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Effect of the ODD-EVEN Traffic Formula in Delhi on the Photosynthetic Activity of *Cassia fistula*

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----------ABSTRACT----------
In an effort to reduce the alarming levels of pollutions in Delhi, the government implemented the odd – even traffic program as an emergency action, the first phase of which was implemented from the 1st to 15th of January 2016, where exclusively odd or even numbered vehicles were allowed to ply on the roads on odd and even dates respectively. The present study was carried out to assess the impact of this decreased vehicular pollution on the photosynthetic activity of Cassia fistula trees growing along some selected roads of the city associated with heavy vehicular pollution and high traffic congestion during normal times. Sampling was done from trees growing close to the roads (less than 5m) at four locations faced with heavy traffic volume normally, while control sampling was done from a location away from traffic exposure. Measurement of photosynthetic pigments was done spectrophotometrically. All measured parameters like Chlorophyll 'a', Chlorophyll 'b', carotenoids and total chlorophyll were found to be significantly increased when thecomparison was made between values obtained during normal traffic and the ones obtained after the reduction in vehicular pollution. The maximum increase in concentration was as high as 14.47%, for Chlorophyll a (South Extension), 12.8% for Chlorophyll b (R. K. Puram), 12.3% for total chlorophyll (South Extension) and 17.2%for Carotenoids (R K Puram). Samples from control site did not show much change in the concentration of studied pigment on these two dates. This study clearly shows that decreased vehicular pollution has a significant impact on the photosynthetic pigments inCassiafistula.

Keywords:*odd- even formula, chlorophyll pigments, carotenoids, vehicular pollution*

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I. INTRODUCTION

Air pollution is not an isolated phenomenon. High vehicular pollution has a distinct impact on the air quality of an area. It is one of the many sources which affect the air quality of Delhi which has worsened tremendously in the recent past. This is because the overallpollution level has grown 5-6 times the normal standards having a detrimental effect on the public health of the city where every third child has impaired lungs. Motor vehicles are responsible for most of the carbon monoxide and lead in the polluted air of cities, and a major portion of the suspended particulate matters (spm), NOx, Volatile organic compounds (voc), fine particles, and toxic chemicals[1][2][3]. They have diverse effects on a lot of metabolic processes in plants also where photosynthetic activities, mitochondrial respiration and stomatal clogging has been frequently associated with increased pollution levels[4]. The phenology, fruiting, flowering and periodicity of plants have been reported to be altered by exposure to pollution from automobiles[5][6].Delhi holds more than 16.6 million registered vehicles in the city as on June 30, 2014, which includes a sizeable number of vehicles that do not follow proper pollution emission norms of the municipal limits.A high volume often leads to massive congestions resulting in litres of fuel being burnt in standing automobiles adding to the emission of toxic pollutants to the air. Concerned with alarming levels of vehicular pollution in the city the Delhi government set out to implement the odd -even program for vehicular usage, where cars carrying odd number plates were to ply on odd days and even on even days respectively. The first phase of this plan was implemented for 15 days from the 1st to the 15th of January 2016.

The aim of the present work is to determine the impact of reduction in vehicular pollution on the photosynthetic pigments of *Cassiafistula*, the golden shower tree belonging to the family Fabaceae. *Cassiafistula* grows to a height of about 10-20m, has pinnately compound leaves and bears flowers which have racemose inflorescence. The fruit is a legume containing several seeds that are used as a purgative[7]. It is a drought-tolerant and temperature tolerant plant so it thrives well in this area.The process of photosynthesis is responsible for most of the organic materials needed for the growth and plant activity reactions. Being dependent on the light capturing

pigments, the photosynthetic process requires large amounts of such pigment molecules in its photosynthesizing cells (up to 5% or more of total dry material). Plants contain an assortment of pigments including the universal chlorophyll 'a' molecule which is assisted by accessory pigments like Chlorophyll b and carotenoids for this important function. An extremely crucial role is played by the chlorophyll molecules in the process of photosynthesis[8]. Therefore, a study involving the quantification of such pigments in response to a changed pattern of pollution exposure is meaningful and important in the estimation of impact, if any.

II. MATERIALS AND METHODS

1.1. Description of study area

The study areas were chosen in Delhi keeping in mind heavy traffic during normal days. Delhi's traffic congestion has doubled in the last eight years and threatens to fail all projections. It is worst among 35 Indian cities and is four times more than Mumbai and Bangalore, (Central Road Research Institute, CRRI, 2006). Assessments carried out on the Ring Road and on some prominent roads show these are overstretched. The Ring Road's total length is 48km and it is a six-lane carriageway. This was designed to carry about 75,000 vehicles a day. But the road carries 1.6 lakh vehicles per day and is expected to carry about 4 lakh vehicles by 2016, (Centre for Science and Environment CSE, 2008). Considering the heavy traffic on the inner and outer Ring Roads, South Ex-AIIMS Highway, BhikajiCama Place, R.K. Puram and Punjabi Bagh were the four sites selected for sampling polluted areasas can be seen inFig. 1. Trees located inside the Lodhi Gardens which were at a distance of over 200m from vehicular traffic were selected as control.

Table 1: Categorization of site of collection of samples

Srl. No.	Dates	Sampling site	Location from Regular traffic zone	Representative Category
1	20-Dec-2015	South Ex-AIIMS Highway	<5m	Polluted
2		BhikajiCama Place	<5m	Polluted
3		R.K. Puram	<5m	Polluted
4		Punjabi Bagh	<5m	Polluted
5		Lodhi Garden	>200m	Unpolluted
6	15-Jan-2016	South Ex-AIIMS Highway	<5m	Polluted
7		BhikajiCama Place	<5m	Polluted
8		R.K. Puram	<5m	Polluted
9		Punjabi Bagh	<5m	Polluted
10		Lodhi Garden	>200m	Unpolluted

Leaves of *Cassiafistula* were collected from all the locations separately before the implementation of the rule as well as after completion of the 15 day trial of the odd – even scheme. The trees of *Cassia fistula* chosen for collection of leaves at each of the heavily polluted sites were not more than 5m from the regular traffic zone and control was collected from a locality, which was at anapproximately200m distance from the highways as can be seen inFig. 1

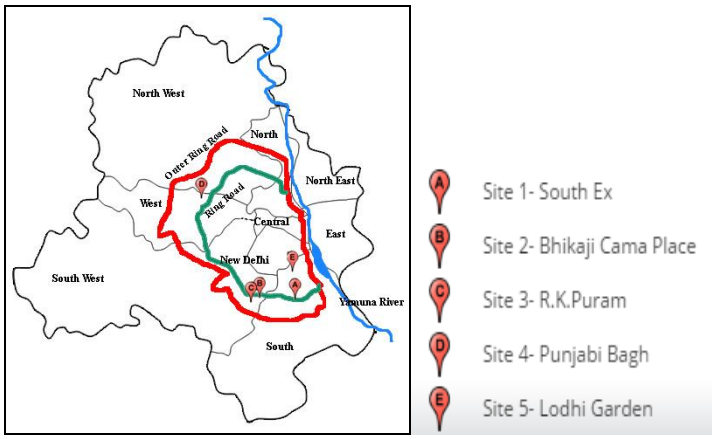

Fig. 1: Showing selected locations facing high vehicular traffic and control location.

1.2. Method

Arnon's (1949) protocol was used for chlorophyll estimation. The leaves were washed and dried. 0.0625g of leaves were weighed on a digital pan balance and were used to prepare chlorophyll extract, in 5 ml of 95% (v/v) Ethanol and successively filtered. The extract was diluted ten folds in water. Spectrophotometric reading was taken at 480, 510, 645 and 663 nm of wavelengths respectively. Readings for each test was taken in triplets and then the values were averaged to get the result. The formulae used for chlorophyll and carotenoid content estimation were as follows:

(1) Arnon's (1949)

Chl a (g l-1) = (0.0127 × A663 – 0.00269 × A645) ×V/W
Chl b (g l-1) = (0.0229 × A645 – 0.00468 × A663) ×V/W
Tot Chl (g l-1) = (0.0202× A645 + 0.00802 × A663) ×V/W

(2) Kirk and Allen (1965)

Carotenoid (μg/g.fr.wt) = A480 + (0.114 × A663) – (0.638 × A645)
where A480= Absorbance at 480nm
where A663= Absorbance at 663nm
where A645= Absorbance at 645nm

III. STATISTICAL ANALYSIS:

Each pigment data was grouped for all locations exposed to traffic pollution on the basis of the date of sample collection. Thus two groups were obtained- one with pigment data for pre odd-even scheme, another with pigment data post odd-even scheme. All data were expressed as mean ± SEM of each group. Variation was considered to be significant at ($P < 0.05$).

IV. RESULTS AND TABLES

Leaves were sampled once before the implementation of the odd– even scheme and second time on the 15th day, at the end of first phase of the scheme. Results show differences in concentration of chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid content of leaves collected on these two dates in Tables 1.1 to Table 1.4.

Table 1.1 Chlorophyll a content ± SD for *Cassiafistula* leaves in mg/g, pre and post ODD-EVEN trials

Timeline/ Location	Site 1	Site 2	Site 3	Site 4	Site 5
20-Dec-15	0.3486 ± 0.0029	0.3092 ± 0.0045	0.3363 ± 0.0024	0.3305 ± 0.0034	0.4473 ± 0.0046
15-Jan-16	0.3990 ± 0.0031	0.3397 ± 0.0052	0.3649 ± 0.0028	0.3673 ± 0.0042	0.4511 ± 0.0051
Percentage Increase	14.47	9.85	8.52	11.14	0.85

Table 1.2 Chlorophyll b content ± SD for *Cassia fistula* leaves in mg/g, pre and post ODD-EVEN trials

Timeline/ Location	Site 1	Site 2	Site 3	Site 4	Site 5
20-Dec-15	0.6300 ± 0.0046	0.5941 ± 0.0046	0.6121 ± 0.0035	0.6516 ± 0.0027	0.8138 ± 0.0056
15-Jan-16	0.7002 ± 0.0058	0.6407 ± 0.0036	0.6910 ± 0.0023	0.6922 ± 0.0046	0.8226 ± 0.0058
Percentage Increase	11.15	7.84	12.88	6.23	1.07

Table 1.3 Total Chlorophyll content ± SD for *Cassiafistula* leaves in mg/g, pre and post ODD-EVEN trials

Timeline/ Location	Site 1	Site 2	Site 3	Site 4	Site 5
20-Dec-15	0.9786 ± 0.0075	0.9034 ± 0.0059	0.9485 ± 0.0064	0.9821 ± 0.0066	1.2612 ± 0.0063
15-Jan-16	1.0993 ± 0.0064	0.9804 ± 0.0056	1.0560 ± 0.0072	1.0596 ± 0.0070	1.2737 ± 0.0053
Percentage Increase	12.33	8.53	11.33	7.88	1.00

Table 1.4 Carotenoids content ± SD for *Cassiafistula* leaves in mg/g, pre and post ODD-EVEN trials

Timeline/ Location	Site 1	Site 2	Site 3	Site 4	Site 5
20-Dec-15	33.433 ± 0.0091	37.256 ± 0.0102	34.233 ± 0.0088	35.255 ± 0.0106	42.621 ± 0.0091
15-Jan-16	36.940 ± 0.0089	39.349 ± 0.0098	40.146 ± 0.0099	37.735 ± 0.0110	42.929 ± 0.0094
Percentage Increase	10.49	5.62	17.27	7.03	0.72

At the end of the fortnight of implementation of scheme, an overall increase was observed in concentration of chlorophyll 'a' in Table 1.1 andFig. 1.1which ranged from 8.52% -14.47% in the leaves collected from the polluted locations. Similar increase was observed in the concentration of chlorophyll 'b' in Table 1.2 andFig.1.2 which ranged from 6.23% to 12.88% in samples from congested areas. There was an improvement in the amount of total chlorophyll in Table 1.3 andFig.1.3 and carotenoid content in Table 1.4 and Fig. 1.4 also in the leaves which was in the range of 4.44% - 11.33% and 5.62% - 17.27% respectively. Relatively higher increase was observed in the concentration of carotenoid pigment when compared to other pigments in the plants after exposure to the scheme as can be seenin Fig. 1.5. It was also observed that concentration of these pigments did not change much in the leaves collected from control site, LodhiGardens, pre and post scheme implementationas can be seen in Fig. 1.5. The concentration of all the pigments was higher in the leaves collected from control site indicating an improved photosynthetic capacity of the plants when exposed to less vehicular pollution. Although the concentration of the studied pigments was highest in plants of control location, the percent increase in response to the scheme was very small in them.

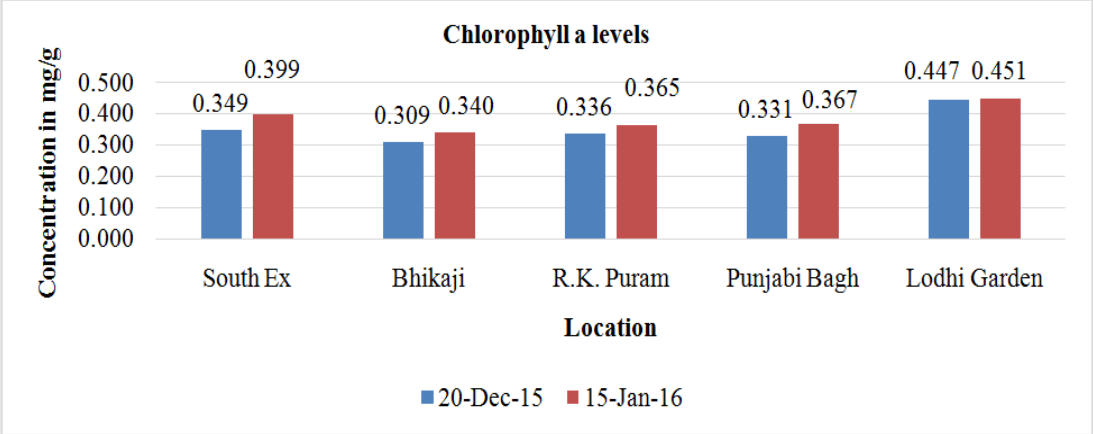

Figure 1.1 Plot showing comparison of Chlorophyll a levels (in mg/g) by Arnon's method in leaves of *Cassia fistula*, pre and post ODD-EVEN trials

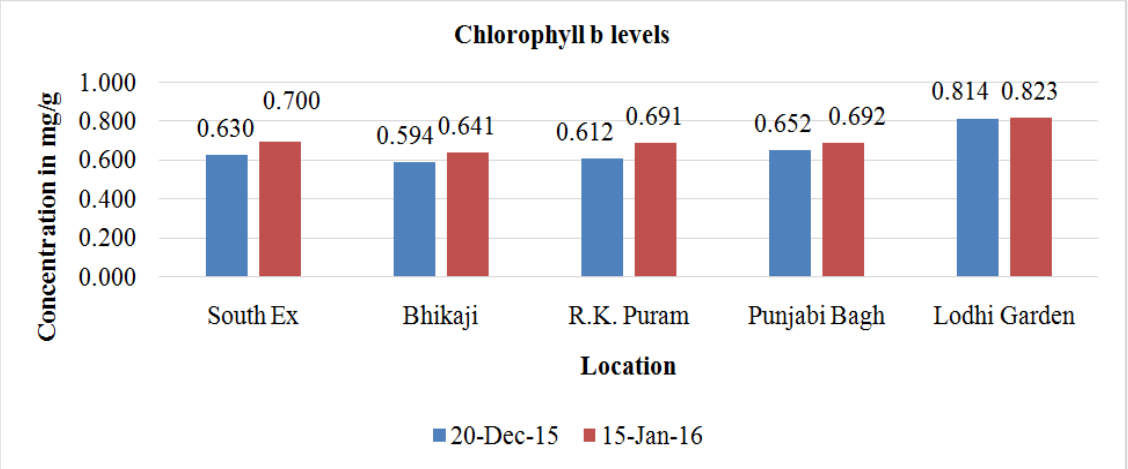

Figure 1.2 Plot showing comparison of Chlorophyll b levels (in mg/g) by Arnon's method in leaves of *Cassia fistula*, pre and post ODD-EVEN trials

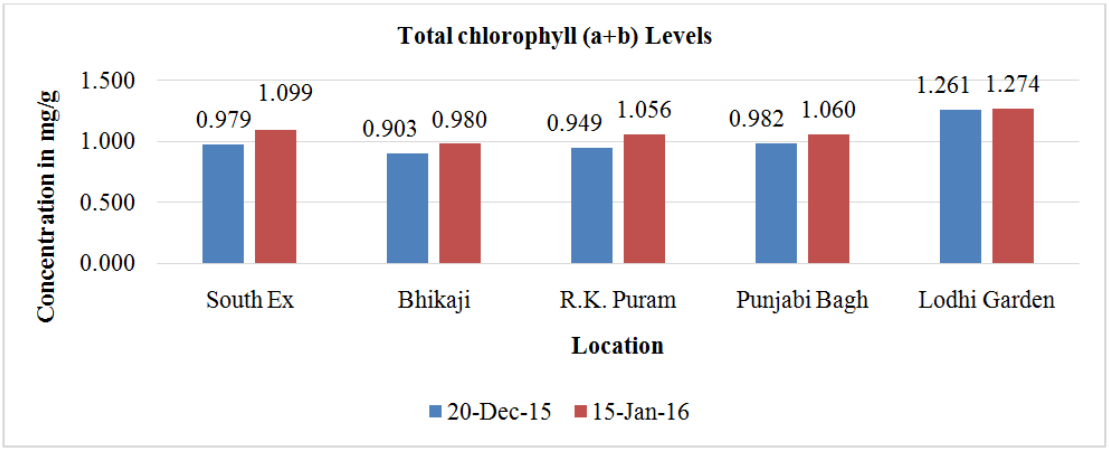

Figure 1.3 Plot showing comparison of Total Chlorophyll (a+b) levels (in mg/g) by Arnon's method in leaves of *Cassia fistula*, pre and post ODD-EVEN trials

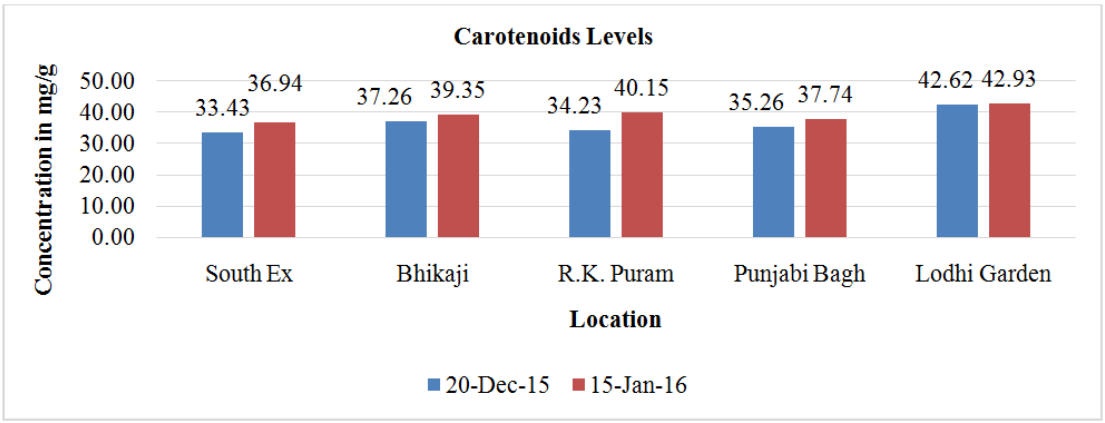

Figure 1.4 Plot showing comparison of Carotenoid levels (in mg/g) by Arnon's method in leaves of *Cassia fistula*, pre and post ODD-EVEN trials

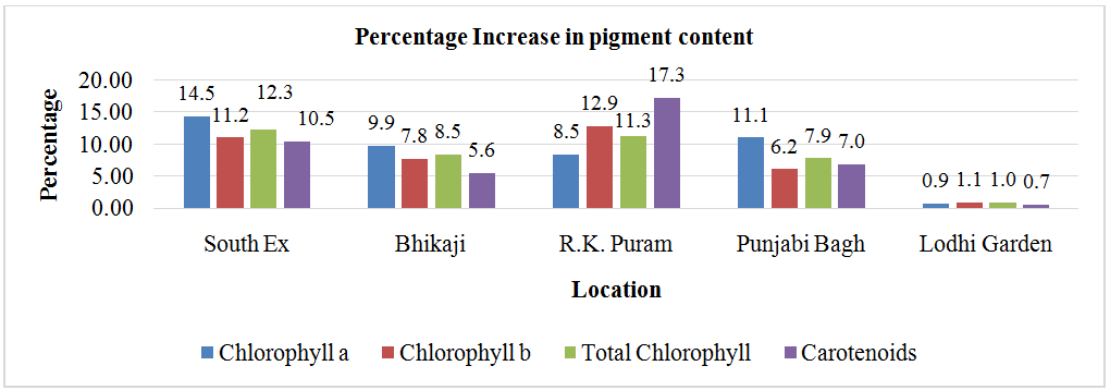

Figure 1.5 Plot showing comparison of percentage increases in pigment levels in leaves of *Cassia fistula* across locations, post ODD-EVEN Trials

V. DISCUSSION

The most sensitive part of the plant to be affected by air pollutants is the leaf. Therefore, the leaf in its various stages of development, serves as a good indicator of the effect of air pollution on plant physiology. Pollutants from vehicular emissions can directly affect the plant by entering into the leaf, destroying individual cells, and reducing the plant ability to produce food. Toxic heavy metals released from automobiles have been found to reduce plant growth and affect morphological parameters[9]. The reduction in leaf area may also result in reduced photosynthetic rate[10]. Studies reflect a reduction in leaf size and in leaf productivity and enhanced senescence in response to air pollution. As per studies doneGostin, [11], epidermal layer in leaves shows marked changes in response to air pollution possibly due to altered stomatal physiology, frequency and size. Leaf injury,

stomatal damage, premature senescence, decreased photosynthetic activity, disturbed membrane sensitivity and reduction in growth and yield in sensitive plant species may be caused due to pollutants[12]. Reduction in the concentration of photosynthetic pigments (chlorophyll and carotenoids) might be due to absorption of pollutants by leaves which directly affects plant productivity[13]. Studies[14] suggest an important role of the fat soluble carotenoids in photosynthetic process. They also protect chlorophyll from photo-oxidative destruction and so play an important role in the overall photosynthetic efficiency of plants[15]. An increase observed in carotenoids, therefore, may be contributing to the photosynthetic vigor of the plant.

A relationship between traffic density and photosynthetic activity, stomatal conductance, leaf senescence and total chlorophyll content has been reported[16]. The gradual disappearance of chlorophyll and concomitant yellowing of leaves are common impacts of air pollution which may be a consequence of decreased capacity of photosynthesis [13]. Implementation of odd-even rule has reportedly led to better air quality in various parts of the world including Paris and Beijing. From this study it can be concluded that reduced vehicular pollution, both particulate and gaseous, led to an overall increase in the levels of chlorophylls 'a', 'b' and total chlorophyll concentration in the leaves of *Cassiafistula* plants at the end of first phase of odd-even trials in Delhi. There was little effect of decreased vehicular traffic on control plants routinely less exposed to vehicular traffic and they had a better level of these pigments in them.

VI. CONCLUSION

Vehicular pollution though not the sole cause of air pollution, adds upto 22% of the total air pollutants in the metropolitan cities. Delhi has made it to the top on the list of world's most polluted cities according to the WHO records. The Recentodd-even scheme adopted by Delhi government had a beneficial impact on the photosynthetic status of *Cassiafistula* trees. Effect of vehicular pollution on chlorophyll content (Chlorophyll 'a', Chlorophyll 'b', total chlorophyll and carotenoids) of *Cassia fistula* exposed to varying degree of vehicular traffic in selected areas of Delhi during the first phase of odd-even scheme led to an increased photosynthetic capacitance of the plant when there was a reduction in the automobile load on the streets. The study also reveals an overall increase in the studied pigments in plants of control site, which are routinely exposed to lesser vehicular traffic.

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