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Effect of vehicular pollution on *Duranta repens* L. in Jammu City

Anil K. Raina* and Chand Bala

Department of Environmental Sciences, University of Jammu, Jammu-180006 (J&K), INDIA
*Corresponding author. E-mail: anilkraina@yahoo.com

Abstract: Experimental potted plants of *Duranta repens* has been exposed to air pollution at major traffic crossings-Amphalla chowk, Dogra chowk, Bikram chowk, Satwari chowk of Jammu city and also inside University Campus in the department which has been taken as a reference site. Sets of 10 plants were kept at each site and analyzed for various micro morphological, anatomical and biochemical parameters to assess the changes due to air pollution. Analysis of data revealed that micro-morphological parameters viz. stomatal frequency, epidermal cell frequency increased significantly while others like size of the stomata, epidermal cells and length, breadth ratio of the epidermal cells decreased significantly in plants kept at polluted location. All the anatomical parameters such as thickness of midrib region, midrib adjoining region, spongy tissue, upper epidermis and vascular bundles decreased significantly in exposed plants. Among biochemical parameters chlorophyll b decreases significantly while ascorbic acid increases significantly. Air Pollution Tolerance Index (APTI) has also been calculated and found to increase significantly in plants kept at polluted location which indicate that the *Duranta repens* serve as sink to air pollutants and can be effectively employed for phyto-monitoring auto exhaust pollution along the road side of the busy traffic ways.

Keywords : Air pollution tolerance index, Anatomical parameters, Biochemical parameters, *Duranta repens*, Micro-morphological parameters, Vehicular pollution

INTRODUCTION

Today's growing population and increasing urbanization has resulted in deterioration of ambient air quality. Air is vital component of earth's environment and slight change in its composition can have varied effect on the growth, development and survival of different organisms on this planet. Vehicular exhaust, one of the important contributors of the air pollution, has increased eight-fold over levels of twenty years ago while industrial pollution in comparisons has risen barely four times over the same period. India is now the world's third biggest emitter of CO_2 pushing Russia into fourth place (Khergamker, 2011).

Air pollution is causing a number of changes in vegetation. Since plants are stationary and continuously exposed to chemical pollutants from surrounding atmosphere, air pollution injury to plants is proportional to the intensity of the pollution. Bio-monitoring of plants is an important tool to evaluate the impact of air pollutions. Several studies have been carried out in India to highlight the effect of air pollution on micro-morphology (Palaniswamy *et al.*, 1995; Morison, 1998; Aggarwal, 2000; Kaur, 2004), anatomy (Salgare and Rawal, 1990; Salgare and Acharekar, 1991) and biochemical (Pratibha and Sharma, 2000; Ramakrishnaiah and Somashekar, 2003; Karthiyayini *et al.*, 2005; Gupta *et al.*, 2009) parameters of different plant species at different places. In Jammu, stray reports are available on the effect of air pollution on plants species (Raina and Sharma, 2003; Raina and Aggarwal, 2004; Raina and Sharma, 2006; Raina and Bala, 2007). Therefore, the present work has been undertaken to assess the qualitative and quantitative effect of air pollution on *Duranta repens*.

MATERIALS AND METHODS

Four major traffic crossings (Amphalla chowk, Dogra chowk, Bikram chowk and Satwari chowk) have been selected on a stretch of national highway 1 A passing through the Jammu city as the polluted site while the Department of Environment, New University Campus has been selected as reference site for comparison purpose. Plant material of same age, selected from nursery of the Department of Floriculture and Landscaping, Govt. of Jammu and Kashmir, Talab Tillo Jammu has been planted in the pots of 8" diameter filled with prepared soil (soil + farmyard manure). For hardening and acclimatization, potted plants has been kept for one month in the nursery of the Department of Floriculture and Landscaping and then these pots has been shifted to (10 pots at each site) each polluted as well as reference sites for recording the observations. Irrigation, manuring and de-weeding of these has been done at regular intervals.

For recording the observation about 50 mature leaves (fifth from tip) have been plucked randomly from plants in the morning hours (about at 10 a.m.) and sealed in a polythene bag in the field. These leave samples have been mixed to represent the composite sample, which are

analyzed for different parameters to represent the averages. Observations have been recorded for two years from July 2007 to July 2009 on seasonal basis (summer, monsoon, autumn and winter) and average of all the seasons has been taken to represent the results. Micro-measurements have been taken with the help of standardized ocular micrometer at 400 x magnification by preparing a temporary mount of epidermal peeling of leaves. Temporary vertical sections of the leaves have also been prepared to record various anatomical parameters with the help of standardized ocular micrometer. Total chlorophyll contents have been determined by Hiscox and Israelstam (1979) method. For determining the Ascorbic acid, method given by Aberg (1958) has been used. pH and relative water contents of the leave samples have been determined by methods given by Singh (1977). Air Pollution Tolerance Index (APTI) has been calculated by using formula of Singh and Rao (1983).

Student-t test was used to find out the level of significance between the various parameters recorded from the polluted and reference sites.

RESULTS AND DISCUSSION

The data recorded on qualitative and quantitative details of various parameters of *D. repens* growing in the polluted and reference sites have been presented in the Table 1, 2 and 3. The values recorded seasonally represent the average of two years. Average of observations recorded for two years on seasonal basis has been taken to represent the results.

Perusal of table 1 revealed that micro-morphological parameters like size of stomata and epidermal cells and length/ breadth ratio of the epidermal cells decreases significantly while the stomatal and epidermal cells frequency and breadth of the epidermal cells increases significantly. The length/ breadth ratio of the stomata and stomatal index (S.I.), however, remained unaffected. Maximum significant values have been observed at Satwari and Amphalla chowk, followed by Dogra chowk and Bikram chowk.

The vehicular pollution, gaseous as well as particulate matter, is known to affect the various micro-morphological parameters. Workers like Bhiravamurthy and Kumar (1983); Chaudhari *et al.* (1984); Saxena (1985); Jhar (1988); Maury *et al.* (1989) Palaniswamy *et al.* (1995); Samal and Santra (2002); Raina and Sharma (2003); Kaur (2004); Raina and Aggarwal (2004); Raina and Sharma (2006); Raina and Bala (2007) have studied the effect of air pollution on different plants at various places and reported decrease in size and frequency of stomata and epidermal cells and also the stomatal index (S.I), while workers like Wagoner (1975); Yunus *et al.* (1982); Saxena (1985); Kumar and Jaishree (1989); Salgare and Iyer (1991); Salgare and Swain (1991); Pal *et al.* (2000) and Raina and Sharma (2003) have reported increase in stomatal and epidermal cell frequency and stomatal index (S.I.) of different plant species.

The reduction in stomatal number and size may be an adaptation to decrease the amount of toxic pollutants especially gases entering the leaf which may otherwise cause injury and death of the tissue of the leaves (Sharma and Butler, 1975). In the present study, the size of stomata has decreased while the number has increased significantly. This may be an adaptation of the plant to increase the area for proper gaseous exchange.

Clogging of stomatal aperture may also take place due to plasmolysis in the guard cells and some subsidiary cells thereby resulting in the shrinking of cells as a whole. In the presence of moisture, dust particles from an alkaline environment at the stomatal opening affect the osmotic relations of the guard and subsidiary cells. As a result, plasmolysis takes place in the guard cells and some subsidiary cells and cells as a whole shrinks resulting in clogging of stomatal aperture (Krishnamurthy and Rajachidambaram, 1980). Concentrations of gases viz. CO_2 and SO_2 may also facilitate closing or opening of stomata. The low dose of CO_2 may induce stomatal opening, while stomatal closure is facilitated by high dose of SO_2 (Noland and Kozlowski, 1979). Stomatal closure at high SO_2 dose may be associated with accumulation of CO_2 in the sub-stomatal cavities due to decline in photosynthesis. It has been reported that air pollution increases cell permeability by damaging the membrane integrity (Keller, 1986) more so in case of sensitive plant species (Forooq and Beg, 1980). Pollutants induced increased cell permeability may cause a loss of water from guard cells to make them flaccid, which results in stomatal closure. Further, encrustation or dust deposition on leaf cuticle due to particulate penetration in to the epicuticular wax may reduce the integrity of the incident light hampering photosynthesis which may, further lead to an accumulation of CO_2 in to the sub-stomatal cavities and hence stomatal closure (Verma and Singh, 2006).

Air born particulate also causes stomatal clogging. Particles having diameters less than the diameters of stomata cause the partial clogging while those having equal diameters to that of stomata completely clogged them (Fluckiger *et al.*, 1977; Fluckiger and Fluckiger-Keller, 1978). Hussain *et al.* (1989) reported stomatal clogging due to the cement dust and automobiles. Air born particulates reportedly decrease the number and size of stomata (Salgare and Chanderani, 1990; Sibek and Gulyas, 1990). Clogging and reduced size of stomata has impaired physiological function and affects the stomatal diffusive resistance (Addicot, 1986). This might have retarded the growth by causing a draught like condition in affecting plants. Ali *et al.* (2008) has reported that 1ppm of SO_2 has

Table 1. Quantitative details for various anatomical parameters of leaves of *D. repens.*

S. No.	Name of the sites / Parameters	University campus	Amphalla chowk	Dogra chowk	Bikram chowk	Satwari chowk	Combined average
1.	Thickness of V.S. of Leaves at midrib region (µm)	509.35±27.79 (460.50-564.69)	397.49±13.35* (364.65-418.83)	408.54±29.02* (345.90-470.92)	419.75±15.39* (381.32-450.09)	395.03±16.13* (354.23-425.08)	426.03±10.53* (403.41-444.67)
2.	Thickness of V.S. of Leaves midrib adjoining region (µm)	243.50±8.06 (229.21-270.88)	226.04± 10.59* (206.29-250.05)	223.96±29.57* (202.12-416.75)	232.79±9.79* (214.62-252.13)	220.54±10.89* (202.12-243.79)	229.37±7.69* (216.29-270.88)
3.	Thickness of palisade tissue (µm)	102.35±6.08 (87.51-112.52)	96.56±6.10* (79.18-112.52)	92.72±6.69* (79.18-108.35)	101.31±4.83 (87.51-108.35)	115.68±6.81* (102.10-131.27)	101.72±2.96 (96.26-108.77)
4.	Thickness of spongy tissue (µm)	93.64±5.64 (79.18-102.10)	90.10±4.84* (77.09-100.02)	86.30±5.71* (72.93-97.93)	93.10±5.07 (83.35-104.18)	94.01±5.91 (79.18-104.18)	91.43±2.54* (85.85-96.68)
5.	Palisade/Spongy ratio	1.12±0.07 (0.95-1.28)	1.10±0.09 (0.93-1.29)	1.10±0.10 (0.92-1.3)	1.10±0.06 (0.97-1.26)	1.08±0.08 (0.88-1.30)	1.10±0.04 (1.01-1.18)
6.	Thickness of lower epidermis(µm)	19.92±2.89 (16.67-29.17)	19.17±1.97 (16.67-25.00)	19.00±2.13 (16.67-27.92)	19.08±1.99 (16.67-25.00)	19.46±2.21 (16.67-25.00)	19.32±1.05 (17.50-21.67)
7.	Thickness of upper epidermis(µm)	21.54±2.32 (16.67-27.08)	19.71±2.38* (16.67-25.00)	18.87±2.12* (16.67-25.00)	19.75±2.39* (16.67-27.08)	19.50±2.37* (16.67-27.08)	19.87±1.05* 18.33-21.67)
8.	Ratio of Upper epidermis /Lower epidermis	1.15±0.12 (0.87-1.43)	1.09±0.14* (0.81-1.5)	1.04±0.13* (0.75-1.25)	1.08±0.15* (0.68-1.4)	1.05±0.11* (0.87-1.3)	1.08±0.06* (0.97-1.21)
9.	Vascular bundles(µm)	182.78±9.06 (164.61-197.95)	164.65±10.72* (135.44-183.37)	171.86±11.36* (143.77-197.95)	195.83±11.97* (164.61-216.71)	168.57±8.85* (150.03-185.45)	176.74±4.52* (166.28-187.12)

* Represents the significant values

Table 2. Qualitative and quantitative details of various micro morphological parameters of leaves of *D. repens.*

S.No.	Name of the sites / Parameters	University campus	Amphalla chowk	Dogra chowk	Bikram chowk	Satwari chowk	Combined average
1.	Average length of stomata (µm)	25.67±1.35 (22.41-28.66)	22.99±1.05* (20.32-26.06)	22.47±1.27* (19.80-25.02)	24.29±1.39* (21.37-27.10)	24.67±1.43* (20.32-27.10)	24.02±0.59* (22.72-25.64)
2.	Average Breadth of stomata (µm)	20.47±1.34 (17.20-22.93)	18.80±1.37* (16.15-21.37)	19.54±1.68* (15.63-23.45)	20.58±1.68 (17.72-26.58)	18.85±1.31* (16.15-21.37)	19.65±0.76* (17.51-21.57)
3.	Stomatal Average length/ Breadth ratio (l/B)	1.30±1.11 (1.04-1.61)	1.28±0.11 (1.03-1.57)	1.26±0.12 (0.99-1.52)	1.26±0.11 (1.02-1.56)	1.31±0.12 (1.06-1.57)	1.28±0.06 (1.15-1.43)
4.	Average size of stomata (L x B) (µm)	530.10±47.60 (434.72-643.38)	436.02±36.44* (362.99-532.53)	438.85±41.64* (315.17-526.01)	491.62±44.51* (384.72-606.43)	475.32±35.15* (408.63-541.22)	474.38±19.94* (432.54-506.88)
5.	Average no. of stomata / $(mm)^2$	87.68±5.80 (74.5-99.5)	91.21±7.21* (78.5-105.75)	88.51±5.97 (72.25-100.75)	100.44±6.90* (85.5-117.62)	86.64±6.10 (72.75-98.37)	90.90±2.96* (85.25-97.4)
6.	Average no .of epidermal cells/ $(mm)^2$	342.18±19.76 (301-386.75)	342.93±15.57 (304.75-368.25)	341.89±30.61 (297.25-462.75)	364.29±36.44* (315.75-479.5)	358.64±22.01* (322.5-425.12)	349.99±12.13* (33.1-397.85)
7.	Average length of epidermal cells(µm)	34.16±3.74 (27.62-43.26)	32.20±2.27* (26.58-38.57)	31.15±2.60* (25.02-38.57)	29.55±2.76* (25.02-38.57)	33.16±2.90 (27.10-38.57)	32.04±1.59* (29.50-36.43)
8.	Average breadth of epidermal cells (µm)	21.53±1.32 (19.28-25.54)	21.90±1.54* (18.24-25.54)	22.86±2.03* (18.76-27.10)	21.53±1.66 (17.72-25.54)	22.87±1.40* (20.32-26.06)	22.14±0.90* (19.94-24.60)
10.	Average length/breadth ratio of epidermal cells (L/B)	1.65±0.22 (1.26-2.24)	1.52±0.17* (1.13-1.96)	1.56±0.17* (1.24-1.96)	1.51±0.17* (1.16-1.87)	1.45±0.14* (1.17-1.76)	1.54±0.11* (1.35-1.87)
11	Average size of epidermal cells (LxB) (µm)	738.55±92.74 (593.39-982.47)	704.94±63.40* (595.56-830.32)	751.20±75.23 (589.04-906.39)	719.55±82.20 (536.88-930.30)	702.72±57.56* (593.39-828.14)	723.39±30.32 (650.34-802.93)
12	Average stomatal index	20.49±1.01 (18.73-23.47)	21.11±1.55* (17.72-24.37)	20.77±1.64 (16.95-24.59)	21.75±1.50* (17.86-25.28)	19.36±1.61* (16.23-23.17)	20.69±0.74 (19.33-22.48)

* Represents the significant values

Table 3. Total chlorophyll, relative water contents, pH and ascorbic acid in leaves of *D. repens* and AAQ class at reference and polluted locations.

S.No.	Name of the sites / Parameters	University campus	Amphalla chowk	Dogra chowk	Bikram chowk	Satwari chowk	Combined Average
1.	Chl-a (mg/gm)	0.00049±0.0000090 (0.00037-0.00067)	0.00043±0.00011 (0.00027-0.00058)	0.00047±0.0000061 (0.00035-0.00057)	0.00047±0.0000092 (0.00036-0.00063)	0.00050±0.0000084 (0.000035-0.00063)	0.00046±0.0000038 (0.00041-0.00053)
2.	Chl-b(mg/gm)	0.00083±0.00012 (0.00068-0.0010)	0.00071±0.00018 (0.00047-0.00010)	0.00066±0.0000086 (0.00052-0.00079)	0.00077±0.00014 (0.00053-0.0010)	0.00072±0.00010* (0.00058-0.00091)	0.00074±0.0000079 (0.00065-0.00089)
3.	TotalChl (a+b)(mg/gm)	0.0012±0.00015 (0.0011-0.0015)	0.0012±0.00018 (0.0010-0.0015)	0.0011±0.00010 (0.0010-0.0013)	0.0012±0.00021 (0.00092-0.0017)	0.0012±0.00012 (0.0011-0.0014)	0.0012±0.0000088 (0.0011-0.0014)
4.	Relative Water Contents (%)	69.01±18.57 (8.31-76.45)	59.66±15.01 (11.34-68.01)	66.65±15.23 (7.87-63.21)	69.37+13.23 (9.26-60.25)	77.97±13.49* (9.57-60.91)	55.91±14.83 (9.27-62.58)
5.	pH	6.54±0.04 (6.5-6.64)	6.42±0.09 (6.26-6.58)	6.51±0.09 (6.39-6.67)	6.47±0.10 (6.27-7.62)	6.21±0.10 (6.08-6.43)	6.43±0.05 (6.34-6.55)
6	Ascorbic Acid(mg/10gm)	6.33±0.39 (5.84-6.96)	7.17±0.57* (6.27-8.17)	7.22±0.58* (6.57-8.03)	6.91±0.66* (6.00-7.75)	7.84±0.69* (6.83-8.78)	7.09±0.37* (6.30-7.52)
7.	APTI (Air Pollution Tolerance Index)	42.02±2.70* (39.12-47.05)	46.73±3.99* (40.20-53.34)	47.70±3.93* (42.73-53.40)	45.34±4.75* (38.12-51.18)	49.32±4.56* (42.67-55.41)	46.26±2.67* (40.57-49.20)
8	Ambient air quality (AAQ) class*	Light air pollution	Moderate air pollution	Moderate air pollution	Moderate air pollution	Heavy air pollution	

*AAQ class has been worked out on the basis of concentrations of gaseous and particulate pollutants in these sites

noticeable difference in aperture size while 0.5 ppm of SO_2 doesn't have any noticeable difference in aperture size.

Air pollution also interferes with the anatomy of the plants. Workers like Salgare and Rawal (1990); Salgare and Acharekar (1991); Swain (1994); Samal and Santra (2002) and Raina and Bala (2007) have reported the decrease in the anatomical parameters in the leaves of some plant species growing in the polluted areas. However, in genera like *Syzygium cumini*, all the anatomical parameters except upper and lower epidermis have been reported to get stimulated by air pollution (Raina and Sharma, 2003).

In the present study almost all the anatomical parameters such as thickness of the midrib region, midrib adjoining region, spongy tissue, upper epidermis, upper and lower epidermis ratio and vascular bundles decreases significantly whereas palisade/spongy tissue ratio, lower epidermis and palisade tissue remained unaffected (Table 2). The intercellular spaces of the plants facilitate more gaseous diffusion. However, the compactness of the leaves reduces the flux of the gases into the leave interior that may further result in poor performance of the plants. Photosynthesis is highly sensitive to air pollution; therefore measurement of chlorophyll in leaves is conceptually regarded as a useful diagnosis to determine the subtle pollutant effects. It is suggested that the pollutant gases such as SO_2, NO_2 and O_3, produces oxyradicals in reaction with pollutants (Sakaki *et al.*, 1983) which causes damage to the membrane and associated molecules including chlorophyll pigment.

Chlorophyll is the index of productivity (Bell, 1980) and synthesis or degradation of chlorophyll play a leading role in the tolerance of the plants to air pollution (Dedio, 1975). Hence higher the chlorophyll contents greater is the tolerance of plants to pollution. Rao and LeBlanc (1966) have reported the degradation of Chlorophyll b due to the formation of chlorophyllide as SO_2 remove the phytol group of the chlorophyll b molecules. In the present study, concentration of Chlorophyll b has been observed to decrease significantly at Dogra and Satwari chowk (Table 3). This may be due to the higher level of pollution as has been reflected in terms of Air Quality Index (AQI) of these crossings (Table 3). Strand (1993) reported that photosynthetic pigment can also be affected at even low concentration of mixture of SO_2 and NO_2. Decrease in chlorophyll contents have been reported by Pandey and Pandey (1994), Agarwal (2000), Ramakrishnaiah and Somashekar (2003), and Kumari *et al.* (2005). However Karthiyayini *et al.* (2005) reported higher contents of chlorophyll in various plant species.

Ascorbic acid is an antiscorbic vitamin and is reported to play an important role in SO_2 reduction. It is a strong reductant and its reducing power is directly proportional to its concentration as suggested by Rao (1979). Its concentration influences many physiological and defense mechanism of plants, the synthesis as well as reducing activity of ascorbic acid is largely dependent on the pH of the cell. It also maintains the stability of plant cell membrane during stress (Dhindsha *et al.*, 1982). Studies have indicated direct relationship between the endogenous level of ascorbic acid and plant susceptibility to air pollution (Chen *et al.*, 1990). Therefore, it is obvious that higher concentrations of ascorbic acid protect the plants from SO_2 toxicity and vice versa.

Concentration of ascorbic acid may increase (Sunitha and Rao, 1997; Agarwal, 2000; Karthiyayini *et al.*, 2005) or decrease (Keller and Schwager, 1977; Sunitha and Rao, 1997; and Agarwal, 2000; Ramakrishnaiah and Somashekar, 2003) in different plant species depending upon their tolerance to the pollutants. In the present study, significantly higher concentration of ascorbic acid has been observed at polluted locations as compared to reference site (Table 3). This may increase the tolerance capacity of the *D. repens* against the higher level of pollutants in the environment.

Air Pollution Tolerance Index (APTI), calculated on the basis of total chlorophyll contents, relative water contents, pH and ascorbic acid content, reflects the tolerance capacity of the plants toward pollution. Plants with higher air pollution tolerance index (APTI) value are more capable to combat air pollution and can be used as sink to mitigate pollution, while plants having low index value show less tolerance and can be used to indicate levels of air pollution (Singh and Rao, 1983). Depending upon the sensitivity of the various plant species, higher values of APTI have been worked out for some plant species growing at polluted areas by various workers Keller and Schwager (1977); Raza *et al.* (1988); Datta and Ray (1995); Sunitha and Rao (1997); Agarwal (2000); Ramakrishnaiah and Somashekar (2003) and Karthiyayini *et al.* (2005) while in some other species decrease in APTI have been reported at polluted locations (Sunitha and Rao, 1997; Swami and Chauhan, 2007). Datta and Ray (1995) maintain that species having low index values are more sensitive to air pollution and vice versa.

The significant increase in the value of APTI at polluted locations (Table 3), in the present study indicates that *D. repens* is capable to combat air pollution and can be used as sink to mitigate pollution. Thus, it can be concluded that *D. repens* can be safely regarded as an ideal species for phytomonitoring of air pollution along the roadside in polluted habitat. Plantation of this species will also lead to rapid amelioration of habitat to cope up with polluted environment.

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