Measuring Substrate Water Potential Changes During Plant Wilt

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Significance to Industry: A better understanding of horticultural substrate water potential can help growers efficiently irrigate their plants during production. Studying plants undergoing drought stress and quantifying both substrate water potential and permanent wilting point can provide information on plant irrigation needs, possibly leading to less frequent irrigation, saving the grower money. Further, understanding that horticultural substrates differ in plant unavailable water (which influences the time it takes for plants to wilt after an irrigation event) may help growers choose substrates that can extend time untill permanent wilting and effectively lengthen the postharvest life of container plants once in a post production retail environment. Plants used in this study were allowed to wilt past the normally accepted range of permanent wilting point of -1.0 MPa to -2.0 MPa and lower, yet completely recovered after rewatering. This study indicates a possible need to extend the permanent wilting point range as well as the need to investigate plant available water related to horticultural substrates.

Nature of Work: Within the past few decades there has been an increase in containerized plant production, leading to an increased interest in watering efficiency (6). There has also been increased interest in plant available and unavailable water within horticultural substrates and their relationship to permanent wilt (2, 5). Plant available water is the water present in the substrate that is readily available for plant use; unavailable water is present in the substrate yet is unable to be taken up by plants (7). It is important to know if plant available and unavailable water varies among commonly used substrates and if these hydrophysical properties can be better understood or modified to enhance the performance of certain substrates for plant production. Permanent wilting point (PWP) is a term used to describe the point in which substrate water potential is too low for plants to recover (8). Research on PWP can help uncover information on plant, water and substrate relationships, and may help growers water more efficiently.

The 15 Bar pressure plates (producing a suction of -1.5 MPa) have been used to determine plant unavailable water in mineral soils for decades. This technique/apparatus was adopted by horticultural scientists and also used to measure water properties of soilless substrates. Recent research has discovered that the 15 Bar apparatus will often produce inaccurate measurements when used on soilless substrates (3, 4). The reason for the inaccurate measurements is thought to be due to a loss in hydraulic conductivity between the pressure plate and the substrate particles which are much larger and more porous than mineral soils (2). Recently, the WP4C dewpoint potentiameter (Decagon, Pullman, WA) has been shown to more accurately measure water potential of highly porous soilless container substrates (1). Soil/substrate materials are placed in small round sample cups and enclosed inside the chamber of the dewpoint potentiameter in order for water potentials to be determined. While inside the dewpoint potentiameter there is a small mirror above the sample with a small space in between. The mirror is heated and cooled until the precise point in which condensation forms on the mirror, this is referred to as the chilled-mirror technique. The dewpoint potentiameter is then able to determine the relative humidity above the sample and subsequently the water potential of the sample in the chamber. The objective of this experiment was to measure the substrate water potential changes during increasing stages of plant wilt of plants grown in a commercial substrate.

The experiment was implemented on April 12, 2013 at a greenhouse located at North Carolina State University, Raleigh, NC. The substrate used in this experiment was Fafard® 4P Mix (Sun Gro Horticulture, Agawam, MA). Thirty-six containers were filled with similar volumes of the 4P substrate and, 18 replications each of vinca (*Catharanthus roseus* 'Cooler Deep Orchid') and marigold (*Tagetes patula* 'Janie Deep Orange') plugs were transplanted into 5-inch containers (ITML Horticultural Products, Middlefield, OH). Plants were placed on a greenhouse bench and arranged in a randomized complete block design. Plants were hand watered as needed with 200 ppm N derived from 20-10-20 Peat-Lite Special (The Scotts Co. Marysville, OH) fertilizer. Four weeks after transplanting, plants were placed in a large plastic container in order to fully saturate the substrate in all containers before allowing plants to dry down. Tap water was then incrementally added to the large container to gradually saturate the substrate from below until the water level reached just below the brim of the containers. Once the containers were submerged (water could be seen glistening on top of the substrate surface of all containers) they were allowed to saturate for 10 minutes, then slowly removed from the tub and placed on a greenhouse bench to freely drain. Plants were then allowed to dry under normal greenhouse environmental conditions and no irrigation was supplied so that plants would naturally wilt. Wilting stages were visually determined as follows, 1) stage one initial flagging; 2) stage two leaves resting towards the stem of the plant and; 3) stage three complete reduction of leaf surface area as leaves lost turgidity. As plants reached each of the three wilting stages the plants were prepared for substrate sampling. Substrate samples were collected by removing the wilted plants from their containers and extracting a 1 cm deep column of substrate down the entire profile (top to bottom) of the root ball. Three replications of each plant species at each wilting stage were collected. After substrate samples were collected the plants were immediately rewatered to see if they would recover from each respective wilt stage. Sampling steps were repeated for each additional wilting stage. Substrate samples were placed in 3.7 cm i.d. x 1.1 cm tall stainless steel sample cups (Decagon, Pullman, WA). The cups containing the samples were immediately sealed and wrapped with Parafilm M® (American Can Co., Greenwich, CT). Samples were then placed in the dewpoint potentiameter to determine water potential of the individual samples. Data were analyzed using Duncan's Multiple Range test (version 9.2, SAS Institute, Cary, NC).

Results and Discussion: Figure 1 illustrates the changes in substrate water potential at increasing stages of wilt for marigolds. Stage one occurred at -0.11 MPa. Stage two wilting occurred at -0.33 MPa which is far below the proposed range for PWP of -1.0 to -2.0 (2) but had moved well beyond this range by stage three at -2.2 MPa. Figure 2 shows the changes in water potential at increasing stages of wilt for vinca. Stage one and stage two wilt occurred at -0.08 and -0.80 MPa respectively. Stage three wilt was at -5.11 MPa far above the PWP range. All plants recovered within 24 hours after rewatering. These data suggest that plant wilt for these species, even when severe, does not mean the plant has reached its permanent wilting point. The permanent wilting point for plants (at least these species tested) appears to be well below the commonly referenced range of -1.0 to -2.0 MPa. Vinca went to substantially lower tensions before wilting (and recovering) compared to marigold which may be attributed to their noted heat and drought tolerance as landscape annuals. These data also reaffirm previous works (2) that the dewpoint potentiameter is capable of measuring substrate water potentials at very low tensions. Further research needs to be conducted on the water potential of plants as wilting occurs between species and substrates. Other parameters should also be further studied to better understand changes in horticultural substrate water potentials including physiological differences in plant species, drought tolerance, root architecture, exposure to heat stress, etc. as these may explain variation in expected readings.

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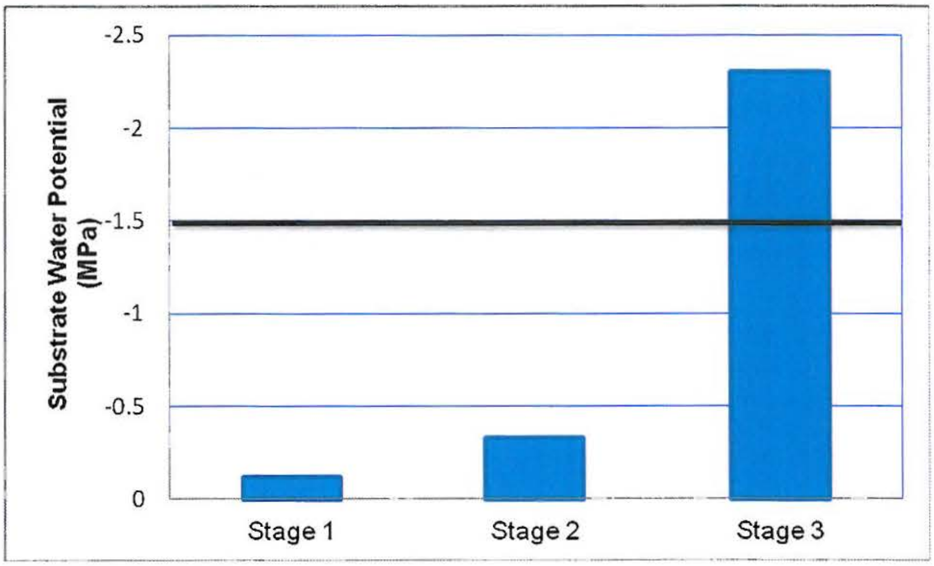

Fig.1 Substrate water potential of Fafard 4P with marigolds allowed to dry to three increasing stages of wilt. Stage one: initial flagging, stage two leaves resting towards the stem of the plant, and stage three complete reduction of leaf surfaces area as leaves lost turgidity. The bold line indicates -1.5 MPa the accepted permanent wilting point for most plants.

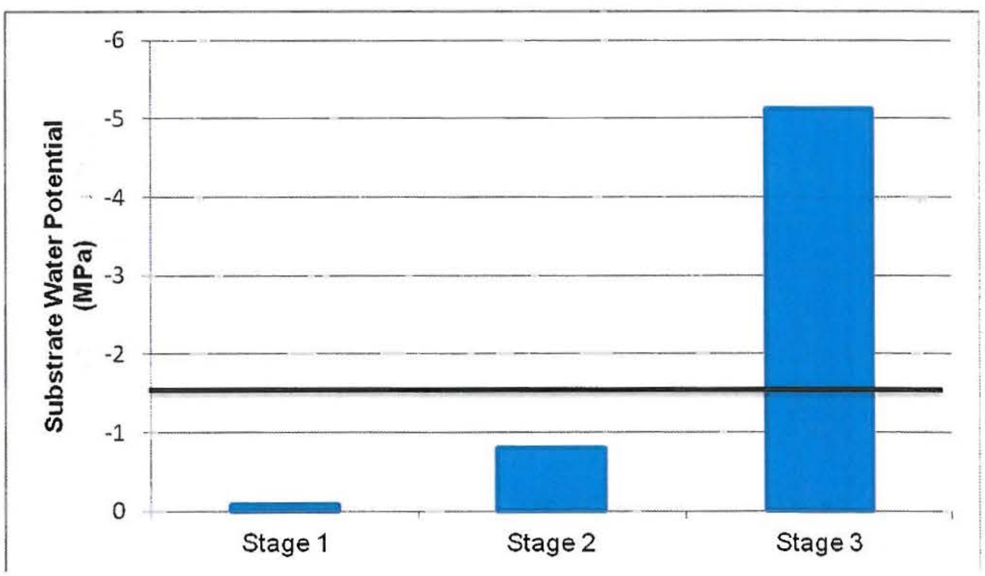

Fig. 2 Substrate water potential of Fafard 4P with vinca allowed to dry to three increasing stages of wilt. Stage one: initial flagging, stage two leaves resting towards the stem of the plant, and stage three complete reduction of leaf surfaces area as leaves lost turgidity. The bold line indicates -1.5 MPa the accepted permanent wilting point for most plants.