UDC 634.22:556.166(496.5)

Dhimiter THOMA, Endrit KULLAJ [1]

SELECTION OF FLOOD – TOLERANT PRUNUS ROOTSTOCKS USING SAP FLOW

SUMMARY

Recent changes in rainfall regime and increased frequency of heavy rains have enlarged the incidence of flooding and therefore the damages to stone fruit production. Myrobalan plums (*Prunus cerasifera*) are known for their resistance to heavy soils and flooding. Selection of appropriate rootstocks is becoming imperative even for dryer climates. Albania is very rich in myrobalans and within this gene pool it should be possible to find resistant genotypes but their screening requires a fast method. The research presented here describes the use of sap flow for selecting resistant genotypes. We have screened several local genotypes of myrobalans as candidate rootstocks for flooding tolerance/resistance. Sap flow sensors were installed on seedlings growing in pots and subjected to flooding. Data from sap flow, soil potential and other meteorological sensors were used to evaluate their ability to recover. The results showed that the genotypes were able to continue to recover after the flooding events. The advantage of the method is to detect the sap flow movement even at very low rates.

Keywords: Myrobalans, flooding resistance, stone fruit rootstocks.

INTRODUCTION

Global climatic change has drastically affected the distribution and quantity of rainfall during the calendar year. In Mediterranean areas, rain is irregular and is concentrated mainly in the spring and fall seasons, leading to flooding and water stagnation in poorly drained soils (Alpert et al., 2002). As a consequence of this stress, the roots in that soil experience an anaerobic environment, which can induce flooding stress and plant death (Pistelli et al., 2012). Plant response to hypoxia depends on species, genotype, age and duration of flooding (Bailey-Serres and Voesenek, 2008).Recent flooding events in Albania have underscored these risks. Although no single weather event of this type can be directly tied to climate change, an increase in extreme temperature and rainfall events such as these are consistent with the best known science of the impacts of climate change (Sutton et al., 2013).

In general, fruit crops require well drained soil for optimum growth and yield. Excess water in the soil (greater than field capacity) can cause plant injury

[1] Endrit KULLAJ, (corresponding author: ekullaj@ubt.edu.al), DhimiterTHOMA, Agricultural University of Tirana, Faculty of Agriculture and Environment, Department of Horticulture and Landscape Architecture, ALBANIA.
Paper presented at the 5th International Scientific Agricultural Symposium "AGROSYM 2014".
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

or death. Flooding has negative effects on most growth and physiological process of woody plants (Kozlowski et al., 1984, 1991; Schaffer et al., 1992). The effects of water logging are more sever when exposure to flooding is prolonged and temperatures are high (Quamme and Stushnoff, 1983). Water uptake and transpiration is reduced and mineral uptake restricted (Kramer, 1969; Rowe and Beardsell, 1973).

Within Prunus, the species peach, almond, and apricot are well known to be less tolerant to water logging (consequently anoxia) than other species, and this has been reported to be due to the differences in metabolism of the cyanogenic glycoside, prunasin. Under anaerobic conditions, prunasin is hydrolyzed to hydrogen cyanide which is autotoxic (Quamme and Stushnoff, 1983). The differential sensitivity of peach, apricot, and plum to waterlogging has been reported to be closely related to their ability to hydrolyse prunasin (Salesses and Juste, 1970; Rowe and Catlin, 1972).

Under the climate change scenarios reported above for Albania, selections for genetic resistance to waterlogging are imperative. Among the different species of Prunus, Myrobalan plum (*Prunus cerasifera* L.) and European plum (*Prunus dome*stica L.) are considered to be flooding tolerant (Ranney 1994). Plums Marianna-2624 (*P. cerasifera* × *P. munroniana*), Myrobalan 29-C (*P. cerasifera*) and Marianna GF-8-1 are considered to be most tolerant, surviving 125 days (Duran, 1976). Different new inter-specific rootstocks between Myrobolan plum and peach x almond hybrids are under evaluation in a breeding program. Breeding has been conducted by several research groups to develop new hybrids that carry water logging tolerance (Dichio et al. 2004, Xiloyannis et al. 2007, Amador et al., 2009). Rootstock Mr.S.2/5, selected from an open-pollination *P. cerasifera* population, is also considered to be fairly tolerant (Dichio et al. 2004). Among the rich Prunus germplasm of Albania (Çakalli et al, 2007; Addante et al. 2008) it is possible to find resistant genotypes of Prunus, especially *Prunus cerasifera* L. Okie and Hancock (2008) discuss the limited use of diploid *P. cerasifera*, a progenitor of hexaploid European plum (*P. domestica*), in genetic improvement of the latter.

Traditionally, the only screening has been done empirically through the selection of rootstocks that withstood more time under flooding. Observations on genetic resistance to water logging have been made after natural flooding (Jawanda, 1961; Bini, 1963). Controlled flooding also has been used to determine cultivar resistance (Ford and Prevatt, 1958; Saunier, 1966; Rowe and Catlin, 1971; Catlin et al., 1977). In controlled methods, plants are first established in containers of soil and then containers are flooded for a set period of time (Quamme and Stushnoff, 1983). However, there is always a need for a fast screening method. The research presented here describes a novel approach in assessing the rate of recovery of rootstocks after a water logging using sap flow. Thermodynamically-based sap flow methods utilize heat as a tracer to quantify the rate at which sap (water) passes through the xylem tissue of a plant.

MATERIAL AND METHODS

Seeds of three selected genotypes of *P. cerasifera* found in dry sites were germinated and seedlings were grown at a stem thickness at the basis of 1.2 cm for sensor installation. The study was carried out in 2014, following a random–block experimental design, at distances of 30 x 30 cm in 1.5 x 2.0 x 2.0 m soil–filled containers. Then they were exposed to complete soil submersion (waterlogging conditions were established first for a longer period of six days and second for one day during June 2014).

Sap flow sensors (SF) EMS 62 (EMS Brno, CZ www.emsbrno.cz), based on SHB (stem heat balance) method (Lindroth et al., 1995, Čermák et al., 2004), were installed on the stem using a special cordless drill to open the holes for needles (0.6 mm diameter) in xyloid stems at 30 cm height (Kullaj 2013). The measuring interval was every minute with 1 s warm-up and storing interval every 15 minutes during June 2014, on 2 plants for each of the selections. Day-to-day variability in sap flow was smaller than plant-to-plant variability. Gypsum block's sensors were placed on the pots at a depth of 10 and 20 cm to measure the soil water potential.

RESULTS AND DISCUSSION

Before the application of the first, long waterlogging event, sap flow dynamics show their normal diurnal patterns, although there are differences between the three selections in their transpiration pattern. Comparisons (after Kullaj et al. 2014) of daily values show that sap flow values of different genotypes are not statistically different but further analysis show that Mrbl#2 has a more rapid flow at the beginning of the day with the increase of vapor pressure deficit whilst Mrbl#3 latter the day and Mrbl#1 in between (Figure 1).

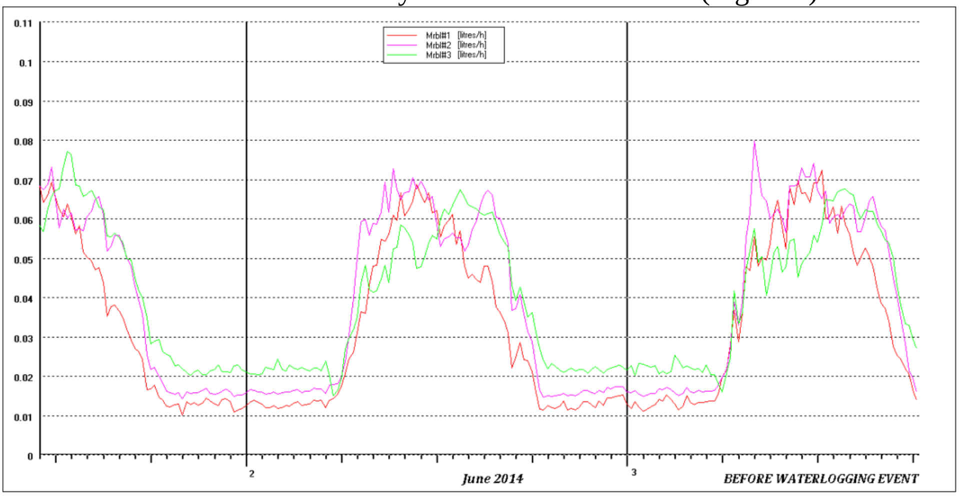

Figure 1. Diurnal patterns of sap flow measured at the stem of Myrobalan seedlings before the waterlogging event

In other studies (Dichio, 2004), the effect of waterlogging on the photosynthetic activity was greater than on transpiration, therefore, that parameter seems to be a valid indicator of the plants' sensitivity to waterlogging. Short – term effects include a decrease in A and gl and an increase in root resistance to water flow. Typically, hydraulic conductivity of the root system is reduced (Schaffer et al., 1992; Andersen et al., 1984; Syvertsen et al., 1983) followed by typical stress symptoms (more negative Ψl, lower gl, and reduced shoot growth). Since transpiration and photosynthesis are coupled, a reduction of transpiration as shown in Figure 2. lower the rate of photosynthesis even after waterlogging has ceased.

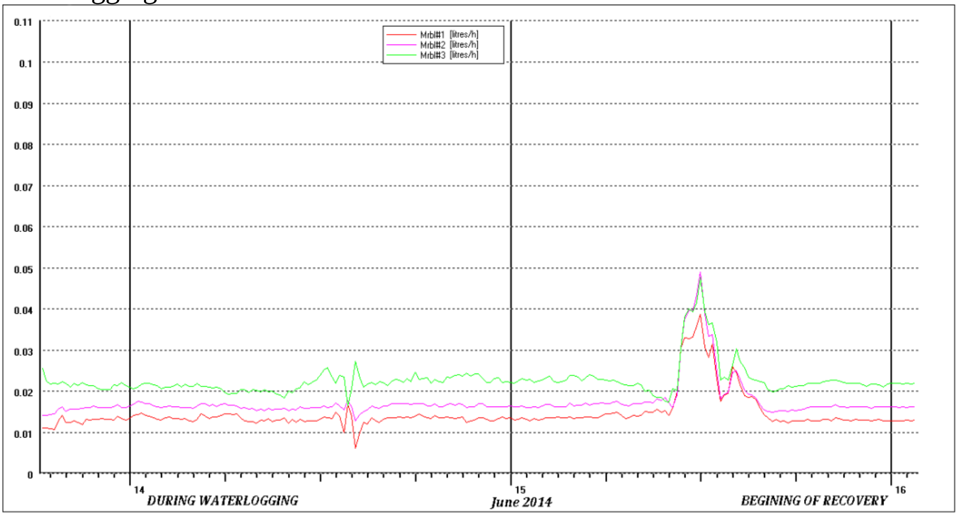

Figure 2. Sap flow values in the last day of waterlogging and just after its cease, showing a gradual recovery of transpiration

The hydraulic conductivity of the root system is disrupted soon after flooding is imposed. According to Flore 1994, this could result in more negative Ψl and an indirect effect on A through inhibition of stomata conductance, gl. Although this occurred in cherry, Beckman et al,. 1987 concluded that if inhibition of A occurred prior to stomatal closure it was in part due to an unknown signal from the root.

As soil flooding results in low oxygen levels and soils may be oxygen depleted within 1 day of waterlogging (Patrick and Mahapatra, 1968). In Figure 3 we notice an immediate reduction in transpiration. As found by other authors (Andersen et al., 1984), Oxygen diffusion rates are inhibited and rates below 0.2 $\mu g\ O_2\ cm^{-2} hr^{-1}\ min^{-1}$ have been correlated with reduced hydraulic conductivity and/or growth in peach.

It is interesting to notice that the same behaviour is observed in terms of sap flow regime between genotypes with Mrbl#2 reaching its maximum transpiration rate quicker than the other genotypes, probably as a result of quicker stomata opening at lower radiation levels.

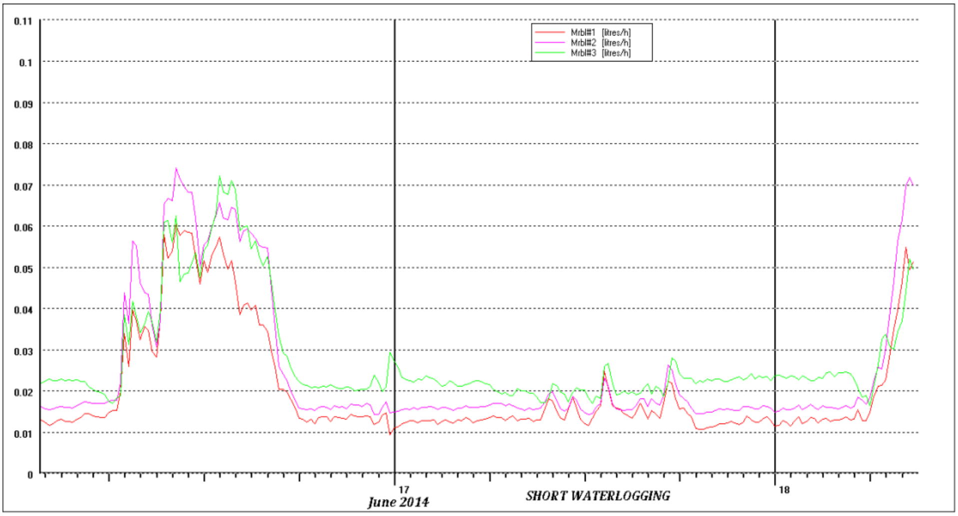

Figure 3. Sap flow values during the short waterlogging event showing an immediate recover afterwards

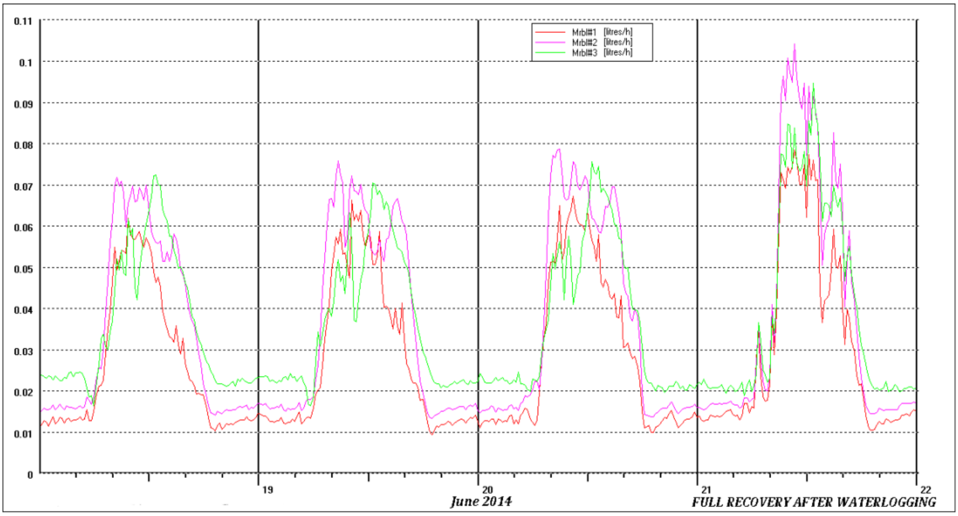

Figure 4. Full recovery of transpiration after the waterlogging event

CONCLUSIONS

The results showed a drastic reduction in transpiration after a waterlogging event on Myrobalan selections. However, all the genotypes recovered after this stress. Although in this particular case, with the duration of waterloggin, we could not discriminate the genotypes in their ability to recover, it was proven that the methodology is very sensitive and produces results in real time. Thus, it could be useful in screening seedlings for their tolerance to anoxia

REFERENCES

Addante, R., Bazzonı, A., Calderaro, M., Camposeo, S., Çakallı, D., Cardone, A., De Bellıs L., Dıgıaro M., Ferrara, G., Gallotta, A., Gıorgıo, V., Godını, A., Gurı, S., Kullaj, E., La Gravınese, G., Novıello, N., Nuzzacı, G., Palascıano, M., Savıno, V. and F. Thomaı (2008). Schededescrittive di cultivar di olivo e drupacee(Descriptions of olive and stone fruits varieties).Progettointegrato per la valorizzazionedelleproduzionitipichelocali (PRINT). INTERREG III-A Italia-Albania.

Alpert, P., T. Bengai, A. Baharad, et al. (2002). The paradoxical increase of Mediterranean extreme daily rainfall in spite of decrease in total values.Geophys. Res. Lett. 29, pp.311–314.

Amador, M.L., S. Sancho and M.J. Rubio-Cabetas (2009). Biochemical and molecular aspects involved in waterlogging tolerance in Prunus rootstocks. ActaHortic. 814, pp. 715–720.

Andersen, P.C., Lombard, P.B. and M.N. Westwood (1984) Leaf conductance, growth and survival of willow and decidous fruit tree species under flooded soil conditions. J. Amer. Soc. Hort. Sci., 109, pp. 132

Andersen, P.C., Lombard, P.B. and M.N. Westwood (1984) Effect of root anaerobiosis on the water relations of several Pyrus species, Physiol. Plant., 62, pp. 245

Bailey-Serres, J. and L.A.C.J. Voesenek (2008).Flooding stress: acclimations and genetic diversity.Annu. Rev. Plant Biol. 59, pp. 313–339.

Beckman, T.G., Flore, J.A. and R.L. Perry (1987) Sensitivity of various growth indices and the production of translocatable photosynthesis inhibitor by containerized one-year-old tart cherry trees during soil flooding.HortScience, 22, pp. 1028 (abstr.)

Bini, G. (1963) Indaginisullaresistenza del pesco e del pero all asfissiaradicale (Investigations on the resistance of peach and pear to root asphyxiation). Riv. Ortoflorofrutticol. 47, pp. 22 – 36.

Catlin, P.B., G.C. Martin and E.A. Olsson (1977) Differential sensitivity of Juglanshindsii, J. regia, Paradox hybrid, and Pterocarysstenoptera to waterlogging.J. Amer. Soc. Hort. Sci. 52, pp. 121 – 129.

Dichio, B., C. Xiloyannis, G. Celano and L. Vicinanza (2004).Performance of new selections of Prunus rootstocks, resistant to root knot nematodes, in waterlogging conditions.ActaHortic. 658, pp. 403–406.

Çakalli, A., Çiçi, I., Kullaj, E. and Myrta, A. (2007).Status of Prunusgermplasm in Albania.ECPGR Report of a Working Group on Prunus - 6th and 7th meeting

Flore, J.A. (1994) Stone fruit. In Schaffer, B. and P.C. Andersen (Eds.)The Handbook of Environmental Physiology of Fruit Crops. CRC Press, Inc.

Ford, H.W. and R.W. Prevatt (1958) Tolerance of four citrus rootstocks to free water in certain sandy soils.Fla. Agr. Expt. Sta. Annu. Rpt. P. 232 – 233.

Jawanda, J.S. (1961) The effect of waterlogging on fruit trees. Punjab Hort. 1, pp. 150 – 152.

Kozlowski, T.T., Kramer, P.J. and S.G. Pallardy (1991) The physiological ecology of woody plants. Academic Press, San Diego.

Kozlowski, T.T (1984). Responses of woody plants to flooding. In Kozlowski (Ed.) Flooding and plant growth, pp. 129 Academic Press, Orlando, FL

Kramer, P.J. (1969) Plant and soil water relationships – a modern synthesis. New York, McGraw-Hill.

Kullaj, E., Lepaja, L., Avdiu, V. and F. Thomaj (2013).Modelling sap flow of young apple rootstocks under various climates. 9th International Workshop on Sap Flow, 4 – 7 June, Ghent, Belgium

Kullaj, E., Domi, H., Spahiu, T. and F. Thomaj (2014a) Behaviour of apple cultivars under a high radiation and temperature regime of Western Plain in Albania.7th International Symposium on Irrigation of Horticulture Crops, Geisenheim, Germany.Acta Hort. (ISHS) 1038, 423 – 428 http://www.actahort.org/books/1038/1038_51.htm

Okie W.R. and J.F. Hancock (2008) Plums. In: Hancock J.F. (ed.) Temperature Fruit Crop Breeding: germplasm to genomics. Springer, Berlin, pp. 337 – 587.

Quamme, H.A. and C. Stushnoff (1983) Resistance to Environmental Stress.In Moore, J.N. and J. Janick(Ed.) (1983) Methods in Fruit Breeding. Purdue University Press

Patrick, W.H.Jr and I.C. Mahapatra (1968) Transformation and availability to rice of nitrogen and phosphorous in waterlogged soils.Adv. Agron., 20, pp. 323

Pistelli, L., Iacona, C., Miano, D., Cirilli, M., Colao, M.C., Mensuali-Sodi, A. and R. Muleo (2012) Novel Prunus rootstock somaclonal variants with divergent ability to tolerate waterlogging.Tree Physiology 32 (3): 355-368 doi:10.1093/treephys/tpr135

Ranney, T.G. (1994). Differential tolerance of eleven Prunus taxa to root zone flooding.J. Environ. Hortic.12, pp.138–141.

Rowe, R.N. and P.B. Catlin (1971) Differential sensitivity to waterlogging and cyanogenesis by peach, apricot, and plum roots. J. Amer. Soc. Hort. Sci. 96, pp. 305 – 308.

Rowe R.N. and D.V. Beardsell (1973) Waterlogging of fruit trees.Hort. Abst. 43, pp. 534 – 544.

Salesses, A. and C. Juste (1970) Recherchessurl'asphyxilradiculaire des arbresfruitiers a noyau. I. Role eventuel des certaines substances presentesdans les racines depeches P. Persica (Research on root asphyxiation of stone fruits. Eventual role of certain substances present in peach roots). Ann. Amerlior. Plantes 20, pp. 87 – 103

Saunier, R. (1966) Method de determination de la resistance a l'asphyxicradiculaire des certainsportegreffesd'arbresfruitiers (Method for the determination of root axphyxation of certain fruit tree rootstocks). Ann. Amerlior. Plantes 16, pp. 87 – 103

Schaffer, B. Andersen, P.C. and R.C. Ploetz (1992) Responses of fruit crops to flooding, Hort. Rev., 13, 257

Sutton, William R., Jitendra P. Srivastava, James E. Neumann, Kenneth M. Strze˛pek, and Peter Droogers. 2013. Reducing the Vulnerability of Albania's Agricultural Systems to Climate Change: Impact Assessment and Adaptation Options. World Bank Study. Washington, DC: World Bank. doi:10.1596/978-1-4648-0047-4.

Syvertsen, J.P., Zablotowicz, R.M. and M.L. Smith Jr (1983) Soil temperature and flooding effects on two species of citrus. I. Plant growth and hydraulic conductivity, Plant Soil, 72, pp. 3.

Xiloyannis, C., B. Dichio, A.C. Tuzio, M. Kleinhentz, G. Salesses, J. Gomez-Aparisi, M.J. Rubio-Cabetas and D. Esmenjaud (2007) Characterization and selection of Prunus rootstocks resistant to abiotic stresses: waterlogging, drought and iron chlorosis. ActaHortic. 732, pp. 246–251.