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Differences in Rainfall Interception during the Growing and Non-growing Seasons in a *Fraxinus rotundifolia* Mill. Plantation Located in a Semiarid Climate

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ABSTRACT

We estimated the rainfall interception loss (*I*), canopy storage capacity (*S*), the ratio of mean evaporation rate from the wet canopy ($\overline{E}$) over the mean rainfall intensity ($\overline{R}$) (mm h^{-1}) ($\overline{E}/\overline{R}$), and free throughfall coefficient (*p*) in a *Fraxinus rotundifolia* Mill. stand located in an afforested Park land in a semiarid region of Iran. For each storm event, *I* was calculated as the gross rainfall (*GR*) minus throughfall (*TF*). *S* was estimated by indirect methods: the minimum, the mean, and the Gash and Morton. Fifty-five rainfall events were recorded (cumulative *GR* 197.2 mm), with 31 events occurring during the growing season (total *GR* 88.0 mm) and 24 events measured during the non-growing season (total *GR* 109.2 mm). The mean ratio of *I* to *GR* equalled 39.2% during the growing season *vs*. 23.9% during the non-growing season. For the growing season, *S* was estimated to be 0.27, 0.21, and 0.23 mm using the minimum, mean, and Gash and Morton methods, respectively. For the non-growing season, these values were estimated to be 0.17, 0.13, and 0.15 mm, respectively. During the growing and non-growing seasons, $\overline{E}/\overline{R}$ were estimated to be 0.13 and 0.11, respectively, with the corresponding *p* values of 0.39 and 0.52. The loss of the leaves resulted in decline in *I*, *S*, and $\overline{E}/\overline{R}$, and increase in *p*. For semiarid regions, these values are useful for solving some water management problems.

Keywords: Canopy storage capacity, Free throughfall coefficient, Seasonal variability.

INTRODUCTION

Trees strongly influences with the hydrology of forest ecosystems (Gash *et al*., 1995; Chang, 2006). Gross rainfall (*GR*) that enters the forest canopy can be temporarily stored, with substantial portion evaporating back to the atmosphere. Upon entering the forest canopy, *GR* reaches the forest floor as throughfall (*TF*), runs down the stems as stemflow (*SF*) or evaporates back to the atmosphere as interception loss (*I*). Throughfall (*TF*) will reach the forest floor directly as direct throughfall (*p*), or drip from the canopy after hitting a branch or leaf (Návar, 2011; Sadeghi *et al*., 2014, 2015). Stemflow (*SF*) is the amount of water flowing to the ground via trunks/stems (Návar and Bryan, 1990), and *I* is the portion retained by canopy cover and evaporated into the atmosphere (Aboal *et al*., 1999; Crockford and Richardson, 2000; Návar, 2013). *I* can represent 10 to 25% of *GR* in deciduous forests (Crockford and Richardson, 1990; Bruijnzeel, 2000; Carlyle-Moses, 2004; Šraj *et al*., 2008; Návar, 2013) and up to 40% in evergreen forests (Gash *et al*., 1980; Asadian, 2007; Návar, 2013). Hence, changes in the forest

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canopy structure will impact I and may alter soil moisture content and surface runoff (Herwitz, 1985; Chang, 2006).

The magnitude of I is greatly affected by the canopy storage capacity (S) and the ratio of mean evaporation rate from the wet canopy, $\overline{E}$ (in mm h^{-1}) to the mean rainfall intensity during rainfall, $\overline{R}$ (in mm h^{-1}) ($\overline{E}/\overline{R}$) (Gash and Morton, 1978; Návar and Bryan, 1994; Návar *et al.*, 1999a, 1999b; Návar, 2013). S is defined as the amount of water stored on a fully saturated canopy when evaporation is negligible and rainfall has ceased (Gash and Morton, 1978; Návar and Bryan, 1990; Sadeghi *et al.*, 2014, 2015). Many factors can affect the size of S including canopy cover, leaf area index, and seasonal variation in leaf area index (Gash *et al.*, 1980, 1995; Návar and Bryan, 1990; Pypker *et al.*, 2005; Muzylo *et al.*, 2009, 2012; Fathizadeh *et al.*, 2013).

I processes are highly variable with season, therefore, measuring the magnitude of I is crucial, in particular during the dry season, in semiarid and arid regions where soil moisture availability, survival of understorey vegetation, as well as local sub-surfaces flow rates are limiting factors for plant growth and vitality (Carlyle-Moses, 2004; Sadeghi *et al.*, 2015). The lack of affordable instruments that directly quantify canopy variables results in the use of indirect methods that include the minimum method (Leyton *et al.*, 1967), mean method (Jackson, 1975), Gash and Morton (1978) method (as described in material and methods), the intercept method (Návar, 1993), and the IS method (Link *et al.*, 2004).

Seasonal changes in the canopy characteristics will alter S, p, and $\overline{E}/\overline{R}$, thereby influencing I (Pypker *et al.*, 2011). During the dormant period, senescence of leaves occurs in deciduous trees and hence S is reduced (Pypker *et al.*, 2011). S, I, and p in deciduous forest alter significantly in leaf and leafless periods (*e.g.*, Návar, 1993; Pypker *et al.*, 2011; Muzylo *et al.*, 2012; Fathizadeh *et al.*, 2013) (Table 1).

In semiarid to arid regions, it is becoming common to afforest to control air pollution and provide green space. The establishment of plantations may alter the hydrology in these regions (Sadeghi *et al.*, 2014, 2015). However, relative to temperate and tropical forests, there has been little research on the impact of canopy structure on I, S and p in semiarid regions (*e.g.*, Herwitz, 1985; Jetten, 1996; Holder, 2004; André *et al.*, 2008; Ahmadi *et al.*, 2009, 2011; Friesen *et al.*, 2013).

Fraxinus rotundifolia Mill. is a native tree that is widely used in plantations in arid and semiarid regions of Iran (Jazirei and Ebrahimi-Rostaghi, 2005). The tree tolerates low and high temperatures (Jazirei and Ebrahimi-Rostaghi, 2005) and is broadly used as an ornamental tree along streets, in gardens, and in forest parks. No research has been reported concerning the stand-based measurement of I for *F. rotundifolia* plantations. The objectives of this research were (1) to break stand level partitioning of GR into TF and I and (2) to estimate seasonal I, S, $\overline{E}/\overline{R}$, and p values for a *F. rotundifolia* afforestation in a semiarid climate zone.

Table 1. Review of canopy storage capacity (S) from various research for the deciduous forest.

Species	S (mm)[a]	Study area	Reference
Carpinus betulus	1.0 (*), 0.65 (×)	United Kingdom	Rutter *et al.* (1975)
Quercus robur	0.88 (*), 0.28 (×)		
Nothofagus	1.5 (*), 1.2 (×)	New Zealand	Rowe (1983)
Asperulo-fagetum	1.28 (*), 0.84 (×)	Germany	Hörmann *et al.* (1996)
Fagus sylvatica	1.1 (*), 0.4 (×)	Belgium	Staelens *et al.* (2008)
Quercus brantii	1.56 (*), 0.56 (×)	Iran	Fathizadeh *et al.* (2013)
Quercus spp.	0.90 (all seasons)	Mexico	Návar (2013)

[a] Star (*) and cross (×) signs denote growing and non-growing seasons, respectively.

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MATERIALS AND METHODS

Site Description

The study was conducted in a 350 m^2 plot located on the Chitgar Forest Park, west of Tehran city, Iran (lat. 35°10´ N, long. 51°10´ E, 1,250 m asl) (Figure. 1). The park was established in 1968 to purify air, provide green space and sustain groundwater. The Park covers an area of 1,450 ha and the slope range is mostly between 2 to 30%. Approximately 12% of the total Park area contains pure stands of *F. rotundifolia*. Mean tree height and diameter at breast height (DBH) were 6 m and 17 cm, respectively. Stand density and basal area are 1,100 stems ha^{-1} and 0.23 m^2 ha^{-1}, respectively. After planting, the stands have not been managed.

There was no meteorological record at the Park. However, a nearby meteorological station, Chitgar Meteorological Station (ca. 4 km distance, 35° 44´ N, 51° 10´ E, and 1,215 m asl), reported that from 1996-2012, mean annual precipitation (± standard error) was 272.0 mm (SE±21.4 mm). The wettest and driest months are March (46.1 mm; SE±10.2 mm) and August (0.8 mm; SE±0.3 mm), respectively. The dry period begins in May and ends in October. The wet period, extends from November to April, and historically contributes 88% of the total annual precipitation. The area has a mean annual temperature of 17.0°C (SE±0.2°C). August is the warmest month with average temperature of 29.3°C (SE±0.3°C) and January is the coldest month (3.8°C; SE±0.8°C). The forest has a semiarid climate by using the De Martonne Aridity Index classification (I_{DM}= 10.1). The prevailing wind direction in the area is from W to NW.

Field Measurements

Gross rainfall, throughfall, and stemflow

Measurements were made from 1 September 2012 to 25 July 2013. The forest has an average growing season of 195 days (1 April to 15 November). *GR* was measured with 10 manual rain-gauges that were 9 cm in diameter and 22 cm in height. The *GR* gauges were placed on the ground in forest openings that were 30 m away from the *F. rotundifolia* stand. *TF* was measured using 50 manual rain-gauges of the same type as

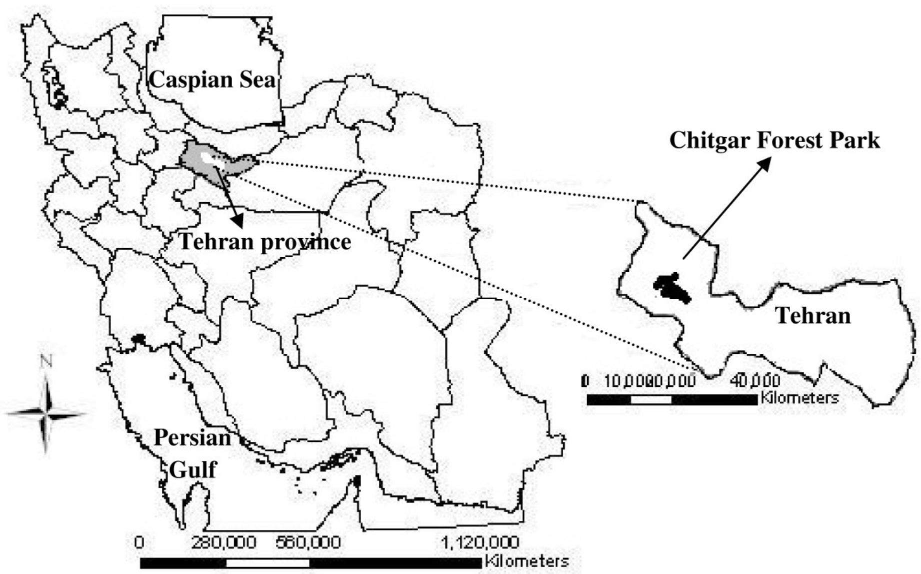

Figure 1. Research site inside the Chitgar Forest Park near Tehran city, Tehran Province, Iran.

the rain-gauges used to quantify *GR*. *TF* rain-gauges were randomly distributed beneath the forest canopy within the study plot. Past research suggests that indirect methods can result in biased estimates of *I* and *S* in areas with high spatial heterogeneity of *TF* (Sadeghi *et al*., 2014). To reduce the potential for bias, we used a large number of rain-gauges (50) that were randomly relocated during the measurement period (Lloyd and De Marques, 1998). Half of the *TF* rain-gauges were relocated every five rainfall events, the other half remained fixed in their positions (Sadeghi *et al*., 2015).

Only rain storms over 0.3 mm were measured and included in the analysis. It was assumed that a wet canopy requires at least 4 hours to completely dry. Field observation showed that the stemflow, *SF*, is not a critical component of *GR* partitioning in our stand, hence, the *SF* measurement was neglected. Consequently, *I* was calculated by subtracting *TF* from *GR*, both of which were measured for each rainfall event. If the rainfall occurred during the day, the water was collected within 2 hours after an event, but if the rainfall occurred late in the afternoon or evening hours, rainfall was measured the next morning. The average from the rain-gauges installed in the open area and underneath the stand was used to calculate *GR* and *TF*, respectively.

Canopy Storage Capacity, the $\overline{E}/\overline{R}$ Ratio, and *p*

We used indirect regression methods that relate *TF* and *GR* to determine the canopy saturation point (P_s). The amount of *GR* that is necessary to saturate the canopy before the drip of *TF* occurs is defined as P_s, which is equal to *S* if *p* is zero, and can be estimated subjectively by finding the inflection point on a graph relating *TF* to *GR* for multiple storms (Leyton *et al*., 1967; Pypker *et al*., 2005; Motahari *et al*., 2013; Sadeghi *et al*., 2014, 2015). Stand level *S* can be estimated by three generally accepted graphical indirect methods that relate *GR* to *TF* (*e.g.*, Leyton *et al*., 1967; Klaassen *et al*., 1998; Link *et al*., 2004; Pypker *et al*., 2005, 2011; Sadeghi *et al*., 2014). The common methods for *S* calculations are described below:

1. Minimum method (Leyton *et al*., 1967): *S* was estimated by fitting a regression line to a graph relating *GR* (*x*-axis) to *TF* (*y*-axis) for *GR* events that were greater than P_s (R_1) and $\overline{E}/\overline{R}$ being negligible. *S* was assumed to equal the x intercept. This procedure has been successfully applied by Návar and Bryan (1990) for semiarid shrubs of NE Mexico.

2. Mean method (Jackson, 1975): This requires two regression lines relating *GR* (*x*-axis) and *TF* (*y*-axis). The first regression line (R_1) is fit to storms where *GR* is $\geq P_s$ (R_1) and a second regression line is fit to storms where *GR* is less than P_s (R_2). The differences between *GR* and *TF* at the intersection point of R_1 and R_2 provides the estimates of *S*.

3. The Gash and Morton (1978) method: Similar to the minimum method, it assumes that evaporation is negligible and estimates *S* by relating *GR* (*x*-axis) *vs*. *TF* (*y*-axis) for storms where *GR* is greater than P_s (R_1). In contrast with the minimum method, Gash and Morton (1978) estimated *S* to be equal to the absolute value of the *y*-intercept *i.e.*, when *GR*= 0.

In addition, $\overline{E}/\overline{R}$, and *p* is usually estimated using the mean method (Jackson, 1975; Klaassen *et al*., 1998; Návar *et al*., 1999a; 1999b; Link *et al*., 2004; Pypker *et al*., 2005; Šraj *et al*., 2008; Sadeghi *et al*., 2014, 2015). One minus slope of R_1 provided an estimate of $\overline{E}/\overline{R}$ and the slope of R_2 provided an estimate of *p*.

Data Analysis

Throughout the study period, the rainfall events were divided into two canopy development stages: the growing season (1 September to 20 November 2012; and 15 March to 25 May 2013), and the non-growing season (21 November 2012 to 14 March 2013). The non-growing season was defined as the approximate date when all leaves on the stand had fallen. The distinction was regularly made (at least weekly) by checking the tree phenology at the site.

RESULTS

Gross Rainfall

From 1 September 2012 to 25 May 2013, 55 rainfall events were recorded (cumulative *GR* 197.2 mm). Thirty one events occurred during the growing (total *GR* 88.0 mm) and 24 events were recorded during the non-growing seasons (total *GR* 109.2 mm). *GR* ranged from 0.3 to 10.1 mm during the growing season and from 0.3 to 14.6 mm during the non-growing season. *GR* averaged 2.8 mm (±0.5 mm) during the growing and 4.6 mm (±0.9 mm) during the non-growing season. Three snowfall events were recorded; however, they were not included in our analysis.

Rainfall Interception

Over the study period, *I* was 35.2 mm, or 17.8% of the cumulative *GR*. Values of *I* for the growing and non-growing seasons were 22.5% (cumulative 19.8 mm), and 14.1% (cumulative 15.4 mm), respectively (Figure 2).

To examine the relationship between *GR* and *I*, *GR* events were categorized into two classes: *GR*< 3.5 mm and *GR*≥ 3.5 mm (Table 2). Mean *I*:*GR* values during the growing season were 48.1% for storms less than 3.5 mm and 20.6% for storms larger than 3.5 mm. In contrast, during the non-growing season, *I*:*GR* was smaller, averaging 35.3 and 12.6% for smaller (*GR*< 3.5 mm) and larger (*GR*≥ 3.5 mm) rainfall events, respectively (Table 2).

The mean *I*:*GR* was equal to 39.2±5.1% during the growing season and 23.9±3.6% during the non-growing season. The *I*:*GR* ranged from 4.3 to 100% of *GR* during the growing season, and from 5.9% of *GR* to 60% of *GR* during the non-growing season.

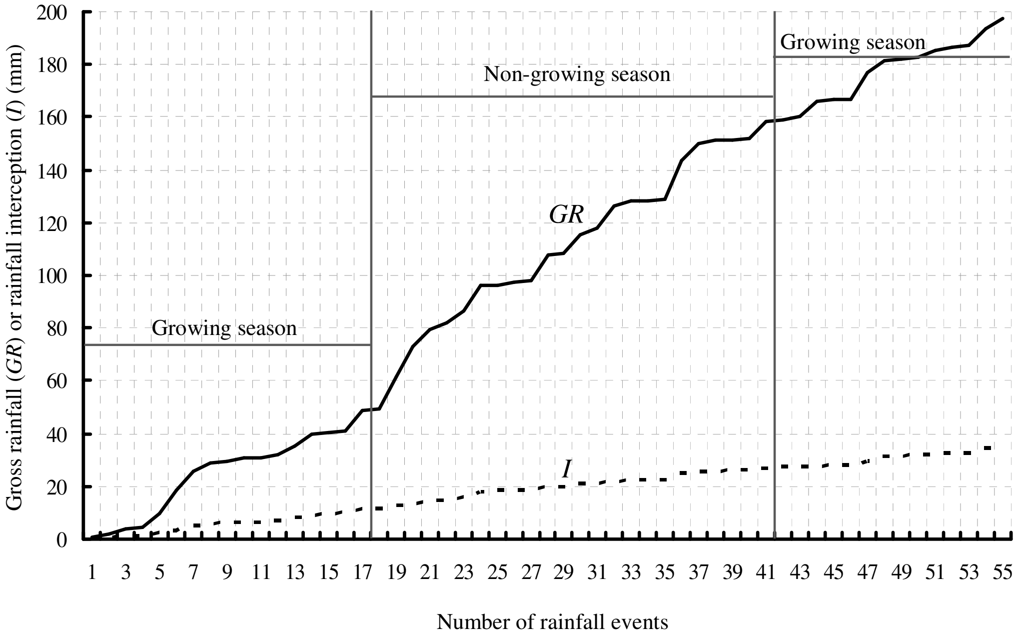

Figure 2. Accumulated gross rainfall (*GR*) and interception (*I*) by *Farxinus rotundifolia* plantation during the measurement period from September, 2012, to May, 2013, within the growing and non-growing seasons.

Table 2. Cumulative gross rainfall (*GR*) depth and the percent of the relative interception (*I*:*GR*) for *Fraxinus rotundifolia* plantation.

	Growing season			Non-growing season		
GR class (mm)	Frequency	*GR* (mm)	*I*:*GR* (%) [a]	Frequency	*GR* (mm)	*I*:*GR* (%)
GR< 3.5	20	24.1	48.1	13	12.6	35.3
GR≥ 3.5	11	63.9	20.6	11	96.6	12.6
Cumulative	31	88.0		24	109.2	
Average (± SE)		2.8 (± 0.5)	39.2 (± 5.1)		4.6 (± 0.9)	23.9 (± 3.6)

[a] Event based average of each class.

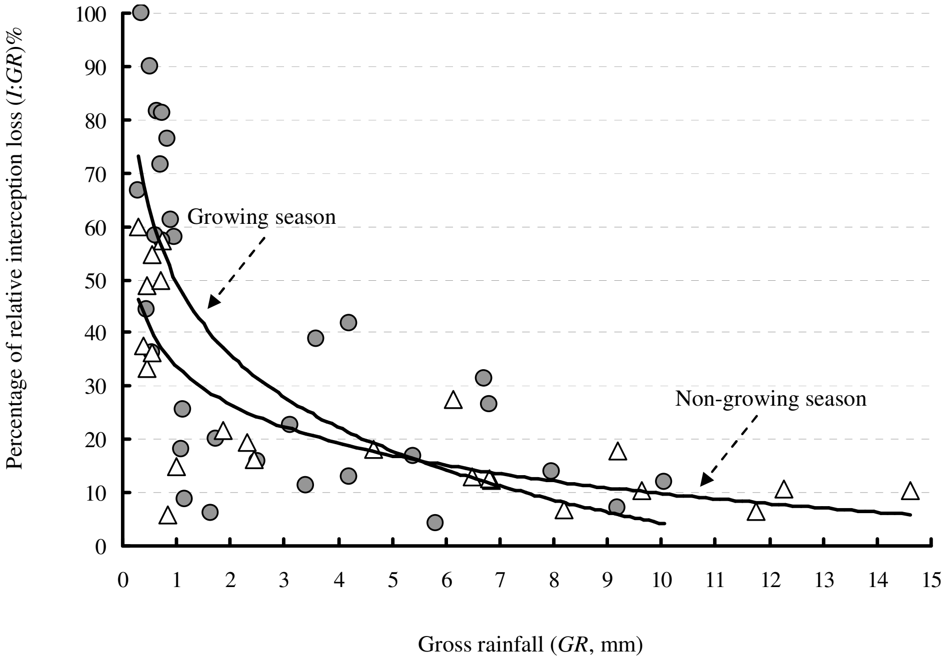

Figure 3. Regression analysis between the percentage of relative interception loss (*I*:*GR*)% and gross rainfall (*GR*) by the *Fraxinus rotundifolia* plantation in the growing season and non-growing season. The regression equations are *I*:*GR*= – 19.65 Ln(*GR*) + 49.5 with correlation coefficient= 0.54, and *I*:*GR*= – 10.43 Ln(*GR*) + 33.46 with correlation coefficient= 0.61, respectively. Filled circles and open triangle denote rainfalls in the growing season and non-growing season, respectively.

Regardless of the season, *I*:*GR* decreased as *GR* increased (Figure 3).

The *I*:*GR* was significantly different between the growing season and non-growing season for the *F. rotundifolia* plantation (t= 3.54, P< 0.01). There was a negative logarithmic relationship between *I*:*GR* and *GR* in both the growing (*I*:*GR*= – 19.65 Ln(*GR*) + 49.50, R^2= 0.54), and non-growing seasons (*I*:*GR*= – 10.43 Ln(*GR*) + 33.46, R^2= 0.61).

Canopy storage capacity, the slope, and the free throughfall coefficients

The canopy saturation points (P_s) were estimated to be 1.0 mm and 0.8 mm in the growing and non-growing seasons, respectively. During the growing season, S was estimated to be 0.27, 0.23, and 0.21 mm using the minimum, Gash and Morton (1978), and the mean methods, respectively (Figure 4). During the non-growing season, these values were found to be 0.17, 0.15, and 0.13 mm for minimum, Gash and Morton (1978), as well as the mean methods, respectively (Figure 5). During the growing and non-growing seasons, $\overline{E}/\overline{R}$ values were estimated to be 0.13 and 0.11, respectively. The coefficient p was calculated to be 0.39 during the growing season and 0.52 during the non-growing season.

DISCUSSION

The choice of tree species for a plantation could alter the amount of I, thereby altering water inputs at the stand-level, landscape and watershed scales (Návar, 1993; Muzylo *et al*., 2012). It is important to measure I for different

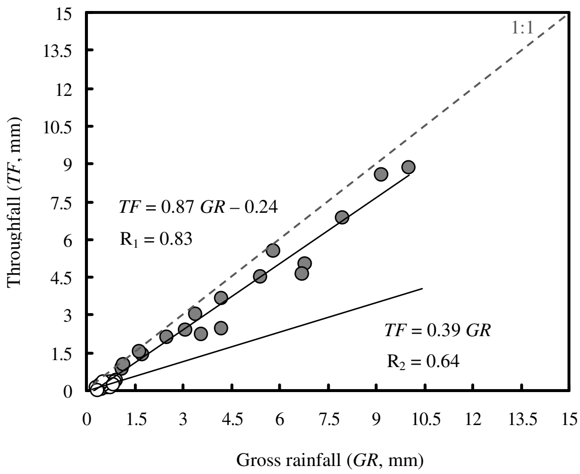

Figure 4. Linear regression analysis between throughfall (*TF*) and gross rainfall (*GR*) by the *Fraxinus rotundifolia* plantation in the growing season. Filled and open circles denote sufficient (R_1) and insufficient (R_2) rainfalls to saturate the canopy, respectively. R refers the Pearson correlation coefficient.

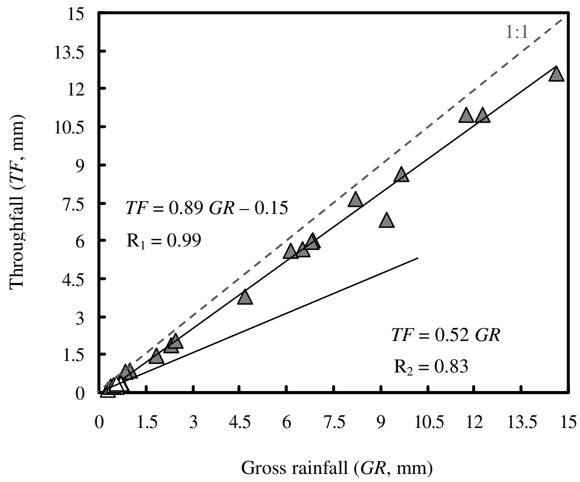

Figure 5. Linear regression analysis between throughfall (*TF*) and gross rainfall (*GR*) by the *Fraxinus rotundifolia* plantation in non-growing season. Filled and open triangles denote sufficient (R_1) and insufficient (R_2) rainfalls to saturate the canopy, respectively. R refers to the Pearson correlation coefficient.

species because it controls the amount of water input to ecosystems. *S* is a fundamental parameter of *I* process. It plays a critical role during small rainfall events in semiarid and arid regions where rainfall is limited (Sadeghi *et al*., 2013). Hence, water management must be aimed at fully enhancing the efficiency of the limited water resources. To date, there are few measurements available regarding the *I*, *S*, $\overline{E}/\overline{R}$ and *p* values in plantations ecosystems in semiarid climate regions. Carlyle-Moses (2004) emphasized the importance of measuring *I* in semiarid climate, as *I* in these environments can be considerable.

Deciduous trees intercept more rainfall during full leaf season than leafless season (Feller, 1981; Neal *et al*., 1993; Hörmann *et al*., 1996; Staelens *et al*., 2008; Muzylo *et al*., 2012) with *I* increasing as leaf area increases (Muzylo *et al*., 2012; Fathizadeh *et al*., 2013). In our study, the average values of *I*:*GR* in growing season (39.2%) and non-growing season (23.9%), and over the periods (17.8%) were similar to the values reported by other researchers. Feller (1981) showed that the annual *I*:*GR* values ranged from 10 to 20% of cumulative *GR* for several *Eucalyptus* (*E. regnans*, and *E. obliqua*) plantations in an arid climate in Australia. Dunin *et al*. (1985) found that the annual *I*:*GR* by *Eucalyptus maculata* was 13% of *GR* in an arid climate zone. In semiarid climate zone in Mexico, Gonzalez-Sosa *et al*. (2009) determined that *I*:*GR* in *Acacia farensiana* and *Prosopis laevigata* trees averaged 21.7, and 20.7%, respectively. Mateos and Schnabel (2001), in a study on a *Quercus rotundifolia* trees in a semiarid region of Spain, reported an annual *I*:*GR* of 26.8%. Motahari *et al*. (2013) reported that the average annual *I*:*GR* value in a *Pinus eldarica* plantation in the Chitgar Forest Park, Iran, was 37%. *I* was estimated by Návar (2013) for oak forests and by Návar *et al*. (1999b) for semiarid, subtropical Tamaulipan thornscrub to be 13.0 and 18.9%, respectively.

Higher *GR* resulted in a shift in the partitioning of rainfall between *TF* and *I*. At higher *GR*, the I:GR ratio declined probably because the importance of *S* diminishes as storms size increase (Sadeghi *et al*., 2014, 2015). This research supports the work of other authors that have demonstrated a decline in *I:GR* as *GR* increased (Crockford and Richardson, 1990, 2000; Staelens *et al*., 2008; Ahmadi *et al*., 2009, 2011; Fathizadeh *et al*., 2013; Motahari *et al*., 2013; Sadeghi *et al*., 2014, 2015). During the study period, *I* increased as the amount of *GR* events increased; however, as expected, higher *I*:*GR* values were obtained for the smaller *GR* events (Rowe, 1983; Staelens *et al*., 2008; Ahmadi *et al*., 2009, 2011; Fathizadeh *et al*., 2013; Sadeghi *et al*., 2013, 2014, 2015). The amount of *I* for small rainfall events are frequently 100% (Horton, 1919). The higher *I*:*GR* values for the small *GR* events is a result of a large portion of incident rainfall retained on the canopy, which evaporates during/after the rain fall.

I partially depends on the size of *S* (canopy storage capacity) (Klaassen *et al*., 1998; Aboal *et al*., 1999; Llorens and Gallart, 2000; André *et al*., 2008; Muzylo *et al*., 2009, 2012; Carlyle-Moses *et al*., 2010; Fathizadeh *et al*., 2013; Motahari *et al*., 2013; Sadeghi *et al*., 2014, 2015). Quantifying *I* requires the calculation of gross precipitation (*GR*), water output (*TF* and *SF*), and controlling factors (such as *S* value, meteorological parameters, as well as vegetation characteristics) (Rutter *et al*., 1975; Herwitz, 1985; Gash *et al*., 1995; Jetten, 1996; Návar *et al*., 1999b; Holder, 2004; Link *et al*., 2004; Muzylo *et al*., 2009; Friesen *et al*., 2013; Sadeghi *et al*., 2015). In this study, three graphical indirect methods for estimating *S* provided values that varied from 0.21 to 0.27 mm for the growing season and ranged from 0.13 to 0.17 mm for the non-growing season. Estimation of *S* is often difficult to obtain from on-site measurement at the study site. Graphical calculations, though perhaps less accurate than direct estimates of *S*, are simple to calculate and to use. *S* under *F. rotundifolia* stand was similar to those found for other deciduous stands (Table 1).

The free throughfall coefficient, *p*, was 0.39 and 0.52 in the growing and non-growing seasons, respectively. As the percentage of canopy cover decreased, *p* increased, and as expected, higher *p* values were observed for non-growing season when the trees were without leaves. Therefore, when modeling *I*, one must account for the differences in these coefficients (Muzylo *et al*., 2009). The differences in abovementioned parameters are not significant compared to the uncertainty of precipitation measurement and its spatial variability. The differences likely result from seasonal variations in leaf area, because *I*, *S*, as well as $\overline{E}/\overline{R}$ typically increase in the growing season. As expected, *p* values decreased when the growing season started. The $\overline{E}/\overline{R}$ values were estimated to be 0.13 in growing season *vs*. 0.11 in non-growing season, and are consistent with the $\overline{E}/\overline{R}$ values reported for oak *spp*. of NE Mexico (Návar, 2013). It is likely that, during the growing season, the mean air temperature was higher than in the non-growing season -the mean daily air temperature during rainy days in the growing season were 21.7 °C *vs*. 18.6 °C in the non-growing season. Moreover, during the growing season, canopy cover is fully leafed; hence, the $\overline{E}/\overline{R}$ rate is higher because canopies have a higher surface area for evaporation. Past research has demonstrated that evaporation from canopy during periods of rainfall depends on meteorological parameters including air temperature, and humidity (Dunkerley, 2000; Asadian, 2007).

CONCLUSIONS

The successful long-term management of plantations in arid and semiarid regions requires consideration of *I*, *TF*, *S*, $\overline{E}/\overline{R}$, as well as *p* values. *I*, *S*, $\overline{E}/\overline{R}$, and *p* differed between the seasons. During the growing season, *I*:*GR*, *S*, $\overline{E}/\overline{R}$ and *p* were found to be 22.5%, 0.24 mm, 0.13 and 0.39, respectively. In contrast, in the non-growing season, these values were 14.1%, 0.15 mm, 0.11 and 0.52, respectively. The leaf loss resulted in decline of *I*, *S* and $\overline{E}/\overline{R}$, and increase in *p*. These values should be considered when managing water resources. Selection of the species used in plantations has important implications in water balance in terms of their influence on *I* and transpiration (loss of water from within the leaves). Hence, forest managers must balance their interest in wood production with the need for water resources management. Important considerations include the influence of the water balance on tree growth/survival and both local and distant irrigation needs that rely on precipitation recharging the aquifer. Moreover, information about *I*, *TF*, *S*, $\overline{E}/\overline{R}$, and *p* would be useful to predict the effects of the silvicultural treatments (*e.g.*, thinning) on water relations and tree growth, as well as the soil water balance.

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تفاوت باران‌ربایی توده دست‌کاشت زبان گنجشک (*Fraxinus rotundifolia* Mill.) در فصول رویش و خزان در اقلیم نیمه‌خشک

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چکیده

هدف از این پژوهش، برآورد باران‌ربایی (I)، ظرفیت نگهداری تاج‌پوشش (S)، نسبت تبخیر به شدت باران در زمان بارندگی ($\overline{E}/\overline{R}$) و ضریب تاج‌بارش مستقیم (p) در توده دست‌کاشت زبان گنجشک (*Fraxinus rotundifolia* Mill.) در اقلیم نیمه‌خشک ایران، بود. I از تفاضل باران (GR) و تاج‌بارش (TF) در هر رخداد بارندگی محاسبه شد. مقدار S با استفاده از روش‌های غیر مستقیم minimum، Gash و Morton، هم‌چنین mean برآورد شد. ۵۵ رخداد GR (مقدار تجمعی ۱۹۷/۲ میلی‌متر) در این مدت ثبت شد که ۳۱ رخداد مربوط به دوره رویش (مقدار تجمعی ۸۸/۰ میلی‌متر) و ۲۴ رخداد مربوط به دوره خزان (۱۰۹/۲ میلی‌متر) بود. درصد میانگین I در هر رخداد GR (I:GR)%، ۳۹/۲ درصد در دوره رویش و ۲۳/۹ درصد در دوره خزان به دست آمد. در دوره رویش، مقدار S، ۰/۲۷ میلی‌متر، ۰/۲۳ میلی‌متر و ۰/۲۱ میلی‌متر به ترتیب با استفاده از روش‌های minimum، mean و نیز Gash و Morton برآورد شد. در دوره خزان این اعداد به ترتیب ۰/۱۷ میلی‌متر، ۰/۱۵ میلی‌متر و ۰/۱۳ میلی‌متر برآورد شدند. مقدار $\overline{E}/\overline{R}$ در دوره رویش و خزان به ترتیب ۰/۱۳ و ۰/۱۱ و هم‌چنین مقدار p در دوره رویش ۰/۳۹ و در دوره خزان ۰/۵۲ برآورد شدند. نتایج این پژوهش نشان داد که از دست دادن برگ‌ها در دوره خزان، سبب کاهش مقادیر I، S و $\overline{E}/\overline{R}$ و افزایش مقدار ضریب p می‌شود. در مناطق نیمه‌خشک، در نظر گرفتن مقادیر این پارامترها برای حل برخی از معضلات مدیریت منابع آبی می‌تواند مورد استفاده قرار گیرد.

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