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Responses of some herbaceous road-side wild plant species against ambient particulate pollution (PM_{10}): A case study from Malda district, West Bengal

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Abstract

The aim of this study was to evaluate the responses of herbaceous plants in dust capturing potential (DCP) and leaf functional traits under ambient PM_{10} pollution alongside SH-10 in Malda district. The study was carried out during the post-monsoon and pre-monsoon of 2019 and assessed that the 24 h average concentration of PM_{10} was 88.6, 87.4 and 121.9 $\mu g.m^{-3}$ during January, February and March, 2019, respectively and exceeded the National Ambient Air Quality Standards (100 $\mu g.m^{3}$) only in March, 2019. The vegetation study revealed that the sequence of dominating species are *Hemigraphis hirta* (IVI - 38.4) followed by *Croton bonplandianus* (IVI - 8.4), *Ageratum conyzoides* (IVI - 8.1), *Mikania micrantha* (IVI - 7), *Chrysopogon zizanioides* (IVI - 5.9), *Achyranthes aspera* (IVI - 5.1), *Pouzolzia zeylanica* (IVI - 3.8), *Euhorbia hirta* (IVI - 3.6), *Oxalis corniculata* (IVI - 2.9), *Centella asiatica* (IVI - 2.6), *Anisomeles indica* (IVI - 2.3), *Rumex dentatus* (IVI - 2) and *Chrozophora rottleri* (IVI - 1.9) whereas the least dominating species are *Argemone. mexicana* (IVI - 0.5), *Passiflora foetida* (IVI - 0.7), *Amaranthus viridis* (IVI - 0.7) and *Leucas aspera* (IVI - 0.9).The study measures and compares the capabilities of these plants to accumulate and retain the PM. DCP of *M. micrantha* was highest (7 mg/cm^2), and of *A. aspera* and *O. corniculata* lowest (0.03 mg/cm^2). Here, leaf functional traits such as net water content (NWC) was maximum in *M. micrantha* and least in *L. aspera*. But, the highest value of leaf water per unit area (LWA) was observed in *M. micrantha* and lowest was exhibited in *R. dentatus* with increasing PM_{10} pollution. Leaf dry matter content (LDMC) was maximum in *P. foetida* and least value was observed in *A. mexicana*. Leaf mass per unit area (LMA) was highest in *A. conyzoides* and lowest in *A. aspera*. One-way-ANOVA results recorded distinct variation in the responses of herbaceous plant species, grown under ambient PM_{10} pollution. The study recommends *M. micrantha, P. foetida*, and *A. conyzoides* species for roadway greening and ecosystem conservation in Malda district and its similar type of climate.

Key words: Air pollution; PM_{10}; Vehicular emissions; SH-10; Dust Capturing Potential; Leaf function traits; Malda district.

INTRODUCTION

Air pollution has become a threat to urban and peri-urban population worldwide (Uka *et al.* 2017). In general, air pollutants can adversely affect human and plant health (Sarkar & Agrawal 2010, 2012) and global environment by changing the ambient air quality (Sarkar *et al.* 2012a,b; Rai 2013; Rai & Panda 2014). Air pollution emanating from PM with aerodynamic diameter less than 10μm i.e., PM_{10} is very harmful, because it can penetrate deep into human lung to create cardiovascular diseases and enters through and/or block stomata in plants (Rai 2013). Vegetation is an effective indicator of the overall impact of air pollution particularly with respect to PM. In terrestrial plant species, the enormous foliar surface area acts as a natural sink for particulate pollutants and exerted a deep influence on the morphological, physiological, biochemical and genetic status of the plant species (Younis *et al.* 2013; Rai & Panda 2014; Rai & Singh 2015). Dust deposition on leaf surface demonstrated reduction in plant growth (Bender *et al.* 2002), irregular leaf gas exchange (Ernst 1982), imbalanced flowering and reproduction of plants (Saunders and Godzik 1986), anomaly in number and area of leaves (Lambers *et al.* 1998). For instance here, it has been reported that the growth, leaves number, plant cover, and total chlorophyll content of *Vitis vinifera* decreased 87.6, 55.4, 85.6, and 34.4% as compared to control plant (*V. vinifera*) after one week treatment of road dust (Leghari *et al.* 2014). To overcome this damage, tolerant plant species possess anti-oxidative defense system (Singh *et al.* 2010; Sarkar *et al.* 2015). The PM_{10} includes different chemical components like elemental carbon, secondary nitrates, and sodium chloride etc. Harrison *et al.* (2004) in their study have been reported that the major chemical composition of PM_{10} is seen to be dominated by elemental carbon (86.18 %), sodium chloride (22.9 %), and secondary nitrates (18.24 %) at road sites in London and Birmingham.

This study aimed to examine the status of PM_{10} concentration in relation to meteorological parameters; to mark out the maximum frequency, density, abundance and IVI of herbaceous plant species; to estimate the impacts of PM_{10} on leaf functional traits; to assess the dust deposition capacity on leaves of selected herbaceous plant species and to identify the tolerant herbaceous plant species based on overall leaf functional and dust capturing potentiality with a view to recommend for roadway greening. The present study has been carried out alongside SH-10 within Malda district, West Bengal.

MATERIAL AND METHODS

Study Area

The present study was carried out alongside State Highway-10 (SH-10) in Malda district of West Bengal, India during the post-monsoon and pre-monsoon of 2019. This district lies between a latitude and longitude of 25^0 32'8" N - 24^0 40' 20"N and 88^0 28'10" E – 87^0 45'50" E. to area 3,733 Km^2.The people depend on agriculture and related business. The climate of the district is characterized by a hot and oppressive summer season, and plentiful rain and moisture in the atmosphere throughout the year (DCHB 2011). The173 km long SH-10 was developed in 2000 (Boral 2015), between Malda town and Hili of Dakshin Dinajpur and 78 km (Table 1) falls in Malda district (https://www.wbtrafficpolice.com/state-highways.php). This state highway is also connected to interior parts of the Samsi and Chanchal blocks of Malda district and acts as lifeline to the people (Boral 2015).

Table 1. Characteristic features of Sate highway-10 (SH-10) based on its length, existing petrol pump and vehicles taking fuel within Malda district.

Sl. no.	Particulars	Information
1	Origin place of SH-10	ITI more (Malda)
2	Termination place of SH-10	Hili (Dakshin Dinajpur)
3	Total length of SH-10 within Malda district	78 km
4	Total number of petrol pump alongside of SH-10 (functional)	12 (Indian oil 8, Bharat petroleum 4)
5	Total number of vehicle taking fuel per day per petrol pump (approx.)	100 - 120
5a	14 wheeler truck (approximate)	1 - 2
5b	12 wheeler truck (approximate)	4 - 6
5c	2 wheeler (bike) (approximate)	70 - 90

Meteorological Parameters

Different meteorological parameters, like maximum (T_{max}) and minimum temperature (T_{min}), relative humidity (RH), total rainfall and sunshine hours at study area have been collected from the office of the Deputy Director of Agriculture (Admn.), Govt. of West Bengal, Malda, West Bengal, India.

Selection of sites for monitoring of PM_{10} and plant sampling

Two monitoring sites (MS-1 and MS-2) and seven sampling sites (S-1 to S-7) were selected beside SH-10 (covering Malda district) based on suitable location and population density (Figure 1). The monitoring sites are characterized by medium traffic density consisting mostly of two and three wheelers, cars, trucks and buses with poorly maintained roads. The sites are devoid of residential and commercial buildings and characterized with dense wild herbaceous plants and commercial mango orchards. Major sources of PM_{10} alongside SH-10 are vehicular emission, road dust, and biomass and waste burning. The sampling sites start off at Taranagar and rest six sites are marked at every ten kilometers distance. If the marked site was near residential or commercial places, then these ten kilometers distance gap was not rigidly followed due to lack of wild herbaceous plants. Hence the one- or two-kilometers distance was added or subtracted to choose the rich plants site. Therefore, all seven sampling sites are located beside SH-10 where wild herbaceous plants are richly grown.

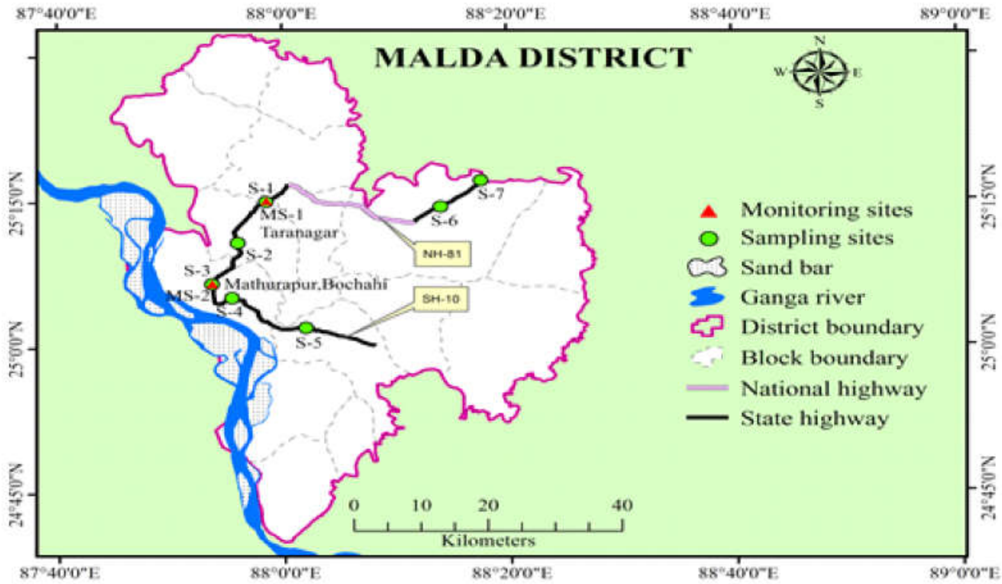

Figure 1. Location map for the study sites

Monitoring of PM_{10}

The PM_{10} was regularly monitored on 24 h basis with the help of fine particulate sampler (Model: GTI-375, Greintech Insr, Pvt. Ltd, India) following the guidelines of CPCB (NAAQS 2011). The concentration of PM_{10} was calculated by dividing the weight gain of the filter by the volume of air sampled (Mukherjee and Agrawal 2018).

Field sampling

The herbaceous species were sampled in 1 x 1 m^2 quadrats at both sides of the SH-10 with a radius of 100 m. Then frequency, density, abundance and their relative values and finally important value index (IVI) of the herb plant species were calculated following the formulae, given by Curtis and McIntosh (1951).

$$\text{Frequency (\%)} = \frac{\text{Total number of quadrates in which the species occurred}}{\text{Total number of quadrates studed}}$$

$$\text{Density} = \frac{\text{Total number of individual of a species}}{\text{Total number of quadrates studed}}$$

$$\text{Abundance} = \frac{\text{Total number of individual of a species in all the quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

Important Value Index (IVI) = Relative frequency + Relative Density + Relative Abundance

Finally, the plants species were selected based on IVI > 0.5 and their specimens were collected for herbarium preparation as described by Jain and Rao (1977). For systematic enumeration, the artificial key of the studied plant species was made following the classification described by Takhtajan in 1997.

Evaluation of plant responses

A total of seventeen (17) herbaceous wild plant species belonging to twelve (12) families have been examined periodically for dust capturing potential (DCP) and diverse leaf functional traits like net water content (NWC), leaf water per unit area (LWA), leaf dry matter content (LDMC), and leaf mass per unit area (LMA).

Healthy and fully expanded mature leaves of similar age and free from any damage or injury from pest or herbivore were collected with three biological replicates (n = 3) of a single plant species from every sampling site, and placed properly in marked polythene bags during morning hours (8.00 – 10.00 A.M.) and thereafter kept in an ice box and then brought to laboratory for further analysis.

The DCP of leaves was determined as described by Prusty *et al.* (2005), with following formula:

$$W = W_2 - W_1 / A$$

Where W = dust content (mg/cm^2), W_1= initial weight of dust, W_2 = final weight of dust, A= total area of leaf in cm^2.

Washed leaves were blotted dry and then traced on graph paper to measure the total leaf area (Saini *et al.* 2011).

NWC of leaves was calculated by using the following formula: fresh weight (FW) - dry weight (DW) of leaves. LWA was determined by dividing FW of leaves with leaf area. LDMC has been determined by dividing DW with FW of leaves. LMA have been estimated by dividing DW of leaves with leaf area (Mukherjee & Agrawal 2018).

Statistical Analyses

At first, normality assumption was determined for all the data sets in different months of the study year using Shapiro - Wilk normality test and distribution was assumed normal based on resulted p values greater than 0.05 in all cases less than 5 % level of significance. But several data which failed the normality test were assumed to be normal as values of Kurtosis and skewness were 3 and 0, respectively. Then observed data were subjected to one-way analysis of variance (ANOVA) for assessing the significance of quantitative changes in studied parameters due to

PM_{10} pollution. Duncan's multiple range tests was performed as post hoc on parameters subjected to ANOVA (only if the ANOVA was significant). All the statistical tests were performed using SPSS software (SPSS Inc., version 16.0).

RESULT AND DISCUSSION

Climate varied among the months during the study period (Table 2). The temperature was maximum during March, 2019 (31.5ÚC) and minimum during January (24.6ÚC). Maximum relative humidity was highest in February (91.6%) and lowest in March (82.5%). However, during the entire study period, total rainfall was highest during February (35.6 mm). Sunshine hours varied from 6.1 to 7.3h during January to March 2019.

Table 2. Different meteorological parameters recorded during the study period

Year	Months	Temperature (°C)		Relative Humidity (%)		Total rainfall (mm)	Sunshine (h)
		Max	Min	Max	Min		
2019	January	24.6 ± 0.2	11.7 ± 0.3	87.1 ± 0.9	45.9 ± 0.9	0	6.1 ± 0.3
	February	27.5 ± 0.4	14.3 ± 0.5	91.6 ± 0.7	46 ± 2.5	35.6	7 ± 0.4
	March	31.5 ± 0.5	17.7 ± 0.5	82.5 ± 1.3	38.3 ± 1.5	1.5	7.3 ± 0.3

The 24 h average concentration of PM_{10} was 88.6, 87.4 and 121.9 $\mu g.m^{-3}$ in January, February and March, 2019 respectively (Figure 3). It exceeded the National Ambient Air Quality Standards (100 $\mu g.m^3$) only in March, 2019. The concentration of PM_{10} was recorded lower during the month of February, 2019. This may be happened due to wash out of PM by rain (Tiwary *et al.* 2008) as total rain fall of February, 2019 was highest (35.5 mm), as compared to

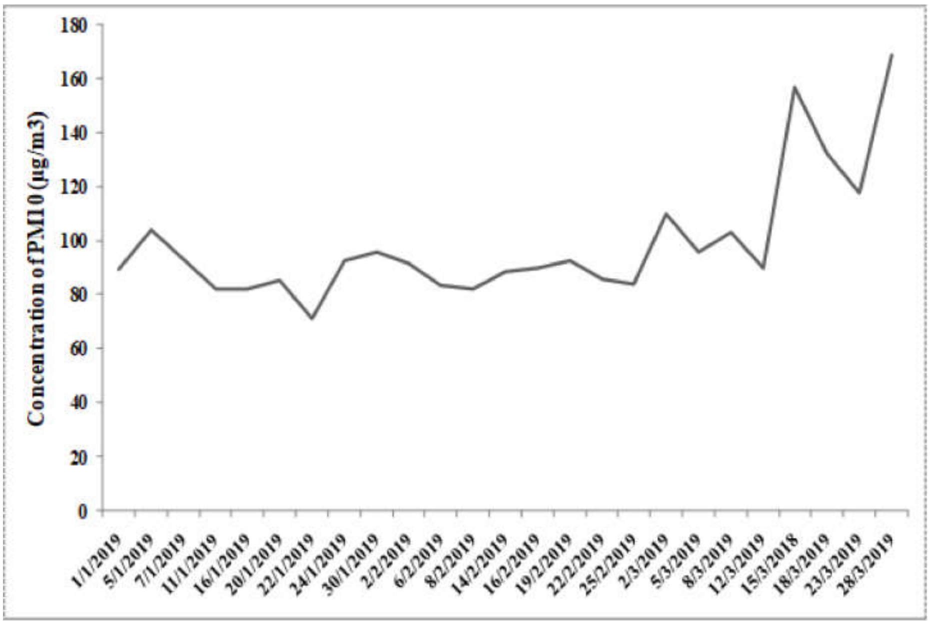

Figure 3. Concentration of PM_{10} ($\mu g/m^3$) in ambient air during study period.

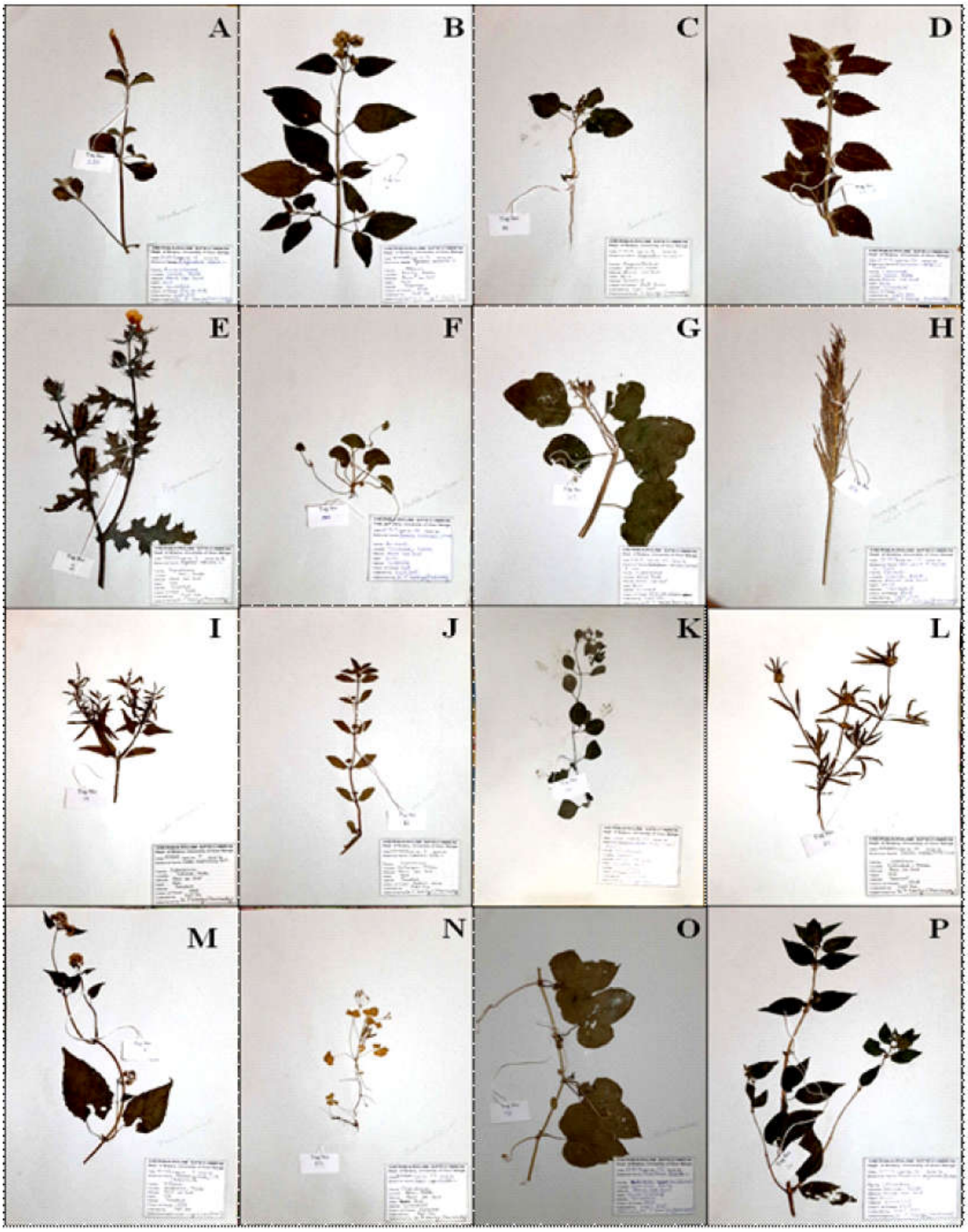

Figure 2. Some pictures of examined herbaceous plant species herbarium sheet, identified by Botanical Survey of India, Central National Herbarium, Howrah, India [A = *A. aspera*; B = *A. conyzoides*; C = *A. viridis* ; D = *A. indica*; E = *A. mexicana* ; F = *C. asiatica*; G = *C. rottleri*; H = *C. zizanioides*; I = *C. bonplandianus*; J = *E. hirta*; K = *H. hirta*; L = *L. aspera*; M = *M. micrantha*; N = *O. corniculata*; O = *P. foetida*; P = *P. zeylanica*]

the rest of the months. The average concentration of PM_{10} was considerably higher during March, 2019 due to different meteorological condition (Singhai *et al.* 2017), such as lower rainfall during March month and for low wind speed under favorable inversion conditions (Srimuruganandam and Nagendra 2010). In addition, other factors such as vehicular smoke (Das *et al.* 2018), wear and tear of brakes, tires, re-suspension of road dust (Thorpe & Harrison 2008) and photochemical reactions of sulfate and nitrate compounds in the atmosphere (Chow & Watson 2006) may be responsible for the higher concentration of PM_{10} at this time.

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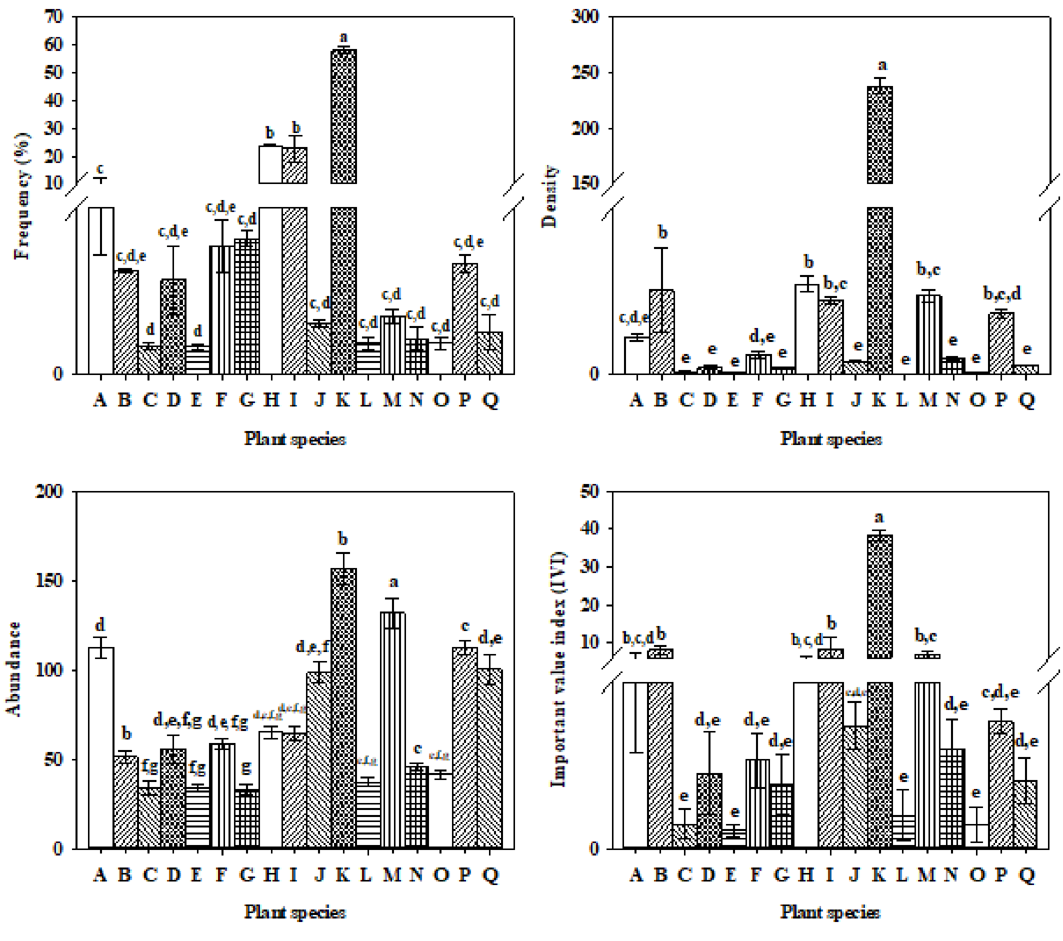

Figure 4. Discrepancy of frequency, density, abundance and IVI of studied plant species, collected from SH-10 within Malda district. Values represent mean ± SE. Bars showing different letters indicate variation according to Duncan's test at $p < 0.05$ [A = *A. aspera*; B = *A. conyzoides*; C = *A. viridis*; D = *A. indica*; E = *A. mexicana*; F = *C. asiatica*.; G = *C. rottleri*; H = *C. zizanioides*; I = *C. bonplandianus*; J = *E. hirta*; K = *H. hirta*; L = *L. aspera*; M = *M. micrantha*; N = *O.corniculata* ; O = *P.foetida*; P = *P. zeylanica*; Q = R. *dentatus*]

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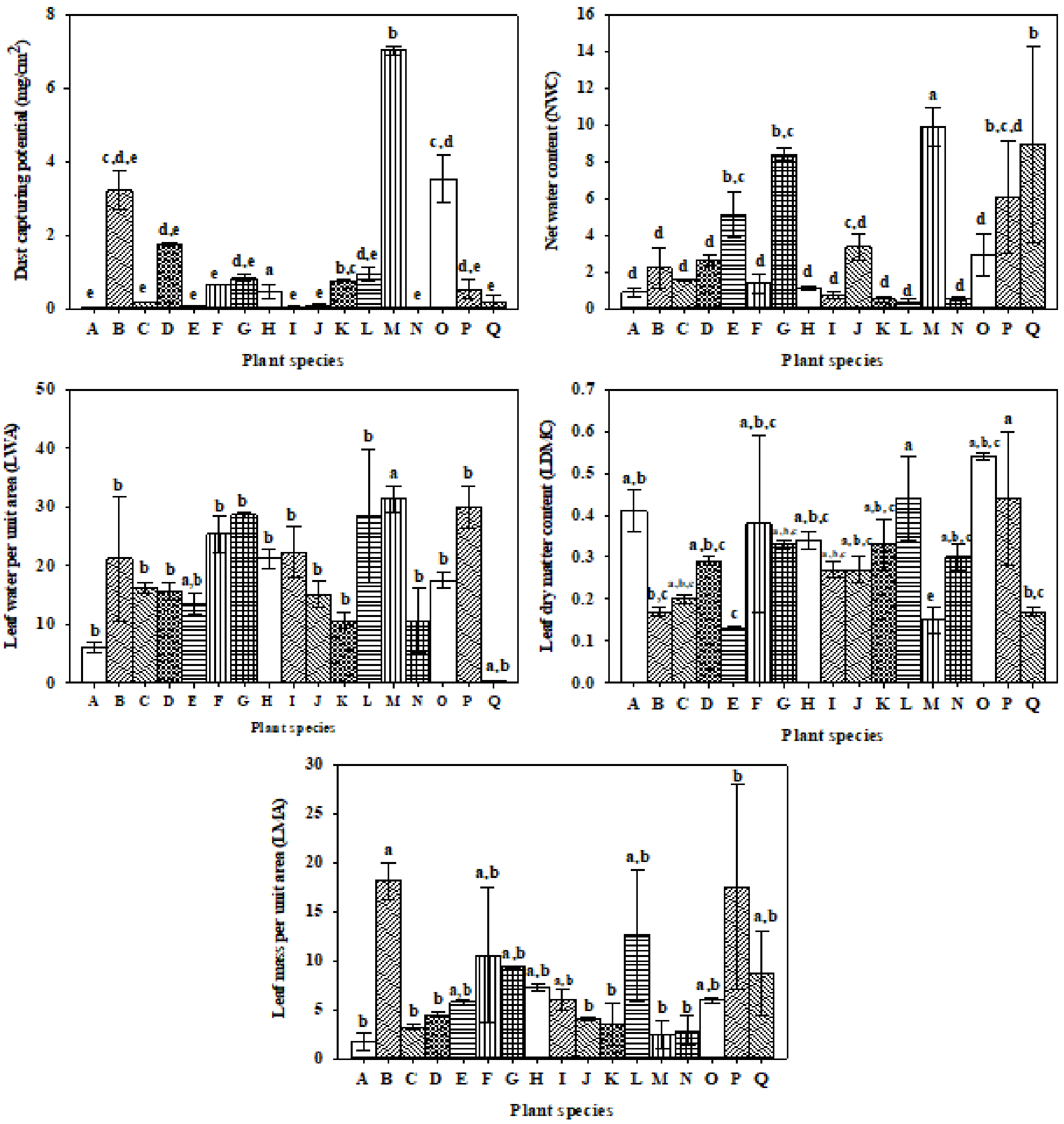

Figure 5. Variation in dust capturing potential and some leaf function traits of examined herb plant species collected from alongside SH-10 within Malda district during analysis period. Values represent mean ± SE. Bars showing different letters indicate variation according to Duncan's test at $p < 0.05$. [A = *A. aspera*; B = *A. conyzoides*; C = *A. viridis*; D = *A. indica*; E = *A. mexicana*; F = *C. asiatica*; G = *C.rottleri;* H = *C. zizanioides;* I = *C. bonplandianus*; J = *E. hirta*; K = *H. hirta*; L = *L. aspera*; M = *M. micrantha*; N = *O. corniculata*; O = *P. foetida*; P = *P. zeylanica*; Q = *R. dentatus*]

Among the seventeen examined herbaceous plant species, DCP varied from 0.03 to 7 mg/cm^2 (Figure 5). DCP of *M. micrantha* was found to be highest (7), whereas, lowest was of *A. aspera* and *O. corniculata* (0.03). The trend of DCP was found as follows; *M. micrantha* > *P. foetida* > *A. conyzoides* > *A. indica* > *L. aspera* > *C. rottleri* > *H. hirta* > C. *asiatica* > *P. zeylanica* > *C. zizanioides* > *R.dentatus* > *A. viridis* > *E. hirta* > *A. Mexicana* > *C. bonplandianus* > *A. aspera* and O. *corniculata*. Four species (*M. micrantha*, *P. foetida A. conyzoides*, and *A. indica*) had higher DCP ranging from 1.7 to 7mg/cm^2 but other thirteen species had DCP less than 1 (0.03 to 0.9 mg/cm^2). One-way ANOVA showed that DCP of *M. micrantha* recorded significant variation as compared to the other examined plant species DCP. Dust capturing potential in different herbaceous plant species depends on the factors like shape, size, orientation, texture, presence/absence of hairs, and petioles of leaf (Prusty *et al.* 2005). Pubescent leaf surface absorbs more pollutants than glabrous one (Das *et al.* 2017). For that reason, the leaves with hairy rough surface are favorable to capturing PM. This holds true for *M. micrantha, P. foetida*, *A. conyzoides*, and *A. indica*. Regardless of the smaller leaves, relatively low DCP observed in *A. aspera*, *O. corniculata*, *C. bonplandianus*, *E. hirta*, *A. viridis*, *C. asiatica*, *H. hirta*, and *L. aspera* may be due to their soft nature of leaves with low rigidity which may have reduced the ability to resist the air-flow (containing PM) and therefore have less turbulence around the leaf boundaries resulting in low levels of DCP (Liu *et al.* 2013).

NWC was maximum in *M. micrantha* and least in *L. aspera*. But, the highest LWA value was observed in *M. micrantha* and lowest was exhibited in *R. dentatus* with increasing pollution load (Figure 5). Hence, higher water content in plants is probably more tolerant to pollutants (Das *et al.* 2018). High water content with increasing pollution load in plants helps to regulate the cellular turgidity and osmotic potential of the cells (Mukherjee & Agrawal 2018). As per ANOVA result, NWC value of *M. micrantha* showed significant variation with NWC values of rest of plant. But NWC of *L. aspera* paraded significant variation with NWC values of *A. mexicana*, *C. rottleri*, *M. micrantha*, and *R. dentatus* but recorded non-significant variation with rest of studied plants. LDMC was maximum in *P. foetida* and least value was observed in *A. mexicana* at higher pollution load. High LDMC implicates a slow rate of biomass production and an efficient conservation of nutrients during increasing pollution load (Wen *et al.* 2004). One-way-ANOVA result showed that LDMC of *P. foetida* exhibited significant variation with *M. micrantha* and showed non-significant variation with rest of plants LDMC values. With increasing pollution conditions, LMA was highest in *A. conyzoides* and lowest in *A. aspera*. During higher pollution, plants distribute more resource in cost of reduction in leaf area, which leads to higher LMA. As per one-way-ANOVA result, LMA values of *A. conyzoides* showed significant variation with the LWA value of *A. indica*, *P. zeylanica A. aspera*, *A. viridis*, *H. hirta*, *M. micrantha*, *O. corniculata* and *E. hirta* but recorded non-significant variation with LWA values of other plant species. Other than, LMA of *A. aspera* exhibited significant variation with LMA values of *A. conyzoides* and also observed non-significant variation with rest of plants LMA values due to higher particulate matter (mainly PM_{10}) emission from vehicles. Based on overall leaf function traits (Mukherjee & Agrawal 2018) and DCP, *M. micrantha*, *P. foetida*, and *A. conyzoides* was the most tolerant herbaceous plant species at higher PM_{10} load.

CONCLUSION

The present study revealed that PM_{10} have substantial impact on the wild herbaceous plant species, growing alongside SH-10 in Malda district. Various leaf functional traits and dust capturing potential behaved differently in the studied plant species. *M. micrantha*, *P. foetida*, and *A. conyzoides* were found to be tolerant and they have the highest capacity to combat $PM_{10,}$ emitted mainly from vehicles and also act as pollution sink and reduce the tremendous effect of PM_{10} and to make ambient atmosphere clean and healthy. Therefore, these plant species can be incorporated into a greenbelt design to restore the ecosystem alongside SH-10 in Malda district and its similar type of climate.

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