Making Greenhouse Irrigation More Efficient: Effects of Substrate Water Content on the Growth and Physiology of Vinca (*Catharanthus roseus*)

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Index words: drought, leaf expansion, photosynthesis, water relations

Significance to Industry: Efficient irrigation is increasingly important in the greenhouse industry to reduce leaching and runoff. Soil moisture sensors can be used to control irrigation and to irrigate based on how much water is lost through transpiration and evaporation . This can be achieved without leaching. Our results indicate that vinca growth increases as the substrate water content increases. The amount of irrigation water needed was surprisingly small: 810 mL/plant was necessary to maintain a substrate water content of 0.47 m^3/m^3 (close to container capacity) for 40 days, or on average 20 mL/plant/day. Leaf expansion was a sensitive indicator of drought stress and plant growth. Leaves that are smaller than normal indicate that plants are drought stressed and plant growth is reduced. Thus, growers may use the size of the uppermost, fully-expanded leaves to monitor crop water status.

Nature of Work: Many states regulate the amount of runoff from agricultural production, so it is becoming increasingly important for greenhouse growers to reduce leaching and runoff. Availability of good quality irrigation water also is an increasingly important issue, especially in urban areas. Automating irrigation by applying water according to plant water use increases irrigation efficiency and reduces water waste, leaching, and runoff. Applying water based on plant use also provides growers with better control over plant elongation and quality and may reduce disease. Water can be applied according to plant use by measuring the substrate water content and applying water at the same rate it is used by the plants. By maintaining a constant substrate water content, irrigation automatically provides the same amount of water as is lost through transpiration and evaporation. Although technically this irrigation approach is relatively simple, there currently is no information on how plants respond to different substrate water contents. The objective of this research was to quantify growth and physiological responses of annual vinca (*Catharanthus roseus*) to different substrate water contents.

Twenty-four vinca 'Titan Burgundy' seedlings were transplanted into containers with 10 L of a peat-perlite growing medium (Fafard 2P; Fafard, Anderson, SC). To allow the seedlings to establish, the growing medium was kept well-watered (water content at least 0.47 m^3/m^3) for one week, after which the treatments were started. The substrates were irrigated at the following water content set points: 0.05, 0.11, 0.17, 0.23, 0.29, 0.35, 0.,41, or 0.47 m^3/m^3. When the substrate water content dropped below the target level, 62 mL of fertilizer solution (200 ppm N, Peter's 20-10-20; Scotts, Marysville, OH) was added to the container. Each treatment was replicated twice. The irrigation system used in this study was based on the system described by Nemali and van Iersel (2006); however EC-5 rather than EC-10 soil moisture probes (Decagon, Pullman, WA) were used. The EC-5 probes were used because they are much less sensitive to EC and temperature, and thus do not need temperature compensation.

Data collected include leaf gas exchange parameters (CIRAS-1; PP Systems, Amesbury, MA), leaf water, osmotic and turgor potential (leaf cutter psychrometers; JRD Merrill, Logan, UT), and the area of the uppermost, fully-expanded leaf at the end of the experiment (LI-3100; Li-Cor, Lincoln, NE). Shoot dry weight also was measured at the end of the experiment. Data were analyzed using regression analysis.

Results and Discussion: The irrigation system functioned well throughout the experiment. It took approximately three weeks for the substrate to dry to a water content of 0.05 m^3/m^3, but after the target substrate water content was reached, the water content remained stable throughout the experiment (Fig. 1). This shows that irrigating plants based on the substrate water content is feasible. No leaching was observed in any treatment.

Plant growth was strongly correlated with the substrate water content. The average shoot dry weight ranged from 0.6 g at a substrate water content of 0.05 m^3/m^3 to 1.8 g at a water content of 0.47 m^3/m^3 (Fig. 2). The different irrigation set points also resulted in large differences in the amount of irrigation water applied. At a substrate water content of 0.05 m^3/m^3, plants received 100mL/plant during the last 40 days of the experiment, as compared to 810 mL per plant in the 0.47 m^3/m^3 treatment.

Substrate water content strongly affected leaf physiology; leaf water and osmotic potential generally increased with increasing substrate water content, but turgor potential was not affected. Stomatal conductance and transpiration were reduced at substrate water contents of 0.05 or 0.11 m^3/m^3. Surprisingly, leaf photosynthesis was not affected by the treatments, and there was no correlation between leaf photosynthesis and plant dry weight (P = 0.49). Although this may seem surprising, it has long been known that there often is little or no correlation between leaf photosynthesis and plant growth (Evans, 1975). The main reasons for this are that leaf photosynthesis measurements do not take into account the total photosynthetically-active leaf area, the efficiency of conversion of photosynthates into dry matter, or the dry matter distribution within the plant.

Leaf expansion was a sensitive indicator of drought stress; the size of the uppermost, fully-expanded leaf was strongly correlated with the substrate water content (Fig. 3). Leaf size also was strongly correlated to shoot dry weight (Fig. 4). This suggests that leaf area, rather than leaf photosynthesis is an important factor controlling growth. Leaf area development may be important because it determines the total area of photosynthetically-active tissue; i.e. if leaf photosynthesis rates are similar, a plant with a large total leaf area will photosynthesize more, and grow faster, than a plant with a small total leaf area. We recently found that the growth of salt-stressed tomato plants also was better correlated with the area of the uppermost, fully-expanded leaf than with leaf photosynthesis (Montesano and van Iersel, 2007).

This strong correlation between leaf size and plant growth gives growers a simple method to monitor whether drought stress may be affecting plant growth: if the leaf size is less than that of a well-watered plant, drought is likely reducing growth.

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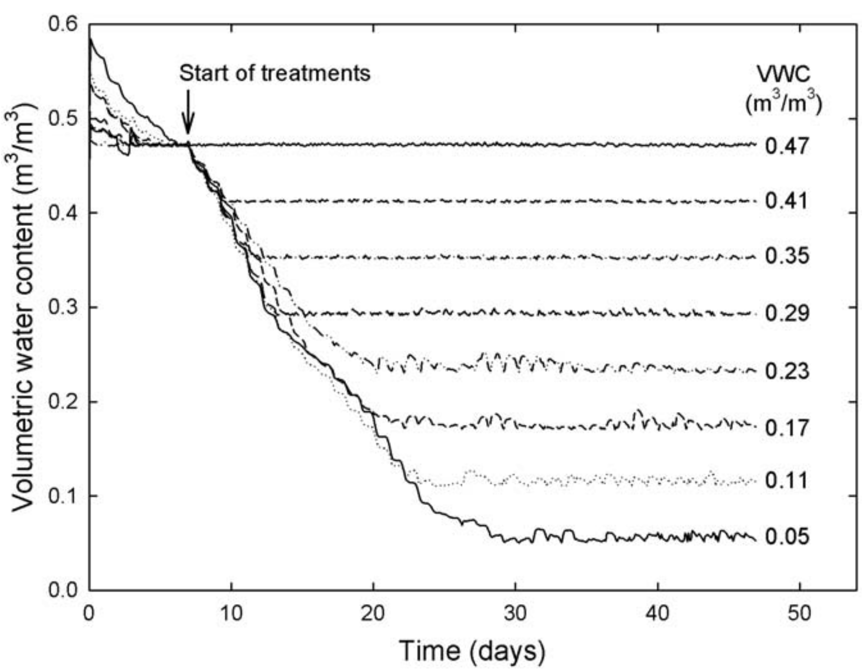

Figure 1. Substrate water content throughout a seven week production period of annual vinca.

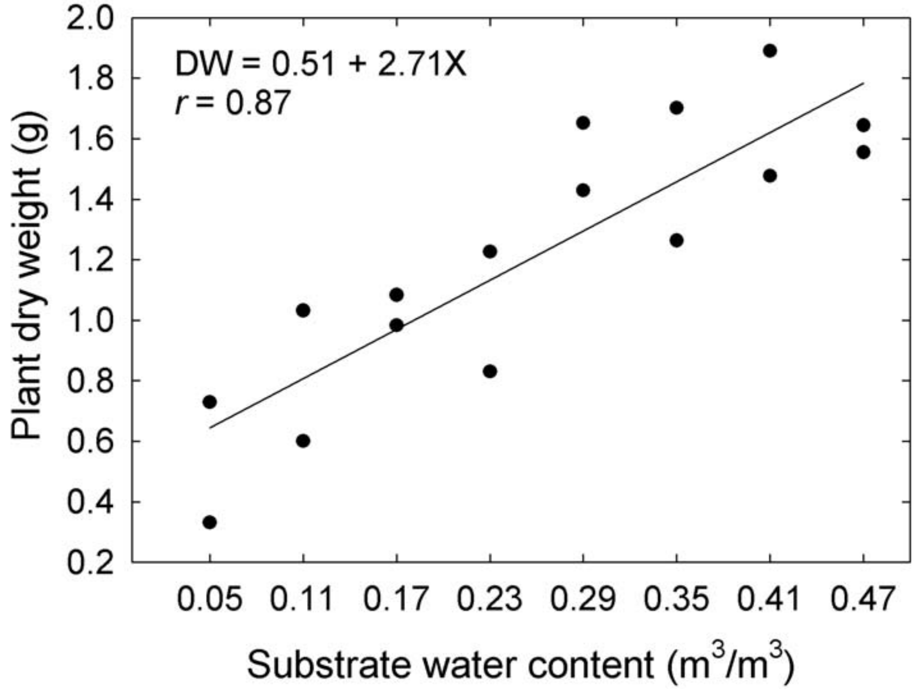

Figure 2. The correlation between substrate water content and shoot dry weight (DW) of vinca. Plant dry weight was higher for plants grown at a higher substrate water content.

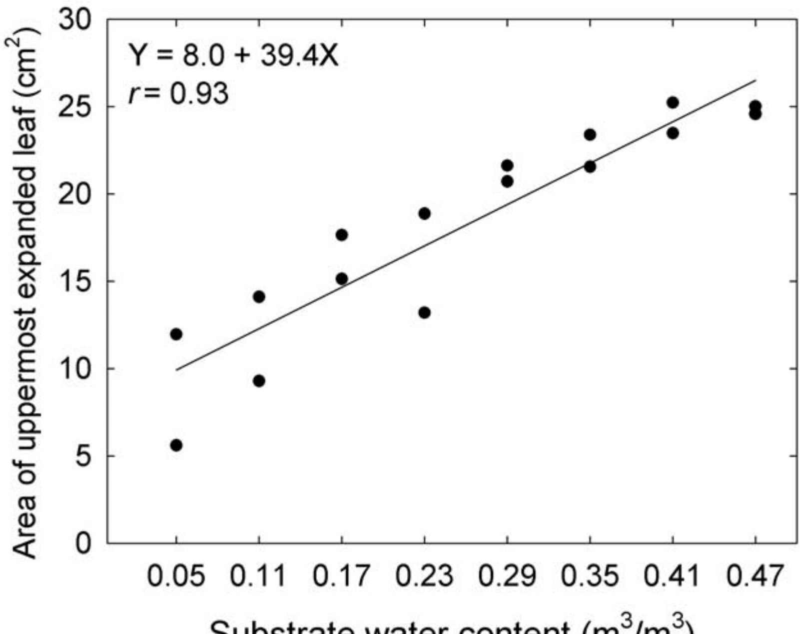

Figure 3. The correlation between substrate water content and the area of the uppermost, fully-expanded vinca leaf.

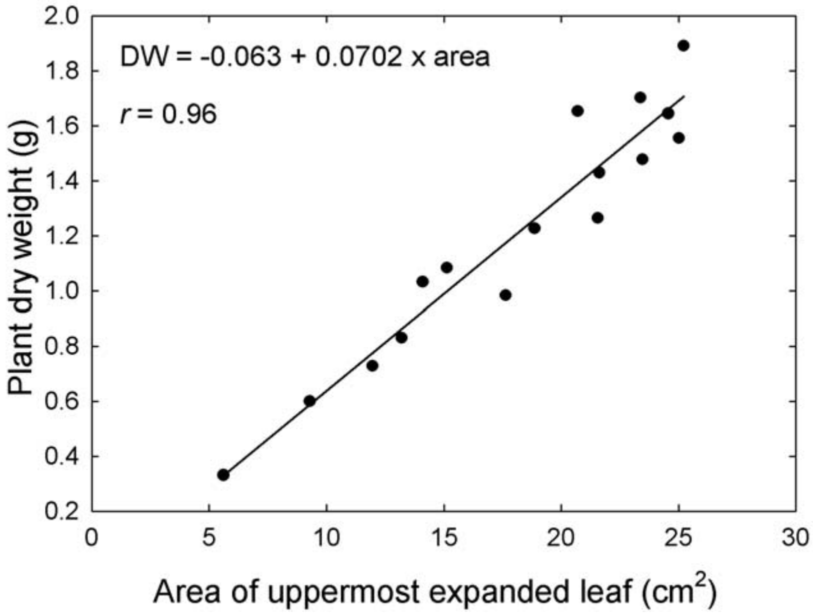

Figure 4. The correlation between the area of the uppermost, fully-expanded vinca leaf and shoot dry weight (DW). These results suggest the leaf expansion and leaf area development are crucial for growth.