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ORGINAL ARTICLE

Rainfall interception loss by a *Cupressus arizonica* Stand

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ABSTRACT
The goal of this research was to quantify rainfall interception (I) in a mature semirid Cupressus arizonica stand afforested in the Chitgar Forest Park near Tehran city, Iran. Measurements of gross precipitation (GR) and through fall (TF) were recorded on an event basis from September 2011 to April 2012. For the measurement period, GR totaled 218.1 mm and I totaled 73.1 mm. I was calculated as the difference between GR and TF. On the event-based scale, the ratio of I:GR ranged between 1.3% and 97.2%, and averaged 36.8%. There was a strong logarithmic correlation between I:GR and GR (R^2 = 0.650; P value ≤ 0.01). As the amount of rainfall events increased, I:GR decreased. The results indicate that intercepted rainfall represents a considerable portion of GR in P. eldarica afforested regions of the semiarid climate zone of Iran.
Keywords: *Afforestation, Cupressus arizonica, Estimation, Iran.*

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INTRODUCTION

Rainfall interception loss (*I*) is the fraction of gross rainfall (*GR*) that is intercepted, stored and subsequently evaporated from the leaves, branches and stems of vegetation. Therefore, quantifying the magnitude of *I* is vital in semiarid and arid regions where soil moisture is a limiting factor affecting plant growth and productivity [7].

Throughfall (*TF*) is the portion of *GR* that reaches the forest floor [14], [43]. Stemfall (*SF*) is *GR* that reaches the ground by flowing down stems/trunks. *I* is estimated using the difference between *GR* and the sum of throughfall (*TF*) and stemflow (*SF*) [42], [43].

For the same vegetation type, the equations frequently differed because of the unique characteristics of each forest stand [12]. Awareness about the amount of rainfall intercepted by different tree species will help managers choose the desirable species. To our knowledge, a comprehensive investigation on the impact of *C. arizonica* on *I* has not been reported for forests in Iran, nor in other countries in the region, despite the widespread use of this species in afforestation efforts. Therefore, the objective of this paper is to quantify how *TF* and *I* are partitioned in a planted *C .arizonica* forest located in a semiarid climate zone of Iran.

MATERIALS AND METHODS

Site Description

The study occurred in a nearly closed canopied, even-aged *C. arizonica* afforestation located in the Chitgar Forest Park of Tehran, Iran. *TF* Measurements were made in a 500 m^2 plot (35°10´ N, 51°10´ E, and 1250 m a.s.l.). Tree density was 1050 trees ha^{-1} and the total basal area was 60.5 m^2 ha^{-1}. Mean tree height and diameter at breast height (DBH) were 9.1 m and 27 cm, respectively. Measurements were performed from September 2011 to April 2012.

Field Measurements

GR was measured by 10 rain-gauges that were 9 cm in diameter and 20 cm in height. The quantity of water in the collectors was measured manually using a graduated cylinder with an accuracy of 1 ml. The average from the 10 rain-gauges was used to estimate *GR*. Rainfall events were defined as separate rain events as long as there was at least 2 h without rain. In this dry climate, 2 h was assumed to be sufficient for the canopy to completely dry [7]. *TF* was measured using 50 rain-gauges of the same design as the rain-gauges used to quantify *GR*. *TF* volume was measured at the same time *GR* was measured. In the present study, *SF* was not directly measured because *C. arizonica* has rough bark and a canopy structure that is similar to other species with low stemflow [22, 12].

RESULTS

From September 2011 to April 2012, 218.1 mm of rain fell in 41 rainfall events. Cumulative *GR* ranged from 0.2 mm to 13.5 mm and mean *GR* depth per event was 5.3 mm. Of the 41 rainfall events recorded during the measurement period, 144.9 mm, or 66.5% of the cumulative *GR* reached the forest floor as *TF*. Mean *TF* was 3.5 mm or 63.2% of *GR*.

Rainfall interception loss (*I*) totaled 73.1 mm, or 33.5% of total *GR* for the study period. The percentage lost to *TF* depended on storm amount, with the percentage varying from 97.2% of *GR* for larger rainfall events (14.4 mm) to 1.3% of *GR* (0.2 mm).

The contribution of *I* to *GR* (relative *I* or *I*: *GR*) was correlated with *GR* (Fig 1). The mean values of *I*:*GR* showed a decreasing trend, with ratio decreasing as *GR* increased. A negative logarithmic significant relationship (R^2 = 0.650; P value ≤ 0.01) was found between *I*:*GR* and *GR*.

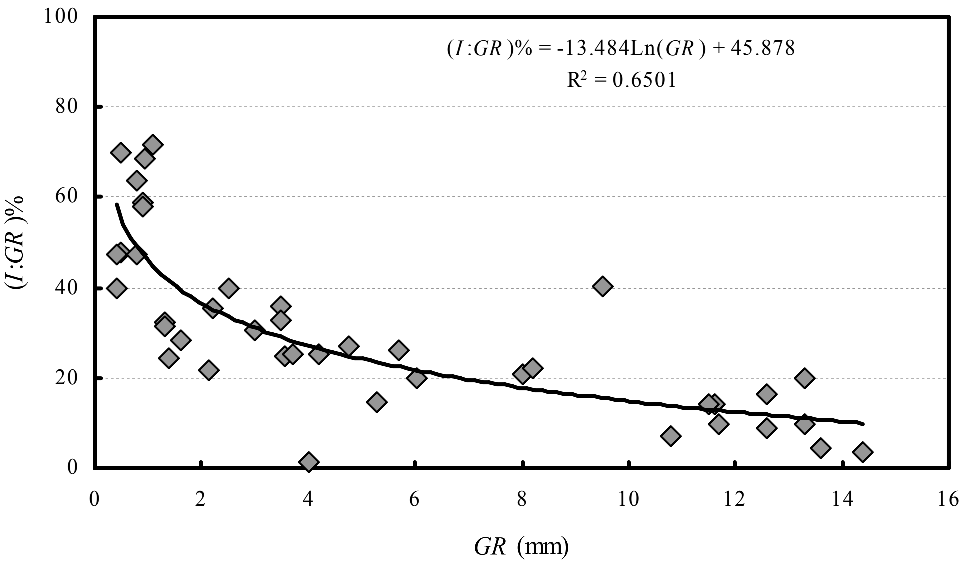

Fig 1. Scatter plots of percent of relative interception (*I*:*GR*)% *vs*. gross rainfall (*GR*) for the *Cupressus arizonica* stand.

DISCUSSION

A review of the literature on rainfall partitioning in various coniferous stands, indicates that the values for *TF*:*GR* and *I*:*GR* obtained in the present study differed slightly with those measured in other needle-leaves forests (Table 1). Llorens et al. (1997) reported that the average values of *TF*:*GR* and *I*:*GR* in a *Pinus sylvestris* forest in Eastern Pyrenees, Spain, were 75% and 24%, respectively. Mahendrappa [42] reported *TF* and *I* for a *Pinus strobus* plantation in Canada to be 65% and 31% of annual *GR*, respectively. In Portugal, the measured value of *TF* in a *Pinus pinaster* forest was 83% of *GR* during the two years of measurement [55]. It is noteworthy that value of *I*:*GR* obtained in our study (37%) was on the high end of the 20% to 40% measured by others in needle-leaved evergreen forests [23], [67]. The partitioning of rainfall into *TF* and *I* in forest ecosystems has been demonstrated to be a function of incident rainfall characteristics (amount, intensity, duration, and temporal distribution of rainfall events) [10], [66], [24], [33], [35], [42], meteorological conditions (air temperature, relative humidity, wind speed, and wind direction) [9] and forest structure (species composition, stand age, basal area, stand density and canopy morphology and architecture) [28], [66], [35], [7], [44], [53], [48], [63]. Given the dry nature of this region, it is likely that the differences in rainfall partitioning reported by other researchers were due, in part, to differences in the above mentioned factors.

Table 2. A review of measured values of relative throughfall (*TF*:*GR*), relative rainfall interception (*I*:*GR*) as well as relative stemflow (*SF*:*GR*) obtained from various researches carried out on different species of pine (stand). *TF*, *SF*, *I*, and *GR* are referred to throughfall, stemflow, rainfall interception, and gross rainfall, respectively.

Tree Species	*I*:*GR*	*TF*:*GR*	*SF*:*GR*	Tree density (Stem ha^{-1})	References
Pinus pinaster	0.171	0.826	0.003	312	Valente et al. [62]
Pinus radiata	0.183	0.728	0.089	1708	Crockford and Richardson [9]
Pinus wallichiana	0.21	0.763	0.027	1200	Singh [58]
Pinus densiflora	0.14	0.83	0.03	1575	Mitsudera et al. [44]
Pinus radiata	0.30	----	----	450	Kelliher et al. [31]
Pinus sylvestris	0.32	0.38-0.53	0.15-0.30	4600	Rutter (1963)
Pinus massoniana	0.272	0.704	0.024	2628	Cao et al. [5]
Pinus sylvestris	0.24	0.747	0.013	2400	Llorens et al. [38]
Pinus radiata	0.265	----	----	1493	Pook et al. [48]
Pinus nigra	0.35	0.65	----	600	Rutter et al. [63]
Pinus sylvestris	0.424	0.576	----	1870	Gash et al. [16]
Pinus strobus	0.307	0.65	0.053	----	Mahendrappa [42]
Pinus resinosa	0.283	0.69	0.007	----	Mahendrappa [42]
Pinus pinaster	0.126-0.21	0.76-0.83	0.01-0.06	800	Loustau et al. [40]
Pinus pinaster	0.125	0.875	----	430	Lankreijer et al. [33]

The size of *GR* had a major impact on the partitioning of rainfall into *TF* and *I* for the *P. eldarica* afforestation in this study. As the size of *GR* increased, the ratio of *I* to *GR* (*I*:*GR*) decreased. A part of the difference in interception loss between this study and others in the literature may have resulted from different storm sizes. However, while *TF* and *GR* were well correlated, the lowest *TF* values was not synchronized with the lowest values of *GR* (0.22), thereby suggesting that the climatic factors also played a very important role in the rainfall partitioning.

CONCLUSION

The study occurred in a *Cupressus arizonica* afforestation in semarid climate zone of Iran. It was observed that rainfall partitioning into *TF* and *I* was strongly affected by the size of *GR*; with the ratio of *I*:*GR* declining as *GR* increased.

This research is the first to document rainfall partitioning in C. *arizonica* afforestation. However, climatic factors, such as wind speed and direction, air temperature and relative humidity, rainfall characteristics, rainfall duration, rainfall intensity, as well as vegetative factors including leaf area index (LAI), canopy architecture, gap fraction and stand density should be considered when rainfall partitioning in afforestations in semiarid climate zone. In the semiarid climate zone of Iran, plant growth and productivity is strongly affected by water availability. Therefore, *I* should be considered when selecting species for afforestation projects in the semi-arid climate regions as it can be significant.

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