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The effect of dust particles on the wettability of some native plants in Zagros Mountains, Iran

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Abstract. In recent years, in addition to pollution from cars, factories and other polluting devices, the country of Iran has been the destination of dust that have entered from Iraq and Saudi Arabia and caused pollution of the climate. In this research, the wettability of some native plants in Zagros Mountains has been investigated experimentally by measuring the contact angle. Sampling of oak trees of *Quercus brantii* Lindl. species was carried out around Khorramabad city, Nozhian waterfall, Chegheni city, and recreation area of Shoorab forest park. Forty samples of oak leaves, red mulberries of *Morus rubra* L. species and white mulberries of *Morus alba* L. species were randomly selected and the contact angle of the water drop on them was measured using a contact angle goniometer and also separately measured by Image J software. Under the influence of the dust, it was observed that the contact angle of the leaf area was completely eliminated, but the contact angle of the abaxial leaf surface had not changed; this change in the contact angle seem to be due to the loss of acylic cyst of the oak leaf caused by the disruption of the photosynthesis operation. Oak trees absorb contaminants. This problem eliminates leaf pores and dry leaves. Also, results show that the oak leaves are hydrophobic and have good resistance to drought. However, the presence of a lot of dust causes water droplets to spread completely on the oak leaves, thus reducing watering to the roots. As a result, dust reduces the resistance and resilience of oak trees against drought. Present study is very important for protection and monitoring of forest health and prevention of the reduction of plant species diversity.

Keywords: Brant's oak, red mulberry, white mulberry, leaf surface, surface contamination, dust accumulation; hydrophobicity, contact angle.

1. Introduction

By studying the wettability of oak leaves in different months of the year, Klamerus and Blonska (2017) found that with change in the season and the influence of atmospheric factors on the oak leaf, chemical changes occur inside the oak leaf and cause the instability of the contact angle on the leaves. The contact angle (wetting angle) is a measure of the wettability of a solid by a liquid. They also found that the lower part of the leaf had more contact angle, and the leaves that were less exposed to sunlight had lower contact angles. Also, dusty particles change the contact angle. As the age of the leaf grows, the contact angle decreases in the fall. They found that regardless of the age of the leaf, the upper leaf area had a higher surface energy than the lower part of the leaf. Wang et al. (2014) examined 60 species of trees and plants in the Chinese province of Shanxi. They found that wettability of water droplets on leaves significantly differed from one species to another. Also, the results showed that maintaining the water drop by leaf is affected by physical and chemical changes. This effect may be the result of capillary action, as well as the adhesion of the leaves surface with water or this adhesion due to surface roughness.

It was shown that the photosynthesis and plant gas exchange rapidly decreased when a large surface of the leaf was covered with a thin layer of water (Lott, 2021). Because the carbon dioxide penetration in water is 10,000 times slower than its penetration into the air. The structure and chemical composition of the wax of the epicuticular layer is not the same in all plants. Depending on the climatic conditions, the leaf may have a hydrophilic or hydrophilic surface. But the structure and chemical composition of the waxy epicuticular layer can be altered by atmospheric pollutants and physical friction by the wind, and thus affect the leaf wettability.

Other studies (Barnes & Brown, 1990; Honour et al., 2009; He et al., 2019) have shown that, in addition to environmental factors, the aciclovir character also plays a significant role in leaf wettability. It should be noted that leaves with a hydrophobic layer do not allow water droplets to remain on the leaf surface. In these plants, droplets can easily slide from the leaf surface and lead to the soil. In this way, the available root water of the plant increases. This feature is very important for plants in arid and semi-arid regions (Holder, 2012). As a result, the hydrophobicity of the leaf increases the activity of photosynthesis and reduces fungal and bacterial diseases in plants (Hanba et al., 2004). A study by Wang and Dai (2016) showed that the effect of epidermal wax distributed on the leaf surface directly affects surface properties. It has been observed that annual precipitation has a significant effect on the leaf hydrophobicity, which is associated with changes in the season and the influence of atmospheric agents on oak leaves (Klamerus & Blonska, 2017).

Dust emission is the greatest source of aerosols and have implications on radiation balance, climate and human and biocenoses health such as respiratory problems and plants (closing of stomata) (Bogunovic et al., 2019). Considering that oak leaf surface is exposed to atmospheric pollutants, microorganisms, fungal and bacterial diseases, and other environmental factors, it is important to be aware of wettability of the leaf area for examining the removal or absorption of small particles. Estimation of leaf damage in the protection and monitoring of forest health and prevention of the reduction of plant species diversity is very important; therefore, it is advisable to identify easy and cost-effective methods that can be taken quickly and on time. So far, no qualified, quantitative data are available about the contamination of leaf surfaces during a whole growing season.

In this study, the wettability of red mulberries of *Morus rubra* species, white mulberries of *Morus alba* species and oak leaves of *Quercus brantii* species are studied by measuring the contact angle of the water drop on the oak leaf surface, differing in micromorphology and wettability in respect to their contamination during one growing season to verify the assumption that sustained water-repellency protects plants from surface contamination. The purpose of this study is to answer the question of how much the wettability of the dominant species of Zagros Mountains in this region can withstand water scarcity and climatic conditions and dust.

2. Methods and materials

2.1. Plant materials

Oak. *Quercus brantii* Lindl., the Brant's oak, is a species of oak native to Western Asia, including Iran, Iraq, Syria, and Turkey. *Quercus brantii* (covering more than 50% of the Zagros forest area) is the most important tree species of the Zagros in Iran.

Morus. In order to examine the effect of dust rejection or absorption through leaf of trees on other tree species in investigated area, the wettability of white mulberry of *Morus alba* L. species and red mulberry of *Morus rubra* L. species in Zagros areas could also be investigated.

Leaves examined in this research are selected from Khorramabad city, Nozhian waterfall, Chegheni city, and recreation area of Shoorab forest park, 48° 21' E, 33° 29' N, which is located in Lorestan province, Zagros region, western of Iran (Fig. 1).

The average annual rainfall in these areas is 499 mm and suspended particles in the air was between 100 and 150 $\mu g\ m^{-3}$ air.

2.2. Measurement

Contact angle measurements were taken using a VIT-ES20 goniometer (Fars EOR Tchnologies Co., Iran) in ambient air at 39–43°C and 14–15% relative humidity (see Fig. 2).

Samples were collected with 10-yr-old trees in the early hours of the morning and in late June to mid-moon, and was immediately transmitted to the laboratory for measuring the contact angle. Two twigs per tree from ten different trees were chosen to receive different radiation.

Figure 3 shows the leaves that were washed with water, and then measurements are made on it.

To ensure the repeatability of the experiment results for an identical condition of the leaf, the measurement is repeated 40 times. The middle of the leaf to 2 cm where the main vein is not being cut and placed in the test point with a double-sided adhesive tape (Kardel et al., 2012). The points that are considered in the accurate measurement of the contact angle of the droplet on the surface of the leaves are:

- All images were taken at certain hours of the day in a room with constant temperature and relative humidity
- Since the epiglottis wax may not be uniformly distributed on the leaf surface, measurements were made from several points from the middle of the leaf surface.
- The temperature of the used water droplet was constant.
- The backlight was adjusted so that the color of the drop image was completely opposite to the background color behind the drop image.

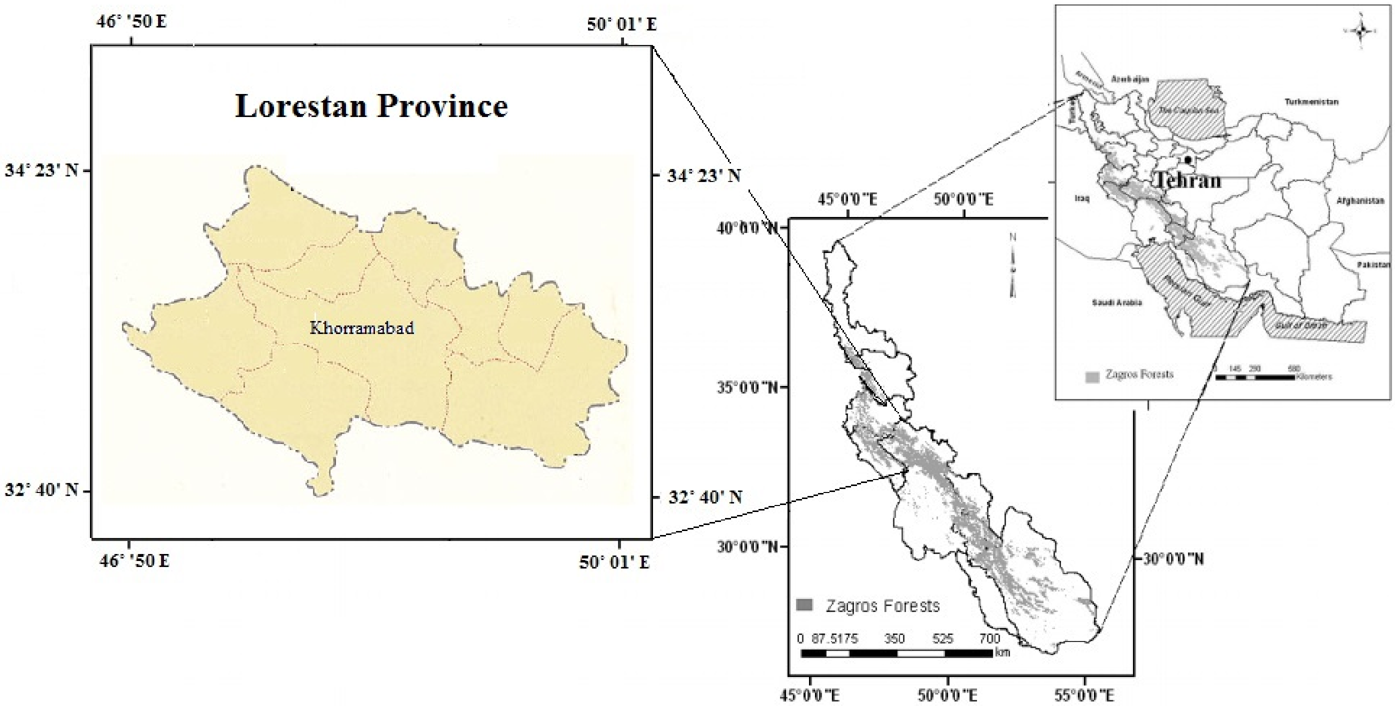

Figure 1. Location of the study site in the Zagros forests of western Iran, Lorestan Province

Figure 2. Angle contact measurement device

Figure 3. The oak tree washed with water

Distilled water was used in this experiment and between one to three drops of 5 to 10 microliters of distilled water was placed on the sample with a nozzle mounted on the device. The system automatically records the left, right, and average contact angles. Figure 4 shows an example of a drop on the surface of the oak tree in the software.

To ensure the accuracy of the measurements, the contact angle was also measured individually using the Image J software via photos stored on the computer (Stalder et al., 2010) (see Fig 5).

The leaves of the tree were first washed with water to eliminate contamination and dust from the leaf surface.

The wettability of the leaf of the tree is considered in accordance with Table 1.

Table 1. Classification of leaf wettability (Aryal & Neuner, 2010)

Classification	Cntact angle (°)
Superhydrophilic	<40
Highly wettable	40-90
Wettable	90-110
Non-wettable	110-130
Highly non-wettable	130-150
Superhydrophobic	>150

Figure 4. A drop on the surface of the oak tree leaf in the software

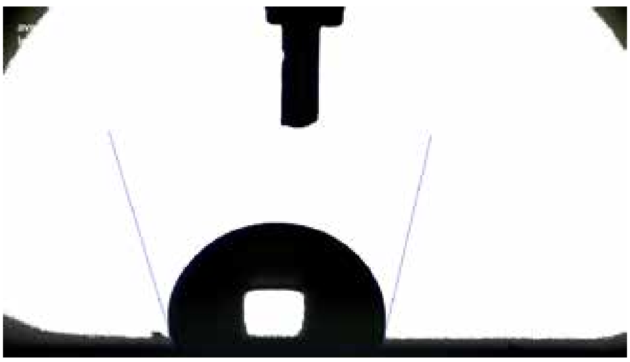

Figure 5. Contact angle measured with Image J software

3. Results

In this section, the results of the two perspectives of the leaf wettability and the dust effects are examined. Figure 6 shows the mean of left and right contact angles of the adaxial and abaxial leaf surface for 40 samples of oak tree.

As shown, the contact angle of adaxial and abaxial leaf surface is about 110.3° and 124.6° respectively. Figure 7 shows the water drop placed on the underside and the adaxial part of the leaf covered with the dusty and the clean leaf.

It is observed that in the presence of dust, water droplets spread on the adaxial leaf surface and do not form any droplet (contact angle equal to zero).

Experiments were also performed in a similar way for white mulberry and red mulberry. The measurement results of white mulberry and red mulberry for comparison with the leaves of the oak tree are presented in Table 2.

Table 2. Contact angle as average ± standard deviation, for oak, white mulberry and red mulberry

Abaxial (°)	Adaxial (°)	Tree type
124.6±7.1	110.3±12.9	Oak
74±6.5	58±7.4	White mulberry
77±8.5	64±11.3	Red mulberry

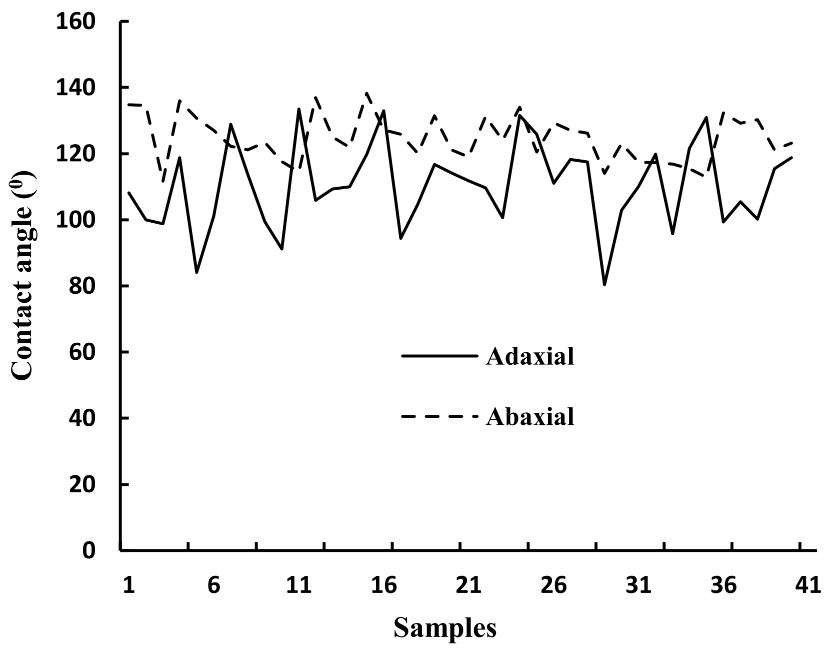

Figure 6. Contact angle of adaxial and abaxial leaf surface of oak tree

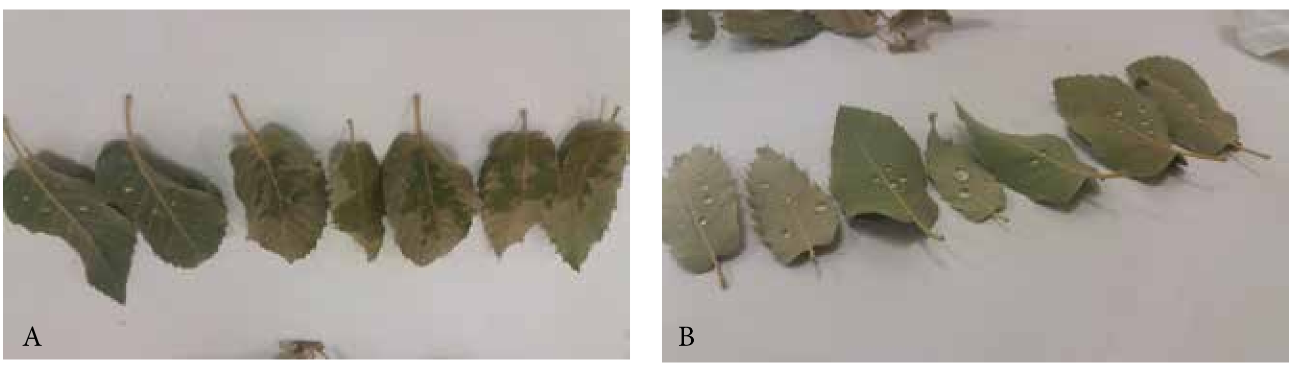

Figure 7. The water drop placed on the polluted leaf and the clean leaf of the oak tree
(From right to left, the first two leaves are clean and the next five leaves are infected with the dust).
A) the adaxial leaf surface; and B) the abaxial leaf surface

4. Discussion

4.1. Contact angle and wettability

As shown in the result, the contact angle of adaxial leaf surface is 110.3° that indicates hydrophobicity. This property prevents water absorption by the leaves of the oak tree. The contact angle of abaxial leaf surface is higher than that of the adaxial one, which is according to other investigators' research (Klamerus & Blonska, 2017; Kardel et al., 2012; Wagner et al., 2003). In these plants, water droplets easily slide from the surface of the leaf and pour down into the tree on the soil, thereby increasing the available water of the root.

4.2. Dust effects

The contamination caused by the presence of dust and soil on the leaves of oak trees can affect wettability. According to Figure 7, it can be stated that the leaf hydrophobicity causes the dust and cornflower to be washed with water droplets from the leaf surface and, with elimination of contamination, increases photosynthesis activity and decreases fungal and bacterial diseases (Pinon et al., 2006).

The measurement conditions of the contact angle of mulberry tree leaves is similar to those of the oak leaves. As shown in Table 2, the leaves of white and red berries are hydrophilic. This means that the leaves of this group of trees, in contrast to the oak trees, allocate less water to the root of the tree. In Figure 7, as expressed, the five left leaves are dusty and the two right leaves are clean. For dusty leaves, it was determined that there is no contact angle or very low contact angle (see Fig. 7A). That is, a water drop on a leaf that is dusty thoroughly spreads. But the abaxial leaf surface is not affected and shows almost the contact angle of the clean leaves. In other words, dust only affects the adaxial leaf surface. On the other hand, contamination and dust accumulation on the surface of the oak leaf inhibit photosynthesis and cause the epiglottis on the leaf surface to disappear. During transpiration, the tree leaves, sends the steam to the air. But dust prevents the vapor to spread in the environment and deposits on the leaf surface and cleans the acuminate on the leaves surface, causing the leaf to be hydrophobic. It can be said that oak trees absorb contaminants and eliminate leaf pores and dry leaves. This problem, in the long time, causes the loss of the foliage and the stiffness of photosynthesis. This conclusion is also in agreement with the others results (Brewer et al., 1991; Darley, 1996; Meravi et al., 2021).

Therefore, leaves with high hydrophobicity have the highest potential for contamination. But in any case, contamination leads to damage to the leaf area. On the dust-contaminated leaf, there are stains of water causing the surface to become clouded; these spots can be caused by plant transpiration. Dust and thimble do not allow the transpiration and release of water vapor from the leaves surface properly and cause infections and fungi in the leaves, and also it can disrupt breathing and photosynthesis. This can lead to the death of the tree in the long time. Dust also reduces carbon dioxide exchange rates.

5. Conclusions

By measuring the contact angle, it was found the leaves of the oak tree were hydrophobic and resistant to low rainfall. The particulates greatly compromise the biological process of the tree through the disturbance of tree breathing.

Under the influence of the dust, it was observed that the contact angle of the leaf area was completely eliminated, but the contact angle of the abaxial leaf surface had not changed; this change in the contact angle seem to be due to the loss of acylic cyst of the oak leaf caused by the disruption of the photosynthesis operation. Oak trees absorb contaminants. This problem eliminates leaf pores and dry leaves. The effect of photosynthesis and plant gas exchange decrease immediately when a large surface of the leaf is covered with a thin layer of dust.

Also the structure and chemical composition of the epiglottis wax layer can change due to atmospheric pollutants such as dust. Also, hydrophobicity of oak tree leaf means that by dropping rain, water droplets are poured down into the tree and the tree is used which is consistent with the low rainfall conditions of the Zagros areas.

It was observed that if the amount of dust is low, the hydrophobic properties of oak leaves are useful and protect the tree and water-repellent leaf surfaces exhibit almost perfect self-cleaning properties ('Lotus-effect'). However, at high levels of dust, this property disappears and is not effective.

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