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Effect of Cement Dust Deposition on Physiological Behaviors of Some Selected Plant Species

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Abstract :- Study was carried out to assess the impact of cement dust on some selected plant species around industrial area. Deposition effect of cement dust on pigmentation was studied in *Azadirachta indica, Pongamia pinnata, Delonix regia, Polyalthia longifolia* and *Ficus religiosa*. Sampling was done about 500 meter distance difference from the cement industry and measurements were taken for all the plant species spectrophotometrically. All the measured pigments were reduced in dust-exposed plant species compared with control site. This is due to deceleration of the biosynthetic processes rather than degradation of pigments. Changes in chlorophyll and carotenoid content were investigated in selected plant species exposed to alkaline dust emitted by the cement industry. The rate of mortality of young branches was high in the area subjected to the cement dust in all the selected plant species whereas *Pongamia pinnata* and *Azadirachta indica* are the most sensitive among them. Unless *Polyalthia longifolia* and *Ficus religiosa* is noted that amount of chl a, b and carotenoids in all investigated plants that are far away from cement dust more than that near from the factory. In general, pollution by the cement dust has caused adverse effects on the photosynthetic pigments and the pH of the leaf extract.

Key words: Assimilating pigments, Bio indicators, Carotenoids, Cement dust, Chlorophyll, Photosynthetic pigments.

1. INTRODUCTION

Air pollution has a diverse effect on much metabolic process in plants such as photosynthetic activities, mitochondrial respiration and stomatal clogging of plants (Miller *et al*., 1973). Industries are emitting toxic substances which adversely affect man's food supply by polluting nearby growing plants. Rapid industrialization and addition of the toxic substances to the environment are responsible for altering the ecosystem (Sarala Thambavani and Saravanakumar, 2011; 2012). The Cement industry plays a vital role in the imbalances of the environment and produces air pollution hazards (Stern, 1976; Sarala Thambavani and Saravanakumar 2011). Physiological disorders such as reduced growth are ultimately due to the cumulative effects of the causal factors on the physiological processes necessary for plant growth and its development (Schutzki and Cregg, 2007). Due to immobility of higher plants, it need a greater protection against several stresses, including low and high temperature, water stress, salinity, metal toxicity, and others. Ambient level of air pollution has been shown to affect stomatal conductance, photosynthesis and root morphology of young beech (Taylor and Davies, 1990). One of the most recent studies of these stresses was a dust accumulation, which provokes severe damage in the photosynthetic apparatus (Santosh and Tripathi, 2008).

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Wind erosion suspends large quantities of dust in the atmosphere that settle back to the earth's surface and are deposited on plant leaves when wind velocities decrease (Armbrust, 1986). Cement factories are major source of pollutants for the surrounding areas (Stratmann and Van Haut, 1966). Dusted plants with quantities of dust deposition ranging from 1 to 48 g/m2 per day; dust falling on the soil caused a shift in the pH level to the alkaline side. It was found that dust deposition affect photosynthesis, stomatal functioning and productivity (Santosh and Tripathi, 2008). A scant numbers of literatures showed that there is a relation between cement dust deposition and physiological process in plant leaves. Since the studying area is suffering from heavy cement dust which deposits on the buildings and plants and producing a significant adverse effect. A periodical study was carried out to study the effect of cement dust pollution on the growth of selected plant species such as *Azadirachta indica(L), Polyalthia longifolia(L), Ficus religiosa(L), Pongamia pinnata(L) and Delonix regia(L)*. Based on the results of these physiological parameters, insight into the mechanism responsible for dust tolerance in different plants will be elucidated.

2. MATERIALS AND METHODS

2.1 Description of study area

The study area was chosen in RR Nagar cement factory which is located in Virudhunagar, TamilNadu. Five dominant plant species *Azadirachta indica, Pongamia pinnata, Delonix regia, Polyalthia longifolia* and *Ficus religiosa* were selected at different locations around cement factory at 500 meter intervals and 5500-6000 m far away from the factory respectively which is shown in the table 1. Selected plant species were collected randomly from the different locations covering the study area in the season of winter.

Table-1: Description of study area

Sl.No	Sampling site	Location from Cement Production Unit	category
1	Site-1	0-500 meter	Polluted area
2	Site-2	1000 meter	Polluted area
3	Site-3	1500 meter	Polluted area
4	Site-4	2000 meter	Polluted area
5	Site-5	2500 meter	Polluted area
6	Site-6	5500-6000 meter	control

2.2 Experimental Findings

The studies were conducted on *Azadirachta indica(L), Pongamia pinnata(L), Delonix regia(L) Polyalthia longifolia(L) and Ficus religiosa(L)* plants growing under natural conditions. The plant samples were selected at different locations from the cement factory at 500 m intervals and the leaves were collected from 50-200 cm height from the ground in the industrial site of the study area and control site of the selected plant species and the leaves were carefully removed from the bark, using a snapper blade and washed with water to remove the dust on the surface of the leaf samples. About 1g of leaves, torn into small pieces in a mortar ground with a pinch of quartz sand and a total of 10 ml of absolute acetone. Initially, add only a small amount of acetone to begin the grinding process. It is much easier to grind the leaves if the extract is a pasty consistency. Add more solvent in small increments while continuing to grind the leaves. For some species may need to add more than the suggested 10ml of acetone. Pour the extract into a 15ml centrifuge tube and centrifuge in the bench top centrifuge at 5000 rpm for 3 to 5 min. Remove the extract to a 10ml graduated cylinder using a Pasteur pipette. Transfer an aliquot of the clear leaf extract (supernatant) with a pipette to a 1-cm-pathlength cuvette and take absorbance readings against a solvent blank in a UV-VIS spectrophotometer at 662, 645, 470, 435 and 415 nm wavelength to determine the concentrations of photosynthetic pigments like chlorophyll-a, chlorophyll-b and carotenoids using the formula given by Lichanthaler (1987).The ratio of Absorbance 435nm to 415nm are the parameter for chlorophyll degradation in the experiment (Ronen & Galun, 1984).

Quantification of pigments (For 100% Acetone)

Chl-a (µg/ml) = $11.24\ A_{661.6} – 2.04\ A_{644.8}$

Chl-b (µg/ml) = $20.13\ A_{644.8} – 4.19\ A_{661.6}$

Carotenoids = $(1000\ A_{470} – 1.90\ C_a - 63.14\ C_b)/214$

2.3 Statistical Analysis

Data from the selected sites for the plant materials were subjected to the two way analysis of variance (ANOVA). Using ANOVA the comparison made between control plant species and polluted plant species. Significance difference was calculated at 0.05%, 0.01% and 0.001% level as per standard method of Gomez and Gomez (1984). The present investigation has been undertaken to study the effect of cement dust pollutant on total chlorophyll, carotenoids, chlorophyll ‘a’ and chlorophyll ‘b’ of selected plant species. In the present study, the cement pollution effects on the performance of selected plant species was observed and the total chlorophyll content decreased significantly in response to cement dust pollutants in polluted plant leaves compared with control of *Azadirachta indica(L), Pongamia pinnata(L), Delonix regia*(L) *Polyalthia longifolia(L) and Ficus religiosa(L).*

Table 2: Changes of Chlorophyll 'a' in selected Plant species due to cement dust pollution

Plants	Control	Site 1	%R	Site 2	%R	Site 3	%R	Site 4	%R	Site 5	%R
A.indica	13.56±3.57	5.31±0.67	60.83	6.59±0.85	51.38	7.88±0.71	41.9	8.79±0.36	35.17	9.15±0.14	32.56
P.pinnata	19.68±6.46	7.35±1.51	62.62	9.84±1.04	49.98	11.55±1.18	49.3	13.5±0.96	31.41	14.32±0.87	27.21
D.regia	16.20±2.28	6.90±0.41	57.43	7.39±0.34	54.35	8.79±1.05	45.71	10.03±1.12	38.11	11.14±0.23	31.22
P.longifolia	13.96±1.13	6.78±0.75	51.43	8.21±0.78	41.14	9.71±1.01	30.45	11.32±0.90	18.88	12.14±0.67	13.02
F.religiosa	12.92±2.03	6.19±0.70	53.28	7.07±0.48	46.67	8.02±0.47	39.48	9.23±1.00	30.39	10.02±1.05	24.41

%R= Percentage of Reduction

Table 3: Changes of Chlorophyll 'b' in selected Plant species due to cement dust pollution

Plants	control	site 1	%R	site 2	%R	site 3	%R	site 4	%R	site 5	%R
A.indica	10.08±2.49	2.94±0.73	70.75	4.21±0.54	58.19	5.19±0.77	48.56	6.82±1.01	32.35	7.59±1.12	24.74
P.pinnata	15.19±4.02	4.08±1.39	73.13	5.58±0.39	63.27	7.72±1.75	49.19	10.05±2.15	33.83	12.14±0.92	20.08
D.regia	12.97±4.72	3.74±1.10	71.11	5.98±1.34	53.88	7.44±0.92	42.6	10.96±2.58	15.52	12.19±3.93	5.98
P.longifolia	13.68±2.44	4.15±1.13	69.61	5.99±1.18	56.17	7.68±0.76	43.85	10.36±1.99	24.27	11.59±2.71	15.26
F.religiosa	11.74±0.98	4.80±1.46	59.12	7.01±0.82	40.32	8.29±0.83	29.38	9.19±0.32	21.73	9.51±0.08	19

%R= Percentage of Reduction

Table 4: Changes of total carotenoid in selected Plant species due to cement dust pollution

Plants	control	site 1	%R	site 2	%R	site 3	%R	site 4	%R	site 5	%R
A.indica	1.19±0.34	1.80±0.29	-50.08	1.38±0.15	-15.3	1.29±0.09	-7.61	0.99±0.26	16.91	0.93±0.44	21.96
P.pinnata	1.56±1.08	1.68±0.31	-7.91	1.61±0.24	-3.63	1.6±0.25	-2.59	1.76±0.21	-12.98	1.59±0.21	-1.92
D.regia	1.35±0.92	1.97±0.28	-46.46	1.75±0.17	-29.63	1.41±0.49	-4.47	1.05±0.38	22.22	0.70±0.26	47.92
P.longifolia	0.58±0.15	0.82±0.33	-41.23	0.5±0.1	14.01	0.64±0.23	-9.52	0.79±0.17	-36.05	0.94±0.15	-61.19
F.religiosa	0.23±0.74	0.42±0.14	-86.48	0.40±0.16	-77.81	0.28±0.05	-22.57	0.35±0.10	-53.62	0.44±0.10	-91.95

%R= Percentage of Reduction

Table 5: Changes of total chlorophyll in selected Plant species due to cement dust pollution

Plants	Control	site 1	%R	site 2	%R	site 3	%R	site 4	%R	site 5	%R
A.indica	23.64±6.01	8.26±1.36	65.06	10.81±1.37	54.29	13.06±1.48	44.74	15.61±1.34	33.97	16.73±1.27	29.22
P.pinnata	34.88±10.39	11.44±2.91	67.2	15.42±1.32	55.77	19.27±2.78	44.74	23.55±3.09	32.46	26.47±1.79	24.1
D.regia	29.18±7.00	10.64±1.50	63.51	13.38±1.64	54.14	16.24±1.69	44.33	20.99±3.36	28.07	23.34±4.17	20.00
P.longifolia	27.65±3.52	10.94±1.87	60.43	14.21±1.95	48.58	17.39±1.77	37.08	21.69±2.83	21.55	23.74±3.39	14.13
F.religiosa	25.01±2.97	10.99±2.13	56.02	14.08±1.25	43.69	16.32±1.26	34.74	18.42±1.24	26.32	19.54±0.97	21.87

%R= Percentage of Reduction

Table 6: Changes of assimilating pigments of chl 'a'/chl 'b' ratio in selected Plant species due to cement dust pollution

Plants	Control	site 1	%R	site 2	%R	site 3	%R	site 4	%R	site 5	%R
A.indica	1.34±0.08	2.00±0.43	-48.56	1.56±0.08	-16.09	1.55±0.09	-14.66	1.32±0.13	1.47	1.23±0.16	8.87
P.pinnata	1.26±0.11	2.14±0.51	-69.34	1.76±0.13	-38.93	1.58±0.23	-24.94	1.45±0.27	-14.92	1.18±0.01	6.98
D.regia	1.69±0.63	2.21±0.67	-30.99	1.34±0.23	20.68	1.20±0.14	28.8	0.98±0.18	41.99	1.01±0.30	40.14
P.longifolia	1.05±0.10	1.78±0.28	-69.48	1.44±0.19	-36.84	1.26±0.01	-19.84	1.13±0.12	-7.96	1.09±0.19	-3.74
F.religiosa	1.12±0.09	1.59±0.50	-42.48	1.02±0.06	8.44	0.97±0.06	12.32	1.00±0.08	10.32	1.05±0.11	5.51

%R= Percentage of Reduction

Table 7: Changes of assimilating pigments of chl a+b/carotenoid in selected Plant species due to cement dust pollution

Plants	control	site 1	%R	site 2	%R	site 3	%R	site 4	%R	site 5	%R
A.indica	28.95±16.20	5.07±1.48	82.48	8.25±1.97	71.49	10.24±1.36	64.63	19.95±8.34	31.07	23.95±12.75	17.26
P.pinnata	60.91±28.64	7.80±2.74	87.19	9.76±0.99	83.96	12.67±2.78	79.2	13.99±2.87	77.03	16.78±1.12	72.44
D.regia	59.64±28.12	5.68±1.20	90.46	7.68±0.85	87.11	19.94±12.07	66.56	27.22±10.03	54.36	36.16±7.86	39.36
P.longifo	50.28±5.68	21.60±11.40	57.05	31.54±8.16	37.28	32.43±7.31	35.5	29.33±5.35	41.67	26.44±7.81	47.4
F.religiosa	30.93±37.09	29.46±7.54	4.74	50.17±21.94	-62.19	63.05±14.61	-103.84	61.33±15.87	-98.26	46.30±8.84	-49.68

%R= Percentage of Reduction

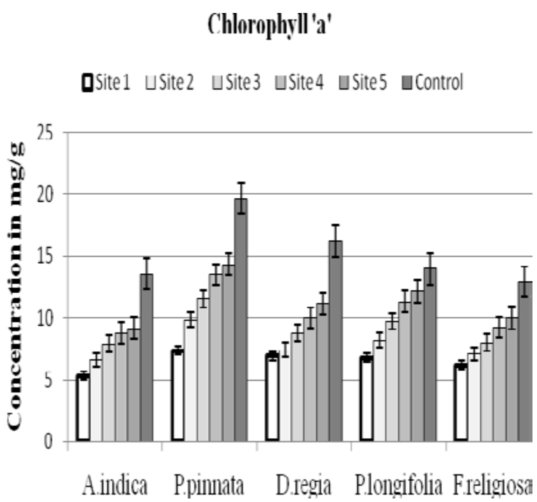

Fig:1 Changes of Chlorophyll 'a' content with standard error bar in selected Plant species

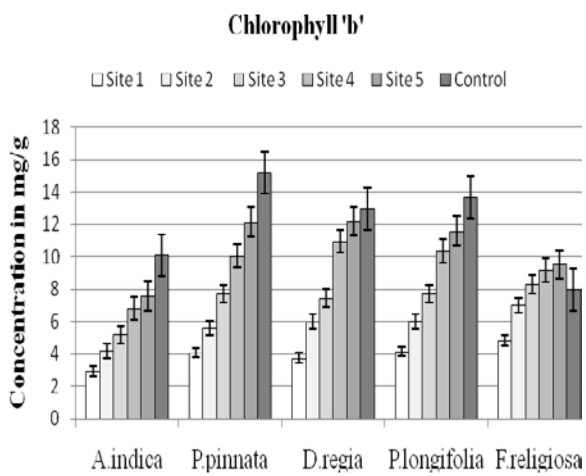

Fig:2 Changes of Chlorophyll 'b' content with standard error bar in selected Plant species.

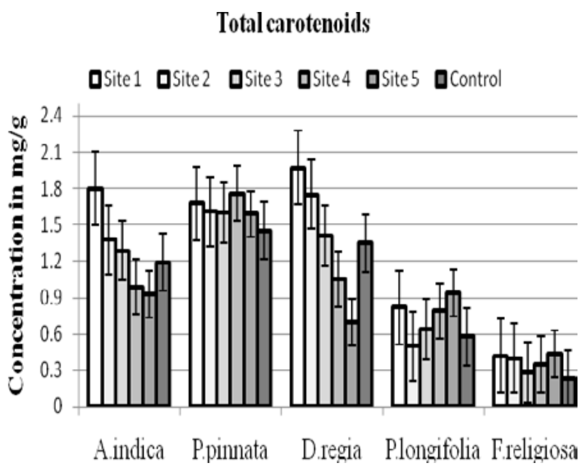

Fig:3 Changes of total carotenoid content with standard error bar in selected Plant species.

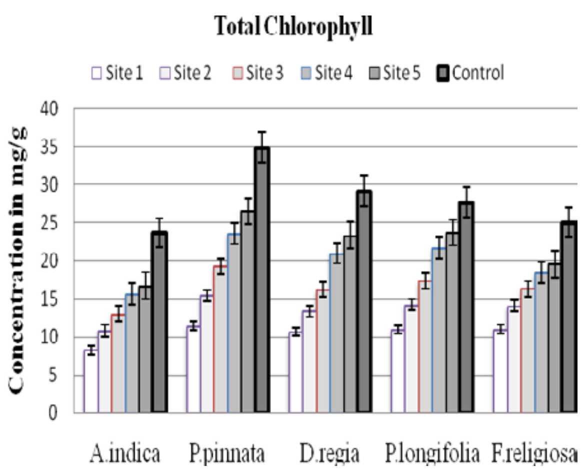

Fig:4 Changes of total chlorophyll (a+b) content with standard error bar in selected Plant species.

3. RESULTS AND DISCUSSION

Dust accumulation altered the chlorophyll and carotenoid contents in all plants in the polluted location (near the factory) compared with plants far from the factory in control site. Greater decrease in chlorophyll a and b contents was clearly observed in *Pongamia pinnata(L)* and *Azadirachta indica(L)* (For chl a about 62.62% and 60.83% and 70.75% and 73.13% respectively). A similar pattern of decrease was occurred in *Polyalthia longifolia(L)* and *Ficus religiosa(L)* but to lower extent (about 51.43% for chl a and 59.12% for chl b, respectively) which is shown in the table 2 & 3 and figure 1 & 2. On the other hand, Chlorophyll a, b, total chlorophyll and chl a/b ratio were significantly increased in *Ficus religiosa(L)* together with increasing dust accumulation in plant leaves near to the factory (Table2 to 6 and Fig.1 to 4). Chlorophyll a/b ratio for the other four studied plants were decreased in the polluted plant's leaves near the factory and compared with plants far from the dust. Also, the change in the carotenoids content showed the same pattern. There was a significant reduction in carotenoids content in all the selected species compared to the control plant species. The chlorophyll/carotenoid ratio decreased maximum in *Pongamia pinnata, Delonix regia and Azadirachta indica* plants near to the factory indicating the increase in carotenoid content with respect to non polluted plants (Table-4). The present results showed that the two locations (polluted and control) received different amounts of cement dust as indicated by the measurements of pH for the leaves' washing solution. The pH ranged in polluted plant from 8.0 - 9.5 and in control site from 6.8 - 7.2), whereas, the accumulation of the cement dust increased the alkalinity of the cell sap for the plant leaves near the factory (9-9.3). Cement dust had a significant effect on the growth of some plant species compared with non cement dusted plants. Toxic compounds such as fluoride, magnesium, lead, zinc, copper, beryllium, sulfuric acid and hydrochloric acid were found to be produced by cement manufacturing plants (Andrzej, 1987; Sarala Thambavani and Saravanakumar, 2011). A quantitative estimation along with dust analysis confirms the ill effects of the cement dust on the plant growth. The pH of dust sample was alkaline in nature; its pH was 9.5 and could be correlated with the findings of Lerman and Darley (1975). They also found a similar range (9.5-11.5) of cement dust pH. The changes in the accumulation of mineral plant nutrients as a result of cement dust were also determined and showed a consistent result with those obtained by Lal and Ambash (1981). It is also suggested that the complete analysis of the cement dust contains all the toxic pollutants should be carried out in detail. The heavy metals present in the cement dust may play an important role in disturbing the various metabolic processes. As it would be possible to recommend these plants in the current study for use as screen or green belts in the industrial localities and adverse urban localities in order to mitigate dust and improve air quality (Yunas *et al*., 1985). Our results are consistent with the results of George and Ilias (2007) who reported that the traces of toxic metals such as chromium and copper are common in some varieties of Portland cement and are harmful to human being and other living systems. Our data indicates that the exposure of plants to dust altered several physiological and biochemical parameters that were triggered. The most apparent effect of stress induced by dust, described in numerous species, is leaf damage (Naidoo and Chirkoot, 2004). Heath and Castillo, 1988 reported that leaf injury is due to diverse alterations at the sub cellular level .Various studies have shown that the main detrimental effect of dust at the sub cellular level is photo system damage (Nanos and Ilias, 2007; Santosh and Tripathi, 2008). Moreover, the presented results clearly showed that dust altered several biochemical aspects, such as photosynthetic pigment in leaves. A significant percentage increase in chl a/b ratio was observed only in *Polyalthia longifolia* which was mainly caused by an increase in chlorophyll *a* content associated with decrease in chlorophyll *b* content. On the other hand, a marked percentage decrease in chl a/b ratio was observed in the other four studied plants. The changes in chlorophyll a and b are possibly due to shading and/or photo system damage due to dust accumulation between the petioles or other effects on stomata. Dust from a cement factory seems to cause substantial changes to leaf physiology, possibly leading to reduced plant productivity. Our results are consistent with Nanos and Ilias, (2007) who reported that cement dust decreased the leaf total chlorophyll content and chlorophyll a/chlorophyll b ratio. As a result, photosynthetic rate and quantum yield decreased. The decrease in the chlorophyll/carotenoid ratio for stressed plants suggested that these relationships could be used as an indicator of tolerance and physiological status of the plants under these stress conditions. According to the results chl a/b ratio were significantly increased in *Polyalthia longifolia* and correlated positively with dust accumulation near to the factory, indicating the presence of protection mechanism of the chloroplast towards the dust pollution. (Lichtenthaler et al., 2000) stated that the increase in the ratio Chl *a*/*b* is always associated with a change in pigment composition of the photosynthesis apparatus towards a more sun-type like chloroplast which possesses less light harvesting chlorophyll proteins (LHCPs). According to our results, chloroplasts, in most studied polluted plant, are known to also compose a higher carotenoid content on a chlorophyll basis than non polluted chloroplasts, which is indicated by the lower values for chlorophylls (*a*+*b*) to carotenoids ratios (table 6). In addition, carotenoids, increased in the dust-stressed plants, not play a role as accessory light harvesting pigments only but they also protect photosynthetic systems against reactive oxygen species (Young, 1991; Asada *et al*., 1998; Loggini *et al*., 1999). Moreover, Young, 1991 reported that this response was induced, not only by changes in the irradiation under which the plants are grown, but also by diverse chemicals or stressors that are often associated with long term stress. Thus the response of studied plants seems to have characteristics in common to dust pollution and in agreement with suggestions made for other species (Shinozaki and Shinozaki, 1996; Tabaeizadeh, 1998).

4. CONCLUSION

The comparison of five plant species of different dust susceptibility permitted determining that the tolerance or sensitivity to dust pollution was clearly manifested throughout the photosynthetic activity. The exposure to dust pollution stress provoked important reductions in photosynthesis in most studied plants except *Polyalthia longifolia*. This study indicates that exposure to particulate deposition may alter plant growth without physical damage to the plant. Moreover, accumulation of dust particulates on studied plant leaves could be a major problem in their production. It was proposed that the pigments content of the light harvesting complex is an important aspect related to the tolerance of plants to dust pollution.

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