RESEARCH ARTICLE

BIO-MONITORING OF ROADSIDE PLANTS AND THEIR RESPONSE TO VEHICULAR POLLUTION- A PHYSIOCHEMICAL APPRAISAL.

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Manuscript Info	*Abstract*

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Rapid industrialization and urbanization coupled with increase in vehicular traffic in the urban areas has become a great threat to air quality, threatening the very existence of the living beings. The present study was conducted to find the effect of air pollution on different plants growing at the road sides and the major aims of this study was to assess the physiochemical effects of air pollutants on the plants. Mature leaves of ten plants (*Mangifera indica, Chromolaena odorata, Hyptis suaveolens, Alstonia scholaris, Hibiscus rosasinensis, Psidium guajava, Bougainvillea glabra, Ficus benghalensis, Adenanthera pavonina and Macaranga peltata*)growing luxuriously on roadsides with their respective controls were selected. Dust trapping efficiency was significantly higher in the polluted leaves. Total chlorophyll and sugar content were less in the leaves of plants growing in the polluted area compared to those growing in non polluted area. Increased content of proline and malondialdehyde were recorded in the polluted leaves and can be considered as an adaptation to protect plants against air pollution. The present study concluded that the metabolisms of common roadside plants are significantly changed in response to higher concentrations of air pollutants as compared to the control site. The marked increase of proline content further suggests that these plants offer suitable choice for the bio-monitoring of air pollution. In brief, the use of urban roadside plants as bio-indicators or bio markers is an inexpensive and convenient technique and thus offers an eco sustainable green tool for monitoring air pollution in future.

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Introduction:-
As the present society move with the catchword of uncontrolled development, it leads to more environmental devastation, which is a serious global concern. Some natural and human activities introduce gases and particulate matter, which contaminate air and cause air pollution. Pollutants have been increasing due to rapid industrialization, increasing heavy traffic load, rapid economic development and higher level of energy consumption by the increasing population. Increase in the number of vehicles in cities and even in villages creates many hazardous environmental problems.

Changes in the gaseous composition of earth's atmosphere due to human activities have become a prime concern of today's world. Normal atmosphere consists of about 78% nitrogen, 21% oxygen, 0.93% argon, 0.038% carbon

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dioxide, and several other gases in trace amounts. The discharge of pollutants in air can cause changes in these constituents of atmosphere. Urban air pollution which poses a significant threat to animal, plants and human health, is receiving more attention nowadays as a growing share of the world's population is now living in urban centers and demanding a clear urban environment.

Air pollution is one of the burning and serious environmental problems in big cities of India. India and other developing countries have experienced a progressive degradation in air quality due to industrialization, urbanization, lack of awareness, number of motor vehicles, use of fuels with poor environmental performance, badly maintained roads and ineffective environmental regulations (Chauhan and Joshi, 2008). Air pollution in several large cities of India is amongst the highest in the world (Agrawal, 2005). According to an estimate, dust pollutants comprise around 40% of total air pollution problem in India (Khan et al., 2005).

In metro cities automobiles are one among the major cause of atmospheric pollution. Motor vehicles and their usage developed very rapidly in the world. In last couple of decades, it has been observed with great concern that the density of vehicles in cities of India have increased enormously. Vehicular pollution contributes to 70% of total air pollution in Delhi, 52% in Mumbai and 30% in Calcutta (C.P.C.B., 2003). Most of the cities situated in North India are facing problems with the presence of unusually high concentration of air pollutants.

The same is the case with Kerala. Even the villages of Kerala are jam-packed with heavy traffic. As a result, the pollution due to vehicles shows a tremendous increase, not only in urban areas but also in villages. Motor vehicles are one of the major source of pollutants and it account for the world's air pollution more than any other human activity. They are responsible for the release of carbon monoxide and lead in the air of cities, and also a major portion of the volatile organic compounds, fine particles, and toxic chemicals. The increasing number of transport vehicles   and the resulting heavy traffic may produce heavy metals and other toxic compounds into the atmosphere that may cause adverse health effects in human beings, affect plant life and impact the global environment by changing the atmosphere of the earth. There is no method, which can completely control the emission of pollutants at the source.

Plants growing on roadsides are mostly exposed to this pollution and hence studies on the impact of automobile pollution on plants have attracted much interest. Urban vehicular pollution can directly and indirectly affect local and regional air quality by altering the urban atmosphere. Faulty and badly maintained automobile vehicles release carbon particles, unburned and partially burned hydrocarbons, tar materials, lead compounds and other elements in the environment due to incomplete combustion of fuel which are the constituents of petrol. The deposition of these trace elements, gaseous pollutants, nitrogen oxides (NO), carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), etc. on the leaves of road side plants will affect the physiological and biochemical functions of the plants.

The biotic community has become adapted to the increased particular chemical constituent levels of environment for a long time as a part of natural selection. Therefore, any alterations occurring to these abiotic factors, due to pollution, can cause changes in the biotic community as there is a continuous give and take between organisms and environment. Organisms are adapted to escape or avoid a stressful condition. But plants being immovable literally, escaping from a polluted place is not possible. In case of plants, the molecules they take in from air and soil makes the entire living tissue and has a significant relationship with the environment they survive. The biochemical changes of plants can be an indication of pollution as it may be due to the effort of plant to adapt to the stressed environment.

It has been reported by many researchers that plants can check the pollutants by adsorbing and metabolizing them from the atmosphere. Therefore, the role of plants in the air pollution control has been increasingly recognized in recent years. Plants act as a sink or even as living filters to minimize air pollutant by developing characteristic response and symptoms. Moreover, roadside plant leaves are in direct contact with air pollutant, hence they must be examined for their bio-monitoring potential (Cohen et al., 2004; Sharma et al., 2007).

The present study brings out the effects of air pollution, especially the vehicular pollution on plants in the field condition. The attempt was to identify the biochemical changes of ten selected plants grown in heavy automobile polluted area.

The major goals of the present study includes the evaluation of the physiological and metabolic effects of air pollutants on ten different plants in field condition, investigation of the dust trapping efficiency and stomatal index of leaves and finally the examination of the ecological adaptations developed in these plants due to the stressed condition.

Materials and methods:-
Plant material:-
Leaves of ten different plants (*Mangifera indica, Chromolaena odorata, Hyptis suaveolens, Alstonia scholaris, Hibiscus rosasinensis, Psidium guajava, Bougainvillea glabra, Ficus benghalensis, Adenanthera pavonina and Macaranga peltata*) were collected randomly from roadside of Thokilangady-Kuthuparamba road of Kannur district, Kerala, India. This particular area was chosen because Thokilangadi is a junction where The Coorg-Thalassery road and Baveli-Kuthuparamba road meets. Therefore, vehicles from both these roads will be travelling through this area heading to or coming from Kuthuparamba, the nearest town from this area.

The road is busy equipped with numerous vehicles including buses to both the routes, trucks, cars and other automobiles. The number of vehicles, including two wheelers, four wheelers (cars and medium vehicles) and heavy vehicles passing through this segment was calculated at peak traffic time (8 AM to 6 PM). An average of 50000 vehicles was estimated to cross this area per day. As control, leaves of plants from areas of comparatively less or no pollution (from riverside and sacred groves) were collected. Leaves were collected from plants of almost same age and size in order to minimise the errors. Twenty leaves per species were collected from the branches facing towards the roadside in the early hours of morning (10 AM to 12:00 AM) through random selection. Leaf samples were kept in polythene bags, brought to the laboratory and physiological and biochemical parameters were studied immediately.

Physiological parameters:-
Photosynthetic pigments:-
Estimation of chlorophyll contents were done according to the method of Arnon (1949). Fresh samples were crushed in 80% acetone and the homogenate was centrifuged at 5000 rpm for 10 min at 4°C. The absorbance was read at 663, 646 and 750 nm against the solvent blank (80% acetone).

Stomatal index (SI):-
A leaf segment of an area of $1cm^2$ from each specimen was cut and immersed in water. The lower (abaxial) surface was separated with dissecting needle and forceps and rinsed with clean water. Each specimen was stained with 1% aqueous safranin for 3 to10 minutes. Excess stains were rinsed off with clean water and were mounted in glycerin. The stomatal index was calculated as suggested by Salisbury et al. (1992).

$$SI = \frac{S}{S + E} \times 100$$

Where, SI is the stomatal index, S- number of stomata/unit area of leaf, and E- number of epidermal cells/unit area of leaf.

Dust trapping efficiency:-
Leaves of roadside plants were collected and weighed each one without removing the dust on it. Then the dust on leaves was removed using a fine brush and weighed again. The differences in weight of leaves were calculated. The area of the leaf weighed was found out. Amount of dust per square centimetre of leaf was estimated as the average amount of dust divided by average area of leaf.

pH of the leaves:-
Leaves of plants from the roadside and non polluted areas were collected separately. They were ground well and centrifuged. The supernatant was collected and measured pH using a pH meter.

Biochemical parameters:-
Total protein:-
Protein concentrations in the enzyme extract was determined following the method of Lowry et al. (1951) using defatted Bovine serum albumin (fraction V) as a standard.

Int. J. Adv. Res. 6(1), 715-725

Total soluble sugar:-
Total soluble sugar was extracted from fresh samples using 80% ethanol and estimated following the method of Dubois et al. (1956). Standard curve was plotted using D-Glucose as standard.

Proline:-
Free proline content was extracted from fresh samples using 3% sulfosalicylic acid and estimated following the method of Bates et al. (1973) using L-proline as standard.

Malondialdehyde content (MDA):-
MDA content was estimated according to the method of Heath and Packer (1968), and was calculated using its molar extinction coefficient of 155 mM L^{-1} cm^{-1}.

Statistical analyses:-
Statistical analysis of the results was carried out according to Duncan's multiple range tests at 5% probability level. Data were subjected to one-way ANOVA using the SPSS software 16.0. The data represent mean ± standard error.

Results and Discussions:-
The present study was focused on bio-monitoring of the air pollution tolerance in different roadside plants. Various physiological and biochemical parameters were studied inorder to assess the tolerance of polluted as well non-polluted plants.

Physiological parameters:-
Photosynthetic pigments:-
The total chlorophyll content of the selected plants tends to be decreased with increasing pollution load as compared with control leaves (Fig. 1). Chlorophyll is said to be an index of productivity and it plays an important role in plant metabolism, hence any alteration in chlorophyll concentration may change the morphological, physiological and biochemical behaviour of the plant. It is well evident that chlorophyll content of plant varies from species to species; age of leaf and with the pollution level as well as with other biotic and abiotic conditions (Katiyar and Dubey, 2001). Thus, the reduction in chlorophyll concentration in the polluted leaves could be due to chloroplast damage (Pandey et al., 1991), inhibition of chlorophyll biosynthesis (Esmat, 1993) or enhanced chlorophyll degradation due to the interference of heavy metal deposition in leaves.

Chlorophyll is often measured in order to assess the impacts of environmental stress since the changes in the pigments are linked with visual symptoms of growth disorder and photosynthetic productivity. Similar results have been reported in plants such as Radish and Lettuce due to cadmium ions in the polluted air, in *Phaseolusaureus*due to mercury, in Mung bean due to lead (Rai et al., 2009) and chromium inhibited chlorophyll content in Wheat (Joshi et al., 2009).
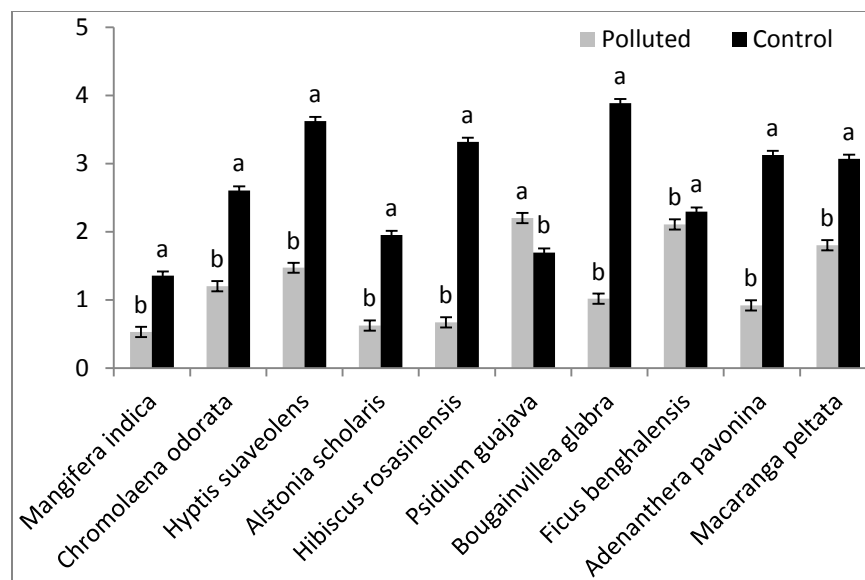
Figure 1:- Total chlorophyll content in the leaves of plants collected from polluted road sides as well as non-polluted areas. Values are the mean ± SE of three independent experiments. Different letters indicate statistically different means at p =0.05.

Stomatal index (SI):-

The present study shows a decline in the stomatal index of the polluted plants as compared to the respective control samples (Table 1). Results demonstrated that air pollution caused significant changes in stomatal index of the leaf. The reduction was prominent in *Psidiumguajava*(42%) and was minimum in *Alstoniascholaris* (15%) (Fig. 2). Reduction in stomatal index at the polluted site may be attributed to the heavily polluted air, containing mainly suspended particulate matter in conjunction with gaseous pollutants emitted from vehicles and other multifaceted sources. As the number of stomata decreases, consequently the number of epidermal cell increases. Decrease in stomata could be regarded as an adaptive feature developed by plants in order to cope up with the effect of the gaseous pollutant which may enter the leaf and create injuries to the tissues and causes death (Mandal, 2006).
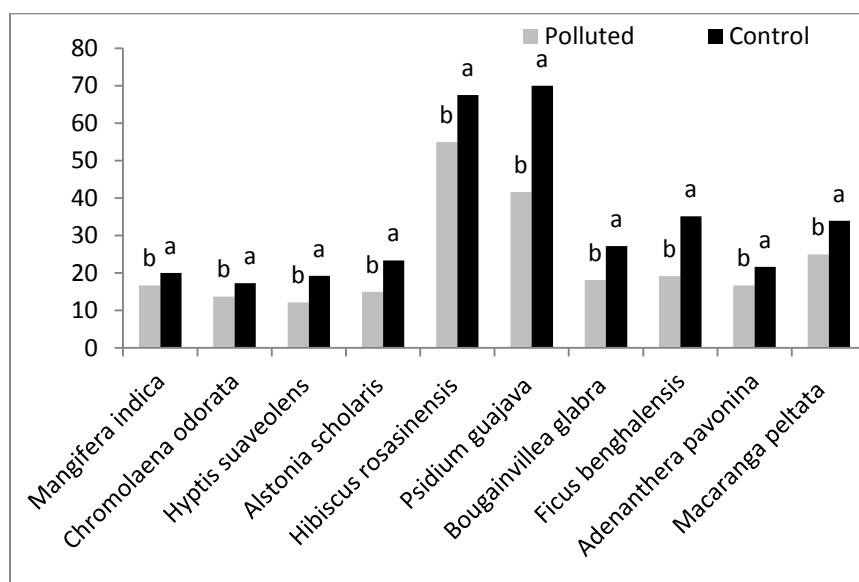

Figure 2:-Stomatal index of the leaves of plants collected from polluted road sides as well as non-polluted areas. Values are the mean ± SE of three independent experiments. Different letters indicate statistically different means at p =0.05.

Dust trapping efficiency:-
High dust deposit was recorded for all the plant species collected from roadside compared to their respective control leaves, and the trend of dust trapping capacity among the plant species was: *Hyptis suaveolens> Hibiscus rosasinensis>Chromolaenaodorata>Alstoniascholaris>Bougainvilleaglabra>Macarangapeltata>Psidiumguajava> Mangiferaindica>Ficusbenghalensis>Adenantherapavonina,* as shown in the table (Table 1).

pH of the leaves:-
The change in pH of the selected leaf samples collected from polluted site was significant compared with their respective control. The leaf samples collected from polluted site exhibited a pH change towards acidic side (Table 1), which may be due to the presence of SO_2 and NO in the atmosphere. The gases such as SO_2 andNO_2 induce the formation of H_2SO_4 and HNO_3 in contact with water inside the leaf tissue and thus lowering of the pH of polluted plants. The level of pH affects different pH dependent enzymatic activities of the plants, thus influencing plant growth and development. The lower pH reported in the present study was in correlation with the findings of Prasad and Rao (1982) wherein they reported the reduced pH in sensitive plant species.

It has been reported by many workers that there is a correlation between dust deposition and heavy metal accumulation in plants. However, the present study is not an attempt to analyze the heavy metal deposition in leaves. Moreover, the dust deposition in leaves can be taken as a marker for heavy metal deposition in the selected plants as shown in many studies. Rai (2016) has been reported a positive correlation between dust deposition and heavy metals (Fe, Cu, and Zn). High concentrations of heavy metals in plants may be due to heavy traffic frequency and more commercial and domestic activities when compared to the control site.

Verma and Singh (2006)also demonstrated high metal concentrations and dust deposition at heavy polluted sites compared to the low polluted site when *Ficus religiosa and Thevetia neriifolia*were selectedas a bio-monitoring tool. Highest change in dust content was found in *Ficusreligiosa*. The present result of dust deposition on the leaves of selected roadside plants may thus be taken as an indication of heavy metal accumulation due to automobiles. The intensity of the dust accumulation can be taken as a tool to identify the kind of plants, which acts as a sink of air pollution. High trafficload contributes to high dust fall on the leaves of roadside plants. This also depends upon the level of pollution and structure of leaves as suggested by Joshi andSwami (2007).

Table 1:- Dust trapping efficiency and leaf pH of plants collected from polluted road sides as well as non-polluted areas.Values are the mean ± SE of three independent experiments. Different letters indicate statistically different means at p =0.05.

Sl. No.	Sample	Amount of dust/cm^2		pH	
		Control	Polluted	Control	Polluted
1	*Mangiferaindica*	0.011±0.0004[b]	0.305±0.013[a]	6.29±0.311[a]	5.33±0.232[b]
2	*Chromolaenaodorata*	0.041±0.001[b]	2.7±0.118[a]	5.89±0.28[a]	4.07±0.231[b]
3	*Hyptissuaveolens*	0.066±0.003[b]	3.8±0.11[a]	6.48±0.321[a]	5.13±0.298[b]
4	*Alstoniascholaris*	0.131±0.005[b]	2.4±0.11[a]	5.89±0.287[a]	5.40±0.223[b]
5	*Hibiscus rosasinensis*	0.061±0.003[b]	3.3±0.15[a]	6.70±0.311[a]	6.05±0.291[b]
6	*Psidiumguajava*	0.045±0.002[b]	0.94±0.03[a]	5.97±0.277[a]	4.92±0.213[b]
7	*Bougainvillea glabra*	0.029±0.001[b]	2.2±0.11[a]	6.95±0.315[a]	5.32±0.211[b]
8	*Ficusbenghalensis*	0.011±0.0004[b]	0.13±0.005[a]	4.97±0.213[a]	4.13±0.132[b]
9	*Adenantherapavonina*	0.002±0.0001[b]	0.089±0.003[a]	6.57±0.312[a]	5.78±0.138[b]
10	*Macarangapeltata*	0.115±0.005[b]	2.0±0.11[a]	4.49±0.221[a]	4.18±0.158[b]

Biochemical parameters:-
Total protein:-
The present study recorded a reduction in total protein content for all of the selected plant species except *Chromolaena odorata*and *Psidium guajava*collected from the pollution site as compared to the control (Fig. 3). The probable reason behind the reduction of protein content in the polluted plant might be due to the enhanced rate of proteindenaturation and also due to the breakdown of existing protein to amino acids (Tripathi and Gautam, 2007). Another reason might be the enhanced activity of the degradative enzyme like proteases which catalyses the breakdown of polypeptides into amino acids to resist the stressinduced by pollution.

Maximum reduction in the total protein content was observed in *Mangiferaindica* and *Bougainvillea glabra*. Decline in total protein content due to SO_2 and NO_2 pollutants have also been reported earlier by several workers (Agarwal and Deepak, 2003; Rai and Panda, 2015). Agarwal and Deepak (2003), determined that SO_2 enrichment results in diminished leaf protein levels in two cultivars of wheat by 13% and the decrease is attributed to breakdown of existing protein and reduction in protein synthesis.

However, in *Chromolaena odorata* and *Psidium guajava* there is considerable increase in total protein content in the polluted site when compared to the control plants. In plants, some proteins are synthesized at an enhanced rate under the influence of heavy metals and other pollutants. Phytochelatins form a major class of these proteins, which help in detoxifying and reducing the concentration of cytotoxic free metal ions, by forming phytochelatin metal complexes. These complexes are further sequestered into vacuole. Pinot et al. (2000) and Weber et al. (2006) Thus, the increase in protein content, observed in this study may be due to the deposition of heavy metals and to cope with this effective detoxification process is operational. Significant increase in total protein content was recorded in *Albizzia* plants grown in polluted area (Seyyednejad, 2009).
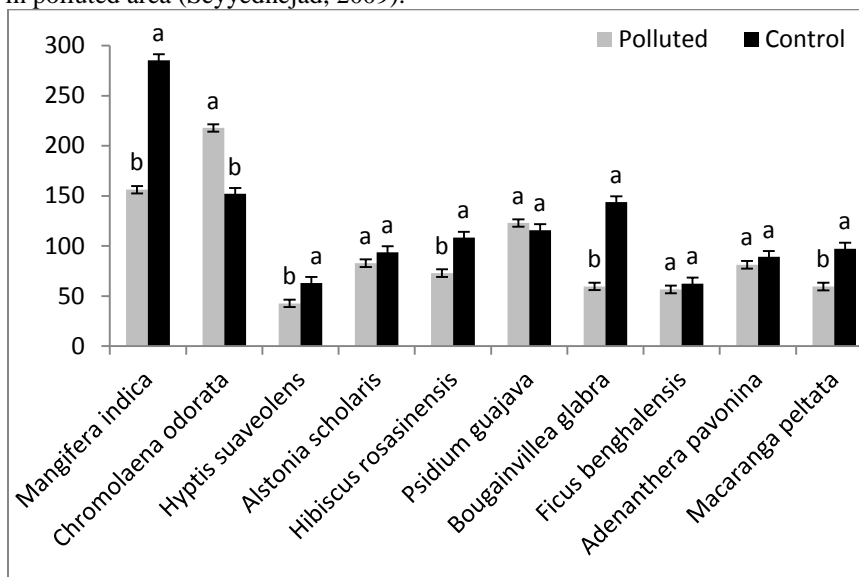

Figure 3: Total protein content of the leaves of plants collected from polluted road sides as well as non-polluted areas. Values are the mean ± SE of three independent experiments. Different letters indicate statistically different means at p =0.05.

Total soluble sugar:-
The concentrations of total soluble sugar content markedly decreased with increasing pollution load at the road side site in the selected plants, except in *Mangiferaindica*, *Macarangapeltata*, *Psidiumguajava* and *Chromolaenaodorata* which showed a considerable increase in the sugar content when compared with the control(Table 2). Reduction in soluble sugar content at the polluted site can be attributed to increased respiration and decreased CO_2 fixation because of chlorophyll deterioration). Pollutants like SO_2, NO_2 and H_2S may cause more depletion of soluble sugar in the leaves of plants grown in a polluted area. The reaction of sulfite with aldehydes and ketones of carbohydrates can also cause reduction in carbohydrate content (Tripathi and Gautam, 2007).

The observed increase in the concentration of sugar content *Mangifera indica*, *Macaranga peltata*, *Psidium guajava* and *Chromolaena odorata* may be attributed to the osmo-regulation and tolerance contributing to the plant survival under adverse environmental conditions (Thambavani et al., 2014). Soluble sugar is an important constituent and source of energy for all living beings. Plants manufacture this organic substance during photosynthesis and breakdown during respiration (Tripathi and Gautam, 2007). Reduction in soluble sugar content in polluted site may correspond with a lower photosynthetic rate and higher energy requirements due to airborne heavy metal stress. The carbohydrate concentrations, indicating the various physiological activities of a plant and it can also determine the plant sensitivity to air pollution (Tripathi and Gautam, 2007).

Proline:-
Out of the ten species studied, seven plants in the polluted site showed an increase in proline concentration compared to their control. The increase was maximum in *Alstonia scholaris*and *Bougainvillea glabra*, and was much less in *Macaranga indica* (Table 2).Proline is known to get accumulated in wide variety oforganisms ranging from bacteria to higher plants on exposure to abiotic stress (Ahmed et al., 2008). Proline accumulation in plants can serve as biomarker of heavy metals and other pollutants stress. Plants are known to accumulate high concentration of proline when treated with toxic heavy metals (Costa and Morel, 1994). Several antioxidants such as ascorbate, glutathione, carotenoids and flavonoids are present in higher plants that contribute to protective system against oxidative stress and deactivate the active oxygen species in multiple ways (Asada and Takahashi, 1987). In addition to the above, proline also can act as an excellent antioxidant.

In the present study enhanced levels of proline content was noted in theplants under pollution stress. Proline might be playing an important role in mitigating stress due to its antioxidant properties. Proline may stabilize protein complexes, act as a scavenger of oxygen free radical or function as a signal for regulation of downstream events (Alia and Matysik, 2001; Kaviet al., 2005). The increase in accumulation of proline thus helps the plants to counteract the deleterious effects of pollution stress. Significant increase of proline was recorded in *Albizialebbek*grown in polluted area (Seyyednejad et al., 2009). The concentration of proline increased in *Callistomencitrinus* planted round petrochemical sites in comparison with control site. It has been proposed that proline can act as an electron acceptor, avoiding the damage of photosystems by activated oxygen species.

Table 2:- Total soluble sugar and proline content of plants collected from polluted road sides as well as non-polluted areas.Values are the mean ± SE of three independent experiments. Different letters indicate statistically different means at p =0.05.

Sl. No.	Sample	Soluble sugar (mg/g)		Proline (mg/g)	
		Control	**Polluted**	**Control**	**Polluted**
1	*Mangiferaindica*	12.25±0.57[b]	15.25±0.65[a]	0.17±0.007[b]	2.15±1.11[a]
2	*Chromolaenaodorata*	8.10±0.31[b]	10.35±0.38[a]	0.26±0.011[b]	1.69±0.07[a]
3	*Hyptissuaveolens*	9.37±0.38[a]	8.66±0.34[b]	0.57±0.021[b]	2.57±0.12[a]
4	*Alstoniascholaris*	7.34±0.29[a]	6.33±0.27[b]	0.03±0.001[b]	1.17±0.04[a]
5	*Hibiscus rosasinensis*	14.43±0.65[a]	12.66±0.57[b]	0.87±0.045[b]	2.95±0.15[a]
6	*Psidiumguajava*	10.63±0.42[b]	14.18±0.67[a]	0.02±0.001[b]	2.07±0.13[a]
7	*Bougainvillea glabra*	15.18±0.65[a]	10.89±0.48[b]	0.14±0.006[b]	1.32±0.06[a]
8	*Ficusbenghalensis,*	9.87±0.38[a]	5.82±0.24[b]	0.14±0.002[b]	1.21±0.06[a]
9	*Adenantherapavonina*	9.11±0.38[a]	5.92±0.21[b]	0.46±0.021[b]	1.51±0.06[a]
10	*Macarangapeltata*	6.96±0.284[b]	11.14±0.45[a]	1.16±0.04[b]	1.75±0.08[a]

Malondialdehyde content (MDA):-
In the present investigation, the extent of lipid peroxidation of the selected plant species was studied by estimating the MDA content. The highest increase in malondialdehyde content was observed in *Macarangapeltata*and the lowest was observed in *Hibiscusrosasinensis* (Fig. 4). Accumulation of MDA as a breakdown product of lipid peroxidation is an indicator of oxidative damage due to stress in plants. According to Song et al. (2004) under toxic conditions cellular damage occurs due to the generation of highly reactive oxygen species, which affects the normal metabolism of the cell.

Lipid peroxidation is one of the best criteria to monitor the membrane damage caused by reactive oxygen produced. It occurs when free radicals are generated close to the cell membrane and attack the unsaturated fatty acid side chain of lipid hydroxyl peroxides. As MDA is a well known indicator of oxidative stress it is possible to state that *Macarangapeltata*is highly under the influence of oxidative stress as compared to other plants. The present results substantiate the earlier studies by Zhang et al., (2007), i.e., the free radical generated during pollution cause damage to vital membranes and membrane bound proteins involved in energy producing processes.
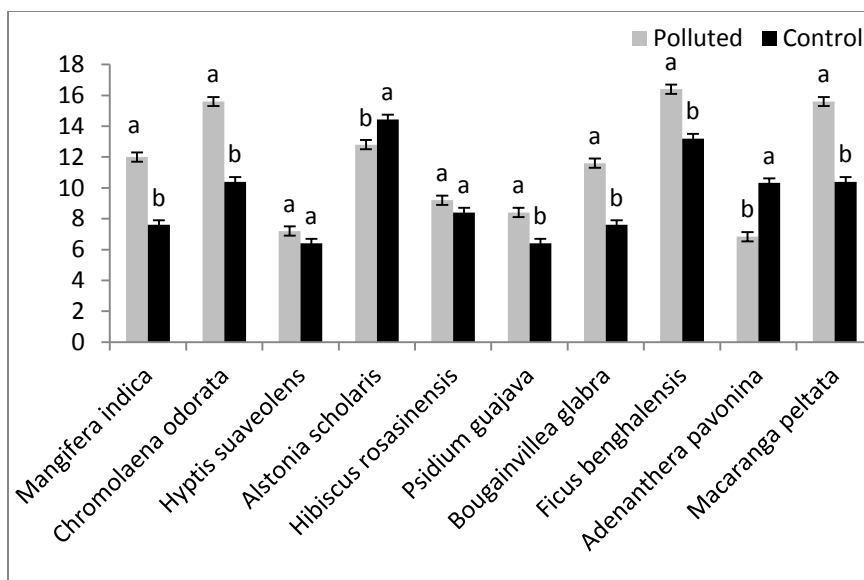
Figure 4:- MDA content of the leaves of plants collected from polluted road sides as well as non-polluted areas. Values are the mean ± SE of three independent experiments. Different letters indicate statistically different means at p =0.05.

Summary and Conclusion:-

In urban areas of both developing and developed countries, predominately vehicular pollution contributes to air quality problem. The worst thing about vehicular pollution is that it cannot be avoided as the vehicular emissions are emitted at the near-ground level where we breathe. Plants, the main green belt component, act as a sink and as living filters to minimize air pollution by absorption, adsorption, detoxification, accumulation and metabolization without sustaining serious foliar damage or decline in growth, thus improving air quality by providing oxygen to the atmosphere. This fact was reinforced in the present study as it reveals the tolerance mechanism operating in response to the air pollution by the selected road side plants.

Higher suspended particulate matter has induced several physiological and biochemical changes in the roadside plants. The observed reduction of total chlorophyll and sugar content might due to the diversion of growth processes to maintenance process. This was in accordance with the increased dust trapping and proline content of the polluted plants over the control plants. However, further research is required in this regard, for reaching conclusive statements. The present investigation is a strong first step and necessitates further effort, which may pave the way to screen the possibility of these plants to be planted in other urban areas with different pollution intensities.

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