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Ambient air sulphur dioxide and sulphate accumulation in deciduous and evergreen plants

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Abstract

Present study is an attempt to evaluate the difference in rate of sulphur dioxide (SO_2) absorption by deciduous (*Ficus religiosa*) and evergreen (*Carica papaya*) plants, under elevated concentration of the gas in ambient air. Two-way ANOVA for SO_2 in air and sulphate (SO_4) accumulation in both the selected plants showed significant difference ($p<0.01$) at different study sites; different months as well as interaction effect of both site and months. The linear correlation coefficient among ambient air SO_2 and SO_4 in leaves was always significant ($p<0.001$) in case of deciduous plant; however, the same in evergreen plants showed heterogeneous result. Air pollution tolerance index (APTI) of *F. religiosa* (deciduous) and *C. papaya* (evergreen) was found to be 19.73 and 81.10 respectively, proving that the former has low tolerance capacity and is sensitive, while the latter is resistant to the elevated ambient air SO_2.

Key words

Sulphate accumulation, Cysteine, Brick kilns, Coal, *Ficus religiosa, Carica papaya*

Introduction

Elevating concentration of sulphur dioxide (SO_2) in the ambient air is normal reporting (Rao *et al*., 2005; Sharma *et al*., 2005). The concentration of SO_2 in surrounding is largely affected by the use of fossil fuel. Brick kilns, located along periphery of cities, play significant role in elevating the SO_2 concentration in the ambient air, as they are fed with sulphur rich, inferior quality of coal (Dwivedi and Tripathi, 2007). There are about 1 lakh small or large brick industries in India. Baking of 1000 bricks require about 180 kg of coal. As an estimate, an average of about 20 million tonnes of coal is being consumed by brick industries each year at national level. On an average 453.6 g of SO_2 is produced by burning of 1 tonne coal (Pandey, 1997). Consequently, 9.072 million kg of SO_2 is being released in the atmosphere by the brick kilns during summer and winter, when the kilns are functional. Objects in vicinity of such area, are subjected to the exposure to very high concentration of SO_2 during the period (Dwivedi *et al*., 2008). Sulphur dioxide toxicity to plants and other organisms is studied to some extent (Tripathi and Dwivedi, 2002 and Renuga and Paliwal, 2004). Increase in ambient air SO_2 directs the sulphate (SO_4) accumulation in the cytosol of leaves (Dwivedi *et al*., 2008). Still paucity of information exists in comparative study of amount of SO_4 accumulation in deciduous and evergreen plants in relation to the elevated ambient air SO_2. Therefore, the present study was conducted using potted *Ficus religiosa* and *Carica papaya* (as the representative of deciduous and evergreen plants, respectively) for comparison of the rate of SO_4 accumulation in the two species, in light of the increasing SO_2 in ambient air.

Materials and Methods

Pot culture experiment was conducted using 20 young saplings of *Ficus religiosa* and *Carica papaya*, each planted in earthen pots of 30 cm diameter filled with garden soil. After one month period of acclimatization the plants were placed around the 4 selected kilns at the 5 most polluted points of Varanasi. Location of the four points were calculated by the Gaussian Plume equation (Turner, 1964), using the variables such as stack height and the annual mean of relative humidity, temperature, wind velocity, wind direction, as suggested by Bowne (1974) and Power (2001). The

plants were placed in wire net chambers (1x1.5x1 m^3). The analysis started in March, 1999 and continued till March, 2000 for 13 months.

Monitoring for SO_2 in the ambient air was conducted using "high volume sampler" following the method described by West and Gaeke (1956). Analysis of SO_4 in the leaves of *F. religiosa* and *C. papaya* was done at fifteen day interval, following the method given by Rossum and Villarvuz (1961). The obtained data were expressed as monthly average. To ascertain sensitivity of the two plant species air pollution tolerance index (APTI) was calculated using the formula given by Raza *et al.* (1985).

Ascorbic acid content was estimated by the method given by Keller and Schwager (1977). Total pigment content was computed by the formulae given by Duxbury and Yentsch (1956) and Maclachlan and Zalic (1963). Leaf sample (0.5 g) was crushed and homogenised in 50 ml deionised water, the mixture was centrifuged and supernatant was collected for detection of pH using pH meter. The percent relative water content (RWC) was calculated by using the initial weight and the dry weight of leaf material.

The data were also subjected to two-way analysis of variance (ANOVA) and linear correlation to study the statistical relationship.

Results and Discussion

Brick industries are functional only during the dry periods *i.e.* from November to the mid June. Monthly variation in the concentration of SO_4 in leaves of both the plants and the concentration of SO_2 in air, along with their ± standard deviation (SD) is shown in Fig. 1.

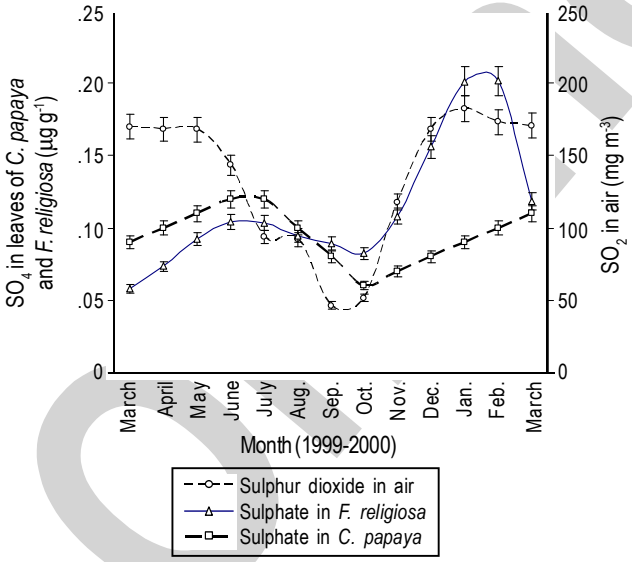

Fig. 1: Monthly mean (±SD) of sulphur dioxide (SO_2) in air and sulphate (SO_4) in leaves of all the sites

Table - 1: Two - way analysis (ANOVA) of sites, months and their interactions (site months)

Variables	Site		Month		Interaction	
	df	F-value	df	F-value	df	F-value
SO_2 in air (µg m^{-3})	3	5068.01*	12	34003.47*	36	1460.71*
SO_4 in levels of *F. religiosa* (µg g^{-1})	3	294.33*	12	618.66*	36	10.53*
SO_4 in leaves of *C. papaya* (µg g^{-1})	3	756.30*	12	185.48*	36	10.14*

* p<0.001, df = degree of freedom

Table - 2: Linear correlation coefficients among ambient air SO_2 and SO_4 in leaves of the two plants at various sites

Sites	Coefficients	
	Deciduous *(F. religiosa)*	Evergreen *(C. papaya)*
Site A	0.39097*	0.23335***
Site B	0.50424*	0.25308**
Site C	0.53820*	0.27124**
Site D	0.42213*	0.84404*

* p<0.001, ** p<0.05, *** N.S., *** N.S.

Mean level of variance (ANOVA) of SO_4 in deciduous plant showed significant difference among the sites (F = 294.33, p<0.001), among the months (F = 618.66, p<0.001) and also interaction effects of sites and months (F = 10.53, p<0.001), as shown in Table 1. On the other hand, mean level of variance of SO_4 in the evergreen plant among the sites (F = 756.30, p<0.001), among the months (F = 185.48, p<0.001) and also the interaction effect of sites and months showed significant importance (F = 10.14, p<0.001). In the case of deciduous plant, the linear relationship of accumulated sulphur showed positive correlation with the ambient air SO_2 (p<0.001) at all the sites (Table 2). At the same time the evergreen plant showed a variety of response as shown in Table 2.

Increasing trend of SO_4 in the leaves of both the plant species were recorded from March to June, 1999 and July 1999 to March 2000 (Fig. 1). Accumulation of pollutants increases with the increasing age of the leaves. It also proves that, the early sprouting leaves are less porous and therefore, they allow fewer amounts of gases (pollutants) to enter inside the leaves, parallel to the findings of Chandra (2003). From Fig. 1 reduction in sulphate of leaves from June to October, 1999 was recorded and correlated to reduction in ambient air SO_2. Since this is rainy season, brick kilns are not functional and the excess SO_2 in air is washed by the rain. October onwards, when the leaves are mature the SO_4 in leaves and SO_2 in ambient air continuously show positive correlation, parallel to the findings of Huang and Murray (1993).

From the pot culture study, it is clear that the deciduous plants (*F. religiosa* in the study) were affected by air pollution more than the evergreen plants (*C. papaya* in the study) as also reported

Table - 3: Air pollution tolerance index (APTI) of the plants

Plant	Ascorbic acid (mg g^{-1} f.wt.)	Leaf extract pH	Total chlorophyll (mg g^{-1} d.wt.)	% relative water content	APTI
Ficus religiosa	7.69	7.10	11.40	55.01	19.73
Carica papaya	32.60	7.50	15.20	71.01	81.10

by Sivasamy and Srinivasan (1997). Plants accumulate the pollutants when they are exposed to it and they assimilate it at the rate depending on their assimilation capacity. Under highly polluted condition when the rate of accumulation exceeds the rate of assimilation, then accumulation of pollutants starts inside the plants (Aerts, 1990). The deciduous plants ultimately get rid of the total accumulated pollutants through the spring leaf fall and the new leaves sprout which are free from any pollutant. On the other hand, in the case of evergreen plants, where leaf fall takes place throughout the year more or less equilibrium is maintained regarding accumulation of the pollutant in the leaves, with little fluctuation. Thus, the evergreen plants are self protected from reaching the threshold level of accumulated pollutants.

Range of variation of SO_4 in deciduous plant was 0.0581 to 0.2014 µg g^{-1} while in evergreen plant it was 0.06 to 0.12 µg g^{-1}. Lower concentration of SO_4 accumulation and slight fluctuation in the value in evergreen plants is due to continuous removal of the accumulated pollutants. Old leaves are continuously replaced by the new ones, through out the year and in doing so, the old leaves would be carrying the excessively accumulated pollutants (SO_4) also along with them.

Lower value of APTI of *F. religiosa* (19.73) shows that it is a sensitive plant. At the same time, *C. papaya* shows high APTI value (81.1) proving it to be a resistant plant for the air pollutants.

Thus, it can be concluded that the response of plants under the SO_2 induced stress condition is similar, but the mechanism to cope with this stress is different in deciduous and the evergreen plants and is very much regulated by the leaf fall. Low concentration of SO_4 in evergreen plants was maintained by the continuous leaf fall, through out the year. It is advisable that the evergreen resistant plants can be employed in abatement and sequestration of SO_2, at the same time the sulphate concentration in the leaves of deciduous plants can be used to express the SO_2 in air, thus acting as the air pollution indicator.

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