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Water Interception and Stemflow in Mediterranean Shrubs Using Rainfall Simulation

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Abstract. Water storage capacity (S) and stemflow (SF) were measured in young plants grown in containers of 8 mediterranean shrubs: *Lavandula latifolia* (LL), *Rosmarinus officinalis* (RO), *Cistus albidus* (CAl), *Cistus ladanifer* (CL), *Medicago strasseri*, *Retama sphaerocarpa* (RS), *Cytisus sp.* (CZ) *and Dorycnium pentaphyllum* (DP). In these young plants S varied among 0.70 mm and 1.46 mm with a mean value of 0.95 mm and no significant difference among species. SF varied among 2.2 % and 25.4 % of the incident rainfall with a mean value of 16.2 %. SF was greater for CZ, LL, CAl, and RO than for RS, CL and MS. These results revealed that different shrub species influence differently over water storage capacity and stemflow.

Key words: Rainfall interception, water storage capacity, stemflow, shrub.

Resumé On a mesuré la capacité de stockage de l'eau (S) et la circulation par la tige (SF) dans des jeunes arbustes cultivées dans des récipients. Il s'agit de 8 arbustes méditerranéens : *Lavandula latifolia* (LL), *Rosmarinus officinalis* (RO), *Cistus albidus* (CAl), *Cistus ladanifer* (CL), *Medicago strasseri*, *Retama sphaerocarpa* (RS), *Cytisus* sp. (CZ) and *Dorycnium pentaphyllum* (DP). Dans ces jeunes plantes S a changé entre 0.70 et 1.46 mm, avec une valeur moyenne de 0.95 mm ; on n'a pas trouvé aucune différence significative parmi des espèces. SF a varié entre 2.2% et 25.4% de la précipitation incidente, avec une moyenne de 16.2 %. Les valeurs de SF furent plus grands pour CZ, LL, CAl, et RO que pour RS, CL et MS. Ces résultats indiquent que les différentes espèces d'arbuste n'ont pas la même influence sur la capacité de stockage de l'eau et la circulation d' eau par les tiges.

Introduction

The difference between gross rainfall and net rainfall is called interception loss (Horton, 1919), which is the addition of water stored on canopy surface and evaporation loss during the storm period from a wet canopy. The relationship can be expressed as: $I = S + \alpha t$, where I is the total interception loss during a storm, *S* is the canopy storage capacity, α is the rate of evaporation during the storm period, and *t* is the duration of the storm, S refers to the maximum volume of water that can be stored on the projected storage area of the vegetation against gravity under still air conditions (Ramírez y Senarth, 2000), and generally is expressed in mm. Stemflow (S_F) is the portion of intercepted water that runs down the plant stems and throughfall is the portion of intercepted water that drip from leaves and stems and fall to the soil. Rainfall interception modifies erosion processes, soil hydrology and watershed water resources (Belmonte *et al.*, 1998) and has important ecological and hydrological implications, because some areas under the trees, such as the one around the base of the plant, could receive more water than others in a precipitation event (Mauchamp and Janeau, 1993).

The effects of typical vegetation of arid and semiarid zones over hydrological processes have been scarcely studied. It is difficult to measure these variables in this kind of vegetation. Moreover it has been frequently thought that its influence was small, because in these regions, vegetation density is small. Nevertheless, recent studies show that the influence of shrub vegetation could be considerable (Cantú y Okumura, 1996, Wilcox, 2002). Changes in vegetation type could be determinant for hydric resources in regions where water is a scarce resource (Owens y Lyons, 2004).

This study is part of a research on mediterranean shrub characterization in relation to its influence on hydrology. In the present communication, first results are shown. A series of rainfall simulations experiments have been carried out with the objective of measuring water storage capacity and stemflow in 8 different mediterranean shrubs.

Material and Methods

Description of the studied species. Eight evergreen species with different structural and morphological characteristics were used. Two of them belong to the *Labiatae* family, two to the *Cistaceae* family, and four to *Fabaceae* family:

Lavandula latifolia (LL), as other lavenders, is a little shrub that grows up to 60 cm in height. It is dense and its opposite, entire, linear-lanceolate and tomentose leaves are borne on erect stems, disposed in little posies. *Rosmarinus officinalis* (RO) is a shrub that grows up between 0.5 and 1.5 m in height. It is a compact shrub and its linear and small leaves stand erect over erect stems.

Cistus albidus (CAl) is a shrub that grows up to 1.5 m in height. It is a highly branched and erect shrub and its leaves are plane, tomentose, opposite and in general erect, that set out erect over the stems. *Cistus ladanifer* (CL) grows up between 1 to 2 m in height. It is distributed forming great patches in acid and dry soils. It is not very dense and its leaves are settled, lanceolated and covered by a gum resin (Labdanum).

Medicago strasseri (MS), an endemic specie of Crete, easily grows to 1-1.5 m in height. It is a dense, upright evergreen, highly ramified from the base. Its leaves are similar to those of lucerne. *Retama sphaerocarpa* (RS) is an open canopy shrub that grows up between 2 an 4 m in height, highly branched, with thin photosynthetic stems, and with little, linear-lanceolates and scarce leaves. *Cytisus* "*zeelandia*" (CZ) is an ornamental plant (*C. praecox x C. dallimorei*) with a structure similar to other *Genisteae* used traditionally in the manufacture of brooms from Asia to Eastern Europe (*C. scoparius*, *C. striatus*, *and C. reverchomii* or *C. multiflorus*). Highly branched and like RS with small and scarce leaves, but with erecter and rigid stems. *Dorycnium pentaphyllum* (DP) plants are highly branched, small and creeping shrubs. They have little trifoliate leaves.

Experimental methodology. Water storage capacity (S) was measured in plants grown up in containers by rainfall simulation (Brandt, 1989). For each plant rainfall was applied during 1 hour. 15 minutes after the end of the rainfall simulation, each plant was weighted, in order to do not measure stemflow and throughfall as S. Experiments were performed in a still and humid atmosphere to reduce the loss of water due to evaporation. Containers were covered with plastic bags to avoid the entry of water.

Rainfall was simulated using a device with 28 nozzles, model SM CE1 (Spraying Systems Co ®) suspended at a height of 1 m above the plants. Rainfall was applied at 13 mm h^{-1} over 4.5 m^2. Stemflow (S_F) was collected during rainfall simulation with an impermeable double channel ring of extruded polystyrene attached at the bottom of the trunk and sealed silicone. The collector had a drain-pipe that channelled the water to a can.

Plants were measured for mean diameter of canopy (D) and height (H) (Table 1). Projected canopy area (A) was measured using digital photography and image analysis. Photographs were taken on the orthogonal direction of the plant at 3 m of height. Each shrub was put over a reference surface. Covered zones were selected using the software Adobe Photoshop CS ® and it was measured with an image analyzer Delta-T Services ® and the software WinDias ®. After finishing the rainfall simulation experiment, each plant was cut at ground level and total and foliar and stem green weight, were measured. Finally total, foliar and stem oven-dry weight were obtained.

S and S_F were measured on 3 plants of DP, RS and MS, 4 shrubs of CAl, CL and LL, 5 shrubs of CZ and 7 shrubs of RO. These variables were measured 6 times for each replication and the mean value was taken as the value of the replication. S was expressed in mm and S_F was expressed as percentage of incident rainfall over the projection canopy area.

Table 1. Characteristics mean diameter (D), height (H), aerial projection canopy (A), green total biomass (GB), dry total biomass (DB), density of aerial dry biomass (DAB), foliar green biomass (FB).

	D (m)	H (m)	A (m^2)	GB (g)	DB (g)	DAB (g of GB m^2)	FB (g)
CAl (*Cistus albidus*)	0.34	0.64	0.07	151.5	61.4	2096	35.0
CL (*Cistus ladanifer*)	0.28	0.77	0.05	107.9	41.0	2063	70.8
CZ (*C. praecox x C. dallimorei*)	0.64	0.91	0.17	313.4	133.0	1829	3.1
DP (*Dorycnium pentaphyllum*)	0.41	0.52	0.11	95.0	41.4	866	31.7
LL (*Lavandula latifolia*)	0.27	0.55	0.07	91.8	37.8	1262	48.1
MS (*Medicago strasseri*)	0.58	0.67	0.21	228.1	83.0	1089	95.5
RO (*Rosmarinus officinalis*)	0.39	0.60	0.08	108.6	46.4	1351	65.4
RS (*Retama Sphaerocarpa)*	0.75	0.91	0.12	213.6	91.3	1779	2.1

Results and Discussion

A mean S value of 0.95 mm was measured for the shrubs studied (Table 2). S varied among 0.70 mm for CZ and 1.46 mm for CAl nevertheless any significant difference was observed among species. Results show a high variability that makes difficult to detect significant differences. These first results have been obtained with small plants, and this could explain this phenomenon. As a plant is greater in volume and structural complexity, more important is its interception capacity (García-Fayós, 2004). Results are close to those obtained by other authors, especially for RS (S = 0.82 mm), close to that obtained by Domingo *et al.* (1998). According to Wood *et al.* (1998) dry and green weight were the 2 variables which appear to have the strongest relationship with the amount of water intercepted. There were a positive correlation between S, green total biomass, and dry total biomass, with Pearson correlation coefficients of 0.49 and 0.41 respectively.

Table 2. Number of replicates and average values of water storage capacity (S) and stemflow (S_F), ± one standard error, for each species.

	n	S (mm)		S_F (%)	
		Mean	Standard error	Mean	Standard error
CAl (*Cistus albidus*)	4	1.46	0.20	21.0 ab	3.7
CL (*Cistus ladanifer*)	4	0.83	0.57	4.0 c	1.4
CZ (*C. praecox x C. dallimorei*)	5	0.70	0.16	25.4 a	3.3
DP (*Dorycnium pentaphyllum*)	3	0.84	0.08	15.3 abc	7.1
LL (*Lavandula latifolia*)	4	0.91	0.13	23.5 a	4.8
MS (*Medicago strasseri*)	3	0.90	0.20	2.2 c	1.4
RO (*Rosmarinus officinalis*)	7	1.14	0.53	19.9 ab	4.7
RS (*Retama Sphaerocarpa)*	3	0.82	0.13	7.7 bc	1.2
Overall Mean	33	0.95		16.2	

Mean S_F observed was 16.2 % of the incident rainfall (Table 2). CZ and LL were the species with the highest values of SF (25.4 and 23.5 % respectively). In contrast, the minimum values were measured for RS, CL and MS (7.7, 4.0 and 2.2 % respectively). CAl and RO, with stemflow values of 21 and 19.9 % respectively, were higher than CL and MS. DP was similar to the rest of the species, due to its variability. Species with erect stems and with their leaves growing erect from the stems are the species with more S_F values (CZ, LL, Cal and RO). Many authors have realized that morphological and structural characteristics of the shrub influence SF. Mauchamp and Janeau (1993) have tested that a structure like a funnel stimulates S_F. Although RS has erect stems, SF values are low, because when it becomes humid, its stems bend down and the water drips, so SF values are lower than other species, like CZ, with apparent similar structures.

The values are very low for species like CL, with leaves that drip to its tip. Values of 7.2 % of S_F has been obtained by Domingo *et al.* (1994) for *Cistus laurifolius*, a species with the leaves in the same orientation that CL. For some species, like RO, values obtained were lower than those observed for Belmonte Serrato (2001). The young specimens used in this study could explain this difference. Nevertheless, for species like RS, similar values were obtained for Domingo *et al.* (1998).

Substantial evidence supports the idea that the knowledge of hydrological processes operating at plant-scale can be crucial to understand the functioning of the heterogeneous landscapes typical of semiarid environments (Domingo et al, 1998). Martínez-Meza and Whitford (1996) demonstrated that water funnelling to the base of the plant, through stemflow, facilitates infiltration through the channels created by root system. So stemflow is a crucial mechanism to storage water efficiently *(*Mauchamp and Janeau, 1993). Taniguchi *et al.* (1996) observed that hydrological effects of S_F were important also for vegetal communities where S_F represented a low proportion of incident rainfall.

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