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Impact Nugget

Studies on molecular and physiological responses of plants show that acclimation of plants to drought depends both on the severity of drought stress (with the most acclimation when drought develops slowly) and on the rate with which the drought stress develops (with more acclimation if the drought stress develops slowly). This has important implications for basic research, where the drought imposition rate and severity are commonly ignored and for plant production in controlled environments, where drought stress is at times used to harden plants off to drought conditions, or for manipulation of secondary metabolite production.

New Facilities and Equipment

Horticulture greenhouse, Athens, GA: Load cells and soil moisture sensors were added to an existing whole plant CO2 exchange system. The system is now capable of continuous monitoring of CO_2 exchange, evapotranspiration, and soil/substrate moisture content. Whole plant conductance for H_2O and instantaneous and long-term water use efficiency can be calculated based on these data.

Unique Plant Responses

ABA can induce wilting. We have observed that high application rates of ABA (applied as a drench) induces wilting in tomato plants, within one or two days. This occurs despite adequate water in the substrate. Although the ABA applications quickly (30 – 40 minutes) result in stomatal closure, relative water content of the leaves drops. This suggests that water supply from the roots is not fast enough to keep up with water loss from the leaves. We have found that ABA greatly reduces the hydraulic conductance of the root system, and this may be the cause of the ABA-induced wilting.

Plant water use and environmental conditions. Part of the difficulty of scheduling irrigation in greenhouses is that there is little quantitative information about plant water requirements, and how they depend on environmental conditions. We developed a model to predict DWU based on days after planting (DAP), daily light integral (DLI), vapor pressure deficit (VPD), temperature, container size, and interactions between these factors and DAP (R^2=0.93 and 0.91 for 'Single Dreams Pink' and 'Prostrate Easy Wave Pink', respectively). DAP and container size were the most important factors affecting DWU, and are indicative of plant size. DLI was the most important environmental factor affecting DWU. These models, describing the DWU as a function the DAP and environmental conditions, may be used as guidelines for water requirements of petunias in greenhouse production, and may improve irrigation scheduling in greenhouses.

Rate of drought stress development and acclimation. The importance of the rate of drought imposition on the response is poorly understood. To test the importance of the rate at which drought stress develops, whole-plant photosynthesis (P_{net}), respiration (R_{dark}), daily carbon gain (DCG), daily evapotranspiration (DET), and water use efficiency (WUE) of vinca (*Catharanthus roseus*), subjected to different drought imposition rates, were investigated. We controlled the rate at which the substrate dried out with an automated irrigation system that allowed pot weight to decrease gradually throughout the drying period. Although all drying treatments decreased P_{net} and R_{dark}, slow drying reduced P_{net} and

R_{dark} less than fast drying. At a $\theta < 0.10$ $m^3 \cdot m^{-3}$, DCG and DET in the slow drying treatment were reduced by ≈ 50%, whereas those in the fast drying treatment were reduced by 85% and 70% at a θ of 0.16 $m^3 \cdot m^{-3}$, respectively. Plants exposed to slow drought imposition maintained a high WUE, even at $\theta < 0.10$ $m^3 \cdot m^{-3}$. Overall, physiological responses to low θ were less severe in plants subjected to slow drying than in plants subjected to fast drying, even though the final θ was lower for plants exposed to slow drying.

Drought severity and plant physiological and molecular responses. To improve our understanding of plant responses to different severities of drought stress, we investigated the leaf physiology, ABA concentration, and expression of genes associated with ABA metabolism and signaling in *Petunia* × *hybrida*. Petunias were grown at different specific substrate water contents (θ = 0.10, 0.20, 0.30, or 0.40 $m^3 \cdot m^{-3}$), using an automated irrigation system. Stomatal conductance (g_s) and net photosynthesis (A) decreased after drought imposition. g_s and A of plants at θ of 0.20 and 0.30 $m^3 \cdot m^{-3}$ partially recovered after the target θ was reached. In contrast, plants at θ of 0.10 $m^3 \cdot m^{-3}$ did not acclimate and maintained low g_s and A. Drought stress increased leaf ABA concentration, which was highly correlated with g_s. Despite the increase in leaf ABA concentration, we saw no effect on the relative expression of ABA biosynthesis genes (*NCED* and *AAO3*) in response to drought stress. However, the ABA catabolic gene, *CYP707A2* was down-regulated in plants at a θ of 0.10 $m^3 \cdot m^{-3}$, suggesting a decrease in ABA catabolism under severe drought. The relative expression of *PLDα*, involved in regulating stomatal responses to ABA, and *ZPT2-3*, a transcription factor related to drought tolerance, at different θ was related to changes in stomatal sensitivity and drought tolerance in petunia.

New Graduate Course

A new graduate course, titled 'Photosynthesis' was developed. This course focuses on molecular and physiological aspects of photosynthesis, and how those are affected by environmental conditions. This course was co-taught by Amish Malladi and Marc van Iersel offered for the first time in spring 2011.

Impact Statement

A large percentage of fertilizer applied to greenhouse crops can be lost through leaching if irrigation is excessive. Soil moisture sensor-controlled irrigation can significantly reduce or even eliminate leaching. If leaching is reduced, growers may use lower fertilizer rates to grow their crops, which can result in significant financial savings. We found that petunias grow fastest at a substrate volumetric water contents (VWC) 0.4 $m^3 \cdot m^{-3}$ and relatively high fertilizer rate (2 - 2.5 controlled release fertilizer g/plant). However, high fertilizer rates reduced flowering, and most prolific flowering occurred at fertilizer rates of only about 0.5 g/plant. With no leaching, approximately 0.4 L/plant of water was needed to grow petunia from plug seedling to full bloom in 23 days at a VWC of 0.4 $m^3 \cdot m^{-3}$. Growers should use relatively low fertilizer rate and efficient irrigation methods to minimize nutrient leaching and produce high quality plants.

Published Written Works

Refereed Journal Articles

Kim, J and M.W. van Iersel. 2011. Abscisic acid drenches can reduce water use and extend shelf life of *Salvia splendens*. *Scientia Horticulturae* 127:420-423.

van Iersel, M.W., S. Dove, J.G. Kang, and S.E. Burnett. 2010. Growth and water use of petunia as

affected by substrate water content and daily light integral. *HortScience* 45:277-282.

Non-Refereed Journal Articles

Kim, J. and M.W. van Iersel. 2010. Photosynthesis and water use of vinca (*Catharanthus roseus*) during drought: the effect of different drying rates. *Proceedings of the SNA research conference* 55:114-120.

Miralles Crespo, J., and M. van Iersel. 2010. Automated control of water content and electrical conductivity in soilless substrates: proof of concept. *Proceedings of the SNA research conference* 55:367-373.

Astacio, M.G. and M.W. van Iersel. 2010. Determining the Effects of Exogenous Abscisic Acid on Evapotranspiration of Tomato (*Solanum lycopersicon*). *Proceedings of the SNA research conference* 55:264-271.

van Iersel, M.W. and S.E. Burnett. 2010. Plant water use and drought stress physiology: Manipulating irrigation for efficient water use and high quality plants. *Proceedings of the Taiwan – USA Symposium on Technology of Cultivation and Molecular Breeding for Ornamental Crops.* T.-F. Hsieh, T.-E. Dai and L.-J. Wang (eds.) Special publication of TARI No. 145. p. 31-54.

Miralles, J., M.W. van Iersel, and Bañón, S. 2010. Development of irrigation and fertigation control using 5TE soil moisture, electrical conductivity and temperature sensors. *The Third International Symposium on Soil Water Measurement Using Capacitance, Impedance and TDT (2010, Murcia, Spain), Applications, Paper 2.10,* p. 1-9.

Scientific and Outreach Oral Presentations

van Iersel, M.W. 2011. Annuals, perennials, and woody ornamantals: How much water do they need? GGIA Wintergreen, Duluth, GA.

O'Meara, L., M. Chappell, and M.W. van Iersel. 2011. Water consumption of *hydrangea macrophylla* as affected by environmental factors. CANR open house, GGIA Wintergreen, Duluth, GA.

Bayer, A., I. Mahbub, M. Chappell, J. Ruter, and M. van Iersel. 2011. Growth of 'panama red' hibiscus in response to substrate water content. GGIA Wintergreen, Duluth, GA.

Astacio M.G. and M. van Iersel. 2011. Unexplained wilting of tomatoes after exposure to large doses of exogenous abscisic acid (ABA). SNA research conference, Mobile, AL.

O'Meara, L., M. Chappell, and M.W. van Iersel. 2011. Water consumption of *hydrangea macrophylla* as affected by environmental factors. SNA research conference, Mobile, AL.

van Iersel, M., W. Ross, S. Dove, M. Chappell, P. Thomas, J. Ruter, and S. Wells. 2011. Substrate water content dynamics in nurseries: Real-time monitoring can improve irrigation practices. SNA research conference, Mobile, AL.

Bayer, A., I. Mahbub, M. Chappell, J. Ruter, and M. van Iersel. 2011. Growth of 'panama red' hibiscus in response to substrate water content. SNA research conference, Mobile, AL.

Kim, J., A. Malladi, and M. van Iersel. 2011. Physiological responses of petunia to different levels of drought stress. SNA research conference, Mobile, AL.

Peter, A., P.A. Thomas, and M.W. van Iersel. 2011. Growth of petunia as affected by substrate moisture content and fertilizer rate. SNA research conference, Mobile, AL.

Soranz Ferrarezi, R. and M.W. van Iersel. 2011. Monitoring and controlling subirrigation with soil moisture sensors: a case study with hibiscus. SNA research conference, Mobile, AL.

van Iersel, M.W. and S.E. Burnett. 2010. Plant water use and drought stress physiology: Manipulating irrigation for efficient water use and high quality plants. *Taiwan – USA Symposium on Technology*

of Cultivation and Molecular Breeding for Ornamental Crops. Taichung, Taiwan.

van Iersel, M. 2010. Getting nutrient timing right. 107th Annual Conference of the American Society for Horticultural Science, Palm Springs, CA.

van Iersel, M. 2010. Converting carbohydrates into biomass: the role of respiration and its importance in modeling plant carbon use. 107th Annual Conference of the American Society for Horticultural Science, Palm Springs, CA.

Miralles, J., M. van Iersel, S. Burnett. 2010. Controlling water content and electrical conductivity in soilless substrates using in situ sensors. 107th Annual Conference of the American Society for Horticultural Science, Palm Springs, CA. http://ashs.org/db/horttalks/detail.lasso?id=838

van Iersel, M.W. 2010. Integrated water and nutrient management in greenhouse production systems. 2010 National Water Conference, Hilton Head, SC.

Astacio, M.G. and M.W. van Iersel. 2010. Determining the effects of exogenous abscisic acid on evapotranspiration of tomato (*Solanum lycopersicon*). SNA research conference, Mobile, AL.

Kim, J. and M.W. van Iersel. 2010. Photosynthesis and water use of vinca (*Catharanthus roseus*) during drought: the effect of different drying rates. SNA research conference, Mobile, AL.