

The use of the sap-flow thermal method to determine the water flow in the shoots of *Physocarpus opulifolius* L. (Maxim.) and *Spiraea japonica* L. and methods of water stress limiting in these plants cultivated in containers

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Increasing water deficit caused, among others, by climate changes, which result in the aquifers lowering, forces the producers of plant material to seek methods of reduction of water consumption or higher control over its use. Limiting the amount of water consumption through less frequent irrigation with the simultaneous use of solutions which decrease transpiration at the same time may be one of the methods of effective water use in container nursery production.

The aim of the study was to determine the rate of water flow in the shoots of two ornamental shrubs species in container cultivation as well as to study the level of water stress and the influence of selected solutions on biometric features and physiological parameters of common ninebark and Japanese meadowsweet. The experiments were conducted in an unheated foil tunnel. Common ninebark (*Physocarpus opulifolius* (L.) Maxim.) 'Red Baron' and Japanese meadowsweet (*Spiraea japonica* L.) 'Macrophylla' were used. Two irrigation options: twice daily irrigation and one-time irrigation every other day, and selected solutions: Moisturin, Root-Zone, Vapor Gard, Actisil, Stabilan, Kelpak, were applied. The research was carried out in a three-month cycle (July–September) in 2012–2014. The rate of water flow in the shoots was measured continuously with the use of Dynagage probes. Shrubs were treated with solutions once (Moisturin, Root-Zone, Vapor Gard and Kelpak) or twice (Actisil, Stabilan). The morphological traits and physiological parameters of shrubs, water content in leaves (RWC and WSD) and water use coefficients (WUE, WUEI) were assessed.

The conducted research has shown that the use of the sap-flow thermal method allows to determine the rate transport of sap flow in shoots, which might be the a helpful indicator for calculating the water intake and thus the plant's demand for water. The sap flow rate depends on solar radiation, frequency of irrigation and the species. The largest flow is recorded in the afternoon hours (11:00–13:00) and the smallest at night (22:00–5:00). Higher frequency of irrigation causes greater sap flow in shoots of Japanese meadowsweet and smaller in common ninebark. The intensity of solar radiation and humidity has the greatest influence on the dynamics of sap flow in shoots of common ninebark while in case of a Japanese meadowsweet it is radiation. More stomata appears in plants irrigated once every two days, bigger ones in common ninebark and smaller ones in Japanese meadowsweet, in comparison to twice-a-day irrigation. The shrubs are lower, have fewer shoots, which are both thinner and characterize with smaller (common ninebark) or larger number of leaves (Japanese meadowsweet). The chlorophyll fluorescence index (F_V/F_M) in common ninebark and Japanese meadowsweet is higher with less frequent irrigation. The solutions applied contribute to the increase of this index. The Root-Zone is the most effective for less irrigated common ninebark and Kelpak for Japanese meadowsweet. Value of the water use efficiency (WUE) depends on the age of plants, frequency of irrigation and the applied solution. Older common ninebark plants (3-year-old) make better use of water with one-time irrigation every other day as compared to younger plants (1-year-old) treated with Moisturin. Younger Japanese meadowsweet shrubs with the same irrigation option make the best use of water after Root-Zone and Stabilan application. Actisil used in both species causes water retention in leaves, which is manifested by higher RWC index and smaller water saturation deficit (WSD) of leaves regardless of the irrigation frequency. In common ninebark, it is beneficial to use Root-Zone in one-time irrigation every other day. The used solutions can modify the morphological traits of common ninebark and Japanese meadowsweet shrubs to a degree depending on the species and irrigation frequency. In the cultivation of Japanese meadowsweet, Vapor Gard, Moisturin and Kelpak, with less frequent irrigation, positively affect the decorative qualities of shrubs (leaf size, shoot diameter, plant height and number of shoots and leaves per shoot). For common ninebark, Actisil, Kelpak and Moisturin with more frequent irrigation have beneficial effect on leaf size, shoot diameter, plant height and leaves number. Application of the sap-flow method and solutions which reduce water use allow to determine the level of irrigation at which plants are not exposed to water stress and their decorative qualities are preserved or even increased. The method of cultivating the common ninebark taking into account twice daily irrigation with the use of Actisil, Kelpak and Moisturin, is the most desirable in container production due to the ornamental qualities of shrubs. For Japanese meadowsweet cultivation, it is recommended to irrigate plants once every other day and use Vapor Gard, Moisturin or Kelpak.

So far, the sap-flow method has been rarely used in case of ornamental shrubs cultivation. A wider application of the method in container nursery production combined with use of solutions that might reduce water use give quantifiable benefits in efficient water use, what might have a significant value in a large-scale cultivation of the most popular ornamental shrubs species.