Research article

Assessment of air pollution impact on micromorphological and biochemical properties of *Pentas lanceolata* Forssk. and *Cassia siamea* Lam.

Lohith Kumar, Hemanth kumar N. K.* and Shobha Jagannath

Department of Studies in Botany, University of Mysore, Manasagangotri, Mysuru-570 006, Karnataka, India

*Corresponding Author: nkhemanthkumar@yahoo.in

[Accepted: 27 May 2018]

Abstract: In the present study an attempt was been made to assess the air pollution effect on micromorphological and biochemical parameters of *Pentas lanceolata* and *Cassia siamea*. There was a decrease in number of stomata in *P. lanceolata* of the polluted site compared to control but in *C. siamea* numbers of stomata were increased in the polluted area when compared to control. The number of clogged stomata was less in control area samples when compared to polluted sample. A number of epidermal cells in *C. siamea* of polluted and control sites showed a significant difference. Stomatal index of both species was found to be reduced in polluted site when compared to control. Leaf surface area in both the plant species decreased from control to polluted area and leaf colour changes from green to pale yellow/dark in a polluted area of both the plant species. Chlorophyll a, b and total chlorophyll content in both the plants were found to be significantly different in control and polluted plants. Ascorbic acid, relative water content, pH and Air Pollution Tolerance index was found to be significantly different between control and polluted plants. Based on the present study results two plant species i.e., *P. lanceolata* and *C. siamea* are categorized in to intermediate and sensitive respectively. Thus they can be considered as bio indicators of air pollution.

Keywords: Air pollution - APTI - Chlorophyll - Ascorbic acid.

[Cite as: Kumar L, Hemanth kumar NK & Jagannath S (2018) Assessment of air pollution impact on micromorphological and biochemical properties of *Pentas lanceolata* Forssk. and *Cassia siamea* Lam. *Tropical Plant Research* 5(2): 141–151]

INTRODUCTION

Pollution is one of the most pervasive problems in the world due to a rapid increase in population, urbanization and industrialization. The flow of pollutants to air, soil and water is increasing with every passing year and causing irreparable damage to the earth. Environmental pollution consists of five basic types of pollution viz. air, water, soil, noise and light pollution. Among them, air pollution is by far the most harmful form of pollution. The substances that pollute the environment are called as pollutants, these pollutants include gases (sulphur oxides, oxides of nitrogen, carbon monoxide, hydrocarbons, etc.), particulate matter (smoke, dust, fumes, aerosols), radioactive materials and others (Chauhan *et al.* 2004).

Over the years there has been a continuous increase in human population, transportation and vehicular traffic and industries which have resulted in further increase in the concentrations of gaseous and particulate pollutants (Joshi & Swami 2009). Air pollution can directly affect the plants via leaves or indirectly via soil acidification. When exposed to airborne pollutants, most plants showed physiological changes before exhibiting visible damage to leaves (Liu & Ding 2008). Automobiles are responsible for the maximum amount of air pollutants and the crop plants are very sensitive to gaseous and particulate pollution and these can be used as indicators of air pollution (Joshi & Swami 2009). Pollutants can cause leaf injury, stomatal damage, premature senescence, decrease photosynthetic rate, disturb membrane permeability and reduce growth and yield in pollution sensitive plant species (Tiwari *et al.* 2006).

Air pollution stress leads to stomatal closure, which reduces carbon dioxide availability to leaves and inhibits carbon fixation. The net photosynthetic rate is commonly used as an indicator of the impact of increased

air pollutants on tree growth (Woo *et al.* 2007). Sulphur dioxide (SO₂), Oxides of nitrogen (NO_x) and carbon dioxide (CO₂) as well as suspended particulate matter (SPM) when absorbed by the leaves may cause a reduction in the concentration of photosynthetic pigments *viz.*, chlorophyll and carotenoids, which directly affected the plant productivity (Joshi & Swami 2009).

Chlorophyll measurement is an important tool to evaluate the effect of air pollutants on plants as it plays an important role in plant metabolism and the reduction in chlorophyll content corresponds directly to plant growth (Joshi & Swami 2009). Chlorophyll is an index of productivity of the plant. Certain pollutants are known to increase the total chlorophyll content, whereas others decreased (Agbair & Esiefarienrhe 2009). Studies on *Jasminum sambac* (L.) Aiton with respect to foliar epidermal features brought out by a conspicuous decrease in the size of epidermal cells and stomata, and increase in epidermal cells, stomatal and trichome frequency in plants of the polluted population. This modification of epidermal trait could be indicative of environmental pollution and could, therefore be used as bio-indicator of air pollution (Kulshreshtha *et al.* 1994a). An index to identify the tolerance of air pollutants was developed which is known as air pollution tolerance index (APTI) by Singh & Rao (1983). The usefulness of evaluating APTI for the determination of tolerance as well sensitiveness of plant species were followed by several workers (Liu & Ding 2008, Dwivedi *et al.* 2008). Therefore the present study was undertaken to evaluate the effects of air pollution on micro-morphological and biochemical parameters of *Pentas lanceolata* (Forssk.) Deflers and *Cassia siamea* (Lam.) Irwin & Barneby.

P. lanceolata, commonly known as Egyptian Starcluster, belongs to the family Rubiaceae. It is known for its wide use as a garden plant where it often accompanies butterfly gardens. *Cassia siamea* also known as *Siamese cassia*, Kassod tree, Cassod tree and *Senna siamea*, Cassia tree, is a legume in the subfamily Caesalpinioideae. It is a medium-sized, evergreen tree growing up to 18 m with beautiful yellow flowers. It is often used as a shade tree in Cocoa, Coffee and Tea plantations.

MATERIALS AND METHODS

Collection of plant materials

Leaves of *Pentas lanceolata* (Forssk.) Deflers and *Cassia siamea* (Lam.) Irwin & Barneby were collected from the K.R circle Mysuru where main city bus station is located at this junction and Chikkalli which is 5.47 km away from the Mysuru city and has negligible traffic, which served as polluted and control area respectively (Fig. 1).

Micromorphological studies

Leaf sample collected from polluted and control sites were processed for micro morphological studies following the method of Ahmad & Yunus (1985). The mature leaf samples of polluted and control sites were cut into small bits and taken in separate test tubes. 30% of Nitric acid solution was added to each test tube. Then it was boiled in a boiling water bath for 5–10 minutes. Then the leaf bits were washed in distilled water and stained with 2% safranin. Excess stain was removed by washing with distilled water and mounted using glycerin jelly. The following micro-morphological parameters were studied it includes number of stomata, number of epidermal cells, number of closed stomata, number of opened stomata, number of clogged stomata, stomatal index, size of the stomatal aperture, number of trichomes and size of the trichome. Stomatal index is calculated following the method of Salisbury (1927).

$$\text{Stomatal index (I)} = \frac{S}{E + S} \times 100$$

Where,

S= number of stomata.

E= number of epidermal cells.

Biochemical studies

The leaves from both plant species were plucked randomly and brought to the laboratory in polythene bag and preserved at 4°C until further analysis. The samples were analyzed for different biochemical parameters like p^H (Sing & Rao 1983), Total chlorophyll content (Arnon 1949), Ascorbic acid (Behrens & Madere 1994) and Relative Water Content (Sing & Rao 1983) all these parameters were analyzed within 24 hours of their harvesting.

Chlorophyll estimation

The chlorophyll content of leaves was determined following the method of Arnon (1949). The volume of extraction was made up to 100 mL by using 80% acetone. The absorbance was read by using spectrophotometer at 645 nm, and 663 nm. The amount of Chlorophyll a, b and total chlorophyll present in the sample was

calculated using the following the formula,

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

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

$$\text{Total Chlorophyll mg/g fresh weight} = \frac{20.2(A_{645}) - 8.02(A_{663}) \times V}{1000 \times W}$$

Where,

A_{645} = Value of Optical Density at 645 at absorption spectra.

A_{663} = Value of Optical Density at 663 at absorption spectra.

V = Volume of extract.

W = Weight of leaf material.

Figure 1. Location of *Pentas lanceolata*: A, Polluted; B, Control and *Cassia siamea*: C, Polluted; D, Control.

Total ascorbic acid

The total ascorbic acid content was determined following the method of Behrens & Madere (1994). One gram of fresh leaves were ground with 5 ml of Phosphate buffer (pH 7.4) and made up to 10 ml using Phosphate buffer, centrifuged at 3000 rpm for 15 minutes. 0.2 mL of supernatant was taken and 1 mL of 5% TCA was added and mixed well. Solution without sample served as blank, 1 mL of 2% DNPH (2-4 Dinitrophenyl hydrazine) reagent was added to this mixture and placed in a boiling water bath for 15 min. and cooled to room temperature. 7 mL of 80% chilled H_2SO_4 was added and the absorbance was read at 540 nm. The total ascorbic acid content was determined with a standard curve prepared by using ascorbic acid.

Relative water content (RWC)

Relative water content of leaf sample was determined following the method of the Singh & Rao (1983), based on the percentage moisture on over dry weight basis by using the formula:

$$\text{Relative water content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Leaf extract pH

One gram of fresh leaves were homogenized in 10 ml of deionized water. The extract was filtered and the p^H of leaf extract was determined by digital p^H meter.

Air Pollution Tolerance Index (APTI) determination

Air Pollution Tolerance Index (APTI) was determined following the method of Singh & Rao (1983).

$$\text{APTI} = \frac{[A(T + P) + R]}{10}$$

Where,

A = Ascorbic acid content (mg g⁻¹)

T = Total chlorophyll mg g⁻¹ fresh weight

P = pH of leaf extract

R = Relative water content of leaf (%).

RESULTS

The present study showed that air pollution causes significant changes in leaf micromorphology of two plant species *Pentas lanceolata* (Forssk.) Deflers and *Cassia siamea* (Lam.) Irwin & Barneby growing at polluted sites in Mysuru when compared with the same plant species growing at the unpolluted site. Air pollution directly affects the micromorphological parameters of the leaf (Table 1). Leaf surface area in both the plant species decreased from control to polluted area and leaf colour changes from green to pale yellow/dark in polluted area of both the species respectively (Fig. 2). There was a decrease in number of stomata in *P. lanceolata* of polluted site (48.8) compared to control (17.4) area but in *C. siamea* number of stomata were increased in polluted area (150.1) when compared to control (91.2). In both the species clogged stomata (Fig. 3) were observed, number of clogged stomata were less in control area samples when compared to polluted sample. A number of epidermal cells in *C. siamea* of polluted and control sites showed a significant difference (405.2) and (201) respectively. But in *P. lanceolata* no such significant differences were observed. Stomatal index is an important parameter to determine the physiological changes in the plant due to air pollution. Stomatal index of both species is reduced in polluted site. Stomatal index of *P. lanceolata* in control is 23.53, it has been reduced to 11.82 in the polluted site, similarly in *C. siamea* (35.07) in control and (27.10) in polluted site.

Figure 2. Leaf size and colour of *Pentas lanceolata*: **A**, Polluted; **B**, Control and *Cassia siamea*: **C**, Polluted; **D**, Control.

Table 1. Micromorphological characteristics of *Pentas lanceolata* (Forssk.) Deflers and *Cassia siamea* (Lam.) Irvin & Barneby from polluted and control site.

Plant names	Number of Stomata	Number of clogged stomata	Number of opened stomata	Number of subsidiary cells	Stomatal index	stomatal pore length	Stomatal pore breadth	Stomatal pore size	Number of trichomes	Trichome length	Trichome breadth
<i>Pentas lanceolata</i>											
C	48.8±1.6 ^a	1.2±0.4 ^b	47.8±1.7 ^a	154.6±4.5 ^a	23.53±0.3 ^a	5.8±0.4 ^a	3.6±0.5 ^a	677.6±4.3 ^a	1.6±0.54 ^b	44.2±2.3 ^a	2.4±0.5 ^b
P	17.4±0.5 ^b	4.1±0.7 ^a	15±0.7 ^b	144.2±4.2 ^b	11.82±0.8 ^b	4.6±0.5 ^b	1.8±0.4 ^b	262.2±5.4 ^b	17.8±0.8 ^a	45.6±2.4 ^b	3.1±0.2 ^a
<i>Cassia siamea</i>											
C	91.2±2.3 ^b	0.2±0.4 ^b	83±2.1 ^b	201±4.1 ^b	35.07±0.8 ^a	3.6±0.5 ^a	1.6±0.5 ^a	231.16±5.6 ^a	11.6±0.8 ^b	11.2±0.8 ^b	1.2±0.4 ^a
P	150.1±4.1 ^a	2.4±0.5 ^a	147.4±2.5 ^a	405.2±3.1 ^a	27.10±2.7 ^b	3.24±0.4 ^a	1.2±0.4 ^b	86.94±2.7 ^b	16.8±1.3 ^a	16.2±0.8 ^a	1.4±0.5 ^a

Note: Mean ± SD followed by the same superscript are not statistically significant between the concentration when subjected to SPSS package version 14.0 according to Turkey's mean range test at 5% level significant. C = Control, P = Polluted.

Figure 3. Microphotographs of stomata of leaf sample from polluted and control areas of *Pentas lanceolata*: **A**, Polluted; **B**, Control and *Cassia siamea*: **C**, Polluted; **D**, Control.

Figure 4. Microphotographs of trichomes of *Pentas lanceolata*: **A**, Polluted; **B**, Control and *Cassia siamea*: **C**, Polluted; **D**, Control.

In leaf sample from polluted area number of trichome increased significantly in *P. lanceolata*. In *C. siamea* there is no such significant difference among polluted and control site (Fig. 4). Stomatal pore size showed a significant difference in both the species. In *P. lanceolata* stomatal pore size in control site, it is 677.6 μm and it has been reduced to 262 μm in polluted site and similarly, in *C. siamea* stomatal pore size is reduced in the polluted (231.16 μm) site than control (86.94 μm) site. In *P. lanceolata* there was significant increase in the number of trichomes in polluted site (17.8) compared to control (1.6) site not only in number but also in length and breadth of trichomes, in *P. lanceolata* trichome length in polluted site was 45.6 μm and in control site it is 44.2 μm no such differences were observed among polluted and control samples in case of *C. siamea*.

Biochemical parameters

1. Chlorophyll content: The chlorophyll a, b and total chlorophyll content in both the plants were found to be significantly different (Fig. 5). In both, the plant species of control and polluted sites do not show a significant difference in chlorophyll a content but they showed a very significant difference in chlorophyll b content i.e., in *P. lanceolata* 0.41 mg g^{-1} F.Wt. in control area and 0.16 mg g^{-1} F.Wt. in polluted area. In *C. siamea* 0.15 mg g^{-1} F.Wt. in control area and it has been decreased to 0.02 mg g^{-1} F.Wt. in polluted area. Total chlorophyll content in both the species was significantly reduced in polluted area compared to unpolluted area. So it clearly indicated that chlorophyll b and total chlorophyll content in both the species is adversely affected by the air pollution.

Figure 5. Changes in Chlorophyll content of leaf sample from polluted and control areas. (Mean $\pm$ SD followed by the same letters are not statistically significant between the concentration when subjected to SPSS package version 14.0 according to Turkey's mean range test at 5% level. Chl a= Chlorophyll a, Chl b= Chlorophyll b, TCH= Total chlorophyll content)

2. Ascorbic acid content: Ascorbic acid content in both the plant species of control and polluted area were presented in figure 6. In *P. lanceolata* reduction in the ascorbic acid content of polluted area (6.56 mg g^{-1}) sample compared to the unpolluted area (18.33 mg g^{-1}) but in *C. siamea* an increase of the ascorbic acid content of polluted area (31.5 mg g^{-1}) when compared to unpolluted (16.43 mg g^{-1}) area.

Figure 6. Changes in Ascorbic acid content of leaf sample from polluted and control areas. (Mean $\pm$ SD followed by the same letters are not statistically significant between the concentration when subjected to SPSS package version 14.0 according to Turkey's mean range test at 5% level)

3. Leaf extract P^H : The pH value of both the plants of polluted and control sites are found to be significantly different (Fig. 7). In *P. lanceolata* pH value is increased in the polluted sample (6.0) compared to control sample (5.4) but in *C. siamea* pH value is decreased in the polluted sample (2.62) compared to control (4.43) respectively.

Figure 7. Changes in pH content of leaf sample from polluted and control areas. (Mean $\pm$ SD followed by the same letters are not statistically significant between the concentration when subjected to SPSS package version 14.0 according to Turkey's mean range test at 5% level)

4. Relative water content: The relative water content in both the plants differed considerably (Fig. 8). Relative water content is increased in polluted (73.33%) sample of *P. lanceolata* compare to control (65.00%) site respectively. And in *C. siamea* relative water content was increased in control (54.6%) samples and decreased in polluted (49.9%) samples.

Figure 8. Changes in Relative water content of leaf sample from polluted and control areas. (Mean $\pm$ SD followed by the same letters are not statistically significant between the concentration when subjected to SPSS package version 14.0 according to Turkey's mean range test at 5% level)

Air pollution tolerance index

The ambient air quality monitoring data at K. R. circle for two months April and May 2016, was obtained from KSPCB, Mysuru (Table 2 & Fig. 9). The concentration of SO_2 , NO_2 , and SPM were within the permissible limits of CPCB. *P. lanceolata* showed APTI values of 17.00 and 11.34 in control and polluted area sample respectively and *C. siamea* do not show significant difference among the plants of polluted (13.39) and control (14.02) area.

Figure 9. Changes in APTI values of polluted and control areas. (Mean $\pm$ SD followed by the same letters are not statistically significant between the concentration when subjected to SPSS package version 14.0 according to Turkey's mean range test at 5% level)

Table 2. Ambient Air Quality Monitoring at K.R. Circle.

S.No.	Month (2016)	SO ₂ (µg m ⁻³)	NO ₂ (µg m ⁻³)	SPM (µg m ⁻³)
1	April	BDL	22.2	53
2	May	BDL	21.1	56

Note: BDL= Below detecting level.

DISCUSSION

The response of leaf character to air pollution will indicate the adverse effect of air pollution, which can be used as bioindicator. Both *Pentas lanceolata* (Forssk.) Deflers and *Cassia siamea* (Lam.) Irwin & Barneby in the present investigation showed a reduction in leaf size in the polluted area compared to unpolluted area. A similar reduction in leaf area was also observed in leaves of *Newbouldia laevis* by Kayode & Otoide (2007) and *Albizia lebbeck* (L.) Benth. under the stress of air pollution (Seyyednejad *et al.* 2009). The stomatal index was found to be decreased in both the plant species under polluted sites as compared to control site. Vehicular pollution is known to affect the stomatal index and it has been reported to decrease in some plants (Bhiravamurthy & Kumar 1983, Pavana *et al.* 2014, Amulya *et al.* 2015, Thara *et al.* 2015). A number of epidermal cells per unit area has also been observed to be affected by the vehicular pollution and their number increased in *C. siamea* in polluted site compared to control site. Salgare & Iyer (1991) have reported the increase in a number of epidermal cells due to air pollution but in *P. lanceolata* number of epidermal cells was decreased in polluted area. A similar study was carried out by Bhiravamurthy & Kumar (1983) have reported a decrease in the number of epidermal cells per unit area due to air pollution.

Clogging of stomata and length of trichomes are also affected by air pollution. The number of clogged stomata is more in polluted site compared to control site and length of trichomes decreased in *C. siamea* in the polluted area but *P. lanceolata* trichome length has increased. The decrease in trichome number and length in polluted population has been observed in *Lantana* and *Calatropis* (Kulshreshtha *et al.* 1994a, b). On the contrary increase in trichome number has been observed. According to Sharma (1977) trichomes help trap the particulate matter falling directly on the leaf surface which otherwise block the stomata pores and adversely affect the process of gaseous exchange. This increased number of trichomes seems to be another adaptation of the stress of air pollution providing an outline defense.

Reduction in the concentration of chlorophyll content in leaves of the polluted area was observed in both the plant species. Similar changes in the concentration of pigments were also observed in leaves of six tree species exposed to air pollution due to vehicle emission by Joshi & Swami (2009). Leaves from the polluted area had significantly lower chlorophyll content than control (Tripathi & Prajapathi 2008, Stevovic *et al.* 2010).

In the present investigation increase in ascorbic acid content in *P. lanceolata* and decrease in ascorbic acid content in *C. siamea* in polluted site gives an idea about variation in the ascorbic acid content of two different species under air pollution stress and their tolerance to air pollution. Increase in ascorbic concentration with respect to the control leaves was also reported by Jyothi & Jaya (2010). The leaf pH values increased in *P. lanceolata* in the polluted area compared with that of control. The leaf pH values decreased in *C. siamea* in the polluted area compared with that of control. Similarly, increased and decreased pH values in plants growing at the polluted site were observed by Patel & Kousar (2011). The increased relative water content in *P. lanceolata* was observed in polluted sites. Similar increased relative water content was observed by Patel & Kousar (2011). In *C. siamea* relative water content was decreased in the polluted sample. Relative water content is associated with protoplasmic permeability in cells, which causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Agrawal & Tiwari 1997).

Among two plant species investigated for APTI *P. lanceolata* showed more tolerance to air pollution than *C. siamea*. Different plant species shows considerable variation in their susceptibility to air pollution. The plants with high and low APTI can serve as tolerant and sensitive species respectively. Also, the sensitivity levels of plants to air pollutants differ from shrubs and trees with identical values, a tree may be sensitive but a shrub may be tolerant to given pollutant. Therefore, the indices for different plant types should be considered separately. The result of present study reveals that these two plant species (*i.e.* *Pentas lanceolata* and *Cassia siamea*) are categorized in to intermediate and sensitive respectively based on their APTI values. Thus, they can be considered as bio indicators of air pollution.

ACKNOWLEDGEMENTS

The authors are thankful to the Head, Department of Studies in Botany, University of Mysore, for providing all the necessary requirements.

REFERENCES

- Agbaire PO & Esiefarienrhe E (2009) Air Pollution Tolerance Indices of some plants around Otorogun Gas Plant in Delta State, Nigeria. *Journal of Applied Science and Environmental Management* 13: 11–14.
- Agrawal S & Tiwari SL (1997) Susceptibility level of few plants on the basis of Air Pollution Tolerance Index. *Indian Forester* 123: 319–322.
- Ahmad KJ & Yunus M (1985) Leaf surface area characteristics as indicator of air pollution. *Symposium on Biomonitoring state Environment* pp. 254–257.
- Amulya L, Kumar NKH & Jagannath S (2015) Air pollution impact on micromorphological and biochemical response of *Tabernaemontana divaricata* L. (Gentianales: Apocynaceae) and *Hamelia patens* Jacq. (Gentianales: Rubiaceae). *Brazilian Journal of Biological Sciences* 2(4): 287–294.
- Arnon DN (1949) Copper enzyme and isolated chloroplast, polyphenoloxidase in *Beta vulgaris*. *Plant Physiology* 24: 1–15.
- Behrens WW & Madere R (1994) Ascorbic acid, isoascorbic acid, dehydroascorbic acid in selected food products. *Journal of Food Composition and Analysis* 7(3): 158–170.
- Bhiravamurthy PV & Kumar PV (1983) Air pollution and epidermal traits of *Calotropis gigantia* (Linn.) R. Br. *Indian Journal of Air Pollution Control* 1: 23–26.
- Chauhan SV, Chaurasia B & Rana A (2004) Impact of air pollution on floral morphology of *Cassia siamea* Lam. *Journal of Environmental Biology* 25(3): 291–297.
- Dwivedi AK, Tripathi BD & Shashi (2008) Effect of ambient air sulphurdioxide and sulphate accumulation in plants. *Journal of Environmental Biology* 29: 78–81.
- Joshi PC & Swami A (2009) Physiological response of some tree species under road side automobile pollution stress around city of Haridwar, India. *The Environmentalist* 27(3): 365–374.
- Jyothi JS & Jaya DS (2010) Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvananthapuram, Kerala. *Journal of Environmental Biology* 31: 379–386.
- Kayode J & Otoide JE (2007) Environmental pollution and leaf cuticular variations in *Newbouldia laevis* Seem. *Asian Journal of Plant Science* 6: 1024–1026.
- Kulshreshtha K, Arjum FK, Singh SN, Ahmed KJ & Behl MM (1994b). Effect of diesel exhaust pollution on cuticular and epidermal features of *Lantana camera* L. and *Syzygium cumini* L. *Journal of Environmental Science and Health* 29: 301–308.
- Kulshreshtha K, Srivastava K & Ahmad KJ (1994a) Effect of automobile exhaust pollution on leaf surface structures of *Calotropis procera* L. and *Nerium indicum* L. *Journal of Botanical Taxonomy and Geological Botany* 105: 185–189.
- Liu YJ & Ding H (2008) Variation in air pollution tolerance index of plants near a steel factory: implication for landscape – plant species selection of industrial areas. *Wseas Transaction on Environment and Development* 4: 24–32.
- Patel AM & Kousar H (2011) Assessment of relative water content, leaf extract pH, ascorbic acid and total chlorophyll of some plants species growing in Shivamoga. *Plant Archives* 11: 935–939.
- Pavana HC, Hemanth kumar NK, Veena M & Jagannath S (2014) Air pollution induced changes on micromorphological and biochemical parameters of two plant species: *Santalum album* L. and *Ficus religiosa* L. *International Journal of Pharmaceutical Research and Development* 6(9): 8–12.
- Salgare SA & Iyer MP (1991) Effect of auto-exhaust pollution on the micromorphology of some weeds. In: Agarwal SK (ed) *Automobile pollution*. Ashish Publishing House, New Delhi, India, pp. 119–134.
- Salisbury EJ (1927) On the causes and ecological significance of stomatal frequency, with special reference to the woodland flora. *Philosophical Transactions of the Royal Society* 216B: 1–65.
- Seyyednejad SM, Niknejad M & Yusefi M (2009) Study of air pollution effects on some physiology & morphology factors of *Albizia lebbek* in high temperature condition in Khuzestan. *Journal of Plant Sciences* 4: 122–126.
- Sharma GK (1977) Cuticular features as indicators of environmental pollution (Water, Air and Soil Pollution). *Earth and Environmental Science* 8(1): 15–19.
- Singh SK & Rao DN (1983) Evaluation of plants for their tolerance to air pollution. In: Proceedings of Symposium on Air Pollution Control, Indian Association for Air Pollution, New Delhi, India, pp. 218–224.
- Stevovic S, Mikovilovic VS & Calic D (2010) Environmental impact on morphological and anatomical structure of Tansy. *African Journal of Biotechnology* 16: 2413–2421.
- Thara SB, Hemanth kumar NK & Jagannath S (2015) Micro-morphological and biochemical response of

- Muntingia calabura* L. and *Ixora coccinia* L. to air pollution. *Research in Plant Biology* 5(4): 11–17.
- Tiwari S, Agrawal M & Marshall FM (2006) Evaluation of ambient air pollution impact on carrot plants at a sub urban site using open top chambers. *Environmental Monitoring and Assessment* 119: 15–30.
- Tripathi BD & Prajapati SK (2008) Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution. *Journal of Environmental Quality* 37: 865–870.
- Woo SY, Lee DK & Lee YK (2007) Net photosynthetic rate, ascorbate peroxidase and glutathione reductase activities of *Erythrina orientalis* in polluted and non- polluted areas. *Photosynthetica* 45(1): 292–293.