J. Himalayan Ecol. Sustain. Dev. Vol. 16 (2021) **ISSN 0973-7502**

Dust Accumulation and its Effect on Plant Species Grown Along National Highways 11 and 89 in Bikaner (Rajasthan)

Leela Kaur*, Aarti Ojha[1] and Nupur Kanwar[1]
[1]Department of Environment Sciences, Maharaja Ganga Singh University, Bikaner, Rajasthan, India
***Corresponding author's email:** leela.kaur@gmail.com

ABSTRACT

Particulate matter can cause serious health hazard owing to their ability to remain suspended for long periods of time and travelling long distances in the atmosphere. Roadside trees can play a significant role in capturing these air suspended pollutants. The objective of this study was to determine the dust accumulation capacity of local desertic plants growing along the roadsides of national highways NH-11 and NH-89 in Bikaner (Rajasthan). Common plant species namely, *Prosopis cineraria*, *Azadirachta indica*, *Calotropis procera*, *Ziziphus nummularia*, *Salvadora persica*, *Ficus religiosa*, *Nerium indicum*, *Acacia nilotica* and *Prosopis juliflora* were chosen for this purpose and the findings revealed that *A. indica* (19.76 %) and *P. cineraria* (19.17 %) expressed highest dust accumulation capacity while *F. religiosa* (9.6 %) expressed lowest. Furthermore, the study analyses the impact of dust accumulation on the leaf chlorophyll content. Chlorophyll content showed variable responses to dust. Highest chlorophyll content was seen in *P. cineraria* at NH-11 (3.395 mg/g) and *P. juliflora* (3.407 mg/g) at NH-89. *A. indica* demonstrated lowest Total Chlorophyll Content (2.642 mg/g). The findings suggest that *P. cineraria* showed significant dust deposition (19.17 %) with minimal effect of dust on its leaf chlorophyll content (3.395 mg/g). The plant species with tolerance to high dust accumulation on their leaf surfaces are preferable as roadside plants.

Keywords: *Dust pollution, Dust holding capacity, Chlorophyll, Plant species, Bikaner*

INTRODUCTION

Outdoor air pollution is a major global public health issue, leading to 6.67 million deaths worldwide and 1.67 million deaths in India annually (Health effects Institute, 2020). Uttar Pradesh, Maharashtra, Bihar, West Bengal and Rajasthan account for over 50 per cent deaths attributed to air pollution in India (Pandey, 2020). Particulate matter with size of 2.5 micrometre ($PM_{2.5}$) is the largest driver of air pollution's burden of disease worldwide. The annual exposure to ambient particulate matter, as the population-weighted mean $PM_{2·5}$, in India in 2017 was 89·9 μg/m^3 (Balakrishnan *et al.,* 2019). Henceforth, it is a prerequisite to combat dust pollution. Activities namely coal mining, quarrying, stone crushing, thermal power plants, cement industries, etc. add huge quantities of dust to the environment (Sett, 2017). Dust pollution in the atmosphere particularly that of pollutant particles below 10 μm have implications on human health. Particles approximately between 5 μm and 10 μm are most likely to deposit in the tracheobronchial tree, while those between 1 μm and 5 μm are deposited in the respiratory bronchioles and the alveoli where they affect gaseous exchange within the lungs and can even penetrate the lungs. Particulate matter smaller than 1 μm in general behave like gas molecules and would therefore penetrate down to the alveoli and can translocate further into the cell tissue and/or circulation system (Kim *et al.,* 2015; Zha *et al.,* 2019).

Roadside sediments are fine particulates varying in size between 0.05 µm and 300 µm which are scattered from road surface by traffic movement remain suspended in atmosphere and later fall down on variety of plant species along roadside landscapes (Shah *et al.*, 2018). Roadside vegetation communities exhibit changes in pH, relative water content and species diversity due to dust fall from highways and roads (Rai & Panda, 2014). A relationship between traffic density and plant photosynthetic activity, stomata conductance, total chlorophyll content and leaf senescence has been reported (Gratani *et al.,* 2000; Honour *et al.,* 2009; Sharma *et al.,* 2017). Foliage of *Quercus ilex* trees was found to have a reduced life span following exposure to high traffic levels in Rome but this was compensated for by higher stomatal conductance, chlorophyll content and photosynthetic activity (Gratani *et al.,* 2000). The response of the plant to dust accumulation may vary with plant species depending on their leaf orientation, leaf surface geometry, phyllotaxy, epidermal and cuticular features, leaf pubescence, height and canopy of roadside plants (Rai *et al.,* 2010; Chaturvedi *et al.,* 2013; Singh & Pal, 2017). Chaturvedi *et al.,* 2013 reported that hairy and rough leaf texture of *Tectona grandis* enables it to accumulate greater dust. Sett (2017) explained that the evergreen plant with horizontal leaves orientation is good dust trapper than an evergreen or deciduous plant with vertical suspended glabrous leaves. Air movement easily disturbs leaves having thin lamina, smooth surfaces, and long petioles. Consequently, such leaves can hold lesser amounts of dust while thick leaves having rough surfaces or hairs on the surface and short petioles can hold large amount of dust and hence are better collectors of dust (Prusty *et al.,*2005)

Chlorophyll is an index of productivity of the plant. Whereas certain pollutants increase the total chlorophyll content, others decrease it (Agbaire & Esiefarienrhe, 2010). Reduction in chlorophyll content of leaves in polluted areas has been reported by many workers at different sites worldwide (Swain *et al.,* 2016). This decrease in plants chlorophyll content due to exposure of heavy dust load is responsible for stomatal closure and further decrease in photosynthesis (McDowell *et al.,* 2008; van der Molen *et al.,* 2011; Meravi *et al.,* 2021). According to Giri *et al.* (2013), there was a reduction of 52.4% in the total chlorophyll content in the leaves of *Azadirachta indica* from polluted site. The concentration of Chl 'a' and Chl 'b' at polluted sites was recorded as 0.49±0.09 mg/g and 0.28±0.10 mg/g showed a decrease as compared to control sites. Chaudhary and Rathore (2018) reported that total chlorophyll content of leaf is inversely proportional to dust accumulation on leaf. A study by Gupta *et al.* (2016) on the effect of dust on medicinal plants at 2 sites showed that levels of chlorophyll decreased with the increase in dust fall fluxes at both the sites. Joshi *et al.* (2009) reported significant reduction in total chlorophyll content of wheat and mustard plants grown at polluted sites. The decrease in concentration of chlorophyll in polluted areas may be due to shading effects by deposition of suspended particulate matter on the leaf surface. It might clog the stomata thus interfering with the gaseous exchange, which in turn increase the leaf temperature, thereby retarding chlorophyll synthesis (Joshi & Swami, 2009).

Plants provide enormous leaf surface for accumulation and impingement of air pollutants (Shah *et al.,* 2018). Thus, vegetation act as natural filters by depositing dust particles on their leaf surface. Deposition of particulate matter on a leaf surface induce changes in morphology and function of leaves (Agbaire & Esiefarienrhe, 2010; Rai & Panda, 2015). Despite of the foliar surface configuration and biochemical changes seen due to dust pollution (Verma & Singh, 2006; Sharma *et al.,* 2017) there are plants that are able to survive in high dust loads due to the synthesis of carotenoids and proteins which give non-enzymatic resistance to plants against numerous abiotic stresses (Prajapati & Tripathi, 2008; Singh & Pal, 2017). The dust interception capability of different leaves depends on leaf structure, phyllotaxy, presence/absence of hairs, presence of wax on leaf surface, size of petioles, and canopy structure. Plants with a waxy coating, rough leaf surface, and short petioles tend to accumulate more dust than plants with long petioles and smoother leaf surface (Prajapati & Tripathi, 2008). Plant species which are more sensitive act as biological indicator of air pollution (Kaler *et al.,* 2016). Besides, the role of plants in reducing atmospheric pollution, they also control soil erosion and enhance the inventive beauty (Yang *et al.,* 2005; Chaudhary & Rathore, 2019). Hence, roadside plantation to remove, detoxify or stabilize persistent pollutants is a green and environment friendly approach for improving air quality (Chaudhary & Rathore, 2018).

The screening of effective plants for particulate sink is very essential for abatement of dust pollution. In furtherance to the above intention, current study has been conducted to investigate leaf dust accumulation and variation in chlorophyll content in leaves of 9 selected plant species namely, *Prosopis cineraria* (Khejri), *Azadirachta indica* (Neem), *Calotropis procera* (Aak), *Ziziphus nummularia* (Jhar Beri), *Salvadora persica* (Pilu), *Ficus religiosa* (Peepal), *Nerium indicum* (Kaner), *Acacia nilotica* (Babul), *Prosopis juliflora* (Kikar or Vilayati Babul) grown alongside NH-11 and NH-89 in Bikaner, Rajasthan. This study compares the capabilities of selected plants with regards to dust accumulation and also provides essential data for recognition and control of air quality as well as for further environmental study.

MATERIAL AND METHODS

Study area

Bikaner is a district in the northwest of the state of Rajasthan, India at a height of 230 m from sea level. The district is bounded by Ganganagar District to the north, Hanumangarh District to the northeast, Churu District to the east, Nagaur District to the southeast, Jodhpur District to the south, Jaisalmer District to the southwest, and Punjab Province of Pakistan to the northwest. Since Bikaner is located in the middle of the Thar Desert, it has an extremely hot and arid climate. The climate in Bikaner is characterised by significant variations in temperature. In the summers, the temperature of the region goes beyond 45°C and in winters, it dips down below 0°C. Annual rainfall of the region is between 260 to 440 mm. The present study was conducted along NH 11 (848 km) connecting Jaisalmer (Rajasthan) and Rewari (Haryana) and NH 89 (300 km) which links Ajmer to Bikaner. The stretch of National Highway 11 selected for this study area runs from Bikaner (28°01'00" N 73°18'43" E) to Dungargarh (28.08°N 74.02°E) in a span of 71 Km and on National Highway 89 the study area extends from Bikaner (28°01'00" N 73°18'43" E) to Nokha (27.6°N 73.42°E) covering a distance of 62 Km. Map of study area was drawn with the help of QGIS software as shown in Fig. 1.

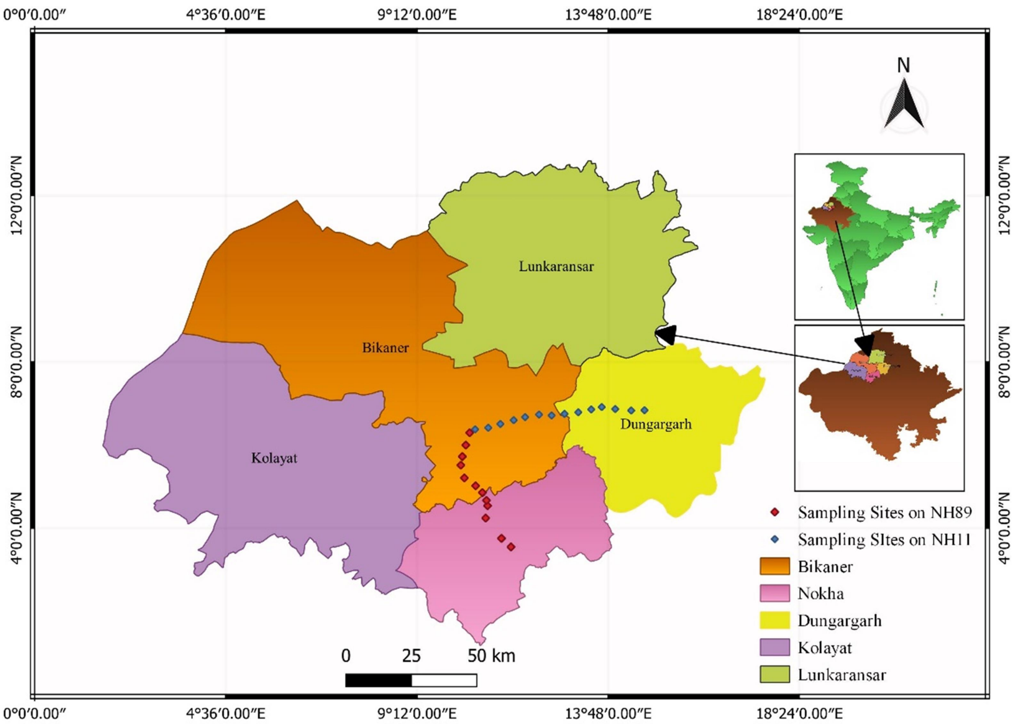

Fig. 1. Map showing sampling locations and study areas NH-11 and NH-89.

Selection and sample collection of plant

Vegetation cover in the region is scarce. Common trees occurring in the area were selected for the study (Table 1). In March 2019, leaves were randomly collected at equal heights from selected species growing approximately 5 meters from road side at an intermittent distance of 5 km along the highways NH- 11 and NH- 89 (Fig. 1). The average dust deposition was derived from 15 sites at NH-11 and 14 sites at NH89 within a sampling period of 24 hours. The track was made by GPS ESSENTIAL app and GPS location coordinate and pictures were taken by using TIME STAMP CAMERA. Leaves from the plants were collected in zipper pouches separately and brought to laboratory for analysis.

Table 1. Characteristics of selected plants at the study site (Adapted from Kaler *et al.,* 2016).

S. N.	Plant species	Family	Habit	Leaf shape	Phyllotaxy	Petiole length	Plant height (m)
1.	*P. cineraria*	Fabaceae	Small tree	Oblong	Alternate	0.5-4cm[1]	3-5
2.	*P. juliflora*	Fabaceae	Small tree/ shrub	Oblong	Alternate	0.5-7.5 cm[1]	12
3.	*A. nilotica*	Fabaceae	Medium sized tree	Ovate/ oblong	Alternate	0.5–2.5 cm	20-25
4.	*A. indica*	Meliaceae	Tree	Lanceolate	Alternate	2-7 cm	15-20
5.	*C. procera*	Asclepiadaceae	Small tree/shrub	Orbicular/ ovate	Opposite	–	1-4
6.	*Z. nummularia*	Rhamnaceae	Shrub	Ovate, elliptic or orbicular	Alternate	–	3 or more
7.	*S. persica*	Salvadoraceae	Small tree/ shrub	Oblong/ elliptic	Opposite	1.3–2.2 cm	6-7
8.	*F. religiosa*	Moraceae	Tree	Broadly ovate/ obcuneate	Alternate	6–10 cm	20
9.	*N. indicum*	Apocynaceae	Small tree/ shrub	Linear/ lanceolate	Opposite	5-7.5 mm	Up to 5

1 petiole + rachis

2 'NA'- not available

Dust holding capacity

For the estimation of dust holding capacity 3 samples of leaves of each species were selected. Initial fresh weight of leaf sample with dust particles was taken. Then the leaf sample was washed thoroughly with distilled water using a spray bottle. After this the leaves were dried with a clean cotton and blotting sheet to remove dust and the dried leaf samples were weighed again. The percentage of dust holding capacity of different leaf samples was calculated by using formula (SOP, 2015):

$$\text{Dust holding capacity}(\%) = \frac{\text{Weight of dust} * 100}{\text{Weight of cleaned leaves}}$$

Where, Weight of dust = $\text{Weight of uncleaned leaves} - \text{Weight of cleaned leaves}$

Estimation of chlorophyll content

Total chlorophyll content analysis was done by Arnon method (Singh *et al.,* 2018). 2.0 g of fresh leaves were blended and extracted with 20 ml of 80% acetone (pre-chilled) followed by centrifugation at 5000 rpm for 5 minutes. The supernatant was then transferred to a 100 ml volumetric flask and the volume was made up to 100 ml with 80% acetone. This procedure was repeated until the residue was colourless. The absorbance of the solution was read at 663 nm and 665 nm against the blank solvent (80% acetone) using spectrophotometer. Calculations were made using the formula given below (Thimmaiah, 1999):

$$\text{Chlorophyll a (mg/g tissue)} = \frac{12.7(A_{663}) - 2.69(A_{645})\ X\ V}{1000\ X\ W}$$

$$\text{Chlorophyll b (mg/g tissue)} = \frac{22.9(A_{645}) - 4.68(A_{663})\ X\ V}{1000\ X\ W}$$

$$\text{Total chlorophyll (mg/g tissue)} = \frac{20.2(A_{645}) + 8.02(A_{663}) \times V}{1000\ X\ W}$$

Where, A= Absorbance of extract at specific wavelength (nm)

V= Final volume of chlorophyll extract in 80% acetone (ml)

W= Weight of the tissue extract (g)

Statistical analysis

The obtained data for dust holding capacity was analysed using t-test between two highways in R version 4.0.4. P value of the data was calculated. If $P > 0.05$ significance level, then data is not significant.

RESULT AND DISCUSSION

Dust accumulation

Analysis of the data revealed that different plant species responded in different ways to dust pollution and even the same plant species responded differently in different environments, depending on the level of dust in the habitat. Thus, plants possess different tolerance capacities depending upon the species, environment and the factors affecting them. Total dust deposition on selected plant species at different sites is shown in Table 2.

Table 2. Dust Accumulation (%) by selected plants in the study area

S.N.	Location	Plant Name	Average Dust Holding Capacity (%)	
			NH11	NH89
1	Location1	*A. indica*	NA	13.22 ± 12.97
2		*C.procera*	10.89 ± 2.2	7.44 ± 4.74
3		*F. religiosa*	NA	7.72 ± 0.85
4		*N. indicum*	3.85 ± 2.67	NA
5		*P. cineraria*	17.28 ± 10.52	19.53 ± 6.62
6		*P. juliflora*	1.66 ± 1.45	7.31 ± 8.65
7		*Z. nummularia*	5.54 ± 2.79	NA

8	Location2	*A. indica*	NA	2.68 ± 1.59
9		*C.procera*	3.43 ± 1.69	10.53 ± 3.17
10		*F. religiosa*	NA	7.64 ± 7.87
11		*P. cineraria*	32.55 ± 3.3	15.58 ± 4.44
12		*P. juliflora*	1.25 ± 0.89	16.7 ± 9.17
13		*S. persica*	7.58 ± 8.77	NA
14		*Z. nummularia*	6.25 ± 2	NA
15	Location3	*A. indica*	23.7 ± 4.12	12.5 ± 10.7
16		*C.procera*	18.06 ± 9.65	26.36 ± 27.07
17		*F. religiosa*	7.41 ± 5.23	7.22 ± 1.72
18		*P. cineraria*	17.7 ± 10.19	9.54 ± 3.75
19		*P. juliflora*	14.15 ± 7.45	3.07 ± 0.44
20	Location4	*A. indica*	19.71 ± 12.34	19.29 ± 8.5
21		*C.procera*	7.6 ± 3.09	3.53 ± 1.09
22		*F. religiosa*	20.16 ± 5.77	4.33 ± 1.9
23		*P. cineraria*	NA	12.15 ± 10.87
24		*P. juliflora*	24.46 ± 4.76	4.29 ± 1.68
25		*Z. nummularia*	9.79 ± 4.73	NA
26	Location5	*A. indica*	24.88 ± 7.26	22.41 ± 9.86
27		*C. procera*	10.76 ± 6.34	4.4 ± 0.55
28		*F. religiosa*	26.03 ± 8.17	5.89 ± 3
29		*P. cineraria*	NA	20.09 ± 11.47
30		*P. juliflora*	19.74 ± 5.61	4.12 ± 2.79
31		*Z. nummularia*	11.45 ± 2.9	NA
32	Location6	*A. indica*	17.26 ± 16.27	23.61 ± 14.91
33		*C. procera*	10.97 ± 2.74	17.57 ± 6.18
34		*F. religiosa*	NA	12.85 ± 11.31
35		*P. cineraria*	19.89 ± 11.14	13.31 ± 6.03
36		*P. juliflora*	15.7 ± 6.44	7.63 ± 4.81
37		*Z. nummularia*	5.82 ± 2.99	NA
38	Location7	*A. indica*	23.33 ± 10.53	9.74 ± 3.06
39		*C. procera*	14.21 ± 6.48	3.82 ± 1.22
40		*F. religiosa*	15.95 ± 4.61	NA
41		*P. cineraria*	35.29 ± 6.66	16.26 ± 13.04
42		*P. juliflora*	21.83 ± 9.83	9.17 ± 2.76
43		*Z. nummularia*	NA	19.76 ± 14.58
44	Location8	*A. indica*	20.79 ± 10.89	22.27 ± 5.7
45		*C. procera*	26.17 ± 11.23	9.29 ± 5.51

46		*F. religiosa*	NA	14.92 ± 1.92
47		*P. cineraria*	24.89 ± 11.45	14.83 ± 9.74
48		*P. juliflora*	13.52 ± 6.23	54.89 ± 3.58
49		*Z. nummularia*	10.42 ± 3.64	NA
50	Location9	*A. indica*	22.59 ± 19.05	22.16 ± 19.22
51		*C.procera*	13.57 ± 5.81	4.08 ± 0.99
52		*P. cineraria*	8.85 ± 4.24	14.94 ± 3.23
53		*P. juliflora*	17.27 ± 7.86	9.42 ± 3.1
54		*Z. nummularia*	4.98 ± 2.74	39.24 ± 19.14
55	Location10	*A. indica*	19.81 ± 11.61	13.8 ± 11.27
56		*C. procera*	27.52 ± 13.29	28.78 ± 18.39
57		*F. religiosa*	9.08 ± 2.47	5.56 ± 3.25
58		*P. cineraria*	20.14 ± 6.72	11.73 ± 2.47
59		*P. juliflora*	NA	21.06 ± 12.62
60		*Z. nummularia*	7.95 ± 1.81	NA
61	Location11	*A. indica*	33.83 ± 17.07	25.72 ± 29.73
62		*C. procera*	17.26 ± 10.73	7.45 ± 4.9
63		*F. religiosa*	2.63 ± 3.18	6.75 ± 2.81
64		*P. cineraria*	12.45 ± 5.11	22.92 ± 7.42
65		*P. juliflora*	20.1 ± 14.71	10.39 ± 5.89
66	Location12	*A. indica*	22.56 ± 16.73	19.03 ± 8.23
67		*C. procera*	10.64 ± 2.38	11.06 ± 7.41
68		*F. religiosa*	1.54 ± 1.35	4.21 ± 0.85
69		*P. cineraria*	21.21 ± 7.15	16.53 ± 2.74
70		*P. juliflora*	9.54 ± 2.2	62.95 ± 10.97
71	Location13	*A. indica*	18.16 ± 16.18	45.65 ± 39.88
72		*C.procera*	15.85 ± 16.63	6.72 ± 3.62
73		*F. religiosa*	15.79 ± 5.69	6.22 ± 3.98
74		*P. cineraria*	23.39 ± 14.95	23.96 ± 28.35
75		*P. juliflora*	8.54 ± 4.12	4.79 ± 4.53
76	Location14	*A. indica*	18.82 ± 6.65	16.45 ± 8.1
77		*C. procera*	19.39 ± 9.52	8.11 ± 8.29
78		*F. religiosa*	3.78 ± 0.72	17.76 ± 4.58
79		*P. cineraria*	34.97 ± 35.88	15.76 ± 2.14
80		*P. juliflora*	6.81 ± 4.79	6.54 ± 5.73
81	Location15	*A. indica*	22.31 ± 11.26	0 ± 0
82		*C. procera*	24.86 ± 9.82	0 ± 0
83		*F. religiosa*	11.21 ± 4.31	0 ± 0

84		*P. cineraria*	16 ± 7.89	0 ± 0
85		*P. juliflora*	12.21 ± 1	0 ± 0

'0 ± 0' site not taken

'NA' plant not available at the site

Location wise variation of the dust fall fluxes on 9 different plants under study is presented in Fig. 2 and 3. Among selected plants, dust deposition percentage is maximum in *P. cineraria* (22.17%) at NH-11 and *A. indica* (17.20%) at NH-89. Highest total dust deposition percentage is observed in *A. indica* (19.76%) while the lowest total dust deposition was on *F. religiosa* (9.6%) (Table 3). The results have been calculated excluding *A. nilotica, N. indicum, Z. nummularia* and *S. persica* due to insufficient data. P-value was 0.378 which is greater than 0.05 significance level. Hence, there is no significant difference in dust accumulation by plants at the two highways.

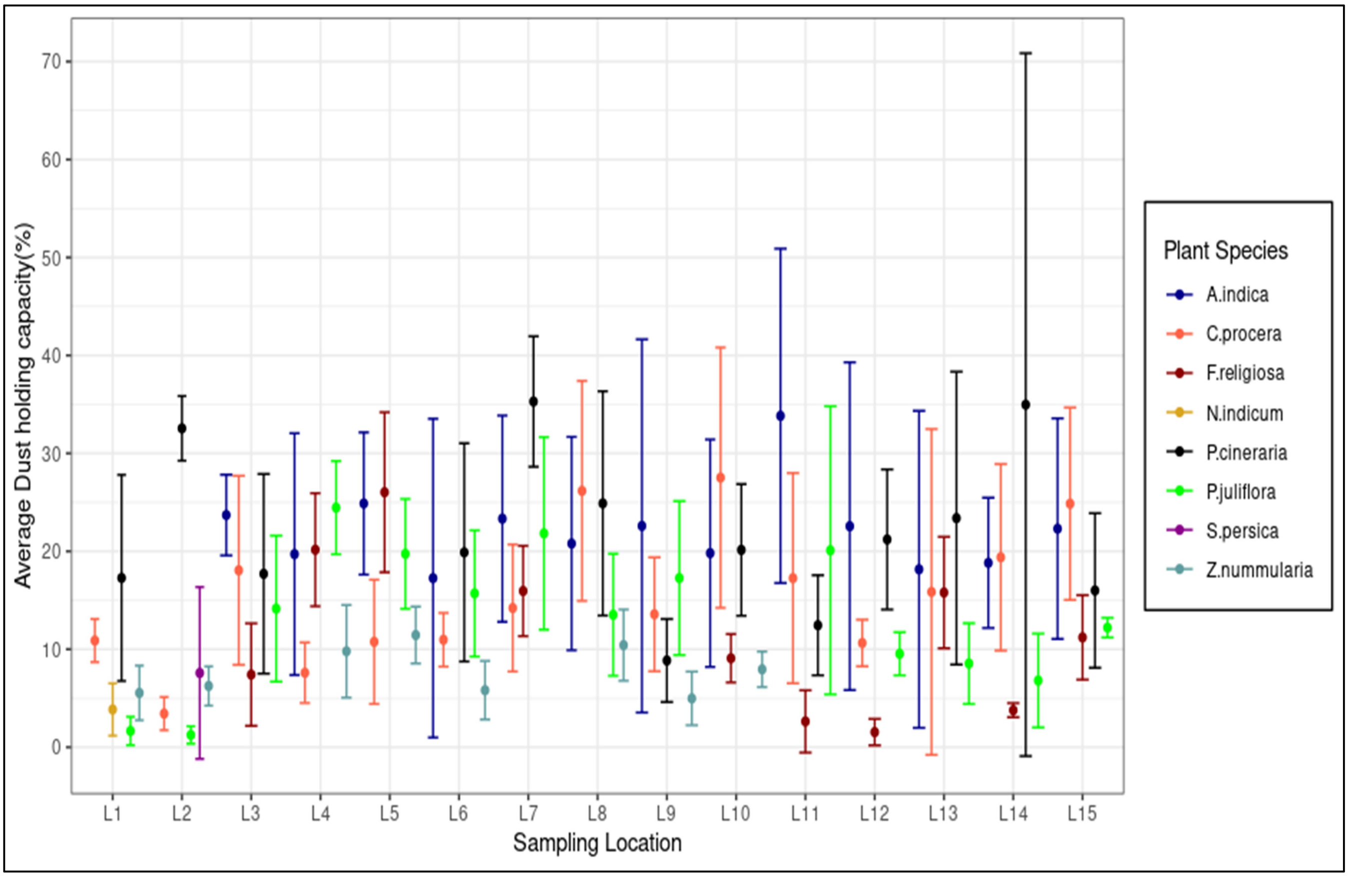

Fig. 2 Box plot showing Dust Holding Capacity of selected plant species at NH-11. Dots indicate average dust deposition and whiskers indicate deviation from average values.

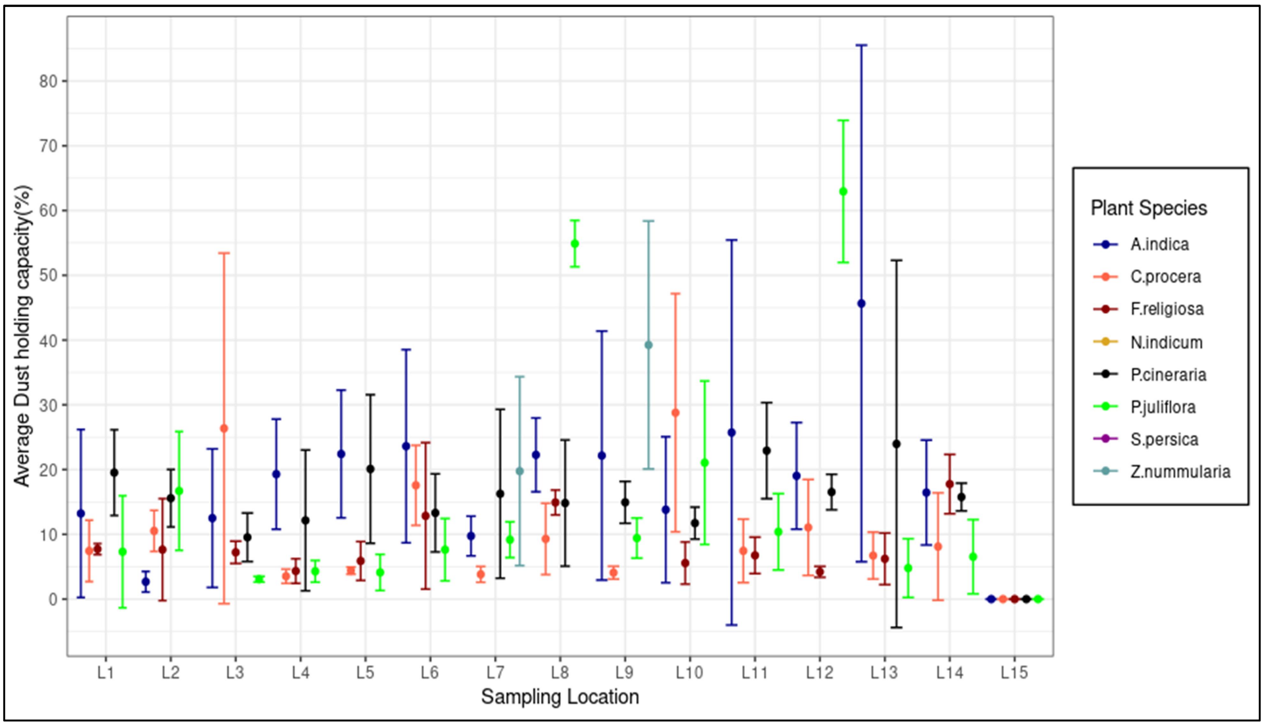

Fig. 3. Dust Holding capacity of selected plant species at NH-89. Dots indicate average dust deposition and whiskers indicate deviation from average values.

Table 3. Total average dust accumulation of plants at both highways.

S.N.	Plant species	Average dust deposition (%)		Total average Dust Holding Capacity (%) w.r.t sites
		NH 11	NH 89	
1	*P. juliflora*	13.88	15.82	14.85
2	*P. cineraria*	22.17	16.17	19.17
3	*A. nilotica*	NA*	NA*	NA*
4	*A. indica*	21.21	18.32	19.76
5	*C. procera*	15.4	10.6	13.00
6	*Z. nummularia*	8.97	29.45	19.21
7	*S. persica*	7.5	NA	7.5
8	*F. religiosa*	10.99	8.27	9.63
9	*N. indicum*	3.4	13.2	8.3

*NA- Not Available

High deposition of dust on *P. cineraria* can be ascribed to their alternate leaf phyllotaxy and short petioles that reduce the movement of leaves in wind. This is in accordance with earlier studies exhibiting petiole length and phyllotaxy as major plant traits influencing dust deposition pattern in plants (Das & Prasad, 2012; Leonard *et al.,* 2016). Alternate leaf phyllotaxy of *P. cineraria* also facilitates its role to act as potential barrier to dust as it has one leaf on each node allowing more exposure to dust than cyclic phyllotaxy (Naik & Somashekar, 2006). *A. indica* showed high dust deposition despite of glabrous leaves having long petioles. Previous studies (Naik & Somashekar, 2006; Leonard *et al.,* 2016; Chen *et al.,* 2017) showed that lanceolate shaped leaves accumulate more dust than obovate and elliptic shaped leaves. This can be accredited to broad leaf bases in lanceolate leaves which restricts the movement of leaf during wind. Thus, the presence or combination of additional traits in *A. indica* including lanceolate leaves, alternate phyllotaxy and increased plant height may be responsible for this result. This is in conflict with the result of previous studies (Chaudhary & Rathore, 2018, 2019) which suggests that *A. indica* is a poor candidate for dust deposition. However, in a study by Swain *et al.* (2016) *A. indica* exhibited highest dust deposition at control. Lower dust deposition on *F. religiosa* may be due to long petioles that help leaf flutter erratically thereby increasing the chance of dust dislodging. The result is in agreement with the previous studies conducted by Prajapati & Tripathi (2008) and Das & Prasad (2012). Our results, therefore, provide support for the hypothesis that certain leaf traits such as petiole length, available hairy structures on the leaf surface, leaf shape, phyllotaxy, and the height of trees are important factors influencing dust deposition on leaves. Presence of cement industry in vicinity of locations 8 and 9 on NH-89 explains the highest dust load observed in plants at these locations.

Total Chlorophyll Content

Chlorophyll is an indicator of productivity of plant and is the principal photoreceptor in photosynthesis. Measurement of chlorophyll is an important parameter to evaluate the effects of air pollutants on plants as chlorophyll plays a critical role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth (Wagh *et al.,* 2006; Abu-Romman & Alzubi, 2015; Swain *et al.,* 2016; Singh *et al.,* 2018). Location wise variation of Chlorophyll a, Chlorophyll b and Total Chlorophyll Content (TCH) of selected plant species under study is shown in Table 4.

Table 4. Variation in chlorophyll content of selected plant species.

Location	Plant species	Chl a (mg/g)	Chl b (mg/g)	Total Chl (mg/g)
NH 11	*C. procera*	1.371	1.271	2.642
	P. juliflora	1.148	2.212	3.359
	P. cineraria	1.184	2.212	3.395
	A. indica	1.371	1.271	2.642
	F. religiosa	1.256	1.436	2.692
NH 89	*C. procera*	1.377	1.247	2.623
	P. juliflora	1.147	2.260	3.407

	P. cineraria	1.185	2.209	3.393
	A. indica	1.372	1.249	2.620
	F. religiosa	1.252	1.440	2.691

Degradation of chlorophyll contents in the leaf due to dust deposition is a common phenomenon (Prajapati & Tripathi, 2008). Dust deposition creates a barrier by covering the leaf surface causing a shading effect and blocking stomata which reduces oxygen uptake from atmosphere thereby decreasing the amount of energy that reaches the photosynthetic reaction centres causing lower synthesis of photosynthetic pigments and its derivatives (Anthony, 2001; Horton & Ruban, 2005; Gupta *et al.,* 2016; Shah *et al.,* 2018). Furthermore dust deposition alters leaf surface pH by dissolution of chemicals present in the dust particulates i.e. metals and polycyclic hydrocarbons in cell sap (Anthony, 2001; Swain *et al.,* 2016). It is evident from the present investigation that chlorophyll content showed variable responses to dust. NH-11 and NH-89 had maximum chlorophyll a in *C. procera* (1.371 mg/g- NH-11; 1.377- NH-89) and chlorophyll b in *P. juliflora* (2.212 mg/g- NH-11; 2.260 mg/g- NH89) as shown in Table 4. Highest Total Chlorophyll content was observed in *P. cineraria* at NH-11 (3.395 mg/g) and *P. juliflora* (3.407 mg/g) at NH-89 while lowest Total Chlorophyll Content was seen in *A. indica* irrespective of study site (Fig. 4). Low chlorophyll content observed in leaves of *A. indica* is due to highest dust deposition on its leaves.

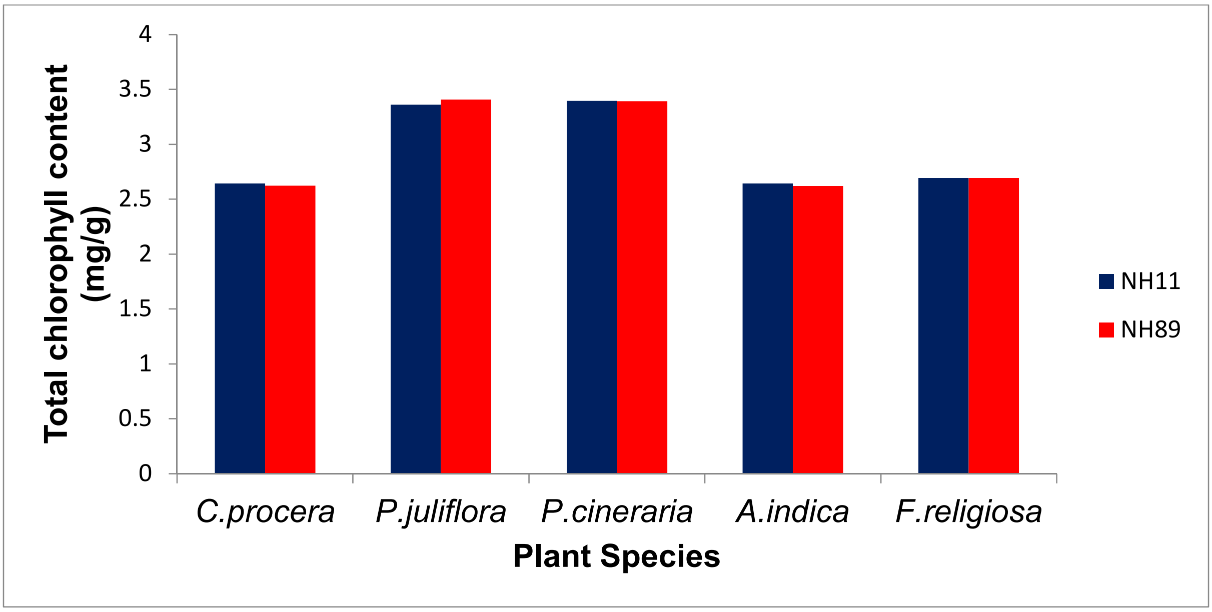

Fig.4. Total chlorophyll content in selected plant species at NH-11 and NH-89.

CONCLUSION

The study indicated that the high dust holding capacity was shown by *P. cineraria* and *A. indica* plants whereas low dust accumulation was found on *F. religiosa*. Traits including leaf shape, petiole length, leaf hairs, phyllotaxy and plant height are important factors influencing dust deposition. A high chlorophyll content was observed in *P. cineraria* (NH-11) and *P. juliflora* (NH- 89). The extent of change in chlorophyll content depends on plant tolerance towards dust and on the chemical nature of the dust. Overall, *P. cineraria* showed good dust deposition with no effect of dust on its leaf chlorophyll content. The study provides baseline data for future study in the study area including the implications of deposited dust on vegetation and the importance of leaf traits in influencing the dust deposition.

ACKNOWLEDGEMENT

This work was supported by the Department of Environmental Science, Maharaja Ganga Singh University, Bikaner (Rajasthan). The authors would like to thank the anonymous editor and reviewers for their comments and suggestions to improve the quality of the paper.

REFERENCES

Abu-Romman, S. and Alzubi, J. 2015. Effects of cement dust on the physiological activities of Arabidopsis thaliana. *Am. J. Agric. Biol. Sci.*, **10**(4): 157–164.

Agbaire, P.and Esiefarienrhe, E. 2010. Air Pollution tolerance indices (apti) of some plants around Otorogun Gas Plant in Delta State, Nigeria. *J. Appl. Sci. Environ. Manag.*, **13**(1): 11 - 14

Anthony, P. 2001. *Dust from walking tracks : Impacts on rainforest leaves and epiphylls*. *September*.

Balakrishnan, K., Dey, S., Gupta, T., Dhaliwal, R. S., Brauer, M., Cohen, A. J., Stanaway, J. D., Beig, G., Joshi, T. K., Aggarwal, A. N., Sabde, Y., Sadhu, H., Frostad, J., Causey, K., Godwin, W., Shukla, D. K., Kumar, G. A., Varghese, C. M., Muraleedharan, P., … Dandona, L. 2019. The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. *Lancet Planet. Health*, **3**(1): 26–39.

Chaturvedi, R. K., Prasad, S., Rana, S., Obaidullah, S. M., Pandey, V. and Singh, H. 2013. Effect of dust load on the leaf attributes of the tree species growing along the roadside. *Environ. Monit. Assess.*, **185**(1): 383–391.

Chaudhary, I.J. and Rathore, D. 2018. Phytomonitoring of dust load and its effect on foliar micro-morphological Characteristics of urban trees. *J. Plant Sci.*, **2**(3): 170 – 179.

Chaudhary, I.J. and Rathore, D. 2019. Dust pollution: Its removal and effect on foliage physiology of urban trees. *Sustain. Cities Soc.*, 51.

Chen, L., Liu, C., Zhang, L., Zou, R. and Zhang, Z. 2017. variation in tree species ability to capture and retain airborne fine particulate matter (PM2.5). *Sci. Rep.*, **7**(1): 1–11.

Das, S. and Prasad, P. 2012. Particulate Matter Capturing Ability of Some Plant Species :

Implication for Phytoremediation of Particulate Pollution Around Rourkela Steel Plant, Rourkela, India. *Nat. Environ. Pollut.,* **11**(4): 657-665.

Giri, S., Shrivastava, D., Deshmukh, K. and Dubey, P. 2013. Effect of air pollution on chlorophyll content of leaves. *Curr. Agric. Res. J.* **1**(2): 93-98.

Gratani, L., Crescente, M.F. and Petruzzi, C. 2000. Relationship between leaf life-span and photosynthetic activity of *Quercus ilex* in polluted urban areas (Rome). *Environ. Pollut.* **110**: 19–28.

Gupta, G. P., Kumar, B., Singh, S. and Kulshrestha, U. C. 2016. Deposition and impact of urban atmospheric dust on two medicinal plants during different seasons in NCR Delhi. *Aerosol Air Qual. Res.,* **16**(11): 2920–2932.

Health Effects Institute. 2020. *State of Global Air 2020. Special Report. Boston, MA: Health Effects Institute.*

Honour, S. L., Bell, J. N. B., Ashenden, T. W., Cape, J. N. and Power, S. A. 2009. Responses of herbaceous plants to urban air pollution: Effects on growth, phenology and leaf surface characteristics. *Environ. Pollut.*, **157**(4): 1279–1286.

Horton, P. and Ruban, A. 2005. Molecular design of the photosystem II light-harvesting antenna : photosynthesis and photoprotection. *J. Exp. Bot.,* **56**(411): 365–373.

Kaler, N. S., Bhardwaj, S. K., Pant, K. S. and Rai, T. S. 2016. determination of leaf dust accumulation on certain plant species grown alongside National Highway- 22, India.*Curr. World Environ.* , **11**(1): 77–82.

Kim, K. H., Kabir, E. and Kabir, S. 2015. A review on the human health impact of airborne particulate matter. *Environ. Int.*, **74**: 136–143.

Leonard, R. J., Mcarthur, C. and Hochuli, D. F. 2016. Urban Forestry & Urban Greening Particulate matter deposition on roadside plants and the importance of leaf trait combinations.*Urban For. Urban Green.* , **20**: 249–253.

McDowell, N., Pockman, W.T., Craig, D.A., Breshears, D.D., Cobb, N., Kolb, T., Plaut, J., Sperry, J., West, A., Williams, D.G. and Yepez, E.A. 2008. Mechanisms of plant survival and mortality during drought: why do some plants survive while others succumb to drought? *New Phytol.* **178**: 719-739.

Meravi, N., Singh, P.K., Prajapati, S.K. 2021. Seasonal variation of dust deposition on plant leaves and its impact on various photochemical yields of plants. *Environ. Chall.* 4: 100166

Naik, P. and Somashekar, R. K. 2006. role of trees in mitigating the problem of dust pollution in stone quarries- A case study Bangalore and Kolar Districts. *J. Ind. Pollut. Control,* **22**(2): 291-296.

Pandey, K. 2020. Air pollution: Half of India's death toll in these 5 states. https://www.downtoearth.org.in/news/air/

air-pollution-half-of-india-s-death-toll-in-these-5-states-74768

Prajapati, S. K. and Tripathi, B. D. 2008. seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution. *J. Environ. Qual.*, **37**(3): 865–870.

Rai, A., Kulshreshtha, K., Srivastava, P. K. and Mohanty, C. S. 2010. Leaf surface structure alterations due to particulate pollution in some common plants. *Environmentalist*, 30(1): 18–23.

Rai, P. K. and Panda, L. L. S. 2014. Leaf dust deposition and its impact on Biochemical aspect of some Roadside. *Int. J. Environ. Sci.*, **3**(11): 14–19.

Rai, P. K. and Panda, L. L. S. 2015. Roadside plants as bio indicators of air pollution in an industrial region, Rourkela, India. *Int. J. adv. res. technol.*, **4**(1): 14–36.

Sett, R. 2017. Responses in Plants Exposed to Dust Pollution. *Hortic. Int. J.*, **1**(2): 53–56.

Shah, K., Amin, N. ul, Ahmad, I. and Ara, G. 2018. Impact assessment of leaf pigments in selected landscape plants exposed to roadside dust. *Environ. Sci. Pollut. Res.*, **25**(23): 23055–23073.

Sharma, B., Sharma, S. and Bhardwaj, S. K. 2017. Effect of pollution on total chlorophyll content in temperate species growing along national highway 5 in Himachal Pradesh. *Proceedings of IEEEFORUM International Conference*, *20th Augus* **3**: 32–35.

Singh, N., Shrivastava, R. and Mishra, A. 2018a. Influence of leaf dust Deposition on Chlorophyll Content of *Bougainvillea spectabilis* and *Lanatana camara* Growing in Vicinity of Jaypee Cement Plant, Rewa (M.P.). *Int. J. Inf. Res. Rev.,* **05**: 5685–5688.

Singh, P. and Pal, A. 2017. Response of dust accumulation on roadside plant species due to open cast mining at Jhansi-Allahabad NH-76, Uttar Pradesh, India. *Trop. Plant Res.,***4**(3): 461–467.

SOP. 2015. *Botany lab manual for B.Sc. Medical semester VI. Department of Botany, DAV College, Jalandhar (Punjab)*, pp. 235.

Swain, S., Narayan Mallick, S. and Prasad, P. 2016. Effect of industrial dust deposition on photosynthetic pigment chlorophyll and growth of selected plant species in Kalunga Industrial areas. *Int. J. Botany Stud.*, **1**(5): 2455–2541.

Thimmaiah, S.K. 1999. *Standard methods of biochemical analysis. Kalyani publishers, New Delhi.*

van der Molen, M.K., Dolman, A.J., Ciais, P., Eglin, T., Gobron, N., Law, B.E., Meir, P., Peters, W., Phillips, O.L., Reichstein, M., Chen, T., Dekker, S.C., Doubkova, M., Friedl, M.A., Jung, M., van den Hurk, B.J.J.M., de Jeu, R.A.M., Kruijt, B., Ohta, T., Rebel, K.T., Plummer, S., Seneviratne, S.I., Sitch, S., Teuling, A.J., van der Werf, G.R. and Wang, G. 2011. Drought and ecosystem carbon cycling. *Agric. For. Meteorol.*, **151**(7): 765-773.

Verma, A. and Singh, S. N. 2006. Biochemical and ultrastructural changes in plant foliage exposed to auto-pollution. *Environ. Monit. Assess.,* **120**(1–3): 585–602.

Wagh, N. D., Shukla, P. V and Ingle, S. T. 2006. Biological monitoring of roadside plants exposed to vehicular pollution in Jalgaon city. *J. Environ. Biol.,* **27**: 419-421.

Yang, J., McBride, J., Zhou, J. and Sun, Z. 2005. The urban forest in Beijing and its role in air pollution reduction. *Urban For. Urban Green.*, **3**(2): 65–78.

Zha, Y., Shi, Y., Tang, J., Liu, X., Feng, C., Collab Affiliation and Zhang, Y. 2019. Spatial-temporal variability and dust-capture capability of 8 plants in urban China. *Pol. J. Environ. Stud.*, **28**(1): 453–462.