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Seasonal Changes in Sulphur Accumulation in Foliage and Bark of Timber Tree Growing Under Pollution Stress.

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Environmental issue has become a big challenge to those societies and institutions which are associating for the protection of the environment. Atmosphere is a mixture of many different gases and suspended of minute liquid or solid particles. The source of these particles is industrial and agricultural activities. Suspended particles in air act as nuclei for formation of cloud and precipitation, while others influence air temperature by interacting with sunlight.

In our country with the growth of industries, more toxic substances are either used as raw material or given off during manufacturing processes in the form of dust, fumes, vapours and gases. These pollutants dissipate in the environment and pose occupational health hazards. Air pollution can cause death, impair health and reduce visibility.

There are some half a million man made substance already present as pollutants in our total environment. These pollutants when get into the air and water disturb the ecological balance of nature. On account of large-scale industrial activities fall of acid rain has been reported [1-5]. This has reduced forest growth. In Canada, thousand of lakes have been destroyed due to acid. Industrial activity, particularly thermal power stations, cement plants oil refineries, chemical complexes, pure metallurgical industries, steel plants and fertilizer complexes cause major problems of air pollution. The effects of air pollution are felt more by the chest and respiratory complaint. Tragic instance of death has also been reported in air pollution episodes in the London smog of 1952 and the Bhopal gas tragedy of 1984. Industrial pollution, particularly from smelters has caused damage of vegetation.

Air pollution basically occurs due to air pollutant such as dust, smoke, mists, fog, fumes and gases. In gases mostly there are sulphur dioxide, hydrogen sulphide, hydrogen fluoride, chlorine and hydrogen chlorides. Oxides of nitrogen, carbon monoxide and organic vapours are emitted by different types of industries, metallurgical industries such as aluminum refineries, steel plants, copper, zinc and lead plant mainly emitted sulphur dioxide, carbon monoxides, fluorides and organic vapours (6-8). In copper plant during the smelting of ores, sulphur dioxide is evolved in stack concentrations of 5-10 % (SO_2). But this can be recovered in the form of sulphuric acid. In nature sulphur exists in elemental form and in several states, including hydrogen sulphide (H_2S), sulphites (SO_2) and sulphate (SO_4). Plants can use it only in the form of sulphate. Sulphur dioxide is the principal constituent of air pollution.

The main source of sulphur dioxides (SO_2) is the combustion of fuels, especially coal, therefore, its concentration in the atmosphere depends upon the sulphur content of the fuel used for heating and power generation(9).

The pollutants interfere with plant growth and the mechanism of photosynthesis (10). Smog, gases and dust reduce the amount of light reaching the leaf and also by closing the stomata.

The opening of the stomata in leaves control gas absorption. When the stomata are wide open absorption is maximum and vice versa, the degree of opening of stomata depend on high light intensity, high relative humidity, adequate moisture supply to the root of the plant and moderate temperature. Most plants close their stomata at night and are therefore much more resistant at night than in the day time (11).

Ray and Winstead in 1986, discovers the increased sulphur deposition in the wood of pine trees in the *Cumberland Plateau* of Kentucky from 1962 to 1986. This study highlights the long-term effect of sulfur deposition on this species in a particular region(12). Rao and Dubey in 1990, investigates into the differential responses of several tropical tree species to SO_2 in field conditions. This research is critical in understanding the variations in plant responses to sulfur pollution in different tree species(13). Katz and *et al* explores the effect of SO_2 fumigation on the chemical constituents of barley, wheat, and alfalfa(14). Patterson in 1958, discusses the colorimetric determination of sulfur and gives details the analytical methods used in the aforementioned studies to measure sulfur content in vegetation and the environment(15).

At high concentration of SO_2 the amount of chlorophyll declines causing chlorosis of leaves. A very high concentration leads to the death of leaves. The leaves absorbed the atmospheric sulphur in the form of SO_2 or SO_3 which later on gets converted into sulphite and then to sulphate. The SO_2 fumigation can increase the sulphate contents of the plants [16].

In the present study, *Dalbergia sisoo*, *Eucalyptus citrodore, Acacia nilotica and Prosopis cinororea* were selected to investigate phyto-toxic effect of SO_2 in plant leaves and barks.

MATERIAL AND METHODS

Five individuals of each tree species of 8 year age viz *Dalbergia sisoo*, *Eucalyptus citrodore*. *Acacia nilotica* and *Prosopis cinororea* were selected at a distance of 2 Km radius (polluted site) and 10 Km radius (control site) from the copper plant. The area has a moderate monsoon type of climate, characterized by a seasonal rhythm and surrounded by Aravali hill range. The monthly average minimum and maximum temperature, relative humidity, wind velocity and rainfall during the investigation period is given in table I. The emitted SO_2 during investigation period was 2% according Meteorological Department of copper plant.

From polluted and control site, each tree newly emerged 20 days old leaves were sampled during the summer, monsoon and winter season. The leaves with an apparently healthy look were collected very carefully from all the sides of the tree crown as well as from the top and bottom side. About 50 samples each were collected from five tree and the samples of individual tree were mixed together.

Bark samples were also collected from the polluted and control site in summer monsoon and winter seasons along with the leaves samples. About 1.5cm thick bark samples were chiseled out of the main trunk, the older and apparently dead parts of the bark were discarded, the bark portion was chopped in five slices and sufficiently dried in an oven at 80^0C. The bark samples were powdered for analysis.

Sulphate sulphur in the leaves and bark samples were determined by following the method of Patterson (1958) [17].

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Table -1: Meteorological data of study area for different seasons.

Season	Temperature (^{0}C)		Average	Relative Humidity (%)		Average (%)	Wind Velocity(F/S)		Average F/S	Rainfall (mm)*		
	Min	Max		Min	Max		Min	Max		Min	Max	Average
Summer April-June 2008	28.80	44.60	42.40	10.00	48.00	30.00	02.60	24.20	14.10	02.00	26.00	06.00
Monsoon July-Sept. 2008	24.40	38.00	32.70	18.00	79.00	68.00	02.30	18.60	09.20	04.00	86.00	46.00
Winter Nov.-Feb. 2008-09	13.50	28.20	24.50	09.00	66.00	41.12	01.80	11.30	08.20	01.00	09.00	04.00

* According to Meteorological Department of Khetri Copper Plant.

Chimney of Khetri Copper Plant

Pollution effect on Vegetation

Table -2: Seasonal changes in sulphate sulphur content in foliage/leaves samples of tree species growing under control and polluted sites.

Tree Species	Site	Summer	Monsoon	Winter
Dalbergia sisoo	P	0.280±0.038	0.446±0.13	0.280±0.016
	C	0.156±0.012(+79)*	0.256±0.11(+74)*	0.215±0.015(+30)*
Eucalyptus citrodore	P	0.330±0.029	0.457±0.023	0.340±0.022
	C	0.192±0.023(+71)*	0.269±0.018(+69)*	0.264±0.026(+28)**
Acacia nilotica	P	0.198±0.033	0.288±0.037	0.191±0.029
	C	0.123±0.017(+60)*	0.191±0.029(+50)*	0.138±0.040(+38)*
Prosopis cinororea	P	0.210±0.015	0.280±0.034	0.160±0.013
	C	0.128±0.011(+64)*	0.181±0.027(+59)*	0.132±0.037(+21)**

Values (% dry weight) are mean ± standard deviation

P- Polluted Site

C- Control Site

*, ** = Significant at $p<0.01$ and $p<0.05$ level, respectively.

(+) Indicates % increase over Control

Table -3: Seasonal changes in sulphate sulphur content in the bark samples of tree species growing under control and polluted sites.

Tree Species	Site	Summer	Monsoon	Winter
Dalbergia sisoo	P	0. 068±0.021	0.146±0.020	0.110±0.025
	C	0.053±0.008(+28) **	0.088±0.016(+65) *	0.060±0.015(+50) *
Eucalyptus citrodore	P	0.144±0.027	0.194±0.27	0.160±0.030
	C	0.104±0.016(+38) *	0.124±0.02(+56) *	0.130±0.021(+23) **
Acacia nilotica	P	0.098±0.016	0.140±0.011	0.138± 0.014
	C	0.064±0.011(+53) *	0.086±0.015(+62) *	0.080±0.012(+72) *
Prosopis cinororea	P	0.052±0.013	0.120±0.015	0.116±0.020
	C	0.040±0.011(+30) *	0.076±0.011(+57) *	0.072±0.013(+61) *

Values (% dry weight) are mean ± standard deviation

P- Polluted Site

C- Control Site

*, ** = Significant at p<0.01 and p <0.05 level, respectively.

(+) Indicates % increase over Control

OBSERVATION

The Meteorological data of the study area for different seasons showing significant fluctuation in the average of temperature, relative humidity, wind velocity and rain fall (Table-1.). The maximum average temperature was recorded in summer season (42.40^{0}C) and minimum average temperature was recorded in winter season (24.50^{0}C) (Fig.1.). The seasonal maximum average relative humidity was recorded during monsoon season (68.00%) and minimum average relative humidity was recorded during summer season (30.00%) (Fig.2.). The seasonal maximum average wind velocity was recorded in summer season (14.10F/S) and minimum average seasonal wind velocity was recorded in winter season. (8.20F/S) (Fig.3.). The seasonal maximum average rainfall was recorded during monsoon season (46.0 mm) and minimum average rainfall was recorded during winter season. (4.00mm). Rainfall data's collected form Research and Development lab of Khetri Plant (Fig.4.).

The present studies showing accumulation of sulphate sulphur content in foliage/leaves and bark samples of the *Eucalyptus citrodore*, *Dalbergia sisoo*, *Acacia nilotica* and *Prosopes cinororea* growing under pollution site were showing significant accumulation during summer, monsoon and winter seasons(Table 2 & 3). The sulphate sulphur content level in both foliage and bark samples from all study sites were higher than the control. The young foliage collected during summer season compared to monsoon and winter showed higher sulphur accumulation. The maximum increase (79%) was recorded in *Dalbergia sisoo* and minimum increase (21%) in *Prosopis cinororea* (Fig.5 & 8). The newly born and developing leaves being physiologically more active, it is due to greater absorption of SO_2 from the ambient atmosphere. *Dalbergia sisoo* is more sensitive for sulphate sulphur content comparison to *Eucalyptus citrodore, Acacia nilotca and Prosopes cinororea.*

The higher plants have high sensitivity to sulphate content which easily reach in the plant leaves through stomata with long term exposure, they accumulate usually in the old leaves more than the younger one [18,19] it has been observed by several other works that increased sulphur contents in the foliage of plants growing in SO_2 enriched atmosphere (Legge, 1988 ; Murray and

Wilson, 1990; Lone and Ghouse, 1994) [20-22] plant respond to SO_2 exposure either by accumulating more sulphate in their internal tissue or by showing visible injuries .

The sulphur dioxide gas is absorbed into the mesophyll of the leaves through the stomata. When the concentration of gas is exceeded, the cells are first inactivated with or without plasmolysis, then killed. When extensive areas of cells are killed, the tissues collapse and dry up leaving a characteristic pattern of interveinal and marginal acute injury and the area become brownish red in colour.

The bark samples of *Dalbergia sisoo*, *Eucalyptus citrodore*, *Acacia nilotica and Prosopis cinororea* collected from the polluted site showed higher accumulation of sulphate compared to control (table-3) (Fig.9-12.). The maximum sulphate sulphur accumulation was reported in *Acacia nilotica* showed an increase of about 53%, 62% and 72% during summer, monsoon and winter season respectively compared to control. The accumulations of sulphate sulphur in the bark samples indicate its translocation from other exposed parts like the foliar organs or the root system and may be deposited due to acid rainfall. The trees growing under polluted site showing significant level of sulphur content compared to control site plants, may be regarded as an adaptive measure to avoid its excess under SO_2 pollution load. Since bark is not the permanent part of the tree and usually gets peeled off after successive intervals. It helps to avoid accumulation of sulphur in plant body.

On the basis of the present investigation, it may conclude that sulphate sulphur accumulation in the trees is species specific. The newly emerged or young leaves were more sensitive to absorb sulphur from the polluted atmosphere compared to older leaves of plant and we recommend that the emission of sulphur dioxide should be reduced and safety training programmes and environment awareness to be intensified.

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