Evaluation Of Tolerance And Sensitivity Of Selected Plant Species With Special Reference To Gasoline Exhaust Pollution

Abhinav Garg, Pallavi Saxena, Chirashree Ghosh

Abstract: Emissions from motor vehicle exhausts have been shown to have deleterious effects on the physiology of plant species. Our present study focuses on evaluating the tolerance and sensitivity of selected plant species viz. Dracaena deremensis (good absorber of VOCs) and Dianthus caryophyllus (susceptible to ethylene and formaldehyde (VOCs)) at selected sites which are differentiated on the basis of high gasoline exhaust emission source (Site I) and less gasoline exhaust emission source (Site II & III). For this, Air Pollution Tolerance Index (APTI) and selected physiological parameters were taken into account i.e. total chlorophyll, ascorbic acid, pH, relative water content, total protein and Nitrate reductase (NR). The results showed that D. deremensis have high chlorophyll content, ascorbic acid content, protein content, with high NR activity as compared to D. caryophyllus at all the selected sites. As per Air Pollution Tolerance Index (APTI) D. deremensis has value of 60.60, 55.25 & 55.93 at Site I, II & III respectively which comes under tolerant range and D . caryophyllus has value of 14.82, 15.41 & 15.93 at Site I, II & III respectively which comes under sensitive range. Thus, study ends up with the conclusion that D. deremensis was found to be more tolerant than D. caryophyllus at all sites and thus D. deremensis can be used as a tool in mitigation of gasoline exhaust pollution and D. caryophyllus can be used as an bioindicator for indicating gasoline exhaust pollution.

Index Terms: Bioindicator, Chlorophyll, Gasoline Exhaust, Nitrate Reductase, Protein, Sensitive, Tolerant, VOCs

1 Introduction

In general, the air pollution in cities has been dominated by CO_2, CO, NOx, SO_2, heavy metals, unburnt petrol, carbon particles and water vapour [1, 2, 3, 4, 5]. The major source of emission of these pollutants is from automobile exhaust. Automobile exhaust contributes significantly to atmospheric pollution especially in developing countries. It has deteriorated air quality and the degree of its contribution to air pollution depends on the traffic flow pattern [6]. The emissions from road traffic have been found to cause damage in vegetation growing in the vicinity of roads and highways [7, 8, 9, 10]. It has also been easy to recognize plant damage that results from high levels of air pollution, but very little is known about the physiological and biochemical effects on plants of long-term exposures to low levels of atmospheric pollutants [11]. There were some of the studies reported by some of the scientists focuses on damage to plant species from gasoline exhaust. For example, spruce Picea abies L. showed a reduction in twig growth, transpiration, and net photosynthesis at roadside locations compared with unpolluted sites [12, 13] and suffered an increased degradation of the epistomatal waxes [10]. Fumigations under controlled conditions were performed by Fluckiger [14], who demonstrated an inhibition of the regulatory ability of the stomata of Populus tremula leaves. Similarly, Kammerbauer et al [12, 9] reported the impairment of photosynthetic capacity and stomatal regulation in Norway spruce (Picea abies L.) which was followed by fumigation. On the basis of various studies, a number of plant species have been proposed and used for biomonitoring of air pollutants from traffic and industries in tropical and subtropical countries [8, 15, 16, 17]. At the same time, very less studies have been reported on those plant species which can be used as a tool in mitigation of gasoline exhaust especially VOCs and also as bioindicator for the same. Hence, our present study focuses on evaluating the tolerance and sensitivity of selected plant species viz. Dracaena deremensis (good absorber of VOCs) [18] and Dianthus caryophyllus (susceptible to ethylene and formaldehyde (VOCs) [19] at selected sites which are differentiated on the basis of high gasoline exhaust emission source (Site I) and less gasoline exhaust emission source (Site II & III) by taking Air Pollution Tolerance Index (APTI) along with few physiological parameters viz. total chlorophyll, total protein, ascorbic acid, pH, relative water content and nitrate reductase.

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2 Methodology

Selected plant species viz. Dracaena deremensis (VOCs tolerant) [18] and Dianthus caryophyllus (VOCs sensitive) [19] were taken at three sites (I, II & III) which are differentiated on the basis of high gasoline exhaust emission source (Site I : CNG-Petroleum Station, Civil Line) and less gasoline exhaust emission source {Site II : Near to traffic intersection area with dense vegetation, Yamuna Biodiversity Park (YBP) and Site III: Away from traffic intersection area with dense vegetation, Field Nursery, University of Delhi, North Campus} during winter season (Nov'10-Feb'2011). Selected two types of plant species were grown in earthen pots (6 X 6 inch) which contains mixture of 3:1 soil and compost (~400 inch soil mixture). These plants were of same age, ~6 weeks old with stem height of ~6 inches for Dianthus caryophyllus and ~12 inches for Dracaena deremensis with ~10 leaves in each plant. Samples were exposed at each site in triplicate (one plant/pot). Sampling was done thrice a month and analyzed in triplicates for the authenticity of the data. Leaves from potted plants were collected in an ice box, and were tested for physiological parameters, like, total chlorophyll [20], ascorbic acid [21], pH [22], Relative water content [22], Protein [23] and Enzyme Nitrate reductase [24] after every seven days from the date of potting. On the basis of four physiological parameters i.e. total chlorophyll, ascorbic acid, pH and relative water content, Air Pollution Tolerance Index (APTI) was calculated to evaluate the tolerance and sensitivity of these selected plant species [22]. For statistical interpretation of data, one way ANOVA (Duncan's Test) was used using SPSS 19.0 version.

3 Results and Discussion

Selected healthy plant species viz. Dracaena deremensisand Dianthus caryophyllus of similar age group were exposed in triplicate set at Site I (CNG-Petroleum Station) and simultaneously at Site II (Yamuna Biodiversity park) and Site III (Field Nursery, University of Delhi). The study was carried out in winter season (27th Oct'10 – 26th Feb'11) and plant samples were analyzed for total chlorophyll, total protein, nitrate reductase expression and Air Pollution Tolerance Index (APTI). No visible physical changes/injury was detected in the plant samples during exposure time. Compared with Site II & III, Site I showed lowest average chlorophyll content in both the plant species viz. Dracaena deremensis(1.24 mg/g f.w.) and Dianthus caryophyllus (0.83 mg/g f.w.) as compared to Site II (1.50 & 1.11 mg/g f.w.) and Site III (2.30 & 1.80 mg/g f.w.) respectively (Fig.1). It has also been clearly depicted from Fig.2(a-c), that the total chlorophyll content of Site I ranges between 0.7-1.89 mg/g f.w. and 0.3-1.4 mg/g f.w. of Dracaena and Dianthus respectively, at Site II 0.9-2.27 and 0.45-1.93 mg/g f.w. and at Site III 1.49 – 3.74 and 1.12 – 3.3 mg/g f.w. of Dracaena and Dianthus respectively. It has also been depicted from Fig.2 (a-c), among the four months in winter season, the lowest chlorophyll content was found in the month of January. According to Saxena and Ghosh [25] and Tiwari and Peschin [26], during winter season the concentration of air pollutants were found to be highest as compared to monsoon and summer season due to low mixing heights and low temperature inversion, there was high accumulation of pollutants. Moreover, it was also stated that among the winter months, January is the most coldest month therefore, it has highest rate of accumulation of air pollutants as compared to other winter months. Therefore, in our present study due to high pollution load in January month, lowest chlorophyll content was observed. From Table 1(a&b), 2(a&b) & 3(a&b) it was clearly depicted the data followed by different letters in a column are significantly different at P≤0.05 which clearly predicts that chlorophyll concentration are different and was lowest in January month followed by February, December and November. The data followed by different letters in a row are significantly different at P≤0.05 which clearly predicts that chlorophyll concentration are different and was found to be less in all the four reported months in Dianthus as compared to Dracaena (Table 1(a&b), 2(a&b) & 3(a&b)). The lowest chlorophyll content was found at Site I which is CNG-petroleum station, near to traffic intersection, metro station, hospital and DU Campus nearby, therefore pollution load is much higher than other selected site (Site II & III).

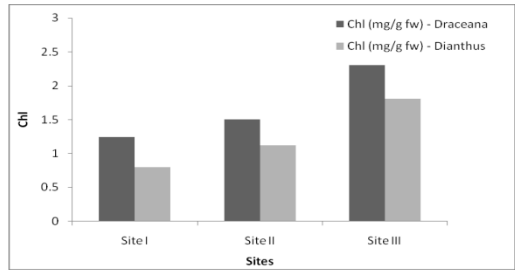

Fig. 1: *Average variation of total chlorophyll of Draceana & Dianthus at selected sites*

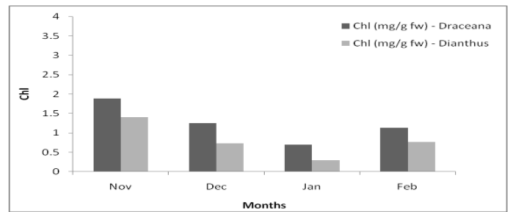

Fig.2*(a) Site I*

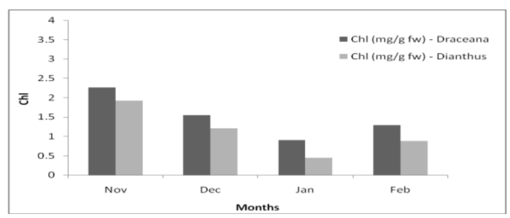

Fig.2*(b) Site II*

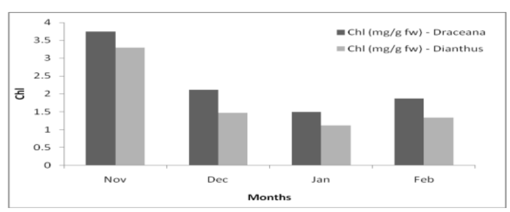

Fig.2*(c) Site III*

Table 1(a)

Variation in Chlorophyll Concentration in different months during winter season (Nov'10-Feb'11) in Dracaena deremensis at Site I (Petrol Pump), The values indicate mean ± standard error

Months	Chl concentration (mg/g f.w.)
November	1.89 + 0.92^{a}
December	1.25 + 0.54^{b}
January	0.70 + 0.18^{c}
February	1.13 ± 0.44^{bc}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05.

TABLE 1(B)

VARIATION IN CHLOROPHYLL CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE I (PETROL PUMP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Chl concentration (mg/g f.w.)
November	1.40 + 0.9^{b}
December	1.73 + 0.37^{a}
January	0.30 + 0.14^{c}
February	1.77 ± 0.21^{a}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05.

TABLE 2 (A)

VARIATION IN CHLOROPHYLL CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE II (YBP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Chl concentration (mg/g f.w.)
November	2.27 + 1.23^{a}
December	1.55 + 0.71^{b}
January	0.90 + 0.43^{c}
February	1.29 ± 0.94^{ab}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05.

In Fig. 3, the protein content of selected plant species has also been taken into account. Similarly, in case of protein, Site I has observed lowest mean protein content in both the plant Species Dracaena (38.90 mg protein/g f.w.) and Dianthus (28.61 mg protein/g f.w.) as compared to Site II (45.4 & 31.63 mg protein/g f.w.) and Site III (61.58 & 43.90 mg protein/g f.w.) of both plant species respectively. In detail, Site I range between 29.75-50.13 and 23.8-35.68 mg protein/g f.w. of Dracaena and Dianthus respectively, at Site II 27.20-70.2 and 22.9-39.80 mg protein/g f.w and at Site III ranges from 50.6-77.39 and 29.99-61.91 mg protein/g f.w of both plant species respectively (Fig.4 (a-c)). It has also been depicted from Fig.4 (a-c), among the four months in winter season, the lowest protein content was found in the month of January. The reason has already been discussed above in chlorophyll section. From Table 4(a&b), 5(a&b) & 6(a&b), it was clearly depicted the data followed by different letters in a column are significantly different at P≤0.05 which clearly predicts that protein concentration are different and was lowest in January month followed by February, December and November. The data followed by different letters in a row are significantly-

TABLE 2(B)

VARIATION IN CHLOROPHYLL CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE II (YBP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Chl concentration (mg/g f.w.)
November	1.93 + 1.07^{a}
December	1.21 + 0.72^{b}
January	0.45 + 0.34^{c}
February	0.88 ± 0.83^{ab}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05.

TABLE 3 (A)

VARIATION IN CHLOROPHYLL CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE III (DU), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Chl concentration (mg/g f.w.)
November	3.74 + 1.07^{a}
December	2.11 + 0.53^{b}
January	1.49 + 0.48^{c}
February	1.87 ± 0.53^{bc}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05.

TABLE 3 (B)

VARIATION IN CHLOROPHYLL CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE III (DU), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Chl concentration (mg/g f.w.)
November	3.30 + 1.08^{a}
December	1.47 + 0.54^{b}
January	1.12 + 0.38^{c}
February	1.34 ± 0.41^{b}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05.

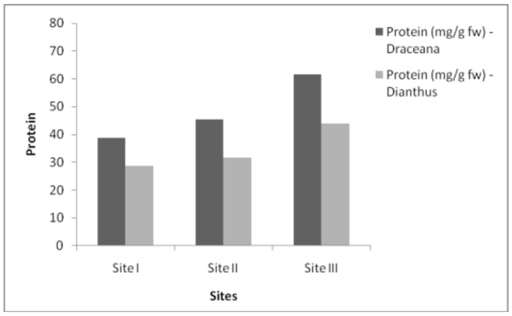

Fig. 3: *Average variation of total protein of Dracaena & Dianthus at selected sites*

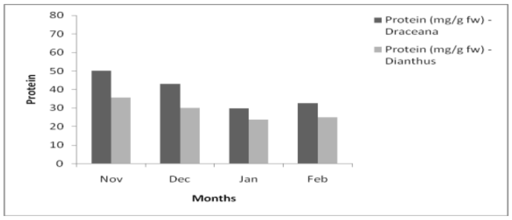

Fig.4 *(a) Site I*

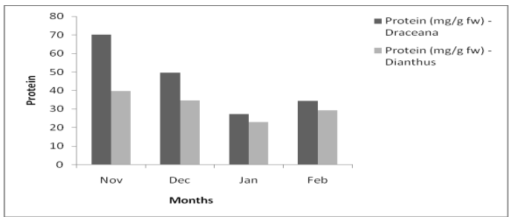

Fig.4 *(b) Site II*

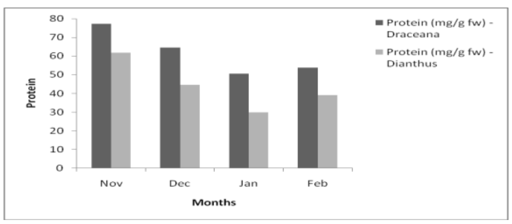

Fig.4 *(c) Site III*

Fig.4 *(a-c) Monthly average variation of Total Protein of Dracaena & Dianthus at Selected Sites*

TABLE 4 (A)

VARIATION IN PROTEIN CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE I (PETROL PUMP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Protein concentration (mg/g f.w.)
November	50.13 + 8.21^{a}
December	43.10 + 8.54^{a}
January	29.75 + 5.92^{b}
February	32.63 ± 8.40^{b}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05

TABLE 4 (B)

VARIATION IN PROTEIN CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE I (PETROL PUMP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Protein concentration (mg/g f.w.)
November	35.68 + 6.43^{a}
December	30.04 + 4.43^{a}
January	23.80 + 4.01^{b}
February	24.92 ± 6.54^{b}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05.

TABLE 5 (A)

VARIATION IN PROTEIN CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE II (YBP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Protein concentration (mg/g f.w.)
November	70.20 + 6.90^{a}
December	49.70 + 6.10^{b}
January	27.2 + 3.5^{c}
February	34.51 ± 3.61^{cb}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05.

TABLE 5 (B)

VARIATION IN PROTEIN CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE II (YBP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Protein concentration (mg/g f.w.)
November	39.79 + 5.0^{a}
December	34.63 + 4.84^{a}
January	22.90 + 3.07^{b}
February	29.2 ± 4.24^{b}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05.

TABLE 6 (A)

VARIATION IN PROTEIN CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE III (DU), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Protein concentration (mg/g f.w.)
November	77.37 + 7.48^{a}
December	64.61 + 7.34^{b}
January	50.60 + 5.04^{c}
February	53.70 ± 5.93^{c}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05.

TABLE 6 (B)

VARIATION IN PROTEIN CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE III (DU), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	Protein concentration (mg/g f.w.)
November	61.91 + 8.29^{a}
December	44.6 + 5.4^{b}
January	29.98 + 4.82^{c}
February	39.10 ± 3.14^{d}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05.

Different at P≤0.05 which clearly predicts that protein concentration are different and was found to be less in all the four reported months in Dianthus as compared to

Dracaena (Table 4(a&b), 5(a&b) & 6(a&b)). From the above discussion, it has been also clearly observed that, Dracaena deremensisshowed higher chlorophyll as well as protein content than Dianthus caryophyllus irrespective of any of the three chosen sites. According to literature reported by NASA [18] that Dracaena deremensisis VOCs tolerant plant species and Dianthus caryophyllus is VOCs sensitive species. Interestingly at our selected sites, the response of the plant species recorded substantiate the observations about their sensitivity, Dracaena was more tolerant than Dianthus. In addition to this, the enzymatic activities of nitrate reductase accelerated in plants exposed to exhaust gases from motor vehicles were also determined. From the Fig.5 it was observed that Dracaena and Dianthus sp. at Site I has highest mean nitrate reductase activity (71.37 & 32.83 nmols NO_2- h^{-1} $gfwt^{-1}$ respectively) followed by Site II (47.25 & 35.57 nmols NO_2- h^{-1} $gfwt^{-1}$) and Site III (37.93 & 21.61 nmols NO_2- h^{-1} $gfwt^{-1}$). Moreover, it has also been clearly reported from Fig.6(a-c) that nitrate reductase activity at Site I ranges between 65.83 – 76.7 & 26.2 – 37.2, Site II has 38.75 – 53.43 & 30.29 & 39 and Site III with 30.25 – 45.91 & 17.34 – 25.1 of Dracaena and Dianthus respectively. From the figures, it has been clearly noted that Site I was showing highest nitrate reductase activity because it is comparatively more polluted sites than other selected sites (Site II & III) as Site I has high gasoline emissions. This activity increase is due to the NOx fraction present in the exhaust emissions, low nitrite values were detected in exposed plants. The function of NOx in gasoline exhaust is to cause acidification of the cytoplasm and may induce photo-oxidative processes, which may cause a disturbance of ionic balance and ATP synthesis [27, 28, 29]. Gaseous NOx is known to be absorbed through the stomata or enters the plant directly through the cuticle [30] and is rapidly converted into nitrate and nitrite [29] and assimilated. This is reflected here at Site I which was having higher total nitrogen content found under the pollution-intensive roadside growing conditions. This parameter of nitrate reductase is the most appropriate physiological parameter which is clearly stated about the effect of gasoline exhaust on plants or in more precisely, the effect of VOCs and NOx on plant species. It has also been depicted from Fig.6 (a-c), among the four months in winter season, the highest NR content was found in the month of January in Dracaena and lowest in case of Dianthus. This was due to the reason that has already been discussed in chlorophyll section that among the four months of winter season, January has got highest pollution load as compared to other months.

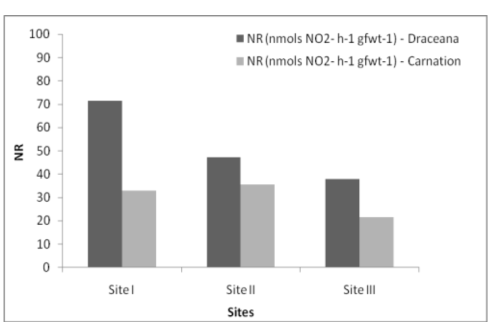

Fig. 5: *Average variation of nitrate reductase of Dracaena & Dianthus at selected sites*

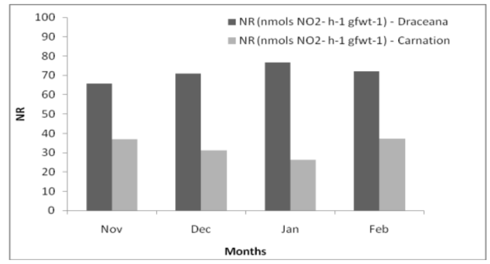

Fig.6 *(a) Site I*

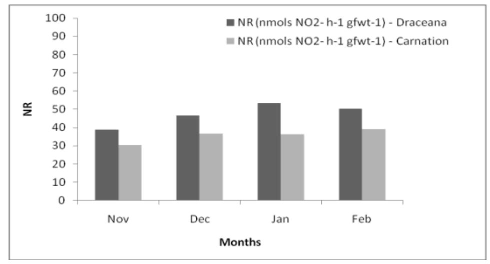

Fig.6 *(b) Site II*

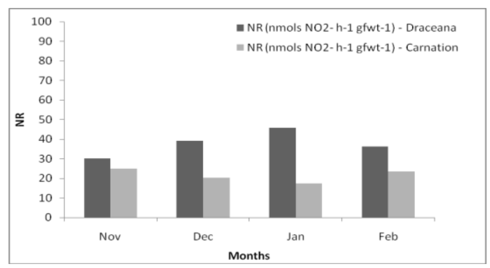

Fig.6 *(c) Site III*

Fig.6 *(a-c) Monthly average variation of Nitrate Reducatse of Dracaena & Dianthus at Selected Sites*

TABLE 7 (A)

VARIATION IN NR CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE I (PETROL PUMP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	NR (nmols NO_2-$h^{-1}gfwt^{-1}$)
November	$65.83 + 8.65^{a}$
December	$70.94 + 6.30^{a}$
January	$76.70 + 7.82^{a}$
February	71.99 ± 7.55^{a}

Each value represents mean of 18 replicates + standard error. Data followed by same letters in a column are non-significant at P≤0.05.

TABLE 7 (B)

VARIATION IN NR CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE I (PETROL PUMP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	NR (nmols NO_2-$h^{-1}gfwt^{-1}$)
November	$36.85 + 2.20^{a}$
December	$31.09 + 3.33^{a}$
January	$26.20 + 1.93^{a}$
February	37.2 ± 2.85^{a}

Each value represents mean of 18 replicates + standard *error. Data followed by same letters in a column are non-significant at P≤0.05.*

Moreover, it has already been discussed above (in protein section) that Dracaena was VOCs tolerant that's why it has high NR content and Dianthus was VOCs sensitive that's why it has lowest NR content. From Table 7(a&b), 8(a&b) & 9(a&b), it was clearly depicted the data followed by different letters in a column are significantly different at P≤0.05 which clearly predicts that NR concentration are different and was highest in January month followed by February, December and November in case of Dracaena but lowest in January in case of Dianthus. The data followed by different letters in a row are significantly different at P≤0.05 which clearly predicts that protein concentration are different and was found to be less in all the four reported months in Dianthus as compared to Dracaena (Table 7(a&b), 8(a&b) & 9(a&b)).

TABLE 8 (A)

VARIATION IN NR CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE II (YBP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	NR (nmols NO_2-h^{-1}gfwt^{-1})
November	38.75 + 4.31^{b}
December	46.64 + 4.71^{a}
January	53.43 + 6.08^{a}
February	50.18 ± 4.78^{a}

Each value represents mean of 18 replicates + standard error. Data followed by different letters in a column are significantly different but with same letters in a column are non-significant at P≤0.05.

TABLE 8 (B)

VARIATION IN NR CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE II (YBP), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	NR (nmols NO_2-h^{-1}gfwt^{-1})
November	30.28 + 5.53^{a}
December	36.72 + 2.92^{a}
January	36.24 + 5.63^{a}
February	39.0 ± 5.24^{a}

Each value represents mean of 18 replicates + standard error. Data followed by same letters in a column are non-significant at P≤0.05.

TABLE 9 (A)

VARIATION IN NR CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DRACAENA DEREMENSIS AT SITE III (DU), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	NR (nmols NO_2-h^{-1}gfwt^{-1})
November	30.25 + 3.74^{a}
December	39.24 + 2.98^{a}
January	45.91 + 3.90^{a}
February	36.34 ± 7.70^{a}

Each value represents mean of 18 replicates + standard error. Data followed by same letters in a column are non-significant at P≤0.05.

TABLE 9 (B)

VARIATION IN NR CONCENTRATION IN DIFFERENT MONTHS DURING WINTER SEASON (NOV'10-FEB'11) IN DIANTHUS CARYOPHYLLUS AT SITE III (DU), THE VALUES INDICATE MEAN ± STANDARD ERROR

Months	NR (nmols NO_2-h^{-1}gfwt^{-1})
November	25.10 + 2.24^{a}
December	20.38 + 2.63^{a}
January	17.34 + 4.89^{a}
February	23.65 ± 5.44^{a}

Each value represents mean of 18 replicates + standard error. Data followed by same letters in a column are non-significant at P≤0.05.

For the purpose of evaluating the tolerance and sensitive nature of plant species at Site I, II & III, the above selected plant species Dracaena deremensis and Dianthus caryophyllus were taken into account. The chlorophyll content, ascorbic acid content, relative moisture content and pH were calculated to determine the Air Pollution Tolerance Index (APTI) of the above selected plant species during winter season (Nov'10-Feb'11). At Site I the average chlorophyll content was found to be higher in Dracaena deremensis with 1.24 mg/g fresh wt with ascorbic acid of 68.60 mg/g fresh wt., pH with 6.7 and relative moisture content with 61.83% as compared to Dianthus caryophyllus with lower chlorophyll content of 0.99 mg/g fresh wt with Ascorbic acid of 27.79 mg/g fresh wt, pH with 4.2 and relative water content 28.07% (Fig.7). Therefore, APTI of Dracaena deremensis was found to be 60.60 and Dianthus caryophyllus was 14.82 (Fig.8) which shows that Dracaena deremensis is more tolerant plant species than Dianthus caryophyllus which is sensitive according to the scale defined by Singh and Rao [22]. At Site II the chlorophyll content was found higher in Dracaena deremensis with 1.60 mg/g fresh wt. with ascorbic acid content of 63.40 mg/g fresh wt, pH with 6.1 and relative moisture content of 63.94% as compared to Dianthus caryophyllus where lower chlorophyll content was found with 1.41 mg/g fresh wt. with ascorbic acid content was found in 30.80 mg/g fresh wt., pH with 4.3 and relative water content 29.68% (Fig. 9). From the calculations, APTI of Dracaena deremensis was found to be 55.25 and Dianthus caryophyllus with 15.41 (Fig.10) which again shows that Dracaena deremensis is tolerant plant species and Dianthus caryophyllus is sensitive one as per the index range of APTI. At Site III, the chlorophyll content was found higher in Dracaena deremensis with 2.27 mg/g fresh wt. with ascorbic acid content of 59.85 mg/g fresh wt, pH with 5.6 and relative moisture content of 66.02% as compared to Dianthus caryophyllus where lower chlorophyll content was found with 1.72 mg/g fresh wt. with ascorbic acid content was found in 27 mg/g fresh wt., pH with 4.2 and relative water content 27.74% (Fig. 11). From the calculations, APTI of Dracaena deremensis was found to be 55.93 and Dianthus caryophyllus with 15.93 (Fig.12) which again shows that Dracaena deremensis is tolerant plant species and Dianthus caryophyllus is sensitive one as per the index range of APTI. From these observations it has been observed that high ascorbic acid content are used to enhance the level of antioxidant system in plants that protects the plants from an array of environmental factors. As a result tolerant plant species poses high ascorbate and high chlorophyll content [31]. Bell and Mudd [32] suggested that tolerance of plants to any of the pollutant may be linked with synthesis or degradation of chlorophyll. Thus, plants having high chlorophyll content under field conditions are generally tolerant to air pollutants. In case of ascorbic acid content, it is a strong reductant and high amounts of this substance favours pollution tolerance in plants [33, 34]. The level of this acid declines on pollutant exposure [33]. Thus, plants maintaining high ascorbic acid level even under polluted conditions are considered to be tolerant to air pollutants. Ascorbic acid, through its reducing power, protects chloroplasts against SO_2-induced H_2O_2, O_2- and OH accumulation, and thus protects the enzymes of the CO_2 fixation cycle and chlorophyll from inactivation [34]. Together with leaf pH, it plays a significant role in determining the SO_2-sensitivity of plants [35, 36]. Its reducing power is more at higher and less at lower pH values. Thus, it may be possible that ascorbic acid protects chloroplasts and chlorophyll functions from pollutants through its pH-dependent reducing power. It has also been reported that, in the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in sensitive than that in tolerant plants [37]. Thus, a higher level of leaf-extract pH in plants under polluted conditions may increase their tolerance level to air pollutants. The last factor is relative water content, in which it has been reported that, RWC is associated with protoplasmic permeability [38], that air pollutants increase cell permeability [39], more so in the case of sensitive species [40]. Pollutant induced increased permeability in cells causes loss of water and dissolved nutrients, resulting in early senescence of leaves [41]. It is likely therefore that plants with high RWC under polluted conditions may be tolerant to pollutants. Thus, the A(T+ P) part of the formula represents the potential of chloroplast to combat pollutants after their entry inside the plant. The addition of RWC to A(T+ P) shows the capacity of the cell membrane to maintain its permeability under polluted conditions. Thus, this combination of four parameters is suggested as representing the best index of the susceptibility levels of plants under field conditions. The response of plants determined through the index values compared well with the susceptibility levels of these plants. On comparison of APTI of Site I II & III (Fig. 13), Dracaena deremensis was found to be tolerant plant species at all the three sites as compared to Dianthus caryophyllus which was found to be sensitive as per APTI index, therefore Dracaena deremensis can be recommended for good air purifier and also can be used as a tool in mitigation of gasoline exhaust pollution especially VOCs and D. caryophyllus can be used as an bioindicator for indicating gasoline exhaust pollution.

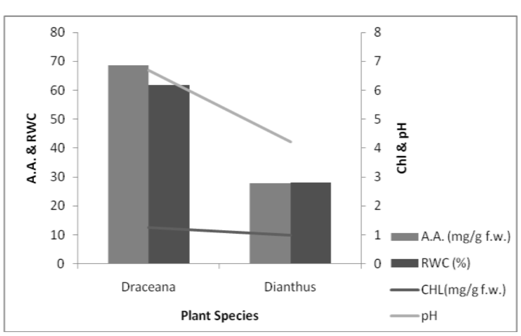

Fig.7: *Variation of physiological parameters at Site I*

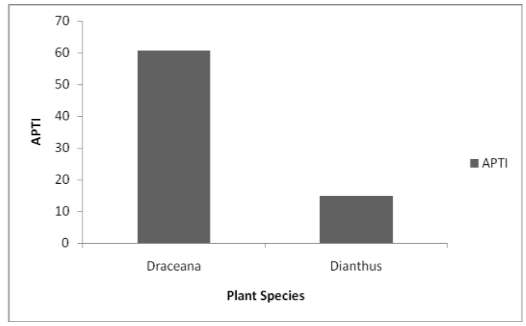

Fig.8: *Variation of APTI at Site I*

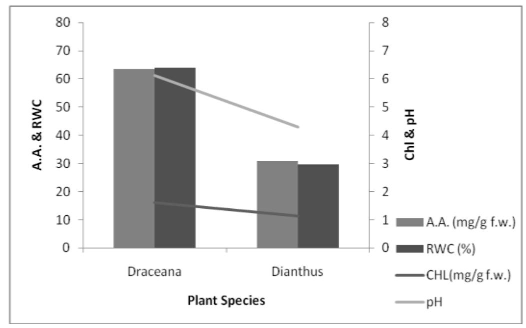

Fig.9: *Variation of physiological parameters at Site II*

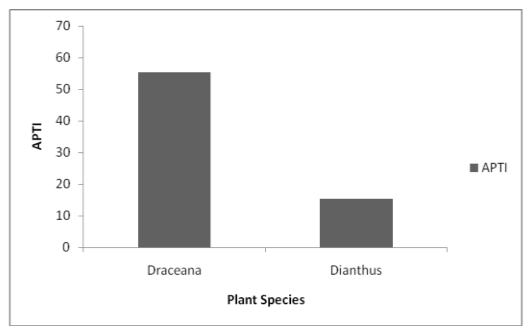

Fig.10: *Variation of APTI at Site II*

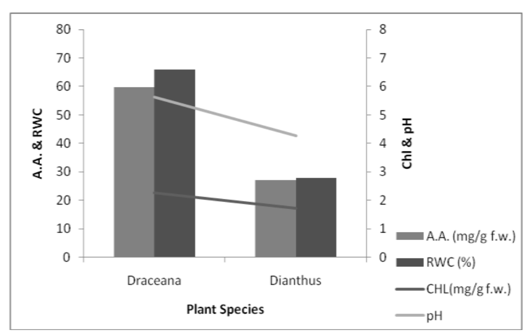

Fig.11: *Variation of physiological parameters at Site III*

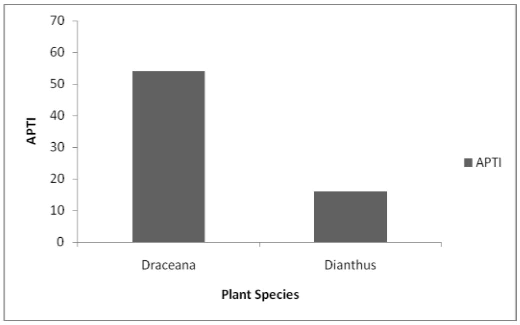

Fig.12: *Variation of APTI at Site III*

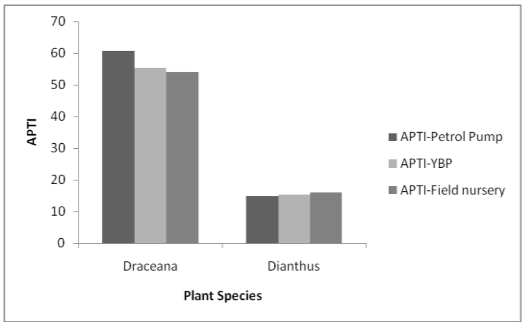

Fig.13: *Variation of APTI in Dracaena and Dianthus at Site I, II & III*

4 Conclusion

1. Dracaena deremensis was found to have higher chlorophyll, protein, Nitrate reductase, ascorbic acid and as per APTI index, it comes under tolerance range at all the three selected sites whereas, Dianthus caryophyllus have lower chlorophyll, protein, nitrate reductase, ascorbic acid and it comes under sensitive range as per APTI index.
2. Dracaena deremensis was found to be tolerant plant species and Dianthus caryophyllus was sensitive plant species. According to NASA, 2010 study, Dracaena deremensis was regarded as good absorber of VOCs in a controlled study of indoor environment whereas Cape, 1997 study, Dianthus caryophyllus was susceptible to ethylene, benzene, formaldehyde etc. (VOCs) in controlled study of both indoor as well as outdoor environment.
3. Dracaena deremensis and Dianthus caryophyllus found to be tolerant and sensitive respectively as per APTI index range in outdoor environment. Hence, can be recommended for good air purifier and also can be used as a tool in mitigation of gasoline exhaust pollution and D. caryophyllus can be used as an bioindicator for indicating gasoline exhaust pollution.

5 Acknowledgments

Authors kindly acknowledge the funding agencies, Department of Science and Technology (DST), University Grant Commission (UGC), Govt. of India and Research and Development Fund, University of Delhi for supporting the study.

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