Caspian J. Environ. Sci. 2018, Vol. 16 No. 3 pp. 231~239

CJES
Caspian Journal of Environmental Sciences

[Research]

Microdust impact on leaf gas exchange parameters in oak species of Northern Zagros forests, west of Iran

Moradi A.[1]*, Taheri Abkenar K.[1], Afshar Mohammadian M.[2], Shabanian N.[3]

1. *Department of Forestry, Faculty of Natural Resources, University of Guilan, Sowmeh sara, Guilan, Iran*
2. *Department of Biology, University of Guilan, Rasht, Iran*
3. *Department of Forestry, Faculty of Natural Resources, University of Kurdistan, Sanandaj, Iran*

* *Corresponding author's E-mail: aiuobmoradi60@gmail.com* (Received: April 18. 2018 Accepted: Aug. 27. 2018)

ABSTRACT

In recent years, the microdust phenomenon has greatly changed in concentration, duration and continuity as well as the frequency of occurrence in comparison with dust storms in the past which has caused a great deal of concern. Microdust is one of the most devastating factors in the environment threatening all animal and plant species. Regarding to the microdust impending threat, its ecological and economic impacts on scarce species is critical. Zagros forests act as an intrinsic filter for microdust in the western region of Iran. This study investigates the effect of microdust on oak, the most important tree in the Zagros forests. So that, three-year old seedlings of three oak species (*Quercus branti*, *Q. libni and Q. infectoria*) were exposed to microdust under natural conditions during spring and summer 2016. We examined the rate of photosynthesis, stomatal conductance, transpiration, internal CO_2, mesophyll conductance, water use efficiency in control and treated plants. The results indicated that microdust had a significant impact on the examined parameters of the three oak species ($P \leq 0.01$). The gas exchange and photosynthetic rates of the treated plants were significantly reduced. In *Q. infectoria*, microdust had the greatest impact on photosynthesis, stomatal conductance, leaf internal CO_2, transpiration and mesophyll conductance. Accordingly, microdust had a substantial influence on photosynthesis and mesophyll conductance in *Q. brantii* as well as the leaf internal CO_2 and mesophyll conductance in *Q. libani*. Therefore, based on these findings, it can be concluded that microdust can disrupt the physiological activities of the examined species. Hence, continuous - exposure to microdust will accelerate the process of destruction of these forests.

Key words: Microdust, Forest trees, Gas exchange, Zagros.

INTRODUCTION

Iran, situated in an arid and semi-arid zone, is frequently exposed to local and synoptic dust flux (Rasooli *et al.* 2011). Studies in recent years have shown that microdust is greatly varied in concentration, duration and continuity as well as the frequency of this occurrence compared to dust storms in the past and so it has caused huge concern. Prolonged drought, reduction of rainfall and relative humidity along with destructive human activities such as war, misusages of water resources and elimination of canebrake has led to drying of lagoons and lakes in Syria and Iraq which has in turn resulted in an increase in microdust. In the west and south-west of Iran, this phenomenon has had more destructive effects and impact on ecology, economy and the health of inhabitants especially in frontier cities and provinces in a short period of time (Shojaii 2011). Zagros forests as the most extensive ecosystem in Iran is composed of various forest communities at different altitudes and latitudes indicating high ecological significance of these forests. These forests are known as major natural filters acting as the lung in the western areas of Iran. Unfortunately, considerable parts of these forests have been lost in recent years and as a consequence decreased the natural barriers in the way of microdust. In fact, microdust is amongst the most destructive factors causing various ecological and economic problems and affecting all animal and plant species. Clearly, destroying vegetation of lagoons is one of the main reasons for the occurrence of dust storms. Eliminating trees and shrubs would multiply the calamity of this occurrence because forests act as filter and absorb vast parts of dust. According to Hiltron (1990) dust - covered leaves receive less light for photosynthesis which in turn affects the reduction of leaf stomatal conductance influence, plant biomass and the rate of photosynthesis. Stomatal conductance is influenced by environmental factors, position at the canopy and the age of the leaves. Moreover, leaves covered with dust absorb more solar radiation that increase leaf temperature (Wijayratne *et al*. 2009).

Other factors such as sandblasting result in the loss of plant leaves which decrease photosynthetic activities and production of grains or fruits. Dust also impacts soil chemistry and might deteriorate other stresses such as drought or pathogen (Farmer 1993). Studies by Singh & Rao (1981) and Chaturvedi *et al.* (2012) examined the effect of industrial particles on development and physiological parameters of crop.

In addition, Chaturvedi *et al.* (2012) conducted an in-depth study of the chemical composition of dust, its particulate size, age of plants and deposition rate. A study by Darley (1996) found that photosynthesis in green beans is reduced (73%) by cement dust load and Cook *et al.* (1981) observed that the rate of the photosynthesis of apple trees reduced up to 90% by ash. Gas exchanges are an effective factor in plant growth (Si Sakht & Zolfaqari 1993). Nanos & Ilias (2007) investigated the reduced stomatal conductance and transpiration rate of olive trees as a result of cement dust. They found that cement dust diminished leaf total chlorophyll content and chlorophyll a/ chlorophyll b ratio leading to a lessening of photosynthetic rate and quantum yield. Similarly, Shukla *et al.* (1990) concluded that chlorophyll content of plants lessened after exposure to cement dust due to the high alkalinity of cement dust. They found that reduced cross sectional area of stomata and interception in the gas exchanges lead to reduced photosynthesis. Despite the outstanding role of forests in microdust absorbance and air filtration, few studies have been conducted to examine the rate of dust absorbance by various forest species. These valuable resources in the Zagros habitat have been facing the problem of microdust in recent years. Hence, we examined the effects of dust on some eco-physiological parameters in three oak species including *Quercus Brantii* Lindl., *Q. libni* Oliv. and *Q. infectoria* Oliv.

MATERIALS AND METHODS

To assess the effects of microdust, three-year old seedlings of oak trees including *Quercus branti*, *Q. libani* and *Q. infectoria* were used. The potted seedlings from Rixlan nursery, Department of Natural Resources from Mariwan city in Iran were transferred to the study region in Chenare district of Mariwan forests on March 4, 2015. This region is on the path of dust movement and positioned at longitude range of 616862 to 621940E and at latitude range of 3940705 to 3947100N in 38s zone in the UTM coordinate system with heights of 1450 and 2100 m above sea level, respectively (Fig. 1). Seedlings were divided into two groups of 15 pots. Five potted seedlings of each species were placed in individual groups. One group was assigned as the dust treatment and the other as control which was washed regularly to remove dust. The seedlings were irrigated once every 3 days from April 6 through July 6 2015. At irrigation, the leaves of control pots were washed to remove dust while water was only poured in the pots with no leaf contact in the dust treatment pots. To have accuracy in the research procedure, the direction of wind on the pots was marked. IRGA (Infrared Gas Analyser), LCI (ADC Company) were used to measure the photosynthetic and transpiration rate, stomatal conductance and the concentration of leaf internal CO_2. All measurements were conducted at 11 AM with light intensity of 1400-1600 μm m^{-2} s^{-1}. To measure these parameters, the third leaf from the branch top (in the same direction) was selected to put in the leaf chamber for 45 seconds (Rohi & Siose Marde 2009).

To determine the water use efficiency (WUE), the photosynthetic rate was divided by the value of stomatal conductance (cf.), and mesophyll conductance was estimated by dividing the photosynthetic rate by the value of leaf internal CO_2 concentration (Rohi & Siose Marde 2009).

After checking the normality of the data and residuals (by Kolmogorov-Smirnov test), data was analyzed as a factorial project including two- factors, type of the species *(Q. branti, Q. libni* and *Q. infectoria)* and microdusts at two levels (one containing micro dust and the other without micro dust as control). Then, Duncan test was performed to study the difference between means when the assumption of equality of variances was conformed. All analyses were conducted using SPSS software, version 23.

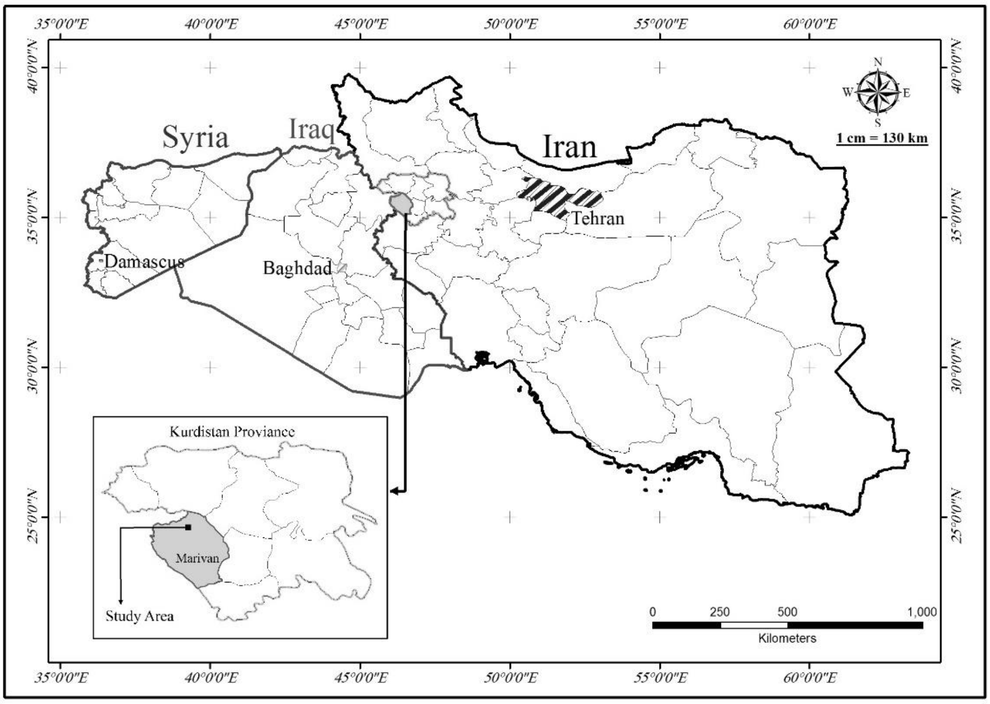

Fig. 1. Location map of the study area.

RESULTS

As shown in Table 1, in general, type of the species did not significantly affect the photosynthetic rates of control plants (P = 0.262). In other words, no significant difference was observed regarding the photosynthetic rates of the examined species. However, microdust deposition influenced the photosynthetic rates of the treated species significantly ($P \leq 0.01$). In addition, the mutual effects of microdust and species on photosynthetic rates was not statistically significant; this means that each factor (species and microdust) influenced the photosynthetic rates independently. According to the results, photosynthesis, stomatal conductance, leaf internal CO_2, mesophyll conductance and water use efficiency were not significantly different amongst the examined species. However, microdust deposition on the leaves of these species significantly influenced the examined parameters (except for transpiration, P = 0.29). To check the variance of means, the Duncan test was used. Table 2 demonstrates a summary of the obtained variables of gas exchange parameters. The results in Table 2 show the statistically- significant influence of microdust on gas exchange rates in the examined species treated by microdust. In *Q. infectoria*, microdust had the most significant impact on photosynthesis, stomatal conductance, leaf internal CO_2, transpiration and mesophyll conductance. Accordingly, microdust had a substantial influence on the photosynthesis and mesophyll conductance in *Q. brantii* as well as on the leaf internal CO_2 and mesophyll conductance in *Q. libani*. However, microdust did not greatly affect the water use efficiency of the examined species compared to the control group.The means comparison charts of investigated parameters in both dust treated and control plants are shown in Fig. 2.

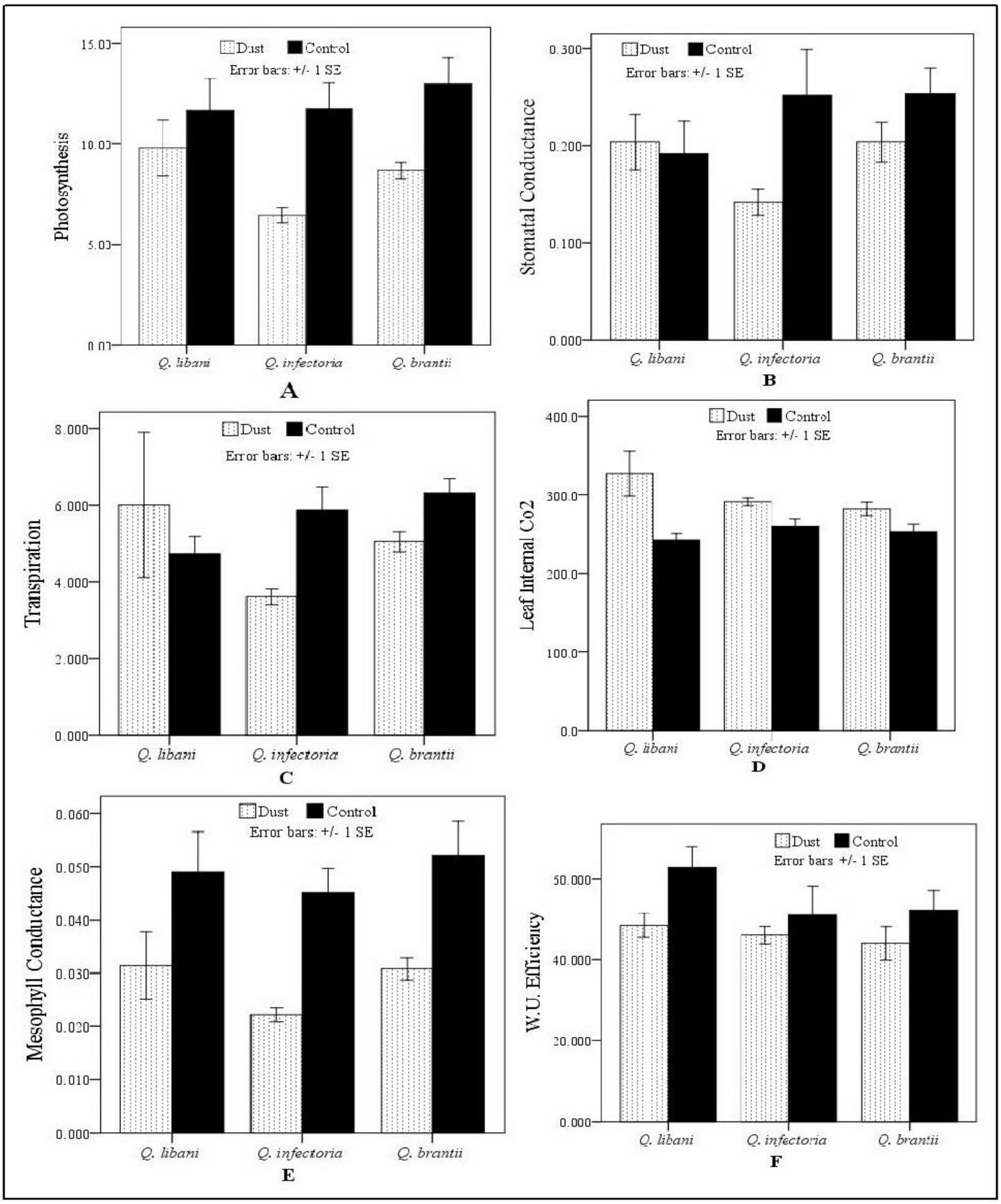

Fig. 2. Comparison of the gas exchange parameters in the examined species under dust effect. A: photosynthesis (μmol CO_2 m^{-2} s^{-1}), B: stomatal conductance (mmol H_2O m^{-2} s^{-1}) C: transpiration (mmol H_2O m^{-2} s^{-1}) D: Leaf internal CO_2 (mmol) E: Mesophyll conductance (mmol CO_2 m^{-2} s^{-1}) F: Water use efficiency (μmol CO_2 mol^{-1} H_2O).

Table 1. The results of analyzed data obtained from the LCI using the ANOVA and Duncan test. ANOVA test on gas exchange data of the examined species treated with microdusts.

variable	source	df	F
Photosynthesis	species	2	1.419 ns
	treatment (microdust)	1	16.43 **
	treatment * species	2	1.15 ns
	fault	24	---
	total	29	---
Stomatal conductance	species	2	0.72 ns
	treatment (microdust)	1	4.01 *
	treatment * species	2	2.05 ns
	fault	24	---
	total	29	---
Leaf Internal CO_2	species	2	0.7 ns
	treatment (microdust)	1	18.1 **
	treatment * species	2	2.56 ns
	fault	24	---
	total	29	---
Transpiration	species	2	0.6 ns
	treatment (microdust)	1	1.1 ns
	treatment * species	2	2.2 ns
	fault	24	---
	total	29	---
Mesophyll conductance	species	2	1.24 ns
	treatment (microdust)	1	23.09 **
	treatment * species	2	0.13 ns
	fault	24	---
	total	29	---
Water use efficiency	species	2	1.6 ns
	treatment (microdust)	1	5.75 **
	treatment * species	2	0.52 ns
	fault	24	---
	total	29	---

ns: not significant*: significant at 5%.
**: significant at 1%.

DISCUSSION

According to the results of the present study, there was no significant difference between the three examined oak species concerning to the gas exchange parameters in control plants unlike treatments with microdust. In general, photosynthetic reduction is one of the main reasons for reducing plant growth. Limiting factors in photosynthesis are categorized into two groups: a) stomatal factors leading to reducing CO2 diffusion in intercellular space as a result of decreased stomatal conductance and b) non-stomatal factors limiting photosynthesis by direct effect of water shortage on biochemical process of carbon production (Sio-se Marde *et al.* 2005). Fischer *et al.* (1998) have reported that the main limiting factor in photosynthesis is the decreased mesophyll conductance.

They believe that a fundamental factor in photosynthesis reducing, is the closure of stomata under drought conditions leading to a decreased stomatal conductance, and as a consequence, reduced photosynthetic rate. In fact, stomatal limitations reduce the rate of photosynthesis and CO_2 concentrations in intercellular space of leaves and in turn, lead to decreased biomass of plants (Lawlor & Cornic 2002). According to previous studies, stomatal factors are limiting ones for photosynthesis (Rohi & Siose Marde 2009). In the present study, results illustrated that stomatal pores are closed by microdust and thus tend to limit gas exchange rates through stomata. In relation to photosynthesis, as exhibited in Fig. 2, trees exposed to microdust had a lower photosynthetic rate compared to control trees in the three examined species. In fact, microdust caused decreased photosynthesis. Microdust could close the stomatal pores. So, closed stomata concerning to the reduced light absorption due to microdust deposition on the leaves might also cause disorders in gas exchanges, hence decreased photosynthetic rate as well as the rate of vegetative products or biomass. Deposition of smaller particle sizes leads to stronger reduced photosynthesis compared to coarse particles (Hirano *et al.* 1990). This effect is seemingly due to the closer lining of dust particles on leaf surface leading to a greater shading effect of photosynthetically active radiation (PAR). The rate of reduction in photosynthesis is directly related to stomatal closure and also decreased light absorption by the covered leaves with microdust. This is the most universal problem in plants exposed to microdust. Takashi (1995) reported that plants exposed to enormous resources of microdust are brought into hazard such as chronic reduced photosynthesis and consequently reduced plant growth. Thus, it was concluded that a diameter of one-millimeter coverage of ash on leaves reduces the photosynthetic rate by 90%. In a lesser diameter, the rate of reducing varies from 25% through 33%. Of course, this effect depends on the condition and the type of the plants. Microdust deposition on leaf area in addition to causing a reduced photosynthesis leads to hasty leaf senescence and therefore a delay in plant development as well as decrease in whole plant function (Arvin *et al.* 2014).

Similar to our results, Takashi (1995) also found that microdust reduced stomatal conductance. Stomata plays a main role in three vital activities: photosynthesis, transpiration and respiration in plants. Williams & Ricks (1974) pointed out that closure of stomata by little particles such as dust in addition to the reduced photosynthesis and transpiration will decrease the rate of respiration, while increase the stomatal resistance of plants at night. However, the level of the negative impact of dust depends on both the size of dust particles and the microstructure of the plants.

A decreased leaf internal CO_2 concentration stimulates stomata to be opened (Mojtahedi & Lesani 2008).

Table 2. Variables of gas exchange parameters of the studied species treated with microdusts.

		Species		
Variables	**Treatment**	***Quercus libani***	***Quercus infectoria***	***Quercus Brantii***
Photosynthesis	Microdust	9.8 ± 1.38^{abc}	6.4 ± 0.39^{a}	8.67 ± 0.4^{ab}
(μmol CO_2 $m^{-2}s^{-1}$)	control	11.68 ± 1.57^{bc}	11.57 ± 1.29^{bc}	13 ± 1.29^{c}
Stomatal Conductance	Microdust	0.2 ± 0.02^{ab}	0.14 ± 0.01^{a}	0.2 ± 0.02^{ab}
(mmol H_2O $m^{-2}s^{-1}$)	control	0.19 ± 0.03^{ab}	0.25 ± 1.29^{b}	0.25 ± 0.02^{b}
Leaf Internal CO_2	Microdust	326.8 ± 28.5^{c}	291.2 ± 4.63^{bc}	282.4 ± 8.25^{ab}
(mmol)	control	242.2 ± 9.06^{ab}	260.8 ± 9.03^{a}	253.4 ± 9.3^{ab}
Transpiration	Microdust	6 ± 1.8^{a}	3.6 ± 0.2^{a}	5.04 ± 0.26^{a}
(mmol H_2O $m^{-2}s^{-1}$)	control	4.73 ± 0.44^{a}	5.87 ± 0.59^{a}	6.3 ± 0.39^{a}
Mesophyll Conductance	Microdust	0.03 ± 0.006^{ab}	0.02 ± 0.002^{a}	0.03 ± 0.002^{ab}
(mmol CO_2 $m^{-2}s^{-1}$)	control	0.04 ± 0.007^{c}	0.04 ± 0.004^{bc}	0.05 ± 0.006^{c}
Water Use Efficiency	Microdust	48.5 ± 3.02^{ab}	46.1 ± 2.2^{a}	44.07 ± 4.2^{a}
(μmol CO_2 mol^{-1} H_2O)	control	62.9 ± 5.11^{b}	51.1 ± 7.1^{ab}	52.3 ± 4.9^{ab}

Similar Roman letters beside means of any parameter indicates no difference at 5% level between attributes.

In the present study, as shown in Fig. 2, although microdust increased leaf internal CO_2 concentration in all three examined oak species, but the gas exchange rates including photosynthesis decreased because of the stomatal blockage by microdust. Generally, stomatal limitations lessen the photosynthetic rates leading to decreased plant production

(Lawlor & Cornic 2002). With respect to non-stomatal limitations, the mesophyll conductance trait (the ratio of photosynthetic rate to internal CO_2 concentration) is a substantial factor. Reduced mesophyll conductance is one of the main limiting factors in photosynthesis (Fischer *et al*. 1998, Barutcular *et al.* 2000). The results of this study showed that microdust lessen mesophyll conductance in the three examined species. The lower mesophyll conductance is an indicator of a lower photosynthetic rate due to decreased amount of CO_2 entrance into stomata. It has been reported that decreasing photosynthetic rate might be accompanied by an increase in the concentration of the leaf internal CO_2, indicating the role of non-stomatal factors impacting photosynthesis (Siose Marde *et al.* 2005). In fact, reducing photosynthesis correlates with both stomatal and non-stomatal factors. However, the decreases in both photosynthesis and stomatal conductance mostly occur due to stomatal limitations. Therefore, based on the present findings, the decreased stomatal conductance of microdust in treated leaves might lessen photosynthesis in the three examined oak species. In conclusion, these results show that microdust is an immense threat to the examined species and generally to the Zagros forests as a single natural filter for microdust. Moreover, there has been no regeneration of trees in these forests resulting in the forests being pushed back toward the old forest. In such a situation, forests are faced to various dilemmas of canopy density reducing, low diversity of plant and animal species, flooding, rising temperatures, the occurrence of microdust storm, as well as reduced atmospheric water storage. In conclusion, microdust is truly the most devastating environmental factor since it affects all animal and plant species causing ecological and economic destruction.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the staff of the Agricultural Research and Education Organization, Dr. Parviz Moradi and Mr. Esmaeil Sohrabi for their useful guidance as well as their laboratorial support. In addition, the authors would like to thank Mr. Hamid Qiyasaddin who coordinated with the nursery and Mr. Amin Rastad who assisted in the forest work undertaken.

REFERENCES

Arvin, A & Cheraqi, S 2014, Study on effects of microdust on quantitative and qualitative processes of reedy growth, variant CP57-614. *Researches on Natural Geography*, 45: 95-106.

Barutcular, C, Genc, I & Koc, M 2000, Photosynthetic water use efficiency of old and modern durum wheat genotypes from southeastern Turkey. In Proceeding of Seminar on Durum Wheat Improvement in the Mediterranean Region: *New Challenges,* Series A: 233-238.

Chaturvedi, RK, Prasad, S, Rana, S, Obaidullah, SM, Pandey, V & Singh, H 2013, Effect of dust load on the leaf attributes of the tree species growing along the roadside. *Environmental Monitoring and Assessment,* 185: 383‑391.

Cook, RJ, Barron, JC, Papendick, R & Williams, GJ 1981, Impact on agriculture of the Mount St. Helens Eruptions. *Science*, 211: 16–21.

Darley, EF 1966, Studies on the effect of cement-kiln dust on vegetation. *Air Pollution Control Association,* 16: 145–150.

Farmer, AM 1993, The effects of dust on vegetation—A review. *Environmental Pollution,* 79: 63–75.

Fischer, RA, Rees, D, Sayre, KD, Lu, ZM, Candon, AG & Saavedra, AL 1998, Wheat yield progress associated with higher stomatal conductance and photosynthetic rate, and cooler canopies. *Crop Science,* 38: 1467-1475.

Hirano, T, Kiyota, M, Kitaya, Y & Aiga, I 1990, The physical effects of dust on photosynthetic rate of plant leaves. *Applied Meteorology,* 46: 1-7.

Hitron, O & Zur, B 1990, Differences in stomatal response within cotton canopy. *Biotronic*, 19: 39–48.

Lawlor, DW & Cornic, G 2002, Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant, Cell & Environment*, 25: 275–294.

Mojtahedi, M & Lesani, H 2008, the life of the green plant. 6th edition, Tehran University Publication, 587p.

Nanos, GD & Ilias, FI 2007, Effects of inert dust on olive (*Olea europaea* L.) leaf physiological parameters. *Environmental Science and Pollution Research,* 14: 212–214.

Rasooli, A, Sari Saraf, B & Mohammadi, QH, 2011, The Analysis of process and appearance of dust, as a continental phenomenon, in western regions of Iran in recent 55 years using non-parametric statistic fashions. *Quarterly of Natural Geography,* 3: 15-28.

Ricks, GR & Williams, RJH 1974, Effects of atmospheric pollution on deciduous woodland. Part 2: Effects of particulate matter upon stomatal diffusion resistance in leaves of *Quercus Petraea* (Mattuschka) Leibl, *Environmental Pollution,* 6: 87-109.

Rohi, A & Sio-se Marde, A 2009, A study on gas exchange in various genotypes of wheat exposed to drought stress. *Scientific Magazine of Sapling & Seeds,* 24: 45-62.

Shojaii, M 2011, Study on occurrence of dust phenomenons and its effects on prevalence of cardiac and respiratory diseases in Khoozestan Province, Iran. MSc. thesis. Islamic Azad University and Islamic Research and Science Institute, Tehran, Iran. 93p.

Shukla, J, Pandey, V, Singh, SN, Yunus, M, Singh, N & Ahmad, KJ 1990, Effect of cement dust on the growth and yield of *Brassica campestris* L. *Environmental Pollution,* 66: 81–88.

Singh, SN & Rao, DN 1981, Certain responses of wheat plants to cement dust pollution. *Environmental Pollution,* 24: 75–81.

Sio-se-Marde, A, Ahmadi, A, Poostini, K & EbrahimZade, H 2005, The stomatal and non-stomatal factors controlling photosynthesis and its relations to drought in wheat sorts. *Magazine of Iranian Agricultural Science,* 35: 93-106.

Takashi, H 1995, Studies on the effects of dust on photosynthesis of plant leaves. Laboratory of Environmental Control in Biology, College of Agriculture, *Environmental Pollution,* 89: 255-261 (In Japanese).

Wijayratne, UC, Scoles-Scilla, SJ & Defalco, LA 2009, Dust deposition effects on growth and physiology of the endangered *Astragalus Jaegerianus* (Fabaceae). *Madroño*, 56: 81–88.

اثر ریزگردها روی پارامترهای تبادلات گازی گونه‌های بلوط در جنگل‌های زاگرس شمالی

مرادی الف.[۱*]، طاهری آبکنار ک.[۱]، افشار محمدیان م.[۲]، شعبانیان ن.[۳]

۱- گروه جنگلداری، دانشکده منابع طبیعی، دانشگاه گیلان، صومعه‌سرا، ایران
۲- گروه زیست شناسی، دانشکده علوم، دانشگاه گیلان، رشت، ایران
۳- گروه جنگلداری، دانشکده منابع طبیعی، دانشگاه کردستان، سنندج، ایران

(تاریخ دریافت: ۹۷/۰۱/۲۹ تاریخ پذیرش: ۹۷/۰۶/۰۵)

چکیده

پدیده گرد و غبار در سالهای اخیر از نظر غلظت و جریان ذرات معلق، تداوم، وسعت و زمان آن متفاوت و بسیار بیشتر از طوفانهای گرد و خاک در سالهای گذشته است و این سبب نگرانی‌های بسیاری شده است. ریزگردها از جمله مخرب‌ترین عوامل زیست محیطی می‌باشند که بر تمام گونه‌های گیاهی و جانوری تأثیر داشته و با تهدید گونه‌های نادر جانوری و گیاهی، ارزش اکولوژیک و اقتصادی آنها را تهدید می کنند. جنگل‌های زاگرس به عنوان یکی از مهمترین فیلترهای طبیعی در مقابل این پدیده، در غرب ایران هستند. این تحقیق به منظور بررسی اثر ریزگرد روی گونه‌های بلوط به عنوان مهمترین گونه درختی جنگلهای زاگرس انجام شد. بدین منظور، نهال‌های سه ساله گونه‌های بلوط (*Quercus brantii*, *Quercus libani*, *Quercus* infectoria)، در قالب طرح فاکتوریل در شرایط طبیعی در منطقه جنگلی مورد مطالعه در طول فصول بهار و تابستان سال ۱۳۹۵در معرض ریزگردها قرار داده شدند. میزان فتوسنتز، هدایت روزنه‌ای، تعرق، غلظت CO_2 درون روزنه‌ای، هدایت مزوفیلی و کارایی مصرف آب فتوسنتزی در نمونه‌های تحت تیمار ریزگرد و شاهد ارزیابی شدند. نتایج تحقیق نشان داد ریزگردها بر روی پارامترهای مورد بررسی در هر سه گونه تاثیر معنی داری دارد ($P \leq 0.01$). میزان تبادلات گازی و فتوسنتز در گونه‌ها تحت تأثیر ریزگرد کاهش یافت. ریزگردها بیشترین تأثیر را در گونه مازودار (*Q. infectoria*) روی پارامترهای فتوسنتزی، هدایت روزنه‌ای، میزان CO_2 درون روزنه‌ای، تعرق و هدایت مزوفیلی داشت. به همین ترتیب ریزگرد در گونه برودار (*Q. Brantii*) روی پارامترهای فتوسنتز و هدایت مزوفیلی و در گونه وی‌ول (*Q. libani*) روی پارامترهای CO_2 درون روزنه‌ای و هدایت مزوفیلی تأثیر معنی‌داری داشت. بنابراین بر اساس نتایج این تحقیق، می‌توان نتیجه گرفت که ریزگردها سبب اختلال در فعالیت‌های فیزیولوژیک گونه‌های مورد مطالعه شده و استمرار جریان ریزگردها، روند تخریب این جنگلها را سرعت می‌بخشد.

*مؤلف مسئول