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Leaf dust accumulation and its relationship with biochemical parameters of different plant species growing along national highway-22, India

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Abstract
The present investigation was undertaken to study the dust interception efficiency of the plant species growing along National Highway-22 from Datiyar to Solan, India. The impact of dust deposition on selected plants and its correlation with various biochemical aspects of leaves such as ascorbic acid, leaf extract pH, total chlorophyll and relative water content was also studied. The dust accumulation pattern in various species was in the order *Grewia optiva> Leuceana leucocephela> Casia fistula> Woodfordia fruticosa> Grewillea robusta> Toona ciliate*. The highest amount of leaf dust 0.112 g m^{-2} was recorded in *Grewia Optiva* whereas, the lowest dust load of 0.008 g m^{-2} was recorded in *Grewille robusta*. The correlation studies showed a significant positive and negative correlation between dust deposition and biochemical parameters.

Keywords: Dust accumulation; ascorbic acid; chlorophyll; leaf extract pH; relative water content

Introduction
The airborne particulate matter commonly known as dust, also referred to be as Respirable Suspended Particulate Matter (RSPM) is one of the major constituents of air pollution, which plays an important role in man-environment relationship. Vegetation provides a natural means of cleaning the atmosphere with large leaf area for impingement, absorption and accumulation of air pollutants present in the environment (Das and Prasad, 2010) [1]. Plants play very important role in improving the ambient air quality. Leaves and exposed parts of the plant act as persistent absorber and filter the air. The removal of pollutants is mainly done by absorption on the leaves and deposition of particulates and aerosols over the leaf surface (Rawat and Banerjee, 1996) [2]. The dust is released through various anthropogenic activities like traffic, industries as well as from natural processes like dust storms. Emissions from vehicles operating on public roads represent a major portion of the air pollutants included in the emission inventories. Agricultural and vehicular activities may generate dust which exceeds the environmental guideline values and its deposition affects the physiology of the plants (Manis *et al*., 2001) [3]. The accumulation of dust on plant leaves also influences the leaf morphology and biochemical characteristics (ascorbic acid content, pH, Relative Water Content, total chlorophyll content) and exerts stress on plant physiology (Prajapati and Tripathi, 2008) [4]. Particulate pollutants can cause many lethal effects on plants like stomatal clogging, reduced photosynthetic activity, leaf fall and death of the tissues (Shrivastava and Joshi, 2002) [5]. Foliar surface of plants is the main receptor of dust as it is continuously exposed to the surrounding atmosphere (Rai and Panda, 2014) [6]. The ability of each plant species to absorb and adsorb pollutants by their foliar surface varies greatly and depends on several biochemical, physiological and morphological characteristics (Seyednejad *et al*., 2011) [7]. Dust capturing capacity of plants depends on their surface geometry, phyllotaxy, orientation, and characteristics such as hair, cuticle, height and canopy of tree and determines the amount of dust a leaf can hold. Thus, the present study was conducted to assess dust accumulation pattern on the leaves of selected plant species growing along the National Highway-22 from Datiyar to Solan and to study the correlation between dust and various biochemical parameters.

Materials and Methods
Study area
The study area lies between North latitude of 30°44’53” to 31°22’01” and East longitude

of 76°36'10" to 77°15'14" and has high vehicular density as it is a major part of tourist route connecting the cities of Chandigarh, Ambala, Kalka, Parwanoo and Shimla the capital of Himachal Pradesh**.** The National Highway-22 connecting a major tourist place and the district being an education hub and gateway to horticulture produce is subjected to continuous heavy traffic load.

Climate and weather conditions

The climate of the district is sub-tropical to sub-temperate type and experience four seasons during the year. The spring season commences from March to April and end in May, summer season falls from June to August, followed by autumn, which falls from September to November and winter from December to February. The average annual rainfall in the district is about 1160 mm and 70 per cent of the rains are received during monsoon months. The average minimum and maximum temperature ranges from 4ºC to 36ºC. May and June are the hottest months, whereas, December and January are the coldest ones.

Survey of the study area

In order to assess the dust accumulation pattern on the leaves of the plants in the study area a detail survey of the National Highway-22 from Datiyar to Solan was conducted. The study area was divided into four sites based on equal distances viz. S_1, S_2, S_3 and S_4 and each site was considered as one replication. Six commonly growing plant species viz. *Cassia fistula, Grevillea robusta, Grewia optiva, Leucaena leucocephela, Toona ciliata* were identified and selected from both the sides of the National Highway. In order to maintain the uniformity, plants of same age and spread growing at iso-ecological conditions were selected under RBD (Factorial) design and the morphological characteristics were studied (Table 1). The results were statistically analyzed and interpreted by using Statistical Package Software version 21.

Table 1: Morphological characteristics of selected plants growing along National Highway- 22.

S. No	Plant Species	Habit	Common Name	Family	Leaf Shape	Leaf texture	Orientation
1	*Cassia fistula*	Tree	Amaltash	Fabaceae	Elliptic	Smooth	Alternate
2	*Grevillea robusta*	Tree	Silver oak	Proteaceae	Lanceolate	Fine	Alternate
3	*Grewia optiva*	Tree	Bihul	Meliaceae	Elliptical, Leaflet- Imparipinnate	Glabrous	Acute
4	*Leucaena leucocephela*	Tree	Subabul	Tiliaceaea	Ovate	Fine	Acute
5	*Toona ciliate*	Tree	Toon	Meliaceae	Ovate lanceolate	Glabrous	Alternate
6	*Woodfordia fruticosa*	Shrub	Dhai	Lythraceae	Ovate	Smooth	Alternate

Sampling of dust and leaves

In order to assess the dust accumulation pattern on the leaves of selected plant species. The observations were recorded in November and December months of winter season. The upper surface of the leaves was cleaned with fine brush and marked for identification. The leaves were then left for 24 hours for dust accumulation and after 24 hours the dust from the selected leaves was collected in the pre weighed butter paper bags with the help of fine brush. After the collection of accumulated dust the leaves were cut from petiole, kept in ice box and brought to the laboratory for further analysis. The individual leaf was measured with Leaf area meter (Model-LI-COR-3100). The samples were weighed using top pan electronic balance and the amount of dust was calculated using the following equation

$$w = \frac{(w_2 - w_1)}{a}$$

Where;

w = dust content (g m^{-2})
w_1 = initial weight of butter paper bag
w_2 = final weight of butter paper bag with dust
a = total area of the leaf (m^2)

Result and discussion

Dust deposition

The dust accumulation on the leaves of the selected plant species in the study area varied significantly from 0.008 to 0.112 gm^{-2} Fig.1. The highest dust accumulation of 0.112 gm^{-2} was recorded in *G. optiva* followed by *L. leucocephela (0.084* g m^{-2}), *C. fistula* (0.052 g m^{-2}), *W. fruticosa* (0.051 g m^{-2}), *T. ciliate* (0.009 g m^{-2}) and lowest of 0.008 gm^{-2} was recorded in *G. robusta*. Dust deposition capacity of plants depends on their surface geometry, phyllotaxy and leaf external characteristics such as presence or absence of hairs, cuticle, length of petiole, height and canopy. The highest amount of dust in the leaves of *G. optiva* may be attributed due to their rough texture. Whereas, the dust load of low magnitude in the leaves of *G. robusta* might be because of long petiole and tall height of the tree. The results are in line with the findings of Vora and Bhatnagar (1986) [8] who have also reported the role of leaf morphological characteristics in dust accumulation on their surfaces. The dust interception is the function of the source and amount of pollutants in the surroundings, morphological characteristics of plants, weather conditions and wind direction Prajapati and Tripathi (2008) [4]. The results are also in line with the findings of Prusty *et al.*, (2005) [9] who reported that dust load increases with increasing number of vehicles. Spatt and Miller (1981) [10] also reported that the dust arising from vehicular traffic settles in large quantities near the highway and rapidly decreases away from the Highway.

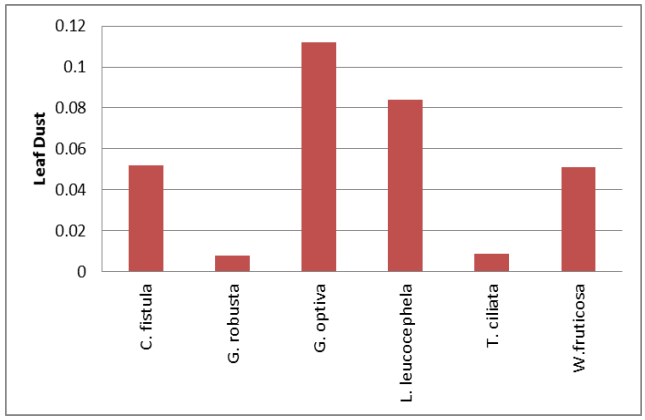

Fig 1: Leaf dust accumulation (gm^{-2}) in tree species growing along National Highway-22

Table 2: Relationship of Leaf dust load with biochemical parameters of different plant species growing along National Highway-22

Species	Ascorbic acid	Leaf pH	Total chlorophyll content	Relative water content
Casia fistula	0.820***	-0.559***	-0.091	-0.464**
Grewiallia robusta	0.973***	-0.427**	-0.763***	-0.120
Grewia optiva	0.906***	-0.511**	0.757***	-0.203
Leuceana leucocephela	0.575***	-0.977***	-0.044	-0.381*
Toona ciliata	0.856***	-0.858***	0.441**	-0.022
Woodfordia fruticosa	0.985***	-0.533***	-0.547***	-0.553***

Significance at probability level α*10 percent
Significance at probability level α** 5 percent
Significance at probability level α***1 percent

Biochemical analysis

1. Ascorbic acid content

The leaf dust load and the ascorbic acid content of the leaves of selected plant species in the study area showed a positive correlation between them i.e., higher the deposition of dust higher the ascorbic acid content in the leaves of the selected plant species (Fig.2).. Table. 2 shows a significantly positive correlation at one per cent with *Cassia fistula, Grevillea robusta, Grewia optiva, Leucaena leucocephela, Toona ciliate* and *Woodfordia floribunda*. The higher content of ascorbic acid shows the adaptive capacity of plants to overcome stress. Ascorbic acid acts as an antioxidant and develops the mechanism of a plant to resist against the adverse atmospheric conditions (Keller and Schwager, 1977) [11]. Ascorbic acid plays a role in the cell wall synthesis, defense and cell division (Conklin, 2001) [12]. High level of ascorbic acid in plants indicates high tolerance level of plant species against pollutions and its lower values rank the plants in a sensitive category against air pollution (Varshney and Varshney, 1984) [13].

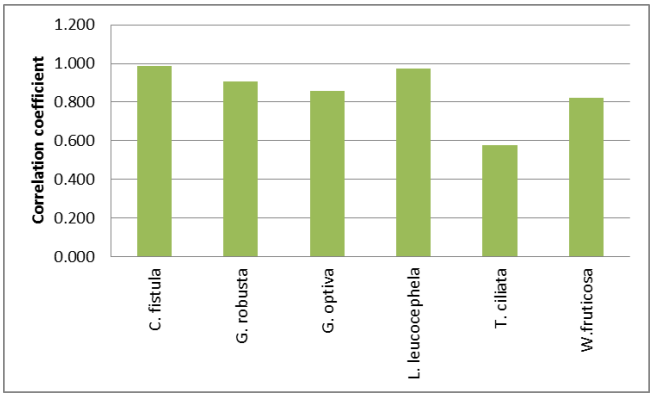

Fig 2: Correlation between leaf dust (gm^{-2}) and leaf ascorbic acid content

2. Total Chlorophyll content

Chlorophyll is the principal photoreceptor in photosynthesis and regulates the productivity as well as development of biomass (Leghari *et al.*, 2014) [14]. Dust accumulation causes severe damage in the photosynthetic pigment and the reduction in chlorophyll content is mainly due to degradation of the photosynthetic pigment (Ninavenave *et al.*,2001) [15]. The leaf dust load and the chlorophyll content of the leaves of selected plant species in the study area showed a significantly negative correlation i.e higher the deposition of dust, lower the chlorophyll content in the leaves of the plant species. *W. fruticosa*, *G. optiva* and *G. robusta* were significantly negatively correlated at 1 per cent level of significance and *T. ciliate* at 5 percent level of significance (Table 2, Fig.3). Degradation of photosynthetic pigment has been widely used as an indication of air pollution (Ninavenave *et al.*,2001) [15].The higher the levels of pollutants, the lower the chlorophyll content as certain pollutants in totality reduce the total chlorophyll content (Allen *et al.*,1987) [16]. Dust accumulation is higher in winters and hinders the incident light falling on the leaf surface and reduces the chlorophyll content thus leading to a reduction in net photosynthesis and the amount light available for photosynthesis. Dust deposition also interferes with gas diffusion between the leaf and air by blocking the stomatal pores (Joshi and Swami, 2009) [17]. The decrease in chlorophyll content of leaves may also be due to the alkaline condition created by dissolution of chemicals present in the dust particulates i.e. metals and polycyclic hydrocarbons in cell sap blocking the stomatal spores for diffusion of air and thus put stress on plant metabolism resulting in Chlorophyll degradation (Anthony 2001) [18]. Dust particles carry many polycyclic hydrocarbon and metals with them which inhibits the production of enzymes required for chlorophyll synthesis and results in reduction of chlorophyll content (Prajapati and Tripathi, 2008) [4].

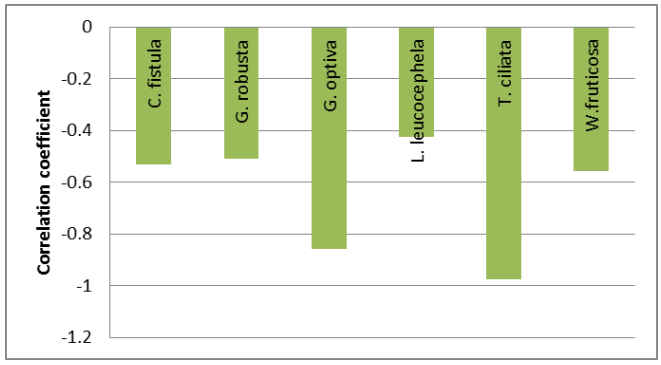

Fig 3: Correlation between leaf dust (gm^{-2}) and leaf chlorophyll content

3. Leaf extract pH

The leaf extract pH showed a significant negative correlation with leaf dust load in all the selected plant species in the study area at 1 percent level of significance except *G. optiva and G. robusta* which showed a positive correlation at 5 percent level of significance (Table.2) which may be due higher dust deposition in winter season and dissolution of dust particles in the cell sap which results in the alkaline conditions (Garg and Kapoor, 1972) [19]. The decrease in pH i.e. negative correlation with dust deposition may be due to acidic condition caused by the presence of acidic pollutants that shift the cell sap pH towards the acidic side and lowers the level of pH and the decline is greater in sensitive species Fig.4. (Rao, 1977) [20]. The leaf extract pH plays a major role in regulating the SO_2 sensitivity of plants. Low leaf pH extract shows good correlation with sensitivity to air pollution and reduced photosynthetic process in plants (Yan and Hui, 2008) [21].

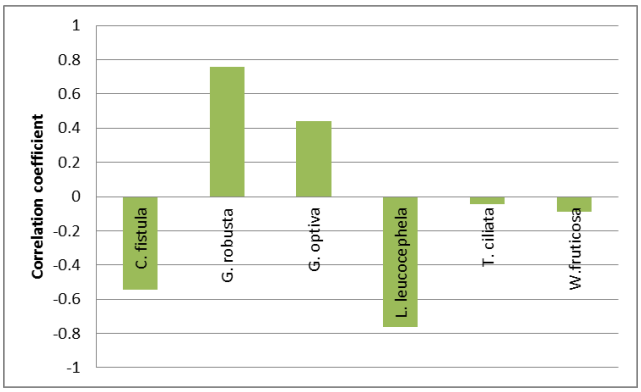

Fig 4: Correlation between leaf dust (gm^{-2}) and leaf extract pH

4. Relative water content

Leaf relative water content is related to several leaf physiological variables, such as leaf turgor, growth, stomatal conductance, transpiration, photosynthesis and respiration (Das and Prasad, 2010) [1]. High dust deposition on leaves clog the stomatal opening and severely affects the transpiration rate. Dust may also absorb water through non-cutinized plant surface such as leaves, stems, and branches along with increased evaporation from the plants because of high temperature would contribute to decreased water content (Rai and Panda, 2014) [6]. The relative water content showed a negative correlation with leaf dust load in all the species Fig. 5. The dust load in *W. Fruticosa*, *C. fistula*, *L. leucocephela* and showed a significant negatively correlation with the leaf relative water content at 1, 5 and 10 per cent level of significance Table 2. However, no significant relationship of leaf dust was noticed with relative water content in *G. optiva*, *G. robusta* and *T. ciliate.*

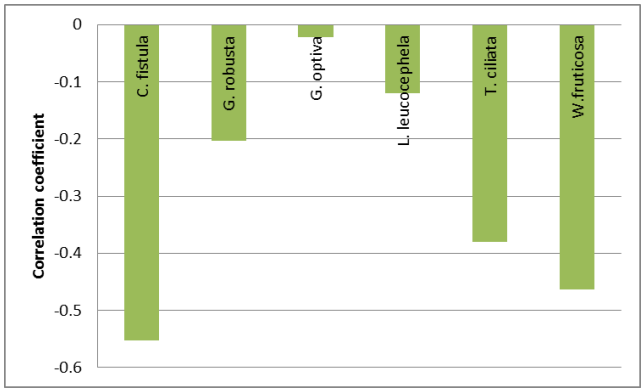

Fig 5: Correlation between leaf dust (gm^{-2}) and leaf relative water content

Conclusion

The study concludes that atmospheric dust accumulation varies with structure, geometry, height, size of petiole, presence or absence of hairs and presence of wax on leaf surface of selected plants. Plants with waxy coating, rough surface with folded margin accumulate more dust than plants with smooth, flat surface without folded margin. The highest amount of leaf dust 0.112 g m^{-2} was recorded in *G. optiva* whereas, lowest dust load (0.008 g m^{-2}) was recorded in *G. robusta*. Dust depositions induce changes in the biochemical parameters by increasing and decreasing their level in the plant leaves. Thus, the correlation studies showed a significant negative correlation between leaf dust and leaf chlorophyll content and leaf relative water content and a positive correlation between leaf ascorbic acid content. Whereas, a positive and negative correlation was observed between leaf dust and leaf extract pH. The extent of such changes depends on plant tolerance towards dust and on the chemical nature of the dust. All these changes exert stress on plant physiology and can serve as an indicator of dust pollution and the plants can be used in the abatement of dust pollution by acting as natural filters.

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