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Eugenia jambolana (L.): The plant as an efficient alternative for controlling air pollution with inherent advantages

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Abstract
The tree, *Eugenia jambolana* (L.) of family Myrtaceae is common around Udaipur city as roadside plant and as a part of forest flora. Its compact branches and closely arranged broad leaves, with shiny surface form enormous leaf area that helps for impingement, absorption and accumulation of air pollutants. All such characteristics help to reduce level of many air-borne pollutants to various extent and justify its role as scavenger. The tree has been identified as an efficient alternative to control air pollution, so it conserves natural atmosphere. It also has potential to save energy in varied forms and most economic means in terms of scientific approach. To investigate air pollution tolerance of the tree along with, its effect on metabolic activities with reference to concentration of air pollutants three sites were selected in polluted and unpolluted areas of the city. The quality of air in terms of sulphur dioxide, nitrogen dioxide, respirable suspended particulate matter and suspended particulate matter along with biochemical parameters of the leaves, i.e., chlorophyll content, total carbohydrate, total protein, dust-capturing capacity, leaf size and enzyme activity were assessed. The data were subjected to analysis of variance, which gave significant values. The results as above support the finding that the investigated tree has better tolerance to air pollutants and have least requirements to grow naturally and as plantations. Our studies confirm that industries are the prominent sources of the elevated level of air pollutants around investigated sites beside vehicular pollution that affect flora, fauna and health of local population.

1. Introduction

Mitigation of air pollution all over the globe has emerged as one of the challenging tasks for environmental management agencies. The status is likely to become more acute with the continued and enhanced rate of anthropogenic activities, industrial expansion and the limitations of carrying capacity of the respective environmental basins. Green-belt development around the industrial and urban settlement acts as a cost-effective solution for air pollution abatement. Tree plantation not only reduce air pollution, but also attenuates noise pollution. Air pollution gets aggravated by the localized developments which happens after countries become industrialized, terminating into: growing cities, increasing traffic, rapid economic developments and industrialization, followed by higher levels of energy consumption. Rapid rise in urban population leads to haphazard city development, increase in consumption patterns and demands for transport, energy, additional infra-structure, etc., so that overall pollution cross standard limits. In India, air pollution has become widespread at present in cities where high concentration of industries, running vehicles along with thermal power plants are the major contributors of pollutants. Vehicular emissions are matter of concern as these are first level sources, having maximum impact on the general population. These also have cumulative effect on the overall air pollution load in many urban areas. All the above mentioned factors have resulted in serious deterioration of air quality in many parts of the globe (Kapoor et al. 2013). Plant's response to environmental factors have often been associated with an increased production of reactive oxygen species (ROS), including hydroxyl radicals (OH·) and hydrogen peroxide (H_2O_2) (Mittler 2002) which can cause oxidative damage of cellular components under biotic and abiotic stresses (Dias de Azevedo Neto et al. 2005). Shannigrahi et al. (2004) evaluated anticipated air pollution tolerance of some plants species meant for green-belt development around an industrial/urban area in India. Pandey (2005) worked out air pollution related phyto-toxicity of a phosphate fertilizer factory in India. Verma and Singh (2004, 2006) investigated biochemical and ultra-structural changes in plant foliage exposed to auto-pollution in Lucknow city. Gostin and Lacramioara (2007) reported structural and micro-morphological changes in leaves of *Salix alba* as caused by air pollution . Chauhan (2008) made a detailed study on the effect of automobile and industrial air pollutants on some selected roadside trees grown in Haridwar. Hasan et al. (2009) studied SO_x emission and pollution control at a Gas Plant. Sharma and Tripathi (2009) presented atmospheric PAHs profile through *Calotropis gigantea* R.Br. leaves in the vicinity of an Indian coal-fired power plant. Kulshreshtha et al. (2009) investigated particulate pollution mitigation of certain plant species. Brighton and Nnenesi (2010) reported presence of atmospheric particulate matter in mining area as pollutants in South Africa. Chun-Chin Wang (2010) proposed that bio-aerosols act as contributors to poor air quality in Taiwan. Govindaraju et al. (2012) evaluated air-pollution-tolerance of plants around lignite-based thermal power station for green-belt development. Kapoor et al. (2009 a, b, & 2012), Bamniya et al. (2012 a, b, c) carried out intensive physiological and biochemical studies on some common tree species around Udaipur city under pollution stress and it was suggested that trees can act as an effective measure to minimize air pollution in urban and rural areas while serving as efficient sink for air pollutants. *Eugenia jambolana* (L.) the investigated tree species is very common in the area/state and with its leaf area can act as efficient controlling agent for many air pollutants in the atmosphere, besides its main advantages. Its compact branches and closely arranged broad leaves, with shiny or waxy surface help in minimizing dust level, as well as, provide shade during intense hot days and rains. With all such inherent advantages of a tree and pollution tolerance capability the tree serves as an efficient alternative to control air pollution and ultimately conserve natural atmosphere. It also helps to conserve energy in various forms and provide most economic means in terms of eco-friendly approach. The studied physiological parameters provide a direct correlation between the intensity of pollutants and the inhibiting response, hence made the study a better way to analyze pollution tolerance of the tree.

Eugenia jambolana (L.), belong to family Myrtaceae and in Indian forests the tree is very commonly found. It is largely cultivated for the fruits which are eaten by birds and man as well and are nourishing. Diabetes patients specially use its fruits and seeds. The juice of the fruits is useful in making vinegar which is very effective either in dyspepsia, enlargement of spleen and some other ailments. The juice of leaves is also useful in dysentery. The bark is largely used in tanning and is also given as a medicine in diarrhoea and dysentery. The wood is very resistant to water effects and largely find its use in building as sleepers for water curbs and in the manufacture of agricultural implements and carts. The tree is sacred for followers of Hindu religion so, largely grown near temples and similar religious places. (Nadkarni, 1954; The Wealth of India, 1962).

2. Materials and Methods

2.1. Study Area

Udaipur (state Rajasthan, India) also known as '*the city of lakes'* is situated about 600 m above the sea level and is located among the lush green hills of Aravali range between 24°35' N latitude and 73°42' E longitude. The city is also known as 'Venice of the East' and has been rated as the 'World's beautiful city no.1' by the travelers and the media worldwide. There are many lakes around Udaipur and within, e.g., Pichhola, Fateh Sagar and Swaroop Sagar and other water bodies in 20-30 km radius of the city are: Badi Tank, Gorana dam, Devas dam, Jaysamand*, Rajasmand, Udaisagar, Vallabhnagar tank, Indrasagar tank, Nandsagar dam, Madar, Thoor tank, etc., the area of which range from few Km^2 to 250* km^2. These wetlands are deeply involved in social, cultural and economic activities of the region. The Udaipur city has a population around 0.6 million and a distinct tropical climate with marked amonsoonal effect. The economy of the city is mainly based on tourism and due to that all over the year thousands of tourist vehicle enter into the city and its adjoining areas where tourist visit depending on their historical and scenic importance. In addition to these local/outside vehicles, the industries located in Madri industrial area also contribute to total magnitude of pollution in the city, because National highway no.8 which connects Mumbai and Delhi (about 1500 km), pass through the city. Beside, all these it is a fact that forest cover and lakes around the region greatly help to minimize the level of pollution hence clean atmosphere attracts tourists in large numbers. With reference to local climate the three seasons occur in a year, i.e., summer (April-June), rain (July-October) and winter (November-March). The average temperature ranges from 5°C in winter to maximum of 41°C in summers, normally. The average annual rainfall ranges between 62.5 cm to 125 cm during normal monsoon regime.

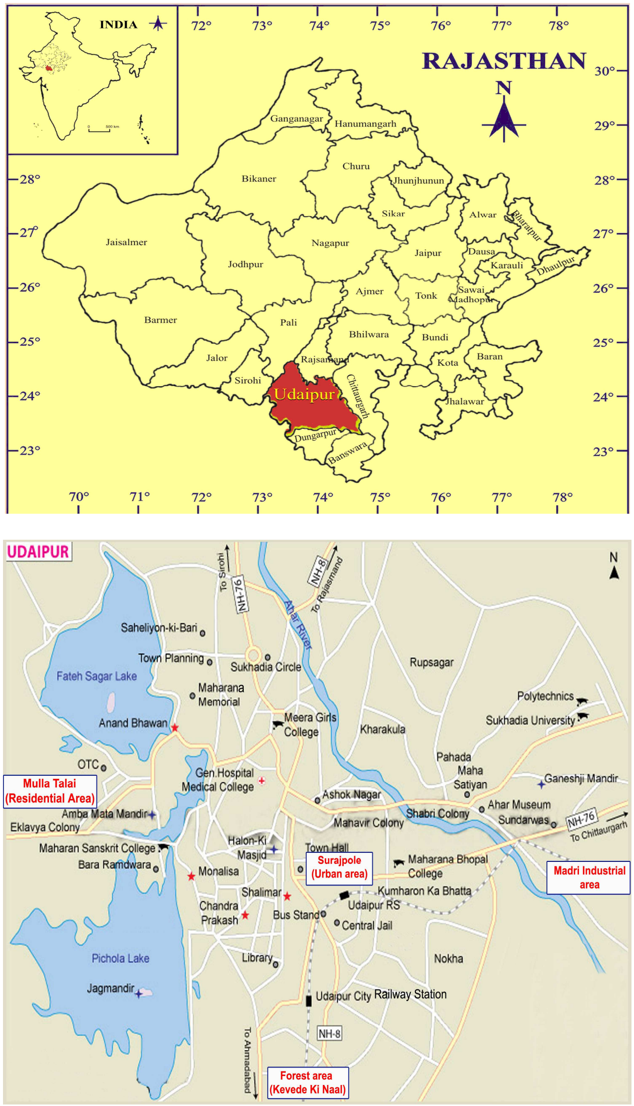

Fig. 1. *Location of investigation sites.*

In present investigation the effect of ambient air quality was studied using tree species common in the area: *Eugenia jambolana* (L.) of family Myrtaceae. To assess the harmful effects of air pollution on the biochemical and physiological parameters of plant growth along with morphological changes studies were conducted on three selected sites , viz., Urban area (Surajpole, lying at 24°34'45.95"N and 73°41'46.31"E and elevation 612 m; source of pollution are increasing vehicular traffic and rising dust), Industrial area (Madri Industrial Area, lying at 24°35'01.23"N and 73°44'59.52"E and elevation 600 m; source of pollution- vehicular traffic, as well as, industrial pollutants) and Forest area (Kevede ki Naal, lying at 24°25'00.90"N and 73°46'05.40"E and elevation 449 m; source of pollution- vehicular traffic, as it lies along state highway). Sometimes at these sites mobile units of state department of pollution monitoring record their observations, which is insufficient and not regular.(sulphur dioxide).

2.2. About the Plant

Eugenia jambolana (L.), belong to family Myrtaceae and in Indian forests the tree is very commonly found. It is largely cultivated for the fruits which are eaten by birds and man as well and are nourishing. Diabetes patients use its fruits and seeds specially. The juice of the fruits is useful in making vinegar which is very effective either in dyspepsia, enlargement of spleen and some other ailments. The juice of leaves is also useful in dysentery. The bark is largely used in tanning and is also given as a medicine in diarrhoea and dysentery. The wood is very resistant to water effects and largely find its use in building as sleepers for water curbs and in the manufacture of agricultural implements and carts. The tree is sacred for followers of Hindu religion so, largely grown near temples and similar religious places. (Nadkarni, 1954; The Wealth of India, 1962).

2.3. Sample Collection

The ambient air quality and toxic effects of air pollutants on the tree species as above were investigated at three sites for two consecutive years, i.e., from September, 2007 to October, 2009 on bimonthly basis. Initially these sites were ascertained and concentration of different air pollutants, viz., SO_2 (Sulphur dioxide), NO_x(Nitrogen oxides), Suspended particulate matter (SPM) and Respirable suspended particulate matter (RSPM) was monitored into 100 transects (100x100m) with a difference of 10 meters. Observations presented on the basis of recording in a day at different times indicate mean value of all these sites, i.e., morning (07:00 hrs), noon (12:00 hrs) and evening (18:00 hrs). The leaves of the samples were brought in polythene bags to the laboratory and activity of enzymes were studied immediately. For further analysis samples were preserved at -14°C in freezer till analyzed for different parameters within 24 hrs of their harvesting. Observations taken indicate mean value of all these sites on the basis of minimum three recordings in a day.

2.4. Methodology

The plant growth parameters studied were: amount of chlorophyll a, chlorophyll b, total chlorophyll, carotenoids (Jensen 1978). Their absorbance was measured by Systronix spectrophotometer 108 UV-VIS model in visible range using 80% acetone as solvent. The activities of two oxidative enzymes peroxidase and polyphenol oxidase were studied along with the above parameters in the described schedule (Mahadevan and Sridhar, 1982). Dust-capturing capacity of the leaves of sample trees was another parameter which substantiated our data on the effect of ambient air pollution and its monitoring. Dust-capturing capacity and leaf size of the leaves of sample trees were measured by following Pandey et al. (2003). Total carbohydrate (Dubois et al. 1956) and total protein (Lowry et al. 1951) of the plant samples were determined as a soluble fraction. Ambient air samples were collected using High volume sampler (Envirotech model, APM-410) and Respirable dust sampler (Envirotech model APM 460) with suitable gas attachment. Suspended particulate matter, and Respirable suspended particulate matter were collected on glass fiber filter papers by using high volume sampler and respirable dust sampler (Rehme et al. 1984). Particulate concentrations were determined gravimetrically by recording pre- and post-sampling filter weights and considering the sampled air volume. Gaseous pollutants were scrubbed separately in 0.1 M potassium tetrachloromercurate and sodium hydroxide (0.1N), respectively. These absorbing solutions were later analyzed colorimetrically for SO_2 through the modified West and Gaeke (1956) method and NO_2 through the modified Jacob and Hochheischer (1958) method. Results indicated significant differences between sites and months/seasons.

All the results obtained related to present study were subjected to statistical analysis, e.g., correlation and regression of ambient air pollution data, as well as, analysis of variance were computed between different physiological growth parameters, viz., amount of chlorophyll-a, chlorophyll-b, total chlorophyll, total carbohydrates, total protein, dust- capturing capacity of the leaves of trees and total leaf size, etc., as per methods described by Gomez and Gomez (1984).

3. Results & Discussion

3.1. Primary Pollutants

All the results obtained are in terms of mean values of air pollutants at the sites of investigation during the course of study (two years). It became clear that in generation of various air pollutants industries stand first followed by urban areas studied and lastly minimum values have been indicated in forest areas, where there is some vehicular traffic as the area lie near national highway so the existing pollution may be due to climatic disturbances and other factors that have their own minor role in minimizing or / in generation of air pollutants (Table 1).

Coefficient of correlation among various parameters of air quality of forest area recorded were: SO_2 and NOx (r = + 0.6998), SO_2 and SPM (r = +0.07440), SO_2 and RSPM (r = +0.6881), NOx and SPM (r = + 0.9060), NOx and RSPM (r = + 0.9508), SPM and RSPM (r = + 0.8981) during September, 2007 to August, 2008. During September, 2008 to August, 2009 these were SO_2 and NO_X (r = + 0.7672), SO_2 and SPM (r = + 0.8289), SO_2 and RSPM (r = + 0.7509), NOx and SPM (r = + 0.9187), NOx and RSPM (r = + 0.9528) and SPM and RSPM (r = +0.9285). The values in urban area were: SO_2 and NOx (r = - 0.3478), SO_2 and SPM (r = + 0.0115), SO_2 and RSPM (r = - 0.0772), NOx and SPM (r = - 0.3675), NOx and RSPM (r = - 0.2031), as well as, correlation among SPM and RSPM was + 0.1128. During September, 2008 to August, 2009 the correlation coefficient was: SO_2 and NOx, SPM, RSPM was = + 0.08585, -0.2861 and -0.1107 respectively and NOx and SPM (r = -0.4393) and NOx and RSPM (r = - 0.5301), SPM and RSPM was = + 0.7259. In industrial area, during September, 2007–August, 2008 the values were SO_2 and NOx (r = - 0.0741), SO_2 and SPM (r = + 0.5943), SO_2 and RSPM (r = + 0.4061) and NOx and SPM (r = + 0.1074) and NOx and RSPM (r = + 0.0639) and SPM and RSPM was = + 0.8690. During September, 2008 to August, 2009 the correlation between SO_2 and NOx, SPM, RSPM was = - 0.5233, -0.4646 and-0.3333, respectively and between NOx and SPM (r = - 0.3180), NOx and RSPM (r = -0.5598) and between SPM and RSPM was (+ 0.5898).

Table 1. *Mean values of Ambient Air Quality during September, 2007-August, 2009 in studied sites of Udaipur City.*

Sampling Station	Range of Mean Concentrations of Air Pollutants (μg/m^3)							
	SO_2		NO_x		SPM		RSPM	
	Min.	Max.	Max.	Min.	Min.	Max.	Min.	Max.
Madri Indudtrial Area	5.36	16.03	21.74	40.64	131.49	915.76	35.58	746.06
	5.07	14.21	25.55	63.94	131.48	571.40	36.96	196.31
Forest area	2.53	6.29	23.94	37.65	204.00	309.50	73.50	110.05
	2.55	6.69	24.80	39.00	197.50	353.50	75.35	110.50
Urban area	5.35	10.72	21.44	35.64	78.17	375.33	26.67	179.52
	4.99	8.30	24.35	48.38	00.00	493.09	25.59	147.55

3.2. Biochemical Parameters

During the first year of study, in urban and industrial areas chlorophyll-a, chlorophyll-b and total chlorophyll were observed to be the highest during July-August, 2008, whereas in forest area it was so during November-December, 2007 (chlorophyll-a and total chlorophyll) and July-August, 2008 (chlorophyll-b). The amount of carotenoids in urban area recorded maximum during March-April, 2008 (0.190 mg/g) and minimum during September-October, 2007 (0.019mg/g). In industrial area it was the highest during November-December, 2007 (0.129 mg/g) and lowest during March-April, 2008 (0.0135 mg/g) and in forest area it was so during July-August, 2008 (0.224

mg/g) and September-October, 2007 (0.06 mg/g), respectively. Total carbohydrate and protein content were found to be highest during November-December, 2007 (6.6 mg/g, 6.0 mg/g, 9.2 mg/g and 10.2 mg/g, 8.3 mg/g, 15.0 mg/g, respectively in urban, industrial and forest areas).The highest and lowest dust-capturing capacity in urban area recorded 2.6381 mg/cm^2 and 0.588 mg/cm^2, in industrial area 5.290 mg/cm^2 and 1.057 mg/cm^2 and in forest area 0.926 mg/cm^2 and 0.2108 mg/cm^2, respectively. In forest area leaves recorded to be largest during November, 2007 to February, 2008 (72.0 cm^2) whereas in urban and industrial areas it was so during March-April, 2008 (Fig. 2-8). Oxidative enzymes of the plants remain more active when plant is subjected to any stress, in present case it is the stress developed by the presence of various kinds of pollutants in the ambient air of the study sites. Activity of polyphenol oxidase in leaf tissues of urban area (Surajpole) was at lowest level during months of November-December, 2007. While it recorded higher in other months of the year in the order of May-June, 2008 > September-October, 2007 (abnormal highest activity at 150 seconds)> July-August, 2008 > January-February, 2008 > March-April, 2008 (maximum activity). While in samples of Madri Industrial Area, the activity was at minimum level during months of September-October, 2007. While it increased in other months of the year in the order of January-February, 2008 (highest activity) > May-June, 2008 > July-August, 2008 >November-December, 2007> March-April, 2008. In the samples of forest area (Kevede ki Naal), the activity of the enzyme was at lowest possible ebb during months of July-August, 2008. While it was definitely higher in other months of the year in the order of May-June, 2008 > November-December, 2007>March-April, 2008 > September-October, 2007> January-February, 2008. In leaf samples of urban area (Surajpole), the activity of peroxidase increased (from initial level to highest level at 20 seconds interval up to 180 seconds) during all the months studied. The order of increased activity was November-December, 2007, January-February, 2008 followed by September-October, 2007, July-August, 2008, May-June, 2008, and March-April, 2008 (highest activity). In the samples of Madri Industrial Area, the activity of peroxidase was observed to rise (from initial level to highest level at 20 seconds interval up to 180 seconds) in the pattern as above during months of March-April, 2008 (highest activity), May-June, 2008, January-February, 2008, September-October, 2007 followed by July-August, 2008.

Table 2. *Biochemical parameters of Eugenia jambolana (L.) at different investigation sites of Udaipur city during first year of study.*

Parameter Studied	Sites	Sep.-Oct.,07	Nov.-Dec.,07	Jan.-Feb.,08	March-April,08	May-June, 08	July- Aug.,08
Chl-a (mg/g)	Urban	0.237	0.490	0.211	0.015	0.212	0.558
	Industrial	0.441	0.459	0.201	0.075	0.0013	0.348
	Forest	0.586	0.600	0.276	0.193	0.329	1.174
Chl-b (mg/g)	Urban	0.221	0.282	0.194	0.054	0.195	0.878
	Industrial	0.059	0.181	0.158	1.650	0.029	0.226
	Forest	0.284	0.313	0.229	0.421	0.349	0.882
Total Chlorophyll (mg/g)	Urban	0.456	0.731	0.453	0.264	0.407	1.436
	Industrial	0.153	0.683	0.382	0.039	0.106	0.570
	Forest	0.521	0.891	0.480	0.641	0.678	1.756
Carotenoids (mg/g)	Urban	0.019	0.141	0.090	0.190	0.100	0.180
	Industrial	0.087	0.129	0.081	0.013	0.045	0.106
	Forest	0.060	0.149	0.121	0.189	0.107	0.224
Total Carbohydrates (mg/g)	Urban	6.400	6.600	6.500	3.550	4.800	4.550
	Industrial	6.000	6.00	4.400	2.950	3.500	0.100
	Forest	8.800	9.200	7.100	6.520	6.450	7.430
Total Protein (mg/g)	Urban	7.000	10.200	7.000	6.560	8.470	6.340
	Industrial	4.500	8.300	6.400	2.320	1.080	4.600
	Forest	12.000	15.000	13.300	8.850	10.480	9.200
Dust Capturing Capacity (mg/ cm^2)	Urban	0.588	1.600	0.827	2.638	2.402	1.052
	Industrial	5.290	2.677	4.950	4.427	4.448	1.057
	Forest	0.584	0.901	0.211	0.759	0.926	0.777
Leaf Size (cm^2)	Urban	56.000	66.000	55.000	68.270	58.280	57.000
	Industrial	50.000	49.500	51.000	61.000	49.000	56.750
	forest	62.000	72.000	72.000	70.500	64.750	62.910

Data obtained were subjected to analysis of variance between different physiological growth parameters, viz., amount of chlorophyll-a, chlorophyll-b, total chlorophyll, total carbohydrates, total protein, dust capturing capacity of the leaves of trees and total leaf size. The F-calculated (all treatments) was 537.113*, while F-tabulated was 1.620 (at 5% level of significance) and 1.969 (at 1% level of significance); its SEM (Standard Error of Mean) was 0.856 and CD 5% (Critical Difference at 5% level of Significance) as 2.395 and CD 1% (Critical Difference at 1% level of Significance) as 3.167. The F-calculated (between growth parameters) was 6.839*, while F-tabulated was 2.087 (at 5% level of significance) and 2.792 (at 1% level of significance); its SEM was 0.349 and CD 5% as 0.978 and

CD 1% as 1.293. The F-calculated (between areas) was 6079.767*, while F-tabulated was 3.072 (at 5% level of significance) and 4.787 (at 1% level of significance); its SEM was 0.494 and CD 5% as 1.383 and CD 1% as 1.828. The F-calculated (areas x growth parameters) was 10.443*,while F-tabulated was 1.775 (at 5% level of significance) and 2.234 (at 1% level of significance); its SEM was 0.856 and CD 5% as 2.395 and CD 1% as 3.167. The mean was 9.649 and CV% (Coefficient of variation) was 21.719. All the values of 'F' were found to be highly significant.

It was observed that chlorophyll-a recorded higher during May-June, 2009 at all the three sites (0.626 mg/g, 0.544 mg/g and 0.796 mg/g in urban, industrial and forest areas, respectively) and lower during March-April, 2009 (0.187 mg/g, 0.157 mg/g and 0.199 mg/g in urban, industrial and forest areas). Chlorophyll-b recorded highest during November-December, 2008 and lowest during March-April, 2009 in urban and industrial areas, whereas in forest area it was higher during May-June, 2009 (0.332 mg/g) and lower during March-April, 2009 (0.007 mg/g). The higher value of total chlorophyll was recorded during May-June, 2009 in urban (0.881 mg/g) and industrial area (0.711 mg/g) and during November-December, 2008 in forest area (0.894 mg/g). Its lowest value were estimated during March-April, 2009 at all the three sites. In industrial and forest areas carotenoids were recorded highest during November-December, 2008 (0.132 mg/g and 0.153 mg/g, respectively) and lowest during March-April, 2009 (0.030 mg/g and 0.052. mg/g, respectively). In urban area its highest and lowest values were recorded during May-June, 2009 (0.154 mg/g) and during September-October, 2008 (0.0176 mg/g). The concentration of carbohydrates were recorded higher in the samples of forest area (10.3 mg/g) in March-April, 2009 and lower in the samples of industrial area (3.1 mg/g) in May-June, 2009. In industrial and forest areas protein concentration recorded higher during November-December, 2008 (8.0 mg/g and 15.2 mg/g respectively) and in urban area it was so during March-April, 2009 (12.3 mg/g). The highest and lowest dust-capturing capacity were recorded during November-December, 2008 (1.655 mg/cm^2) and March-April, 2009 (0.501 mg/cm^2) in urban area, September-October, 2008 (5.333 mg/cm^2) and July-August, 2009 (1.491 mg/cm^2) in industrial area and May-June, 2009 (0.761 mg/cm^2) and January-February, 2009 (0.220 mg/cm^2) in forest area. Highest leaf size was measured in the samples of forest area during September-October, 2008 (87.0 cm^2) and lowest in the samples of industrial area during November-December, 2008 (50.25 cm^2) (Fig. 2-8).

Table 3. *Biochemical parameters of Eugenia jambolana (L.) at different investigation sites of Udaipur city during second year of study.*

Parameter Studied	Sites	Sep.-Oct.,07	Nov.-Dec.,07	Jan.-Feb.,08	March-April,08	May- June, 08	July- Aug.,08
Chl-a (mg/g)	Urban	0.242	0.488	0.207	0.187	0.626	0.603
	Industrial	0.451	0.451	0.206	0.157	0.544	0.202
	Forest	0.591	0.591	0.270	0.199	0.796	0.624
Chl-b (mg/g)	Urban	0.211	0.271	0.184	0.001	0.255	0.264
	Industrial	0.049	0.188	0.164	0.025	0.167	0.042
	Forest	0.274	0.303	0.220	0.007	0.332	0.273
Total Chlorophyll (mg/g)	Urban	0.446	0.723	0.444	0.164	0.881	0.381
	Industrial	0.164	0.676	0.371	0.150	0.711	0.224
	Forest	0.516	0.894	0.490	0.200	1.129	0.867
Carotenoids (mg/g)	Urban	0.018	0.135	0.091	0.035	0.154	0.138
	Industrial	0.092	0.132	0.087	0.030	0.125	0.066
	Forest	0.612	0.153	0.112	0.052	0.197	0.140
Total Carbohydrates (mg/g)	Urban	6.550	6.800	6.670	6.350	4.600	5.150
	Industrial	6.500	6.000	4.850	5.550	3.100	4.600
	Forest	9.000	9.500	7.300	10.300	6.800	6.700
Total Protein (mg/g)	Urban	7.200	10.640	7.280	12.300	8.600	4.700
	Industrial	4.840	8.000	6.200	1.400	1.800	4.400
	Forest	12.400	15.200	13.000	13.400	10.010	5.700
Dust Capturing Capacity (mg/ cm^2)	Urban	0.594	1.655	0.836	0.501	1.516	0.982
	Industrial	5.333	2.786	4.970	1.895	3.875	1.491
	Forest	0.574	0.902	0.220	0.298	0.761	0.236
Leaf Size (cm^2)	Urban	56.250	66.500	54.500	67.000	65.660	73.750
	Industrial	50.750	50.250	50.300	52.750	52.500	67.250
	forest	87.000	72.500	71.750	79.750	80.000	84.500

Activity of polyphenol oxidase in leaf tissue of urban area (Surajpole) was at lowest level during months of November-December, 2008. While it was definitely higher in other months of the year in the order of January-February, 2009 (highest activity) > July-August, 2009> September-October, 2008 > May-June, 2009> March-April, 2009. The activity of polyphenol oxidase in leaf tissue of Madri Industrial Area was at low ebb during months of January-February, 2009 but it was increased (higher) in other months of the year in the order of March-April, 2009 < November-December, 2008 < July-August, 2009 < May-June, 2009 < January-February, 2009 (highest activity observed). Its activity in forest area (Kevede ki Naal) leaf tissue was at lowest level during months of July-August, 2009. While it was higher in other months of the year in the order of March-April, 2009< January-February, 2009<

September-October, 2008 < November-December, 2008< May-June, 2009. In samples of urban area (Surajpole), the activity of peroxidase increased (from initial level to highest level at 20 seconds interval up to 180 seconds and increased further up to 180 seconds) in the order of March-April, 2009 <January-February,2009 <November-December <2008, July-August,2009 <September-October, 2008< May-June, 2009 (highest activity observed). In the samples of Madri Industrial Area, the activity of peroxidase increased (from initial level to highest level at 20 seconds interval up to 180 seconds and increased further up to 180 seconds) in the order of March-April, 2009<November-December, 2008<July-August,2009<September-October, 2008<January-February, 2009<May-June, 2009 (highest activity observed). In leaf tissue samples of forest area (Kevede ki Naal), the activity of peroxidase increased from initial level to highest level at 20 seconds interval up to 180 seconds during months of November-December, 2008<July-August, 2009<January-February, 2009 < March-April, 2009 < May-June, 2009< September-October, 2008 (highest activity observed) During second year of study the value of (all treatments) F-calculated was 410.304*,while F-tabulated was 1.620 (at 5% level of significance) and 1.969 (at 1% level of significance); its SEM was 1.082 and CD 5% as 3.029 and CD 1% as 4.004. The F-calculated (between growth parameters) was 8.576, while F-tabulated was 2.087 (at 5% level of significance) and 2.792 (at 1% level of significance); its SEM was 0.442 and CD 5% as 1.237 and CD 1% as 1.635. The F-calculated (between areas) was 4564.445*, while F-tabulated was 3.072 (at 5% level of significance) and 4.787 (at 1% level of significance); its SEM was 0.625 and CD 5% as 1.749 and CD 1% as 2.312. The value of (areas **x** growth parameters) F-calculated was 17.719*, while F-tabulated was 1.775 (at 5% level of significance) and 2.234 (at 1% level of significance); its SEM was 1.082 and CD 5% as 3.029 and CD 1% as 4.004. The mean was 10.430 and CV% was 24.405. All the values of ‘F’ were found to be highly significant.

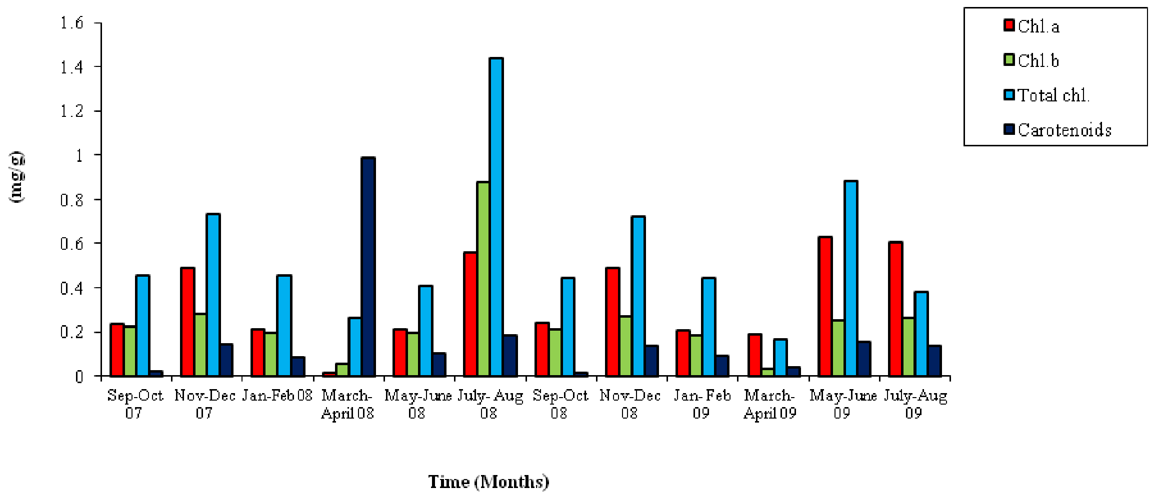

Fig. 2. *Amount of photosynthetic pigments of Eugenia jambolana (L.) in urban area of Udaipur city during study period.*

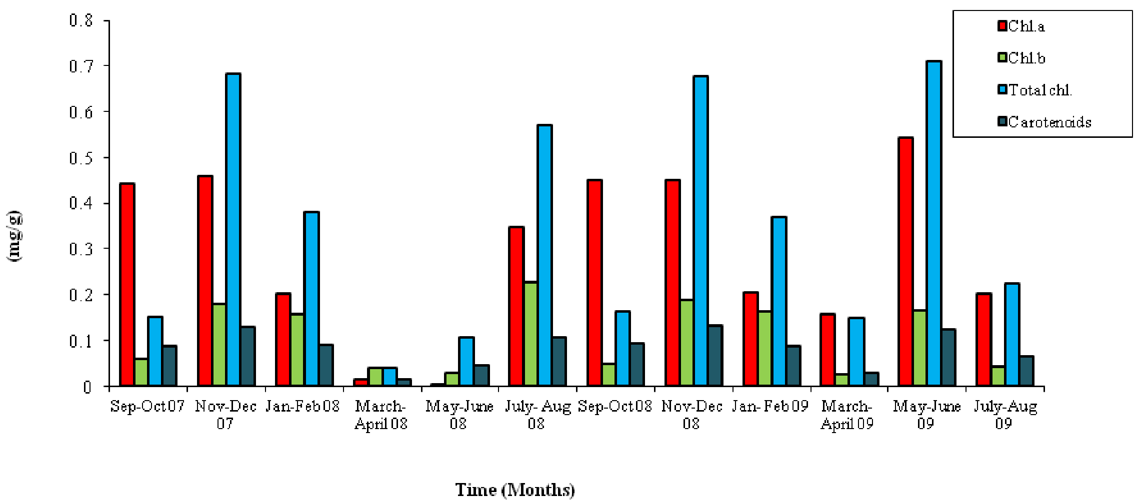

Fig. 3. *Amount of photosynthetic pigments of Eugenia jambolana (L.) in industrial area(Madri) of Udaipur city during study period.*

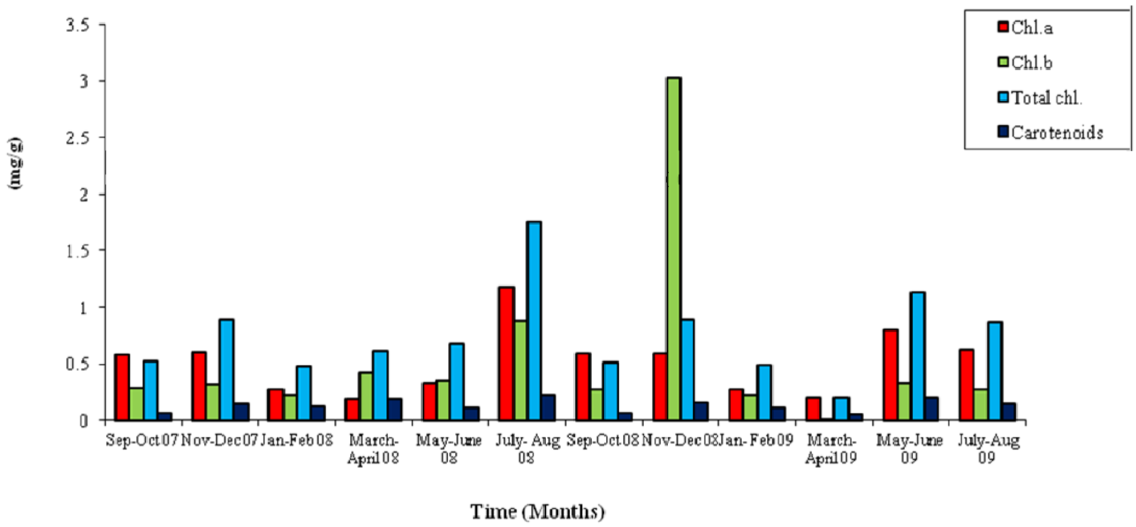

Fig. 4. *Amount of photosynthetic pigments of Eugenia jambolana (L.) in forest area (Kevede ki naal) of Udaipur city during study period.*

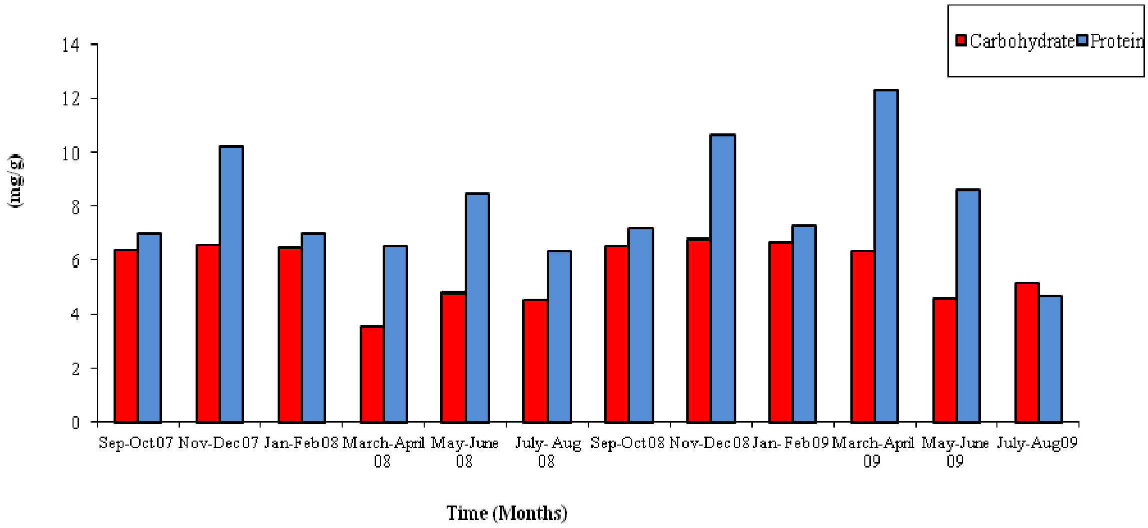

Fig. 5. *Amount of protein and carbohydrate of Eugenia jambolana (L.) in urban area of Udaipur city during study period.*

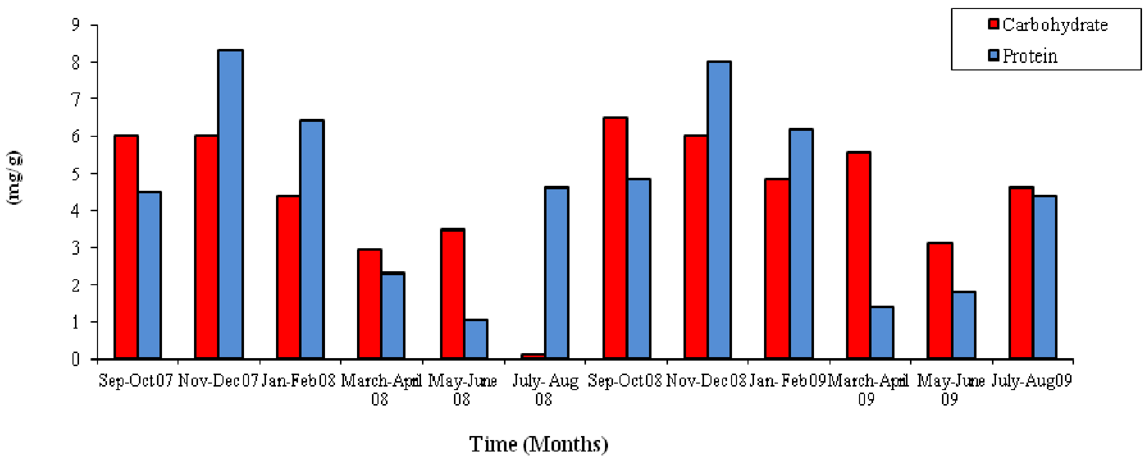

Fig. 6. *Amount of protein and carbohydrate of Eugenia jambolana (L.) in industrial area (Madri) of Udaipur city during study period.*

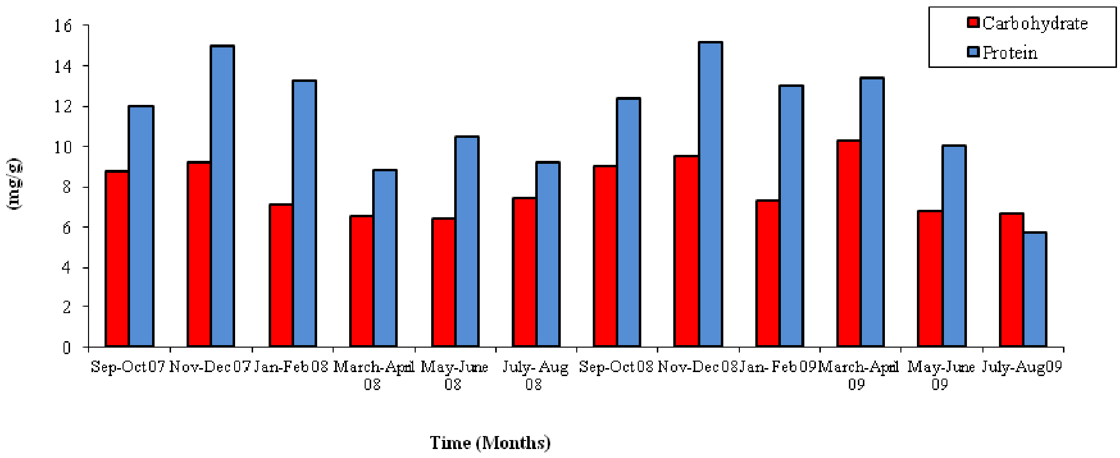

Fig. 7. *Amount of protein and carbohydrate of Eugenia jambolana (L.) in forest area (Kevede ki naal) of Udaipur city during study period.*

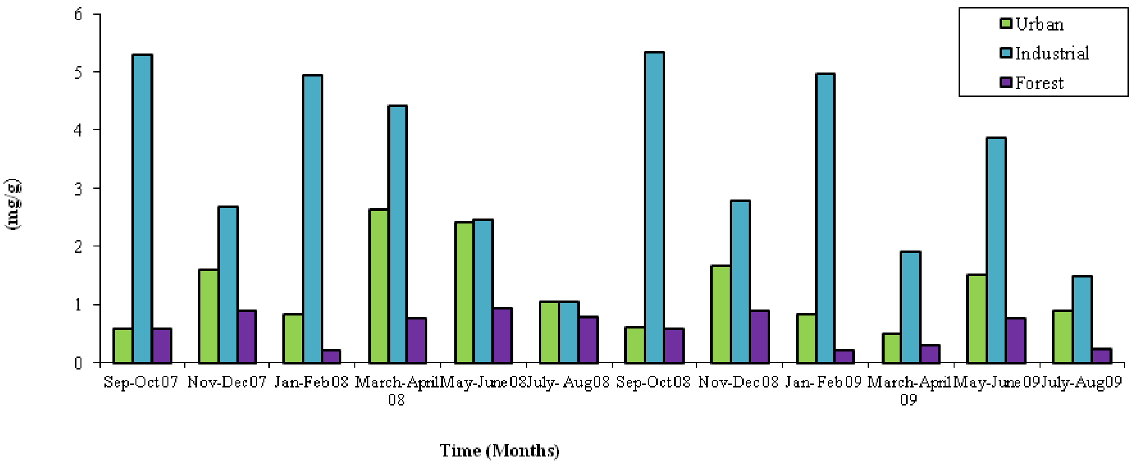

Fig. 8. *Comparative foliar Dust capturing capacity of Eugenia jambolana (L.) in urban, industrial and forest area of Udaipur city during study period.*

4. Discussion

The tree *Eugenia jambolana*, is common around Udaipur city as roadside plant and as a part of forest flora. Its compact branches and closely arranged broad leaves, with shiny surface form enormous leaf area that helps for impingement, absorption and accumulation of air pollutants. Our results on ambient air quality of the studied site and biochemical parameters of the plant reveal that wherever reduction in biochemical attributes of have been caused it was higher in polluted sites and least in forest area which have negligible pollution. This is also true of physical damage visible on the exposed plant parts. In the light of above it has been observed that decrease in size of epidermal cell and stomata, and increase in the number of epidermal cells, stomata and trichomes occur on exposure to SO_2 pollution. On the basis of laboratory studies the leaf surface traits are divided into three categories. The first category comprises of traits such as leaf weight, stomatal frequency, trichome density and length, epidermal layer and leaf thickness that are considered to be most sensitive to air pollution. The second category includes the traits such as thickness of cuticle and epidermal layer. Present studies support the observations that precipitation accelerates the deposition of particulate matter and gaseous pollutants on the ground, but also helps minimum deposition of dust on the leaves of the vegetation in the vicinity in all the sites studied. That is why pollutant concentrations recorded minimum during rainy season. During winter months frequent late night and early morning thermal inversions inhibit vertical mixing and dispersion of pollutants/dust and thus raising the concentration of SO_2 and NO_2 (elevated winter concentration of SO_2 and NO_2) around the sites. Normally, the photosynthetic activity depends on the quantity and quality of chloroplast pigments. The total chlorophyll content in affected plant was relatively low under environmental stress, showing the maximum loss at early stage of plant growth. Chlorophyll b was more significantly affected than chlorophyll a, possibly due to induced chlorophyllase activity or inhibition of chlorophyll b synthesis (Nighat et al. 2000; Bamniya et al. 2012 a, b). Our data (Table 2, 3) on dust pollution also explain reduction in chlorophyll concentration in the polluted leaves as chloroplast is damaged by exposure to vehicular gaseous emission. Their other effects are: the N deficiency which may inhibit chlorophyll biosynthesis. It is suggested that at pH 2.2–3.5, free H^+ ions are generated in the cell due to the split of HSO_3 in SO^-_3 and H^+, and displace Mg^{++} from tetrapyrrole ring of the chlorophyll molecule to degrade it into a pheophytin molecule which is photosynthetically inactive. SO_2 pollution may reduce chlorophyll contents due to production of superoxide radicals as a result of the reaction of sulphite with chlorophyll under illumination. The carbohydrate or sugar estimates of plant samples indicate that the pollutants often reduce plant productivity. Possible degradation of membrane lipids with possible hydrolysis of proteins inducing quantitative changes in amino acid composition and an increase in reducing sugars prior to the appearance of visible symptoms has also been indicated (Kapoor et al. 2009 a, & 2012) and Kapoor (2014).

Trees act as a formidable means to control air pollution the concept has been supported by us and other workers in the field, as trees like *Codleum, Polyalthia, Jasminum, Carica, Lawsonia,, Holoptelea integrifolia* L., *Ficus benghalensis* L., *Mangifera indica* L., *Dalbergia sissoo* Roxb., *Pongamia pinnata* (L.) Pierre , *Cassia*, *Shorea robusta* and *Mallotus phillipinensis* have been found having very effective tolerance indices to bio-monitor the level of air pollution (Kauser et al. 1999; Swami et al. 2004; Kapoor et al. 2009 a, b; 2012; 2013 and Bamniya et al. 2012 a, b, c). Sharma et al. (2005) studied seasonal evaluation and spatial variability of suspended particulate matter in the vicinity of a large coal-fired power station in India. Pal et al. (2002) proposed that leaf surface characters play a role in plant resistance to auto-exhaust pollution and occurrence of significant dust accumulation and reduction in leaf pigment content in vegetation (Prusty et al. 2005) near the national highway is very common which affects plants growth characteristics, this finding is supported from our dust-capturing capacity data (Table 2 & 3). Singh et al. (2003) investigated growth responses of wheat (*Triticum sativum* L.) when exposed to ambient air pollution under varying fertility regimes. Olteanu et al. (2007) reported the physiological responses induced by atmospheric pollutants on Gymnosperm species in the industrialized areas of Romania. Verma et al. (2006) worked out foliar responses of *Ipomea pestigridis* L. to coal-smoke pollution. Intensive studies on the effects of air pollution on yield and quality of mung bean grown in peri-urban areas of Varansi were made by Agrawal et al (2006). While Sharma and Tripathi (2009) analyzed biochemical responses in tree foliage exposed to coal-fired power plant emission in seasonally dry tropical environment around Dehradun area (and reports of Chauhan 2010 a, b) where photosynthetic pigment changes in some selected trees have been induced by automobile exhaust; these observations are similar to us where we have observed reduction in chlorophyll pigments, metabolic contents and enzyme activities which shift to a reduced level in presence of air pollutants. Kapoor et al. (2009 a, b; 2012; 2013) and Bamniya et al. (2012 a, b, c) made elaborative studies on significant effects of air pollutants on some common tree species, using physiological and biochemical processes along with morphological features in tree species which occur naturally and used for plantation in India and other regions of the world wherever these thrive successfully.

By the study of the morphological, physiological and biochemical parameters (photosynthetic pigments, metabolites, dust capturing capacity) along with enzymatic studies and similar studies it is clear that the tree species investigated *Eugenia jambolana* (L.) has great degree of tolerance to air pollutants and can serve successfully as an efficient alternative to control air pollution along with inherent advantages being medically and economically important (The Wealth of India, 1962). All the parameters studied exhibited slight inhibition of the processes which make the plant tolerant and manageable too in the areas of plantations. If, such trees are managed properly these can help greatly in controlling air pollution caused naturally and through vehicles in addition these plantations conserve great amounts of energy depending on the physiography of the area.

5. Conclusion

Pollutants induce chemical changes in plant tissues, which then affect metabolic and growth processes and/or cause appearance of visible symptoms and damage. Several studies have reported hydrolysis of proteins inducing quantitative changes in amino acid composition and an increase in reducing sugars prior to the appearance of visible symptoms. Urban forests ameliorate climate and human comfort by reducing the amount of radiant energy absorbed, and evapo-transpiration, which affects transport and diffusion of energy, water vapour (H_2O), and pollutants like CH_4, SO_2, NO_2, etc. Thus improve air quality and aesthetic value of landscape by their presence. Roadside plantations are also an effective way to improve community relations. The advantage of using trees and shrubs for roadside plantings is their long lives and large size, i.e., they can make a positive visual impact for a long time. Additionally, the long-term maintenance requirements for trees and shrubs are much lower than for herbaceous ornamental plantings. The tree species that has all the qualities mentioned above being effective and tolerant and, it can be concluded that *Eugenia jambolana* (L.) family Myrtaceae can successfully be grown in area for monitoring air pollution, where it is mild and droughts are common. It is an ideal tree species to control pollution effectively and it can indicate the metal ion concentration also in certain industrial areas. By its plantation mitigative measure at the polluted sites to control generation of particulate matter and the air quality in the required can be ensured. By all of above practices affected areas could be brought within the national ambient air quality protocol threshold limit.

Acknowledgments

This study is part of ongoing research being carried out on the theme of Environmental monitoring and Sustainable

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