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Research Paper

Impact of aeolian dust accumulation on some biochemical parameters in black saxaul (Haloxylon aphyllum Bunge) leaves: a case study for the Aran-Bidgol region, Iran

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Abstract: Many factors threaten the survival of desert plant species. One of the most prevalent is aeolian dust accumulation, generated by soil surface disturbance. Nevertheless, the influence of aeolian dust accumulation on plant physiology has hardly been investigated. Therefore, the effect of aeolian dust accumulation on some biochemical parameters in *Haloxylone aphyllum* was evaluated for the pan-Asiatic distribution and its key role in desert rehabilitation. The amount of dust trapped by an increasing coverage of (20%) was 1.77, 1.80, 2.43, 2.10 and 2.72 times of that by the control, respectively. Reductions in chlorophyll *a* (Chl. *a*), chlorophyll *b* (Chl. *b*) and total carotenoids (Cr) were observed in the leaf samples among the treatments. The ratio of Chlorophyll a/b and chlorophyll (*a*+*b*)/Cr showed a negative correlation with dust accumulation. The obtained data revealed that, aeolian dust accumulation induced a surge of changes in biochemical (total nitrogen and, total Soluble Sugar content, main and accessory Photosynthetic Pigments) and thus in physiological performance.

Keywords: Nitrogen content, Photosynthetic Pigments, Soluble Sugars, Vegetation component

Introduction

Windblown dust is a common feature of arid ecosystems where scarcely vegetated soils act as a major source of small particulate matter (Sharifi *et al*., 1997). Dry deposition studies have revealed that dust accumulation mainly depends on the roughness and composition of the soil surface (Saxena *et al*., 1992). Vegetation cover is a crucial factor affecting wind erosion and airborne dust accumulation in semi-arid and arid regions (Zhao *et al*., 2005; Yuchun *et al*., 2011) and vegetation is an important sink for airborne materials originating from natural and anthropogenic sources (Hosker and Lindberge, 1982).

Many factors threaten the survival of desert plant species. One of the most prevalent is aeolian dust, generated by soil surface disturbance (Upekala *et al*., 2009). Dust may settle on leaves, twigs and bark surfaces of plants for extended periods of time, especially in desert environments where low rainfall frequency prevents the removal of deposited dust particles from leaves and other plant surfaces. Dust deposition on aboveground plant organs may induce various chemical or physical changes (Grantz *et al*., 2003). Excessive dust deposition in arid lands is known to cause low primary production (Van Heerden *et al*., 2006) and a change in biochemical parameters like chlorophyll, protein, soluble sugar, and free amino acid content in the leaves (Tripathi and Mukesh, 2007).

Haloxylon aphyllum and *H. persicum* (Chenopodiaceae) (having the common names of black and white saxaul, respectively) are dominant vegetation components of the sandy and clay deserts across Central Asia. They are very widely distributed in Middle Asia, the Middle East, Iran, North-West China (Kashgar and Dzhungar regions) and deserts in the Near East (Botschantzeva 1944, Vladimir *et al*., 1999).

In Iran, re-planting of degraded lands has widely been carried out to reduce the environmental problem of wind. More than forty years ago, for the sake of stabilizing the degraded lands some indigenous trees and shrubs, such as *H. aphylum, H. persicum, Calligonum comosum* and *Seidlitzia rosmarinus*, have been planted on large area of the region (Alizadeh, 2004). Aran-Bidgol is one of the regions in Iran which is prone to desertification and where indigenous species have been re-planted.

Insight in the effectiveness of vegetation, and the role of specific species in reducing aeolian dust transport, is fundamental for selecting a suitable species or group of species which are suited for replanting of degraded land (Burri *et al*. 2011). Most studies concentrated on the relationships between vegetation cover and wind erosion (Dong *et al*., 1996; Li *et al*., 2007; Mu and Chen, 2007) and only a few studies have been conducted to quantify the dust trapping capacity of vegetation and the effects of dust deposition on leaf biochemical parameters.

In this study we hypothesize that an increase in vegetation coverage would improve the efficiency of dust accumulation, thereby shading leaves and adversely affecting photosynthetically related biochemical parameters. To test this hypothesis, a field experiment was conducted with saxaul (*H. aphyllum* Bunge) trees planted at three different coverage densities. The objectives were to (1) explore the effect of saxaul plots on trapping aeolian dust; and (2) to assess of the dust deposition effects on some photosynthetically related biochemical parameters of saxaul plants.

Martial mad Methods

The study was carried out during May to Augustus (2012), with no raining during the period, in Nāsr-ãbād (Aran-Bidgol city, Isfahan Province, Iran). The prevailing climate is of the arid type. The average annual temperature is about 19 °C, while annual precipitation is about 100 mm, unevenly distributed through the year and, potential annual evaporation amounts ~2500-2700 mm. The study area is located at 34-34°10' N, 51° 27'-51° 35' E, and at 850–950 m a.s.l.

Cover determination: the cover plots were chosen with the following conditions: 1) the dominant tree species had to be black saxaul tree; and 2) seedlings shorter than 0.30 meter were classified as undergrowth and did not influence the canopy cover estimate. For all the cover plots, canopy cover was estimated at noon when sun was perpendicularly shining on the tree canopies. In this situation, canopy gaps are appearing on the soil after passage of the sun light through the canopy. The canopy cover was estimated from circular plots with a radius of 10 meters by subtraction of the sunlit surfaces from the total plat area. Cover treatments were chosen based on the method proposed by Korhonen *et al*. (2006). We considered three saxaul coverage densities, i.e. open canopy (OC) 20% of the sky is obstructed by saxaul canopies (saxaul coverage less than 5% did not occur), moderately closed (MC) 40% of the sky is obstructed by tree canopies, and closed canopy (CC) at least 60% of the sky is obstructed by tree canopies), and a control without vegetation. Treatments (Ctrl, OC, MC, and CC) were arranged based on a randomized completely design (RCD) with four replications.

Dust deposition measurement: For each replication, dust deposition was measured at top and beneath the canopy with two dust-deposition gauges (Australian Standard AS/NZS 3580). The deposited dust, in each gauge, was washed with 100 ml distilled water into a pre-weighted 500 ml bottle assembly and this bottle was kept over a hot plate. After complete evaporation of the water the bottles were cooled in desiccators and the amount of dust in bottles was weighed (Yashoda *et al*, 2011). The amounts of deposited dust were calculated by subtracting the amount of collected dust on deposition gauges at top and below the canopy. At the end of the study period leaves was collected from each replication, dust washed-off leaves were used for biochemical analysis. Leaf samples were taken from white saxaul seedlings inside a glasshouse situated in the study area as control.

Biochemical analysis: Leaf pigments were extracted from 0.2 g dust washed-off leaf materials using 5 ml 80% acetone. Light absorbance at 663, 644 and 452.5 nm was determined using a spectrophotometer. The contents of chlorophyll (*a*, *b*) and carotenoids (Cr) were calculated quantitatively as described by Metzner *et al* (1965). Total soluble sugars (TSS) in the leaf were analyzed by the phenol sulphuric acid method of Dubois *et al*. (1951). Foliar total nitrogen content (TNC) was determined by digesting the samples in sulfuric acid (H_2SO_4) followed by analysis of total N by the Kjeldahl method (Bremner and Mulvaney, 1982).

Data from different treatments were evaluated by analysis of variance (ANOVA) according to a completely randomized design with four replications. Means were statistically compared among treatments by Duncan's Multiple Range Test (DMRT) at the $P \leq 0.05$ level**.**

Results

Effect of vegetation coverage on dust deposition: with increasing vegetation coverage, dust accumulation also increased and reached a maximum at CC (Fig.1). Compared to the control (0.804 g m^{-2} d^{-1}), the three coverage treatments trapped significantly more dust. The treatments OC, MC and CC trapped dust at a rate of 1.43, 1.96, and 2.19 g m^{-2} d^{-1}, respectively, an increase with 77, 143, and 172%, respectively, compared to the control.

The amount of dust trapped by different coverage treatments demonstrated three different steps: the first step is from Ctrl to OC, the amount of dust trapped rapidly increased from 0.804 g m^{-2} d^{-1} to 1.43 g m^{-2} d^{-1} (0.626 g m^{-2} d^{-1}), the second step is from OC to MC, where the amount of dust trapped moderately increased from 1.43 g m^{-2} d^{-1} to 1.96 g m^{-2} d^{-1} (0.53g m^{-2} d^{-1}), and the third step is from MC to CC, where the amount of dust trapped slowly increased from 1.96 m^{-2} d^{-1} to 2.19 m^{-2} d^{-1} (0.23 m^{-2} d^{-1}). With respect to the amount of dust trapped at each coverage treatment, this is denoted that the gain in additional amount of dust trapped is not linearly increasing with degree of cover (Fig. 1c).

Effect of dust deposition on biochemical characteristics: At the end of the experiment, leaf samples were analyzed for chlorophyll, soluble sugars, and total nitrogen content. All the biochemical indicators exhibited significant variation among different treatments.

Chlorophyll *a* content decreased progressively with increase in dust accumulation (Table 1). The maximum Chl.*a* (10.62 µg g^{-1} FW) content was observed for the control treatment and it decreased significantly at MC (8.37 µg g^{-1} FW). A significant reduction in Chl. *b* was observed at MC compared to the control treatment and continued to decrease towards CC (3.28 µg g^{-1} FW). The content of photosynthetic pigments [Chl. (*a* + *b*)] decreased significantly with increasing coverage with a reduction of 21% at CC, when compared to the control treatment. An increase in dust accumulation provoked significant decreases in carotenoid concentration with values of 2.12 and 1.58 µg g^{-1} FW, in control and CC respectively (Table 1). In agreement with the observed trend for the individual pigments dust accumulation also significantly decreased total pigment content (TPC) with increasing coverage density compared with the control treatment. TPC showed 20% reduction at CC as compared to the control treatment. The ratio of Chl. (*a*+*b*) to Cr [Chl. (*a*+*b*)/Cr] was significantly lower for MC and CC compared to the control treatment and OC.

Table 1: Change in some biochemical indices (BCI) in *H. aphyllum* as affected by aeolian dust deposition (ADD).

BCI	Chl. *a* (µg g^{-1})	Chl. *b* (µg g^{-1})	Chl. (*a*+*b*) (µg g^{-1})	Cr (µg g^{-1})	TPC (µg g^{-1})	Chl. (*a*+*b*)/Cr
ADD (g m^{-2} d^{-1})						
Ctrl	10.70±1.12^{a}	4.11±0.40^{a}	14.73±1.23^{a}	2.12±0.16^{a}	16.58±1.80^{a}	7.00±0.51^{a}
OC	9.74±0.83^{b}	3.87±0.31^{b}	13.61±1.08^{b}	2.03±0.27^{a}	15.64±1.50^{b}	6.70±0.65^{a}
MC	8.49±0.86^{c}	3.51±0.58^{c}	12.00±0.97^{c}	1.91±0.18^{b}	13.91±0.46^{c}	6.28±0.45^{c}
CC	8.37±0.73^{c}	3.58±0.37^{c}	11.71±0.85^{c}	1.86±0.23^{c}	13.57±0.29^{c}	6.40±0.56^{b}

Different letters in each column show significant difference at $P < 0.05$ by Duncan's Multiple Range Test (DMRT). Chl. *a*: chlorophyll *a*; Chl. *b*: chlorophyll *b*; Chl. (*a*+*b*): chlorophyll *a* and *b*; Cr: carotenoid; TPC: total pigment content; Ctrl: control; OC: open canopy; MC: moderately closed canopy; CC: closed canopy.

TSS was for all treatments significantly lower compared to the control, with the lowest values observed for MC. TNC decreased with increasing dust deposition, and all treatments were significantly lower compared to the control, with a reduction of 12.9%, 19.5% and 34.2%, for OC, MC and CC, respectively (Fig. 1a, b).

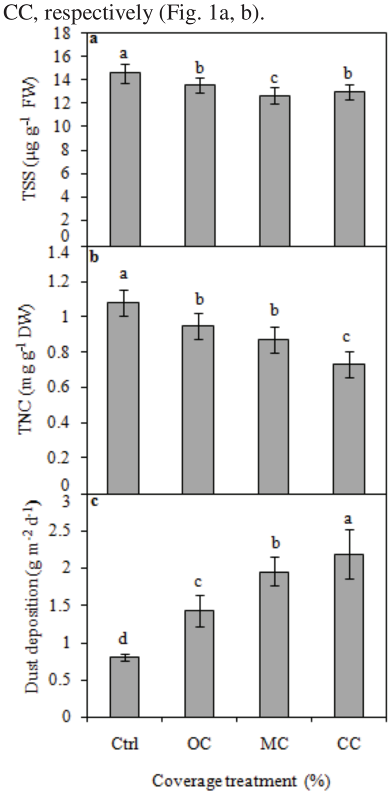

Figure 1. Total soluble sugars (TSS) (a), total nitrogen content (TNC) (b) and aeolian dust deposition (ADD) in leaves of black saxaul trees at increasing coverage levels. Vertical bars represent standard errors (n=4). Different letters denote statistical difference by Duncan's Multiple Range Test (DMRT) ($P < 0.05$) among treatments.

Discussion

Vegetation, and especially woody vegetation as shrubs and trees, has been suggested to play an important role in trapping of dust, because its roughness reduces reducing wind speed, which on its turn increases dust deposition and reduces re-suspension of deposited dust (Yuchun *et al.,* 2011; Hoffmann *et al*., 2007; Zhao *et al*., 2007; Zhang *et al*., 2005). Several studies demonstrated that also soil erosion decreases with the increase of aerodynamic roughness, so that the effect of vegetation on aeolian dust is double, i.e. by increasing dust deposition, and by reducing soil erosion. Dust deposits normally mainly on leaves as it forms the largest interception area, but there is also dust interception on the woody structures (Wang 2004), and especially in the leafless season, as they play an important role in the roughness characteristics of the vegetation. As the leaves of *H. aphyllum* are very small dust deposition will mainly occur on the branches (Zhang *et al*., 2002; Brenton*et al*., 2009). So, one of the major effects of leaf dust deposition is a shading effect. The overall decrease in leaf pigments with increasing vegetation cover (see Table 1) indicates leaf shading effects due to dust interception and accumulation. Although dust deposition at the leaf surface itself was not measured, visual observations indeed indicate an increasing dust deposition with increasing vegetation cover.

These results are consistent with those obtained by Galmés *et al*. (2007) and, Elsheery and Cao (2008) who concluded that the reduction in pigments content can be considered as a consequence of dust deposition. It would be good to list some decrease the chl. a/b ratio (Pearcy and Sims, 1994; Tewary *et al*., 2002). We observed that dust accumulation also led to a decrease in chl. a/b ratio (Table 1), which was also found for olive trees by Nanos and Ilias (2007) who reported that cement dust decreased total leaf chlorophyll content and the Chl. a/b ratio. Leaves which have grown in more shady environments have typically lower Chl a/b values (Malavasi and Malavasi, 2001), which supports our statement that a major effect of dust deposition is through shading. Just as in our research Van Heerden *et al*. (2007) and, Salara and Saravana (2011) reported leaves did not show lesions symptoms due to dust deposition, but they also observed leaf senescence in form of chlorophyll degradation was induced due to leaf dust accumulation.

Carotenoids protect photosynthetic organisms against potentially harmful photo-oxidative processes and are essential structural components of the photosynthetic antenna and reaction center. They play a pivot role as accessory plant pigments (Paulsen, 1997). As our study clearly demonstrated that increasing dust deposition decreased carotenoid content of *H. aphyllum* leaves, it suggests that, this pigment plays a role as an accessory light harvesting pigment (Swami *et al*., 2004) While its role as protector against harmful photo-oxidative processes is less likely due to the shading caused by the dust. The observed decrease in Chl. (*a*+*b*) / Cr ratio in plants at different coverage treatments can be interpreted as evidence of a depression in the photosystem II photochemical efficiency (Naidoo and Chirkoot, 2004). Besides effects of dust deposition on leaf pigments we also observed a decrease in TSS and TNC due to increased dust deposition (Fig.1a, b).

Soluble sugar is an important constituent and source of energy for all living organisms. Plants manufacture this organic substance during photosynthesis and it is consumed during respiration. TSS concentration is, thus, indicative for the physiological activity of a plant and it determines the sensitivity of plants to dust accumulation. Reduction in TSS can be attributed to a decreased CO_2 fixation because of chlorophyll deterioration (Elsheery and Cao, 2008; Sarala and Saravana, 2011), and due to a lower amount of intercepted light due to the shading by the dust particles. TNC was markedly decreased with increasing dust accumulation. Alterations in TCN are typically related to stress responses, such as salt, drought and air pollution stresses (Riccardi *et al*., 1998, Iker *et al*. 2007; Wang *et al*., 2012), but seem also to be indicative for stress induced by dust deposition on leaves.

From the interpretation of the obtained data, one can conclude that, aeolian dust accumulation induced a surge of changes in biochemical parameters (total nitrogen content, total soluble sugars, main and accessory photosynthetic pigments) indicating an overall decrease in physiological performance with increasing deposition. We propose the use of pigments as an easy indicator for screening of the tolerance of plants to aeolian dust pollution.

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