climbed rapidly out of measurement range by afternoon the following day. The plants wilted at 5:45 PM and the plot was irrigated again.

Experiment 3

An experiment was conducted to examine why soil moisture tension in the rootballs decreased at night. Pansies with and without shoots removed were planted and irrigated as before, but twice as many plants were used and the soil around half of the plants and rootballs was covered with a woven black plastic mulch. Tensiometers were placed with the porous cups either in the rootball or 2 cm below the rootball. The mulch was used to minimize evaporation. The experiment began in mid-October, and occasionally heavy rain interfered its management. Results of a 36-hour period following one rainstorm are presented in Figure 4. As expected, the tension in unmulched rootballs with shoots removed increased much more than in mulched rootballs (Fig. 4a). In addition, the tension in unmulched rootballs was greater than in the soil beneath them, but in mulched rootballs the tension was the same as it was in the subtending soil. At night, tension in mulched rootballs and in the subtending soil barely changed, but in unmulched rootballs the tension decreased slightly at night and the tension of the subtending soil increased by a similar amount. The sharp decline in tension in all rootballs in early morning on October 19 was the result of heavy rainfall.

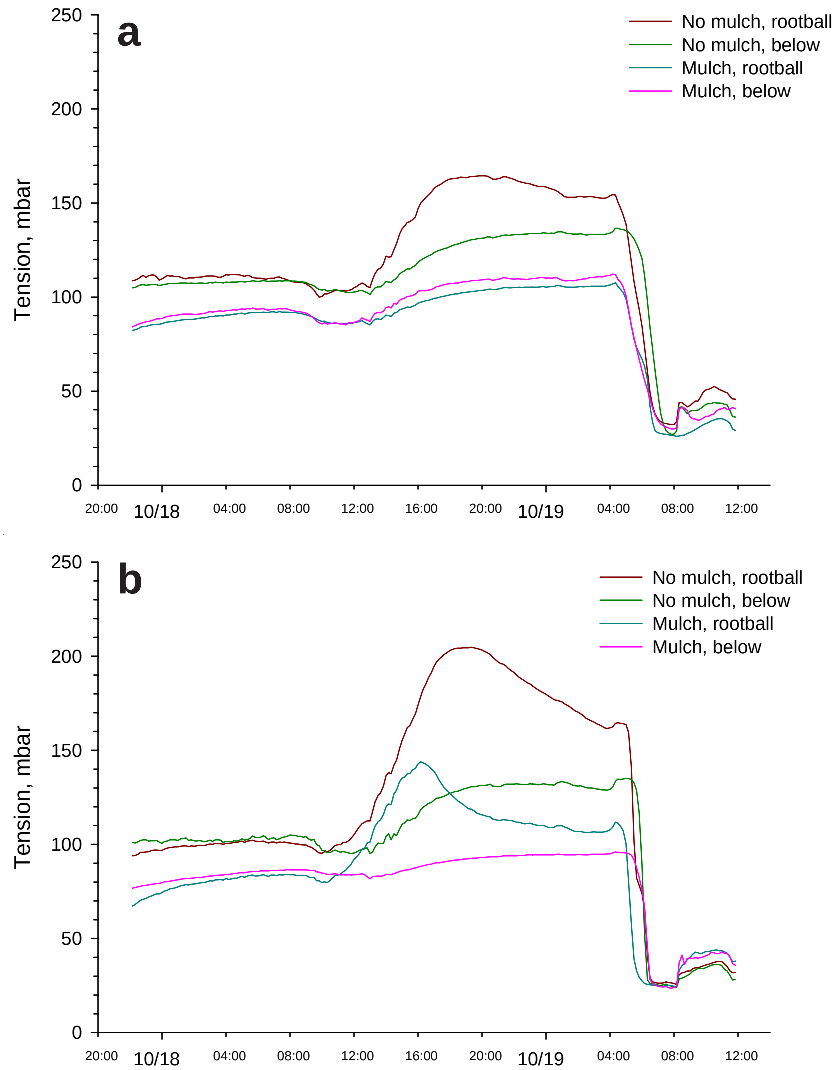

Figure 4. Changes in soil moisture tension in rootballs of transplanted pansy. (a) Rootballs with shoot removed; (b) Rootballs of intact plants. Experiment was conducted on October 12-19.

The tension of both mulched and unmulched rootballs of intact plants increased during the afternoon, but the increase in tension was about 100 mbar in the rootballs of the unmulched plants and only 60 mbar in the rootballs of the mulched plants (Fig. 4b). There was only a gradual change in tension, from 80 to 90 mbar, below the rootball of mulched plants, but the tension below the unmulched plant rose from 100 to 130 mbar. During the night the tensions in the rootballs of both mulched and unmulched plants decreased by 30-40 mbar and the tensions below the rootballs increased slightly. Based on these results, it appears that the decrease in tension at night is due to upward movement of water.

Conclusions

The specialized tensiometers used in these experiments were useful for characterizing soil water relations in and around the rootballs of transplanted bedding plants. It is clear that drainage, evaporation, and transpiration all act to remove substantial amounts of water from the rootballs, especially during conditions that cause high rates of evapotranspiration. About two-thirds of available water in the rootball is lost to drainage within an hour after irrigation. It is unlikely that this loss can be prevented or mitigated. However, it is possible that practices which reduce evaporation or transpiration could prevent plant water stress and allow for successful bedding plant establishment. One practice we had not previously considered, but which now appears to be important, is the compaction of soil around the rootball at planting. We will study effects of this compaction on rate of root growth and plant survival. In addition, we will investigate effects of several other factors, including mulch, root disturbance, irrigation frequency, container size, shading, and root:shoot ratio.

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