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Rainfall and dust interception potentials of oak trees and plantations in the Zagros region

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ABSTRACT

The Persian oak, *Quercus brantii* trees and to a lesser extent, man-mad plantations in the Zagros region of western Iran have been in decline since 2000. The decline is assumed to be partially connected with invasions of dust and particulate materials created in neighboring countries. We measured rainfall interception (*I*) and quantified the amount and size of dust and particulate material (*PM*) deposited on leaves of *Q. brantii* as well as *Pinus brutia* and *Cupressus arizonica* man-made trees after rainfall (*GR*) leaching. Throughfall (*TF*) was measured using the sixteen rain gauges randomly located under the crown of individual species. *GR* was measured using rain gauges fixed in an open field nearby to the species and *I* was computed as the difference between *GR* and *TF*. Seven and three *GR* events and corresponding collected *TF* were centrifuged and dried out to measure the amount and size of intercepted *PM* by the species, respectively. Fifteen *GR* events occurred during the study period (cumulative *GR:* 128.9 mm). The mean ratio of *I* to *GR* equaled 35% for *Q. brantii* against 53% for *P. brutia* and 45% for *C. arizonica*. We found out that mean rainfall event (7.83 mm) during the measurement period was able to wash off *PM* content by 3.6, 6, and 6.8 mg per square meter of crown projected area (*CPA*) for *Q. brantii*, *P. brutia*, and *C. arizonica*, respectively. The ratio of *PMs* smaller than 5 µm was lower in *TFs* (mean: 15.4% for all species) compared to open field 27.2%. All species presented approximately the same potential for *PM* absorption. *P. brutia* and *C. arizonica* were capable of absorbing larger *PMs* compared to *Q. brantii*. The results showed that exotic species demonstrated satisfactory potentials in absorbing particulate material nevertheless their higher interception capacity should be considered while they are recommended for afforestation in the semi-arid climate of the Zagros region.

Keywords: *Cupressus arizonica*, Forest decline, Particulate material, *Pinus brutia*, *Quercus brantii*, Throughfall.

INTRODUCTION

Zagros forests of western Iran cover a vast area of the Zagros Mountain ranges, stretching from Piranshahr in northwest of Iran to the vicinity of Firooz-Abad with a length of 1300 km and of 200 km width. The semi-arid Zagros forests cover 5 million hectares are mostly dominated by sparse stands of Persian oak (*Quercus brantii* var. *persica*) (Gherboudj *et al*. 2017). These natural forests and reforestation activities, to a lesser extent, with exotic species like cypress (*Cupressus arizonica*) and Turkish pine (*Pinus brutia*), have been in decline since 2000. Forest degradation, frequent droughts, overgrazing, and invasion of dusts created from adjacent countries are assumed to reduce the ability of Zagros forests to deal with environmental stresses (Gherboudj *et al*. 2017). One of the predominant hypotheses in decline of the *Q. brantii* trees in Iran is invasions of dust and particles (Attarod *et al*. 2016; Attarod *et al*. 2017). Research indicated both North Africa and Middle-East as the major

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potential sources of dust in the world (Gherboudj *et al*. 2017). As trees gradually deposit particulate materials (*PM*) on their leaves, their photosynthesis and growth activities becomes slow, or even, the tree may die off and further *PM* deposition reduces (Grantz *et al*. 2003). On the other hand, *PM*s, especially PM_{10} and $PM_{2.5}$ are the main causes of heart (Bartell *et al*. 2013; Yang *et al*. 2016) and respiratory diseases (Goudarzi *et al*. 2017; Khaniabadi *et al*. 2017). These dusts can have severe impacts on human health of local population and forest ecosystems in the west and south west of Iran. Impacts of Middle-East dust storms on public health of Iranian people are frequently reported in recent years (Goudarzi *et al*. 2017; Khaniabadi *et al*. 2017). The semi-arid Zagros mountainous forests of western Iran form a natural barrier hindering the spread of these pollutants (Khaniabadi *et al*. 2017). Studies on air filtration capacity by vegetation showed that trees and shrubs can effectively deposit *PMs* on the surface of their leaves. The amount of filtration depends on species, meteorological conditions, leaf microstructure and *PM* properties (Cai *et al*. 2017; Muñoz *et al*. 2017; Shi *et al*. 2017). This function of vegetation is particularly important to pollution mitigation both in cities and remote areas. Although many studies have been carried out in the world concerning vegetation potential of *PM* absorption, no research documented this potential in Iran, where forest areas are specifically vulnerable to *PM* pollution (Attarod *et al*. 2016). One of the important factors indicating *PM* absorption by plants is rainfall interception process. When it rains, a proportion of rainfall never reaches the forest floor, as it is intercepted by leaves, branches, and stems and subsequently evaporated by a process called interception loss (*I*). However, throughfall (*TF*) is the part of the incident rainfall (*GR*) which passes through the forests canopy, either directly in gaps or interacting with the vegetation (Van Dijk *et al*. 2015). *TF* contents changes as incident rainfall passes through the forest canopy so that the amount of dusts and *PMs* in the *TF* can alter as they are washed off from leaves. The objectives of this study were thus to (i) compare *I* and *TF* quantities by *Q. brantii* individual trees as well as exotic species of *P. brutia*, and *C. arizonica*, widely planted in reforestation activities in the Zagros region with a semiarid climate, and (ii) quantify the amount and size of dusts deposited on individual trees washing through leaching process.

MATERIALS AND METHODS

Site description

Measurements were carried out in Shurab Forest Park (hereafter SFP) (33° 26´ N, 48° 10´ E, and elevation: 1250 m a.s.l) located 25 km away from Khoram-Abad City, Lorestan Province, west of Iran (Fig. 1). The area of the park is 570 ha and positioned inside the Zagros forests. Meteorological data recorded by Khoram-Abad Meteorological Station (33° 26´ N, 48° 17´ E, 1150 m a.s.l.) was employed to describe climatic conditions. During the period 1951-2014, mean yearly precipitation was 493 mm (SD ± 125 mm) and the wettest and driest months are March (83 mm) and July and August (0.2 mm), respectively. Mean annual temperature (T) was 17.3 °C (SD ±1.3 °C), with July being the warmest month [mean daily *T:* 30.5 °C] and January is the coldest (T: 4.8 °C). Mean daily wind speed (*WS*) was 1.7 m s^{-1}. The ‘‘de Martonne’’ climate classification categorized the study site as semi-arid climate type [(de Martonne aridity index (I_{DM}): 14.2] (Tabari *et al*. 2014).

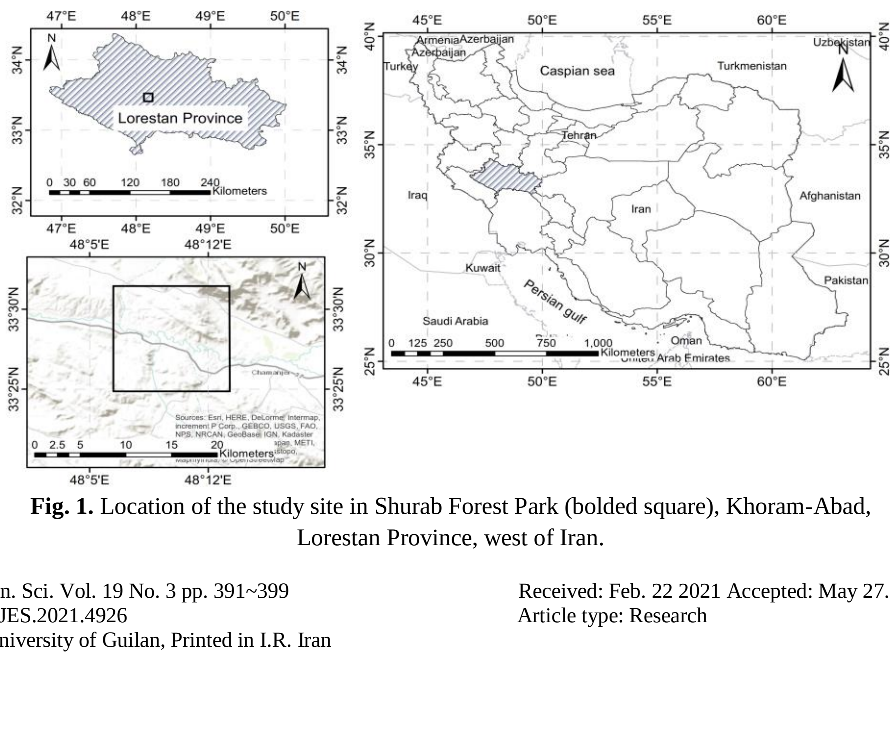

Fig. 1. Location of the study site in Shurab Forest Park (bolded square), Khoram-Abad, Lorestan Province, west of Iran.

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Pollution data provided by the Lorestan environmental bureau recorded 577 dusty days over-standard *PM* concentration (mean: 550 µg m^{-3}) during the period 2008-2015. It is noteworthy that standard concentrations for PM_{10} and $PM_{2.5}$, are 50 and 35 µg m^{-3} not occurred more than 35 times per year. Moreover, the region has experienced 109 dusty days with different size particles percentages (PM_{10} = 63%, $PM_{2.5}$ = 35%, and PM_1 = 2%) in the period from April 2014 to March 2015.

Trees selection

Five typical, even-aged, healthy, and isolated trees of *P. brutia*, *C. arizonica*, and *Q. brantii* with similar morphological features were selected (Table 1). The selected trees represent stand's characteristics located at *SFP*. Mean height and diameter at breast height (*DBH*) were 7.2 m and 20 cm for *P. brutia*, 5.8 m and 15.2 cm for *C. arizonica*, and 7 m and 32 cm for *Q. brnatii*, respectively (Table 1). Crown projected area (*CPA*) which is the projected edges of the crown to a horizontal surface (Levia 2004) was measured using a clinometer and a tape. The crown radius was measured as the horizontal distance from the center of the tree bole to the edge of the crown. To obtain the best estimate of mean crown diameter (*CD*), the average of four cardinal directions (*N*,*E*,*S*, and *W*) of the crown radii was used (Ahmadi *et al*. 2009).

Table 1. Characteristics of trees in Shurab Forest Park (*SFP*). DBH: Demeter at Breast Height; C_L: Crown Length; *CPA*: Crown Projection area.

Species	Tree No.	*DBH* (cm)	Height (m)	C_L (m)	(*CPA*), m^2
	1	19	7.1	5.7	7.3
	2	20	7.8	6.4	20.4
Pinus brutia	3	22	7.4	6.0	22.0
	4	19	6.4	5.1	16.2
	5	20	7.5	6.2	21.6
	1	16	6.1	5.2	13.8
	2	17	5.6	4.5	13.5
Cupressus arizonica	3	13	5.4	4.2	16.6
	4	13	5.5	4.0	8.8
	5	17	6.3	5.2	14.2
	1	45	7.8	5.7	71.8
	2	26	6.3	4.3	29.2
Quercus brantii	3	27	6.3	4.6	29.8
	4	32	7.1	5.2	52.8
	5	30	7.6	5.4	45.4

TF quantity

TF was measured using cylindrical plastic gauges, 9 cm in diameter and 20 cm in height. The experimental network for each tree consisted of 16 gauges at four main orientations —*N*, *W*, *S*, and *E* (four gauges per direction) on the ground beneath the *CPA* of each tree in a radial layout centered on the trunk. The water was collected within 4 h after day-time events and the next morning for the night-time events. To measure *GR*, six gauges, the same type of manual gauges used for measuring *TF*, were placed in an open area near the stands (approximately 20 m away from the selected trees). The average of the six gauges was used to estimate *GR*. We ignored stemflow (*SF*) measurements since *SF* typically accounts for less than 2% of annual precipitation in rough-barked, needle-

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leaved trees (Lankreijer *et al*. 1993, Llorens 1997, Llorens & Gallart 2000, Zhongjie *et al*. 2010). Therefore, *TF* was assumed to be equal to *TF = GR –I*.

TF quality

Seven *GR* events and corresponding collected *TF* were centrifuged and dried to measure the amount of intercepted *PM* deposited on the trees and leached subsequently by rain. Three events were then selected for particle size analysis based on dust events which occurred at least three days before rainfalls. Particle size analysis was done using Fritsch Laser Particle Size Analysette 22 (Fritsch International. Co). All the data were statistically analyzed by Microsoft Excel 2013 and SAS 9.4®. Mean comparisons were done using Duncan method at 5% level of significance.

RESULTS

Interception quantity (I)

Fifteen *GR* events occurred during the study period. Mean collected *GR* was 8.60 mm, with high variation (*SD*: 5.50 mm) ranging from 1.13 to 25.34 mm. Cumulative *GR* was 128.9 mm. Results showed that the species were significantly different in terms of *I* and *I:GR* ratio. *P. brutia* demonstrated the highest significant *I* quantity (mean event-based value *I*: 4.14 mm) against *Q. brantii* (2.49 mm) and *C. arizonica* (3.41 mm) (Fig. 2).

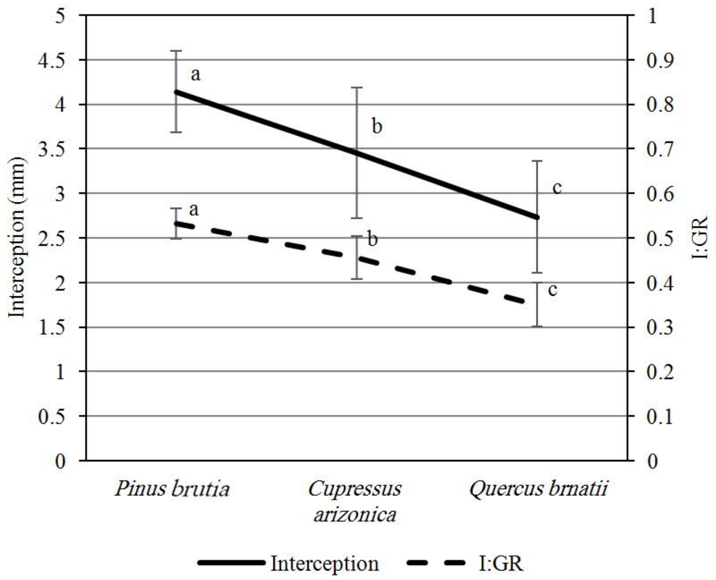

Fig. 2. Interception (*I*) and mean relative interception (*I:GR*) of *Quercus brantii, Pinus brutia*, and *Cupressus arizonica.* Error bars represents standard error of mean. Dissimilar letters represent the differences at 0.05 level of significance.

Accordingly, the mean relative interception (*I:GR*) varied from 0.53 for *P. brutia* to 0.35 for *Q. brantii* (Fig. 2). *I:GR* ratio ranged from 0.33 to 0.98 for *P. brutia*, from 0.21 to 0.92 for *C. arizonica* and from 0.16 to 0.77 for *Q. brantii* (Fig. 3). Significant negative power relationships were observed between mean values of *I:GR* and *GR* for the *P. brutia* ($R^2 = 0.484$), *C. arizonica* ($R^2 = 0.512$), and for *Q. brantii* ($R^2 = 0.519$) so that the proportion of *GR* intercepted by all canopies and loss through evaporation decreased as the size of the rainfall events increased.

The amount of particulate materials (PM)

Our data showed that the mean *PM* amount washed by mean rainfall event (7.83 mm) during the measurement across the *Q. brantii* were higher than those of *P. brutia* (36% higher) and *C. arizonica* (45% higher), however, the difference was found to be statistically significant only for *C. arizonica* and *Q. brantii* (Fig. 4). The *PMs* contents were clearly corresponded to the trees' *CPA*, however, the difference between *CPA* of *Q. brantii* and other species reflected no difference of *PM* content in *TF*. Table 2 presents average event-based *TF* and *PM* of each species. We found out that mean rainfall event was able to wash off *PM* content by 3.6, 6, and 6.8 mg per square meter of *CPA* for *Q. brantii*, *P. brutia*, and *C. arizonica*, respectively.

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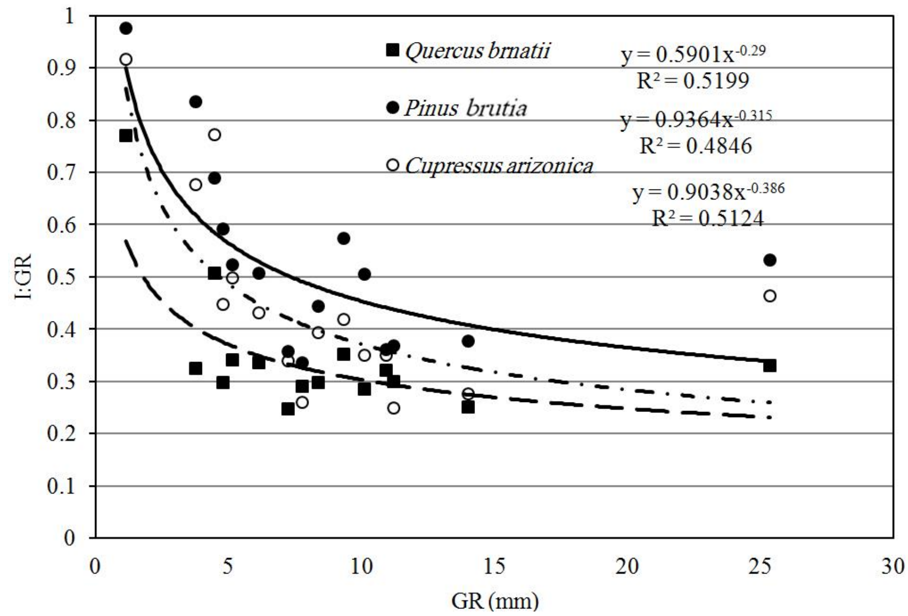

Fig. 3. The relationship between event-based relative interception (*I:GR*) and gross rainfall (*GR*) for the individual *Quercus brantii*, *Pinus brutia,* and *Cupressus arizonica*. Each point refers to a rainfall event.

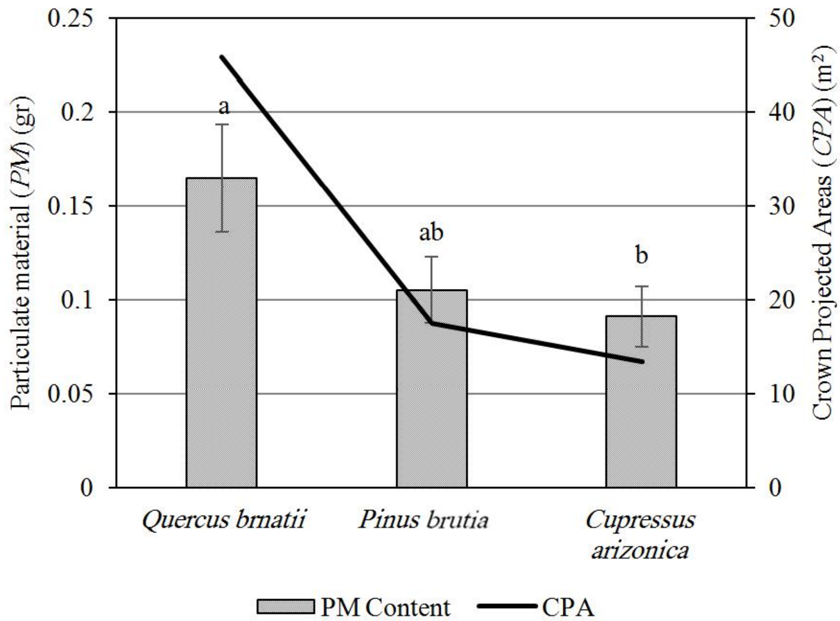

Fig. 4. Average amount of particulate material (*PM*) washed by mean rainfall size for seven events (mean: 7.83 mm) *vs.* mean crown projected area (*CPA*) of *Q. brantii*, *P. brutia,* and *C. arizonica*. Error bars represents standard error of mean. Dissimilar letters indicate significant differences at 0.05 level of significance.

Size distribution

All trees showed roughly the identical potential in terms of particle size absorption. Analysis of *PM* size distribution showed that all three species were capable of absorbing *PMs* larger than 100 µm (Table 3). However, *C. arizonica* and *P. brutia*, tend to absorb *PMs* with larger size compared to *Q. brnatii*. Moreover, the ratio of *PMs* classified in the *PM* size classes 30-50 and 50-100 µm were higher for the trees compared to open field. The majority of *PM* size (approximately 80%) included in the open field rainfall had less than 30 µm in diameter. This value corresponded to 51.8%, 42.5%, and 59.1% for *C. arizonica*, *P. brutia* and *Q.brantii*, respectively. Moreover, *P. brutia*, showed a less capability for absorbing *PMs* in the 10-30 µm class. Although the ratio of *PMs* more than 20 µm decreased with increasing *PM* diameter in the open field, the ratio of *PMs* with diameter between 20 to 70 µm increased by increasing diameter in all *TFs* (Fig. 5).

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Table 2. Average amount of particulate material (*PM*) collected by corresponding rainfall (*GR*) and throughfall (*TF*) for *Quercus brantii*, *Pinus brutia*, and *Cupressus arizonica*, with different crown projected areas (*CPA*).

Event No.	*GR* (mm)	Species	*TF* (mm)	*PM* (mg)	*CPA* (m^2)
		Q. brantii	5.86	232	45.8
2	8.35	*P. brutia*	4.64	346	17.5
		C. arizonica	5.06	253	13.4
		Q. brantii	3.37	127	45.8
3	5.13	*P. brutia*	2.45	82	17.5
		C. arizonica	2.58	81	13.4
		Q. Brantii	7.42	127	45.8
4	10.91	*P. brutia*	6.97	95	17.5
		C. arizonica	7.1	33	13.4
		Q. brantii	4.06	84	45.8
5	6.11	*P. brutia*	3.01	57	17.5
		C. arizonica	3.47	131	13.4
		Q. brantii	5.49	247	45.8
6	7.75	*P. brutia*	5.15	45	17.5
		C. arizonica	5.73	60	13.4
		Q. brantii	5.42	188	45.8
7	7.22	*P. brutia*	4.63	64	17.5
		C. arizonica	4.77	45	13.4
		Q. brantii	6.05	120	45.8
8	9.33	*P. brutia*	3.97	46	17.5
		C. arizonica	5.42	36	13.4

Table 3. Mean size distribution of particulate materials (*PM*) for three rainfall events (Events No 2, 5 and 8) included in the throughfall (*TF*) of *Quercus brantii*, *Pinus brutia*, and *Cupressus arizonica* and one event (event No 1) collected in the open field.

	Particulate material ratio (%)			
PM **size class (μm)**	***C. arizonica***	***P. brutia***	***Q. brnatii***	**Open field**
1-5	14.3	16.2	15.9	27.2
5-10	11.4	9.0	12.2	16.9
10-30	26.0	17.3	31.1	36.0
30-50	16.8	21.7	19.0	13.4
50-100	25.3	24.8	19.5	6.4
100-150	4.2	5.3	2.1	0.1
150-200	1.1	2.4	0.3	0.0
200-250	0.5	2.0	0.1	0.0
250<	0.4	1.3	0.0	0.0

DISCUSSION

Our results revealed that the interception capacity of the native species (*Q. brantii*) (*I*:*GR*=35%) is significantly lower than those of exotic species (*I:GR C. arizonica* = 45.6% and *P. brutia* = 53.2%). Fathizadeh *et al*. (2012) reported that *I*:*GR* was 64.1% for individual oak trees during the leafed period in the Zagros forests. Literature reviews suggested that conifers tend to have greater interception capacity than broadleaved species (e.g. Carlyle-Moses & Gash (2011)). The results confirmed that the amount of *GR* impacted significantly rainfall partitioning process into *TF* and *I*. As *GR* increases, the ratio of *I* to *GR* (*I*:*GR*) decreases; frequent small storms typically result in the greater proportion of *GR* lost to *I* (Fig. 3), similar to the other research (e.g., Sadeghi *et al*. 2014, 2015). This research confirmed that interception loss contributes a remarkable amount of incident rainfall; therefore, its measurement is a significant element in the assessment of water balance in the Zagros forests. Partitioning rainfall in forest ecosystems was approved by previous researchers to be a function of incident rainfall characteristics (amount, intensity, duration, and temporal distribution of rainfall events), meteorological conditions (air temperature, relative humidity, wind speed, and wind direction), and forest structure (species composition, stand age, stand density, and canopy morphology and architecture) (Marin *et al*. 2000, Xiao *et al*. 2000, Hall 2003, Fleischbein *et al*. 2005, Toba & Ohta 2005, Deguchi *et al*. 2006, Staelens *et al*. 2008, Khosropour

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et al. 2013). For example, significant difference of *I:GR* values among *Q. brantii*, *P. brutia*, and *C. arizonica* can be attributed to larger leaf area index (*LAI*) of *P. brutia* (Sadeghi *et al*. 2016). Xu *et al*. (2017) found out that the rainfall intensity had significant effect on the amount of dust wash off process. Although our *TF* measurements suggested that *PM* was the highest in *Q. brantii* compared to others, no significant relationship was detected for *TF* amount and *PM* content for all species. The *PM* content of *TF* in *Q. brantii* was 40% lower than *P. brutia*, and 47% lower than *C. arizonica* when *CPA* was considered. This indicates that *Q. brantii* absorbed lower *PM* amount per unit area (1 m^2), i.e. the *PM* leaching from leaf surface was lower for *Q. brantii* compared to *P. brutia* and *C. arizonica*. Cai *et al*. (2017) showed that *PM* deposition on vegetation leaves significantly depends on life form and life type. They demonstrated that weekly *PM* deposition was significantly lower in deciduous plants compared to evergreens. Additionally, *PM* deposition on broadleaf trees are significantly lower than conifers (Cai *et al*. 2017).

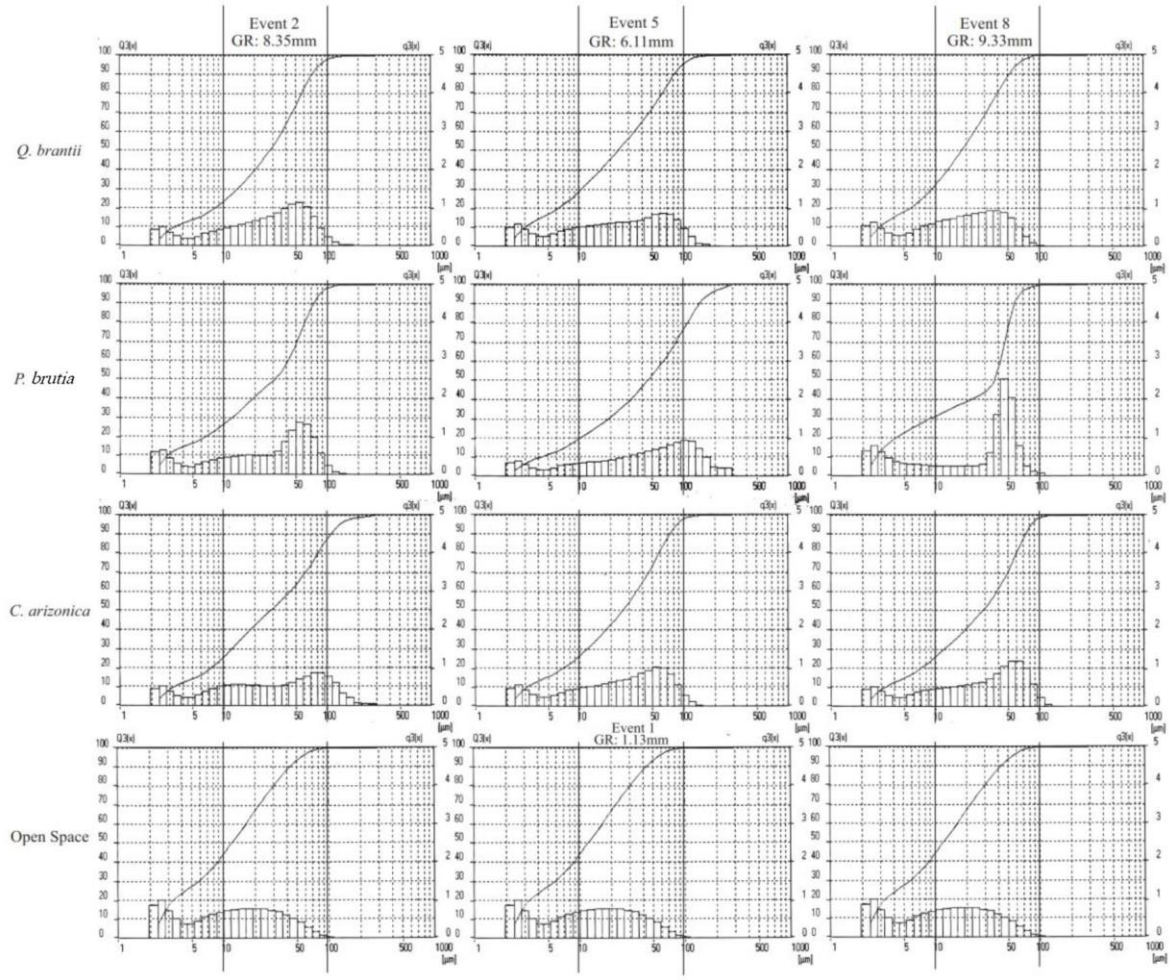

Fig. 5. Event-based size distribution of particulate materials (*PM*) included in the throughfall (*TF*) of *Quercus brantii*, *Pinus brutia*, and *Cupressus arizonica*. Open field *PM* analysis was done only for event 1.

Particle size analysis demonstrated that *PM* content of *TF* for the three species demonstrated roughly similar size distribution; however, *P. brutia* were able to intercept bigger particles size (Table 3). Instead, 5-30 µm particles were washed off from *P. brutia* to a lesser extent (especially in 10-30 µm class). It means that different species can capture different size of particles based on leaf characteristics (Cai *et al*. 2017). It is noteworthy that *PM* size with less than 30 µm in diameter presented lower fraction in *TFs* of all species compared to open field implying that a fraction of smaller size particles remain in the trees crowns. Research suggested that small size *PMs* up to 2 µm can penetrate leaf stomata (Song *et al*. 2015). This might explain why particle size of 1-5 µm have the highest difference between open field and *TFs*. However, 5-30 µm particle sizes can effectually adhere to leaf surfaces, while larger particles can wash off from leaves (Cai *et al*. 2017). Open field collectors were not able to catch particles larger than 100 µm, but the *TFs* contained particle size up to 250 µm. This shows that during the

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rainfall events, large size particles are not suspended in the air and they can only take off the ground in dry weather. Hence, one of the effective physical barriers to such particle size is the trees crown.

CONCLUSION

Individual trees of *Q. brantii* indicated lower rainfall interception potential compared with *P. brutia* and *C. arizonica* introduced widely for reforestation initiatives in the Zagros region. We examined rainfall interception and dust accumulation ability of a dominated tree, i.e., *Q. brantii*, in the Zagros forests against man-made exotic species (*P. brutia* and *C. arizonica*). The exotic ones played more significant role for absorbing particulate material, especially those with larger size than 50 µm in diameter. *PM* size distribution revealed that small *PMs* (30 µm>) collected in *TF* samples were lower than that of the open field concluding that either the species are not capable of absorbing smaller size particulate materials or the deposited materials were not simply leached by rainfall events.

REFERENCES

Ahmadi, MT, Attarod, P, Mohadjer, MR, Rahmani, MR & Fathi, J 2009, Partitioning rainfall into throughfall, stemflow, and interception loss in an oriental beech (*Fagus orientalis* Lipsky) forest during the growing season. *Turkish Journal of Agriculture and Forestry*, 33:557-568.

Attarod, P, Rostami, F, Dolatshahi, A, Sadeghi, SMM & Zahedi Amiri, Gh 2016, Do changes in meteorological parameters and evapotranspiration affect declining oak forests of Iran?. *Journal of Forest Science*, 62: 553-561.

Attarod P, Sadeghi SMM, Pypker TG, Bayramzadeh V 2017, Oak trees decline; a sign of climate variability impacts in the west of Iran. *Caspian Journal of Environmental Sciences*, 15: 375-386.

Bartell, SM, Longhurst, J, Tjoa, T, Sioutas, C & Delfino, RJ 2013, Particulate air pollution, ambulatory heart rate variability, and cardiac arrhythmia in retirement community residents with coronary artery disease. *Environmental Health Perspectives*, 121: 1135-1141.

Cai, M, Xin, Z & Yu, X 2017, Spatio-temporal variations in PM leaf deposition: A meta-analysis. *Environmental Pollution*, 231:207-218.

Carlyle-Moses, DE & Gash, JH 2011, Rainfall interception loss by forest canopies. Forest Hydrology and Biogeochemistry: Springer. pp. 407-423.

Deguchi, A, Hattori, S & Park, HT 2006, The influence of seasonal changes in canopy structure on interception loss: application of the revised Gash model. *Journal of Hydrology*, 318: 80-102.

Fathizadeh, O, Attarod, P, Pypker, TG, Darvishsefat, AA & Zahedi Amiri, Gh 2012, Seasonal variability of rainfall interception and canopy storage capacity measured under individual oak (*Quercus brantii*) trees in western Iran. *Journal of Agricultural Science and Technology*, 15: 175-188.

Fleischbein, K, Wilcke, W, Goller, R, Boy, J, Valarezo, C, Zech, W & Knoblich, K 2005, Rainfall interception in a lower montane forest in Ecuador: effects of canopy properties. *Hydrological Processes*, 19:1355-1371.

Gherboudj, I, Naseema Beegum, S & Ghedira, H 2017, Identifying natural dust source regions over the Middle-East and North-Africa: Estimation of dust emission potential. *Earth-Science Reviews*, 165: 342-355.

Goudarzi, G, Daryanoosh, SM, Godini, H, Hopke, PK, Sicard, P, De Marco, A & Rad, HD, *et al*. 2017, Health risk assessment of exposure to the Middle-Eastern Dust storms in the Iranian megacity of Kermanshah. *Public Health*, 148: 109-116.

Grantz, D, Garner, J & Johnson, D 2003, Ecological effects of particulate matter. *Environment International*, 29: 213-239.

Hall, RL 2003, Interception loss as a function of rainfall and forest types: stochastic modelling for tropical canopies revisited. *Journal of Hydrology*, 280:1-12.

Khaniabadi, YO, Daryanoosh, SM, Amrane, A, Polosa, R, Hopke, PK, Goudarzi, G, Mohammadi, MJ, Sicard, P & Armin, H 2017, Impact of Middle Eastern dust storms on human health. *Atmospheric Pollution Research*, 8: 606-613.

Khosropour, E, Attarod P, Shirvany A, Matinizadeh M, Fathizadeh O 2013, Lead and cadmium concentrations in throughfall of *Pinus eldarica* and *Cupressus arizonica* plantations in a semi-arid polluted area. *Caspian Journal of Environmental Sciences*, 11:141-150.

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Lankreijer, H, Hendriks, M & Klaassen, W 1993, A comparison of models simulating rainfall interception of forests. *Agricultural and Forest Meteorology*, 64:187-199.

Levia, DF 2004, Differential winter stemflow generation under contrasting storm conditions in a southern New England broad-leaved deciduous forest. *Hydrological Processes*, 18:1105-1112.

Llorens, P 1997, Rainfall interception by a Pinus sylvestris forest patch overgrown in a Mediterranean mountainous abandoned area II. Assessment of the applicability of Gash's analytical model. *Journal of Hydrology*, 199: 346-359.

Llorens, P & Gallart, F 2000, A simplified method for forest water storage capacity measurement. *Journal of Hydrology*, 240: 131-144.

Marin, CT, Bouten, W & Sevink, J 2000, Gross rainfall and its partitioning into throughfall, stemflow and evaporation of intercepted water in four forest ecosystems in western Amazonia. *Journal of Hydrology*, 237:40-57.

Muñoz, D, Aguilar, B, Fuentealba, R & Préndez, M 2017, Environmental studies in two communes of Santiago de Chile by the analysis of magnetic properties of particulate matter deposited on leaves of roadside trees. *Atmospheric Environment*, 152: 617-627.

Sadeghi, SMM, Attarod, P & Pypker, TG 2015, Differences in rainfall interception during the growing and non-growing seasons in a *Fraxinus rotundifolia* Mill. plantation located in a semiarid climate. *Journal of Agricultural Science and Technology*, 17: 145-156.

Sadeghi, SMM, Attarod, P, Pypker, TG & Dunkerley, D 2014, Is canopy interception increased in semiarid tree plantations? Evidence from a field investigation in Tehran, Iran. *Turkish Journal of Agriculture and Forestry*, 38:792-806.

Sadeghi, SMM, Attarod, P, Van Stan, JT & Pypker, TG 2016, The importance of considering rainfall partitioning in afforestation initiatives in semiarid climates: A comparison of common planted tree species in Tehran, Iran. *Science of the Total Environment*, 568: 845-855.

Shi, J, Zhang, G, An, H, Yin, W & Xia, X 2017, Quantifying the particulate matter accumulation on leaf surfaces of urban plants in Beijing, China. *Atmospheric Pollution Research*, 8:836-842.

Song, Y, Maher, BA, Li, F, Wang, X, Sun, X & Zhang, H 2015, Particulate matter deposited on leaf of five evergreen species in Beijing, China: Source identification and size distribution. *Atmospheric Environment*, 105: 53-60.

Staelens, J, De Schrijver, A, Verheyen, K & Verhoest, NE 2008, Rainfall partitioning into throughfall, stemflow, and interception within a single beech (*Fagus sylvatica* L.) canopy: influence of foliation, rain event characteristics, and meteorology. *Hydrological Processes*, 22: 33-45.

Tabari, H, Talaee, PH, Nadoushani, SM, Willems, P & Marchetto, A 2014, A survey of temperature and precipitation based aridity indices in Iran. *Quaternary International*, 345:158-166.

Toba, T & Ohta, T 2005, An observational study of the factors that influence interception loss in boreal and temperate forests. *Journal of Hydrology*, 313: 208-220.

Van Dijk, AIJM, Gash, JH, Van Gorsel, E, Blanken, PD, Cescatti, A, Emmel, C, Gielen, B, et al. 2015, Rainfall interception and the coupled surface water and energy balance. *Agricultural and Forest Meteorology*, 214–215: 402-415.

Xiao, Q, McPherson, EG, Ustin, SL, Grismer, ME & Simpson, JR 2000, Winter rainfall interception by two mature open-grown trees in Davis, California. *Hydrological Processes*, 14:763-784.

Xu, X, Zhang, Z, Bao, L, Mo, L, Yu, X, Fan, D & Lun, X 2017, Influence of rainfall duration and intensity on particulate matter removal from plant leaves. *Science of The Total Environment*, 609:11-16.

Yang, HC, Chang, SH, Lu, R & Liou, DM 2016, The effect of particulate matter size on cardiovascular health in Taipei Basin, Taiwan. *Computer Methods and Programs in Biomedicine*, 137:261-268.

Zhongjie, S, Yanhui, W, Lihong, X, Wei, X, Pengtao, Y, Jixi, G & Linbo, Z 2010, Fraction of incident rainfall within the canopy of a pure stand of Pinus armandii with revised Gash model in the Liupan Mountains of China. *Journal of Hydrology*, 385:44-50.

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