

Effect of Air Pollution on the Anatomy Some Tropical Plants

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Received December 23, 2013; Revised February 10, 2014; Accepted February 12, 2014

Abstract The problem of impact of air pollutants on vegetation is quite complex. Our knowledge on the impact of air pollutants on different plant species comes largely from the morphological and physiological investigations. The effects of pollutants on different tropical plants have conceived relatively little attention than the tropical animals. The observations recorded in the present study on the extent of circumference of shoot axis, cortex area, pith, xylem area, fibre length, and the number of stomata/field of *Abutilon indicum* G.Don, *Croton sparsiflorus* Morong and *Cassia occidentalis* Linn. has clearly indicated that air pollutants emitted from the clay industry and automobile exhaust exercised a decisive influence on the above parameters. A statistical analysis of the data obtained from the study showed a significant reduction in circumference of shoot axis and xylem area of the plants. But cortex and pith areas did not show any significant variation between the control and the polluted samples.

Keywords: *air pollutant, particulate matter, shoot axis, vessels, stomata*

Cite This Article: Dipu Sukumaran, "Effect of Air Pollution on the Anatomy Some Tropical Plants." *Applied Ecology and Environmental Sciences*, vol. 2, no. 1 (2014): 32-36. doi: 10.12691/aees-2-1-5.

1. Introduction

The effects of agricultural, industrial and technological changes on our environment during the last century have been tremendous. The living cells undergo many physical and biochemical processes of growth; within a narrow range of factors such as temperature, light water and nutrients. Air pollution is a social disease, a disease generated primarily from the activities of man, adversely affecting his health and welfare [1]. Pollution stress can alter plant growth and the effects are often extensive [2]. We are facing the fact that in relatively recent times, the total amount and complexity of toxic pollutants in the environment are increasing day by day. Stratmann & Van Haut [3] dusted plants with quantities of dust ranging from 1 to 48 gm⁻² day⁻¹; dust falling on the soil caused a shift in pH to the alkaline side, which was unfavorable to oats but favorable to pasture grass. Darley *et al.* [4] noted that plants were stunted and had few leaves in the heavily dusted portions of an alfalfa field downwind from a cement plant in California. Brandt & Rhoades [5] observed significant changes in structure and composition of the seedling, shrub, sapling, and tree strata when they compared dusted and non dusted forest communities in the vicinity of limestone quarries and processing plants.

Considerable reduction in pigment (chlorophyll *a*, chlorophyll *b* and carotenoids) and sugar contents were observed at sites receiving higher pollution load. Ascorbic acid exhibited significant positive correlation with pollution load [6]. The incremental concentrations of pollutants depend on the energy balance in the atmosphere,

which determines the stability and turbulence (both thermal and mechanical), and the thickness of the mixing layer [7]. The influence of meteorological conditions on air quality deterioration is widely studied subject. The local climate around an industry has a lot to do with the air pollution [8].

The plants growing in polluted environment often show symptoms of various injuries, debility and premature ageing. Various pollutants like SO₂, CO₂, N₂O, NO, HF, chlorine and particulate matter discharged into atmosphere from automobiles, industries and power stations. These pollutants cause serious injuries internally as well as externally to plants and plant cells. A perusal literature reveals that there is little information on the effect of air pollutants on plant tissues. Hence the present study is undertaken with a view to record the effects of air pollution on various tissue systems of *Abutilon indicum*, *Croton sparsiflorus* and *Cassia occidentalis*.

2. Materials and Methods

The present study has been carried out at S.N. College Campus at Kollam district, Kerala, India as control site and Kochuveli in Thiruvananthapuram district, Kerala, India as polluted site 60 km far from each other. English Indian Clays (PVT) Ltd. Industrial complex is situated at Kochuveli, Thiruvananthapuram. China clay is being used in the factory as the raw material. White clay is spreading during the clay drying process and clings on the surrounding vegetation. Automobile exhausts mainly from the clay transporting trucks also contributing much to the air pollution in the area.

The plant species used for the study is *Abutilon indicum*, *Croton sparsiflorus* and *Cassia occidentalis*. The samples were collected with the help of chisel and hammer. The third internode is taken for study. Leaves from plant were collected and the number of stomata/field was recorded from the lower epidermis. Soon after collection, the samples were fixed in the Formalin-Acetic-Alcohol (FAA) on the spot itself. The plant materials were kept in the fixative for a week and then transferred to Alco-Glycerol mixture for preservation and softening. The wood samples were macerated to obtain vessel segments and fibers. Fixed samples were sliced tangentially at a thickness of about 1 mm. The slices were treated first with distilled water and then with 40% HNO₃ till the elements got free from each other. The macerated elements were washed and stained and mounted in 5% glycerol for microscopic study. After softening, the fixed materials were washed thoroughly in running water and were sectioned in a sliding microtome at a thickness of 20 µm. Heiden Lain Iron Haematoxyline and Bismark Brown method is used for staining [9]. For testing the significance student's T test is used.

3. Results

The data pertaining to *Abutilon indicum*, which showed a significant reduction in circumference of the shoot axis and the xylem area in the polluted samples. Cortex and pith areas did not show any significant variation between the control and polluted samples. Vessel length was found to vary from 244.8 µm to 340.0 µm in the control and from 258.8 µm to 353.6 µm in the polluted samples. The mean values were 290.0 µm and 299 µm in the control and polluted samples respectively. The vessel width ranges from 34.0 to 68.0 µm with an average value of 44.0 µm in the control and from 34.0 µm to 81.6 µm with an average value of 51.0 µm in the polluted samples. The fiber length varied from 816.0 µm to 1740.0 µm with an average value of 1169.0 µm and from 1088.0 µm to 1564.0 µm with an average value of 1251.0 µm in the control and polluted sites respectively. The average value recorded for the number of vessels mm⁻² were 85.9 in the control and 62.5 in the polluted samples and those for stomata/field were 30.0 in the control and 33.0 in the polluted samples (Table 1, Table 2).

Table 1. Data on the anatomical changes due to air pollution in *Abutilon indicum*

Sl.No.	Parameters	Control	Polluted	t-test	Table value of t	
		Mean ± SD	Mean ± SD		1%	5%
1	Circumference (mm)	10 ± 7.954	8.2 ± 3.17	2.768	4.604	2.776
2	Cortex area (mm)	0.58 ± 0.312	0.6 ± 0.382	1.891	4.604	2.776
3	Xylem area (mm)	4.7 ± 0.517	3.3 ± 0.443	2.977	4.604	2.776
4	Pith area (mm)	1.7 ± 0.701	1.36 ± 0.756	1.761	4.604	2.776
5	Number of vessels/mm ²	85.93 ± 4.121	62.5 ± 3.981	4.054	2.704	2.021
6	Vessel length (µm)	290 ± 10.784	299 ± 9.485	0.625	2.704	2.021
7	Vessel width (µm)	44 ± 2.614	51 ± 2.6706	4.092	2.704	2.021
8	Vessel area mm ²	0.56 ± 3.326	0.29 ± 0.236	3.326	4.604	2.776
9	Fiber length (µm)	1169 ± 57.89	1251 ± 38.497	5.868	2.704	2.021
10	Number of stomata/field	30 ± 1.221	33 ± 1.0266	2.564	2.704	2.021

Table 2. Percentage Variation caused by air pollution in *Abutilon indicum*

Sl.No.	Parameters	Abutilon indicum
1	Circumference (mm)	26.52
2	Cortex area (mm)	7.5
3	Xylem area (mm)	17.77
4	Pith area (mm)	22.4
5	Number of vessels/mm ²	-38.46
6	Vessel length (µm)	14.81
7	Vessel width (µm)	18.18
8	Vessel area mm ²	48.35
9	Fiber length (µm)	5.68
10	Number of stomata/field	-32.24

The data collected on *Croton sparsiflorus* showed a significant reduction in circumference of shoot axis and xylem area occurred in polluted samples. The cortex and pith areas did not show much variation between the control and the polluted samples. Vessel length ranged from 272.0 µm to 435.2 µm with an average value of 367.2 µm in the control samples and from 231.2 µm to 408.0 µm with an average of 312.8 µm in the polluted samples. The ranges of vessel width were from 34.0 µm from 54.4 µm with a mean value of 44.9 µm and from 27.0 µm to 54.4 µm with mean value of 36.7 µm in the control and the polluted samples respectively.

Table 3. Data on the anatomical changes due to air pollution in *Croton sparsiflorus*

Sl.No.	Parameters	Control	Polluted	t-test	Table value of t	
		Mean ± SD	Mean ± SD		1%	5%
1	Circumference (mm)	17 ± 3.47	12.49 ± 2.18*	2.977	4.604	2.776
2	Cortex area (mm)	16 ± 0.17	0.085 ± 0.038 ^{NS}	1.821	4.604	2.776
3	Xylem area (mm)	4.5 ± 0.57	3.7 ± 0.46	3.821	4.604	2.776
4	Pith area (mm)	0.58 ± 0.15	0.45 ± 0.09 ^{NS}	.164	4.604	2.776
5	Number of vessels/mm ²	101.56 ± 7.85	140.62 ± 27.6**	5.143	2.704	2.021
6	Vessel length (µm)	367.2 ± 12.47	312.6 ± 14.37**	4.248	2.704	2.021
7	Vessel width (µm)	44.88 ± 1.90	36.72 ± 2.08**	4.7	2.704	2.021
8	Vessel area mm ²	0.91 ± 0.79	0.47 ± 0.28	1.85	4.604	2.776
9	Fiber length (µm)	561.95 ± 15.95	530 ± 20.78 ^{NS}	1.913	2.704	2.021
10	Number of stomata/field	38 ± 0.911.355	50 ± 1.45**	5.778	2.704	2.021

** Significant at 1%, * Significant at 5%, NS-Non significant

The fiber length was found to vary from 448.8 µm to 707.2 µm with an average of 561.9 µm in the control

samples and from 380.8 µm to 680.0 µm with an average value of 530.0 µm in the polluted samples. The average

values recorded for the number of vessels/mm² and the number of stomata/field were 101.6 and 38.0 respectively in the control samples and the corresponding values of the polluted samples were 140.6 μm and 50.0 μm . The statistical analysis showed a significant increase in the number of vessels mm⁻² and in the number of stomata/field. Conversely, the vessel length and vessel width underwent a decrease to a highly significant level in the polluted samples. The variations in the vessel area and fiber length between the control and the polluted samples remained statistically insignificant (Table 3, Table 4).

Table 4. Percentage Variation caused by air pollution in *Croton sparsiflorus*

Sl.No.	Parameters	<i>Croton sparsiflorus</i>
1	Circumference (mm)	18
2	Cortex area (mm)	-2
3	Xylem area (mm)	29.78
4	Pith area (mm)	20
5	Number of vessels/mm ²	27.26
6	Vessel length (μm)	-3.1
7	Vessel width (μm)	-15.9
8	Vessel area mm ²	48.21
9	Fiber length (μm)	-7.01
10	Number of stomata/field	-10

Table 5. Data on the anatomical changes due to air pollution in *Cassia occidentalis*

Sl.No.	Parameters	Control	Polluted	t-test	Table value of t	
		Mean \pm SD	Mean \pm SD		1%	5%
1	Circumference (mm)	16.9 \pm 2.815	12 \pm 2.12*	2.737	4.604	2.776
2	Cortex area (mm)	0.27 \pm .227	0.26 \pm 0.182 ^{NS}	1.688	4.604	2.776
3	Xylem area (mm)	5.2 \pm 0.647	3 \pm 0.849*	2.954	4.604	2.776
4	Pith area (mm)	4.6 \pm 1.16	4.2 \pm 0.166 ^{NS}	0.270	4.604	2.776
5	Number of vessels/mm ²	57 \pm 7.849	64 \pm 27.6**	5.04	2.704	2.021
6	Vessel length (μm)	335 \pm 11.536	299 \pm 12.815**	3.038	2.704	2.021
7	Vessel width (μm)	46 \pm 2.73	57 \pm 3.58**	3.85	2.704	2.021
8	Vessel area mm ²	0.42 \pm 0.27	0.3516 \pm 0.73**	4.821	4.604	2.776
9	Fiber length (μm)	829 \pm 46.411	848 \pm 34.03 ^{NS}	1.739	2.704	2.021
10	Number of stomata/field	65 \pm 2.5278	79 \pm 2.115**	5.5818	2.704	2.021

** Significant at 1%, * Significant at 5%, NS-Non significant

However the vessel width, vessel area, number of vessels/mm² and the number of stomata/field are increased to a highly significant level under the influence of air pollutants. The fiber length did not show significant variation (Table 5, Table 6).

Table 6. Percentage variation caused by air pollution in *Cassia occidentalis*

Sl.No.	Parameters	<i>Cassia occidentalis</i>
1	Circumference (mm)	28.9
2	Cortex area (mm)	3.7
3	Xylem area (mm)	42.3
4	Pith area (mm)	8.69
5	Number of vessels/mm ²	- 12.28
6	Vessel length (μm)	10.75
7	Vessel width (μm)	- 23.9
8	Vessel area mm ²	16.28
9	Fiber length (μm)	2.29
10	Number of stomata/field	- 21.5

4. Discussion

Impact of gaseous and particulate pollutants on anatomical features was studied by Wang and Wieger [9]. It is evident from the table that a highly significant increase in the fiber length and vessel width occurred in the polluted atmosphere. However, the number of

The data collected on *Cassia occidentalis* exhibited a significant reduction in the circumference of shoot axis and xylem area in the polluted sample. But the cortex area and the pith did not show any significant variation between the control and the polluted samples. Vessel length varied from 163.0 μm to 394.0 μm with an average value of 335.0 μm in the control and from 204.0 μm to 394.0 μm with an average value of 299.0 μm in the polluted sample. The width of the vessel varied from 27.0 μm to 47.0 μm with an average value of 46.0 μm and from 27.0 μm to 60.0 μm with an average of 57.0 μm in the control and polluted samples respectively. The fibre length was found to vary between 530.0 μm to 1292.0 μm in control and from 544.0 μm to 1428.0 μm in the polluted samples. Their average value of fibre length was 829.0 μm and 848.0 μm in the control and polluted samples respectively. The mean values of number of vessels mm⁻² and number of stomata/field were 57.0 and 65.0 respectively in the control and 64.0 and 79.0 in the polluted samples. The statistical analysis revealed a highly significant reduction in vessel length in the polluted sample.

vessels/mm² decreased to a highly significant level in the polluted sample. Besides, a reduction in the vessel area was also found in the polluted sample. The variation in the number of stomata/field was found to be significant only at 5% level. The variation in the vessel length was not significant.

It is well conceived fact that the pollutants reduce wood formation in timber trees and yield in crop plants. The air pollutants like particulate matter from the clay factory and automobile exhaust from transporting trucks cause severe threat to the vegetation. The significant decreases in the circumference of the shoot axis due to low rate of xylem production under the influence of air pollutants were observed. A similar observation has been recorded earlier in case of some timber trees [10,11,12].

However the extent of tissue systems viz. cortex and pith remained statistically unaffected and seem to be resistant to air pollutants. The vessel length decreased significantly as reported earlier in case of some weeds. But contrary to this the vessel length in *Abutilon indicum* is not affected by the pollutants. In the present study, increase in vessel width was observed. It is in conformity with the observations made by Khan *et al.* [11] and Holopainen *et al.* [12]. The vessel numbermm⁻² of xylem is decreased in significant level. Fiber length in *Abutilon indicum* increased. Occurrence of intrusive growth in vessel segments and fibre elements showed a high

percentage in polluted samples of *Abutilon indicum*. This perhaps accounts for the overall increase in length average of these elements in the polluted samples of this plant species.

The significant decrease in the circumference of the shoot axis due to low rate of xylem production under the influence of air pollutants was observed. A similar observation has been recorded earlier in case of some timber trees [10,12]. However the extent of tissue systems viz. cortex and pith remained statistically unaffected and seem to be resistant to air pollutants. The vessel length decreased significantly as reported earlier in case of some weeds [13] and in *Polygonum glabrum* [14]. The present data revealed that the fiber length remained unaffected by the air pollutants. A reduction in stomatal number was recorded as influence of air pollutants in *Callistimone citrinus* [15]. In the contrary to this the number of stomata increased significantly in the polluted samples. Possibly this may be one of the adaptive features to reduce the damage caused by clay dusting.

A significant loss of assimilatory organs and wood in conifers growing in regions loaded by air pollutants was noticed by Konopka *et al.* [16]. While studying the biochemical defense mechanism of plants Srivastava [17] noticed that some of the atmospheric gases at their supra optimum level, become pollutant and evoked various types of visible plant responses which ultimately lead to reduced growth and reproductively.

From the present study it become apparent that the vessel elements are affected more in size and proportion compared to other elements. In other words, they are more sensitive to pollutants than other elements. The different tissues of the same plant differ in their responses to the same pollutant. Stomatal characteristics are often used for biomonitoring of air quality, and the majority of the results on the response of the stomatal characteristics to air pollution are unanimous to optimize stomatal closure efficiency, stomatal density increases and stomatal pore surface decreases due to increasing levels of air pollution [18].

The observations recorded in the present study on the extent of the circumference of shoot axis, cortex area, pith, xylem area, number of vessels/mm², vessel length, on the extent of the circumference of shoot axis, cortex area, pith, xylem area, number of vessels/mm² were observed from control as well as polluted samples of the plant. A statistical analysis of the data obtained from the study showed a significant reduction in circumference of shoot axis and xylem area of the plants. But cortex and pith areas did not show any significant variation between the control and the polluted samples. A marked increase in the vessel width also occurred. There is significant decrease in the number of vessels/mm² and the vessel length remained statistically insignificant. Dipu and Salom [19] studied the biochemical and morphological effect of environmental pollutants on wetland macrophytes. Priyanka Rai and Mishra [20] illustrates that leaf surface characters, including stomata and epidermal cells, in plant species growing along road sides are considerably modified due to the stress of automobile exhaust emission with high traffic density in urban areas. These changes could be considered as indicator of environmental stress.

5. Conclusion

The observations recorded in the present study clearly indicated that pollutants emitted from the industry and automobile exhaust exercised a decisive influence on plant anatomy. The statistical analysis also corroborated the same. From the present data it is also become apparent that the vessel elements are affected more in size and proportion compared to other elements. In other words vessels are more sensitive to pollutants. The different tissues of the same plant differ in their responds to the same pollutant. Further, the different genetic constitutions differ in their responds to the same pollutants in a given concentration.

Acknowledgement

I acknowledge with gratitude the help and support from Prof. & Head Department of Environmental Sciences, University of Kerala.

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