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By

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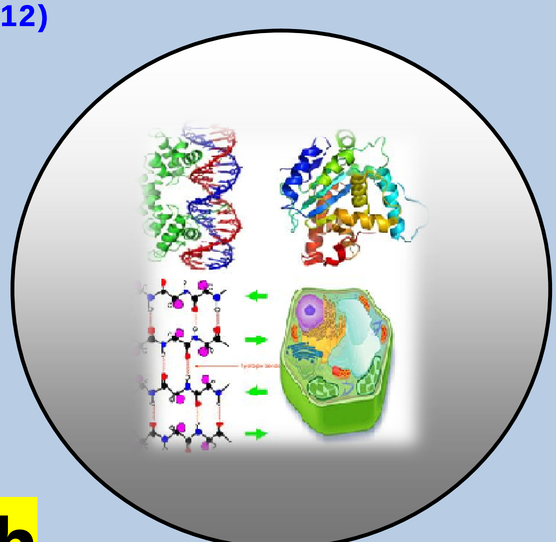

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RESEARCH PAPER

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Air Pollution Tolerance Index of Some Seasonal Crops Growing in Different Industrial Areas of Dhar District (M.P.), India

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ABSTRACT

Air pollution receives one of the prime concerns in India, primarily due to rapid economic growth, industrialization and urbanization with associated increase in energy demands. Air pollutants pose risks on yield of crops depending on the emission pattern, atmospheric transport and leaf uptake and on the plant's biochemical defense capacity. Injury ranges from visible markings on the foliage, reduced growth and yield to premature death of the plant. Air pollutants produce reactive oxygen species (ROS), which adversely affect biochemical processes in plants and reduce their tolerance capacity. Several vital physiological processes such as photosynthetic CO_2 fixation and energy metabolism are also affected negatively by air pollutants. The aim of present study was to observe the effect of industrial air pollution on air pollution tolerance index (APTI) of wheat (Triticum aestivum) & Brown gram (Cicer ariantinum), Maize (Zea mays) and soya bean (Glycine max). The highest value of APTI was observed for maize (8.92).The reduction due to industrial air pollutants in APTI was observed in all four crops i.e. in maize (3.02%), wheat (2.15%) Brown gram (3.23 %), and Soya bean(4.50)% and highest reduction among all these crop was observed in soya bean in sector -3 i.e. (4.50%) and lowest was observed in wheat (0.67%) in sector -1. From the present study it was concluded that wheat APTI value was least affected (rabi crop) and monocotyledons were resistant to industrial air pollution, as compared to dicotyledons. Hence it can be suggested to farmers to grow preferably wheat around industrial area.
Keywords: Air pollution tolerance index (ATPI), Industrial areas, Rabi crop, Dicotyledons, Monocotyledons and Kharif crop.

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INTRODUCTION

Environmental pollutants are becoming threats to the very existence of the living beings. Air pollution has become an extremely serious problem for the modern industrialized world. The chemical composition of the atmosphere is being continuously changed by the addition of gases, particulates and volatiles substances. Industrial air pollution may be a serious threat to agricultural productivity. Keeping in view the information that urban air pollution may be a serious threat to agricultural productivity in areas around urban centers (Rai *et al.,* 2011). Air pollutants can produce a wide range of visible symptoms (acute injury) on crops. Injury to plants as a result of pollutants has been classified as either chronic or acute. Chronic SO_2 exposure may or may not result in foliar injury symptoms depending upon plant susceptibility. It is important to note that reductions in plant growth and productivity from chronic exposure may occur without development of visible chronic foliar injury (Legge AH, Krupa SV., 2002). Leaves are most susceptible parts of a plant to acute injury due to abundance of stomata, which permit penetration of gaseous pollutants such as respirable suspended particulate matter (RSPM), SO_2, NO_x, and heavy metal etc the sensitive tissues of leaves(Heath *et al.*,2009). These phototoxic gases have important and increasing impacts on the livelihoods and consumers through effects on urban and periurban crop production. Air pollutants have the potential to reduce both the yield and the nutritional quality of the crop plants (Rai *et al*., 2010). The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the factors determining resistance and susceptibility. Using plants, as indicator of air pollution is the possibility of synergistic action of pollutants (Lakshmi *et al.,* 2009). Plants sensitivity and tolerance to air pollutants varies with change in Leaf extract pH, Relative water contents (RWC), ascorbic acid (AA) content and Total Chlorophyll content. Study of single parameter may not provide a clear picture of the pollution induced changes; Singh and Rao (1983) have suggested a method to determine Air Pollution Tolerance Index by synthesizing the values of four different foliar biochemical features i.e. Total chlorophyll content, Relative water contents, leaf extract pH and Ascorbic acid so air pollution tolerance index (APTI) which was based on these parameters has been used to know tolerance levels of plant species (Lui Y.J. and Ding H 2008; Singh S. K. and Verma A. 2007). Air pollution tolerance index is used by landscapers to select plant species tolerance to air pollution (Agbaire PO and Esiefarienrhe E, 2009). Hence APTI determination to various crops provides information regarding the tolerance capacity of them to air pollutants and such crops may be recommended to the farmers in industrialized urban and peri-urban areas.

MATERIAL AND METHODS

Study area: Pithampur is located at a latitude 22˚ 37’27” N and longitude 75˚ and 34’58” E at the eastern central border of Dhar District in M.P, about 45 km from Indore. Alttitude is about 550 meter above mean sea level. Pithampur is located about 16 km away from NH-3.

Monitoring of air pollutants

The concentration of different air pollutants viz. NOx, SO_2, and Respirable suspended particulate matter (RSPM) monitored in the ambient air with the help of Respirable dust sampler (RDS) by sucking air into appropriate reagent for 24 hours at the selected area. The apparatus was kept at a height of 2 m from the surface of the ground. Once the sampling was over, the samples were brought to the laboratory and concentration of different pollutants was determined.

Determination of RSPM: Concentration of RSPM was determined using glass fiber filter paper methods. Air is drawn through a size-selective inlet and through a 20.3 X 25.4 cm (8 X 10 in) filter at a flow rate -1132L/min. Particles with aerodynamic diameter less than the cut-point of the inlet are collected, by the filter. The mass of these particles is determined by the difference in filter weights prior to and after sampling. The concentration of particulate matter (PM_{10}) in the designated size range is calculated by dividing the weight gain of the filter by the volume of air sampled.

Determination of NOx: The concentration of NOx was measured with standard method of Modified Jacobs- Hochheiser method (1958), ambient nitrogen dioxide (NO_2) is collected by bubbling air through a solution of sodium hydroxide and sodium arsenite. The concentration of nitrite ion (NO_2^-) produced during sampling is determined calorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)-ethylenediamine di-hydrochloride and measuring the absorbance of the highly colored azo-dye at 540 nm.

Determination of SO_2: SO_2 was measured by Modified West and Geake method (1956). Sulphur dioxide from air is absorbed in a solution of Potassium TetraChloro -Mercurate(TCM). A dichlorosulphitomercurate complex, which resists oxidation by the oxygen in the air, is formed. Once formed, this complex is stable to strong oxidants such as ozone and oxides of nitrogen and therefore the absorber solution may be stored for some time prior to analysis. The complex is made to react with para-rosaniline and formaldehyde to form the intensely coloured pararosaniline methylsulphonic acid.The absorbance of the solution is measured spectrophotometerically at 560 nm.

Sampling: The studies were conducted on Wheat (Lok-1) and Deshi gram of rabi (Ujjain-2) crop, maize (American) and soya bean (JS-335)) of kharif crop growing under field conditions during from 2011-2012. Leaf samples of the selected crops were collected in triplicates for analysis from Pithampur industrial area sector 1, 2 & 3. For control sample leaves of the same crops were collected from Non- polluted area Patthar Mundala Goan. The fresh weight of leaves of all the samples was taken immediately upon getting to the laboratory. Samples were preserved in refrigerator for other parameter.

Procedure

Photosynthetic pigments: - The collected sample leaves were washed with distilled water and cut into small pieces. 100 mg of each fresh leaves were taken for analysis. The samples were crushed with 5ml of 80% acetone in a glass pestle with a pinch of washed sand. The crushed samples along with washing were collected and centrifuged.

The sediment was washed with 2 ml of 80% acetone and again centrifuged for 3 minutes. The final volume of supernatant was made up to 10 ml by adding 80% acetone for analysis. The samples were analyzed with the help of visible spectrophotometer. Absorbance was read at 645 to 663 nm for Chlorophyll, 480 and 510 nm for carotenoids. The concentration of Chlorophyll and carotenoid were calculated with the help of absorption coefficient of Arnon(1949). Following formulae are used: Photosynthetic pigment mg/gm of leaves = Chl.a + Chl.b+ Carotenoid

Chl.a (mg/gm) = 22.7× OD_{663}-2.69 ×$OD_{645,}$ Chl.b (mg/gm) =12.9× OD_{645}-4.68 ×OD_{663}

Carotenoied (mg/gm) =7.6 × OD_{480} – 1.49 × OD_{510}

Relative water content (RWC)

RWC= [FW-DW) / (TW-DW)] x100

FW = fresh weight, DW= dry weight and TW= turgid weight.

Fresh weight was obtained by weighing the fresh leaves. The leaves were then immersed in water over night, blotted dry and weighed to get turgid weight. Now the leaves were dried over in an oven at 70 ˚C and reweighed to obtain the dry weight (Chaudhary C.S., Rao D.N.1977).

Leaf extract pH: 5 grams of the leaves were homogenized in 50 ml deionized water, and then filtered. The pH of filtered leaf extract was determined by using pH meter.

Ascorbic acid content (AA): Ascorbic acid content was measured by using spectrophotemetric method. 1 g of the fresh foliage was put in a test-tube, 4 ml oxalic acid - EDTA extracting solution was added. Then 1 ml of orthophosphoric acid and then 1 ml 5% tetraoxosulphate (VI) added. To this mixture, 2 ml of ammonium molybdate and then 3 ml of water was added. The solution was then allowed to stand for 15 minutes. Then the absorbance was measured at 660 -665 nm with a spectrophotometer (Bajaj KL and Kaur G. 1981).

APTI: Air Pollution Tolerance Index is based on the values of four different foliar biochemical features i.e. Total chlorophyll content, Relative Water Contents, leaf extract pH and Ascorbic acid and it was calculated by using following formulae: APTI = [AA (T + P) + R] / 10

Where

R stands for relative water content in mg/g, AA stands for the ascorbic acid in mg/g,
T stands for the total chlorophyll in mg/g, P stands for pH of leaf extract, (Singh, S. K. and Rao, D. N. 1983).

RESULTS

Table 2.2.1 **:** (1) Showing twenty four hour mean pollutant concentration (μg/m^3) during 2011 at different sites of Pithampur industrial area sector-1, 2 & 3.

Table 2.4.5.1 : (2) Classification of crop sensitive / tolerant to the air pollutant on the basis of APTI value is following. APTI value of crops selected for the study lies in the range 1-16 indicating that they are sensitive to industrial air pollution.

Table 3(a),3(b)and 3(c) showing variations in the studied parameters of Soybean in Sector-1 , Sector-2 and sector -3 versus control respectively. Highest % reduction in APTI was observed in Sector-3 (4.50 %) in July.

Table 3(d),3(e)and 3(f) showing variations in the studied parameters of Maize in Sector-1 , Sector-2 and sector -3 versus control respectively. Highest % reduction in APTI was observed in Sector-3 (3.02%) in July

Table 3(g),3(h)and 3(i) showing variations in the studied parameters of Gram control inSector-1 , Sector-2 and sector -3 versus control respectively. Highest % reduction in APTI was observed in Sector-3 (3.23%) in February.

Table 3(j),3(k)and 3(l) showing variations in the studied parameters of wheat in Sector-1 , Sector-2 and sector -3 versus control respectively. Highest % reduction in APTI was observed in Sector-3 (2.15) in February. Least % reduction in APTI was observed in Wheat. APTI value in control of Maize was 8.92 which is highest among all the studied crop.

Monthly Variations in APTI in Soybean, Maize, Gram and wheat were shown in table 3 (m), 3(n), 3(o) and 3(p) respectively. The Highest % reduction in APTI was observed in July in soybean and Maize. The Highest % reduction in APTI was observed in February in Gram and Wheat.

Table-3 (q), 3(r),3(s) and 3(t) showing Correlation coefficient of ascorbic acid, pH, relative water content and total chlorophyll with APTI in Soybean ,Maize, Gram and Wheat respectively for sector-1, 2 & 3. The results show significant positive correlation between APTI and different biochemical parameters S for all species at different sites. It indicates that ascorbic acid & total chlorophyll content of leaf are the most significant and determining factors on which the tolerance capability of crops depends

DISCUSSION

Concentration of major air pollutants: The average concentration of major air pollutants such as RSPM, SO_2 and NO_X from 2011 is shown in Table-1. Air monitoring conducted in Pithampur industrial area has shown that sector -3 had maximum level of RSPM and NO_2 pollutants and concentration of SO_2 was found higher in Industrial Area Sec-1. Whereas the standard limit prescribed by Central Pollution Control Board (CPCB) of India for RSPM is 60-100 $\mu g/m^3$ for industrial, residential and sensitive areas, respectively, Sulhpur dioxide (SO_2) 50-80 $\mu g/m^3$ and Nitrogen dioxide 40-80 $\mu g/m^3$.

Leaf extract pH: In the present study decrease in leaf extract pH was reported in polluted area site as compared to control. The pH ranged between 4.4 and 8.8 lies in both intermediately tolerant and sensitive plant species (Lakshmi *et al.,* 2009).The decrease in pH is an indication of the development of detoxification mechanism in plant necessary for tolerance (Thawale *et al.,* 2011). Highly acidic condition disrupts the whole metabolic processes including glycolysis which probably due to imbalance of pH gradient within the cells structure (Kuki *et al*., 2009). The high dust accumulation in the winter season in polluted aera may be due to the wet surface of leaves which help in capturing dust, with a gentle breeze and foggy condition preventing particle dispersion. The photosynthetic efficiency has been reported to be strongly dependent on leaf pH and photosynthesis was reduced in plants with low leaf pH (Turk R and Wirth V., 1975).

Decrease trend of chlorophyll content with decrease in pH is probably due to the damage of chloroplast under such acidic condition. Singh and Srivastava, (2002) endorsed the same for incorporation of cement kiln dust into leaf tissues. The presence of SO_2 and NOx in the ambient air causes a change in pH of the leaf sap towards acidic range. Upon diffusion of SO_2 through stomata, gaseous SO_2 dissolves in water to form sulphites, bisulphate and their ionic species with the generation of protons influencing the cellular pH. It is therefore concluded that the pH change towards acidic range observed in most species is due to entry of SO_2 into leaf mesophyll tissue (Kousar *et.al*, 2014).

Relative water content (RWC): In the present study decrease in relative water content was reported in polluted area compared to control (except in case of soybean in sector-2 where increased value was reported: Sector-2 *i.e*. 0.13% in September and October). Higher the RWC in a particular species greater is its drought tolerance capacity (Dedio, 1975). Relative water content presents a useful indicator of the state of water balance of a plant, essentially because it expresses the absolute amount of water, which the plant requires to reach artificial full saturation. The high RWC of the leaf can be explained by the higher rate of availability of water in the soil along with the low rate of transpiration. Leaf water status is intimately related to several leaf physiological variables such as leaf turgour, growth, stomatal conductance, transpiration, photosynthesis and respiration (Paul J Kramer and John S Boyer., 1995). Relative water content value and pH value are used to evaluating the air and dust pollution level. Relative water content value of all control plant species was found to be higher than the polluted plant species, because dust pollutants increases cell permeability, which causes loss of water and dissolved nutrients, resulting in early senescence of leaves (M Loganathan and M H Muhammad Ilyas, 2012).

Total photosynthetic pigment: In the present study decrease in photosynthetic pigments content was reported in polluted compared to control. The plants having chlorophyll content between 4 to 16 mg/gm and 0.90 to 9.38 mg/gm are categorized as intermediately tolerant and sensitive plant. species respectively (Lakshmi *et al*., 2009).Various environmental factors like air, water and soil cause variation in plant leaf pigment content through dust accumulation on leaf surface. The least total chlorophyll content during winter season may be due to the highest amount of dust accumulation on the leaf surface, a factor inhibiting chlorophyll synthesis due to the presence of various metals and polycyclic hydrocarbon, which inhibit the enzyme necessary for chlorophyll synthesis. Dust deposition also affects the light availability for photosynthesis and blocks stomata pores for diffusion of air and thus puts stress on plant metabolism (Anthony, 2001; Sasmita Das and Pramila Prasad 2010). Sulphur dioxide (SO_2) and nitrogen oxides (NO_2) are the most phytotoxic pollutants; these polluting gases enter leaves through stomata, following the same diffusion pathway as CO_2 (Taiz and Zeiger, 2006). Sulfur dioxide induces visible injury to leaves and leads to reduction in photosynthetic pigments In the cells, SO_2 dissolves to give bisulfite and sulfite ion Sulfite is toxic and at low concentrations it is metabolized by chloroplasts to sulfate, which is non toxic and at sufficiently low concentrations, bisulfite and sulfite are effectively detoxified by plants and SO_2 air pollution then provides a sulfur source for the plant (Taiz and Zeiger, 2006).

Dusted or encrusted leaf surface is responsible for reduced photosynthesis and thereby causing reduction in chlorophyll content (Joshi and Swami, 2009). A considerable loss in total chlorophyll, in the leaves of plants exposed to pollution supports the argument that the chloroplast is the primary site of attack by air pollutants such as SO_2 and NOx. Air pollutants make their entrance into the tissues through the stomata and cause partial denaturation of the chloroplast and decreases pigment contents in the cells of polluted leaves. High amount of gaseous SO_2 causes destruction of chlorophyll (Tripathi and Gautam, 2007). Several researches have recorded reduction in chlorophyll content under air pollution (Tiwari et al., 2006; Tripathi and Gautam, 2007; Joshi and Swami, 2007; Joshi and Swami, 2009; Joshi *et al.,* 2009).

Ascorbic acid AA: Ascorbic acid was increased at stress condition; it is a main factor for increasing APTI (Govindaraju *et al.,* 2012). Air pollutants influence various anatomical, physiological and biochemical processes of plants (Okano *et al*., 1985; Soda *et al.,* 2000; Vollenweider et al., 2003). Ascorbic acid is essential for cell wall synthesis, defense and cell division. These responses ultimately accelerate the process of senescence (Kohert *et al.,* 1986). Ascorbic acid plays important role in cell division, defense and cellwall synthesis. It is a natural detoxicant, which may prevent the effects of air pollutants in the plant tissues (Mohammed Kuddus *et. al*., 2011). Varshney and Varshney (1984), the higher Ascorbic Acid content in the plants is an indication of its tolerance against sulphur dioxide pollution. Lower Ascorbic Acid contents in the plant species support the sensitive nature towards the pollutants particularly automobile exhausts.

Table 1. Showing twenty four hour mean pollutant concentration (µg/m^3) during 2011 at different sites of Pithampur industrial area sector-1, 2 & 3.

S.NO.	Sampling point	RSPM (µg/m^3)	SO_2 (µg/m^3)	NO_2 (µg/m^3)
1.	Sector-1, Sampling point:Near Force Motor, Pithampur	207.95	12.82	22.15
2.	Sector-2, Sampling point:Near Piramal Health Pithampur	113.28	9.59	19.06
3.	Sector-3,Sampling point: Near Case New Holland , Pithampur	216.72	11.78	25.97
4	The standard limit prescribed by Central Pollution Control Board (CPCB) of India,	60-100 µg/m^3	50-80 µg/m^3	40-80 µg/m^3

Correlation matrix interpretation: The correlation coefficient values of physiological and biochemical parameters *viz.* pH, relative water content, total chlorophyll and ascorbic acid with air pollution tolerance index (APTI) of different crop plants are presented in Table-(8-11).

The results show significant positive correlation between APTI and different biochemical parameters except relative water content for all species at different sites. It indicates that ascorbic acid & total chlorophyll content of leaf are the most significant and determining factors on which the tolerance depends. Thambavani *et al.,* (2011) also studied high positive correlation between APTI with chlorophyll and ascorbic acid. Debnath Patil *et al.,* (2013) observed that the correlation studies of the different biochemical constituents and APTI it was found that APTI is positively correlated with ascorbic acid content but significant both at 1% and 5% level of significance in DPL and Mamrabazar respectively. APTI is insignificantly related with the relative water content. Total chlorophyll and APTI shows positive correlation at 1% level of significance in Mamrabazar spot.

Table 2. Classification of crop sensitive / tolerant to the air pollutant on the basis of APTI value is following.

S. No	APTI value	Response
1	< 1	Very sensitive
2	1-16	Sensitive
3	17-29	Intermediate
4	30-100	Tolerant

Table 3(a). Variations in the studied parameters of Soybean Sector-1 vs. control.

Month	July		August		September		October	
parameter	**Control**	**Sector-1**	**Control**	**Sector-1**	**Control**	**Sector-1**	**Control**	**Sector-1**
Total photosynthetic Pigment(mg/gm)	**2.85±0.03**	**2.75±0.03 (3.50%)**	**2.80±0.05**	**2.70±0.02 (3.57%)**	**2.77±0.04**	**2.65±0.01 (4.33%)**	**2.74±0.04**	**2.62±0.02 (4.37%)**
Ascorbic acid(mg/gm)	**1.50±0.03**	**1.39±0.01 (7.33%)**	**1.49±0.02**	**1.38±0.01 (7.38%)**	**1.48±0.02**	**1.35±0.01 (8.78%)**	**1.47±0.02**	**1.34±0.01 (8.84%)**
Relative water content	**66.19±1.00**	**65.13±1.53 (1.60%)**	**66.18±0.99**	**65.11±1.00 (1.61%)**	**65.17±2.52**	**65.10±2.64 (0.10%)**	**65.16±2.50**	**65.08±1.56 (0.12%)**
Leaf extract pH	**6.32±0.01**	**6.23±0.01**	**6.30±0.04**	**6.22±0.01**	**6.29±0.01**	**6.21±0.01**	**6.28±0.01**	**6.20±0.01**
APTI	**7.99**	**7.76 (2.87%)**	**7.97**	**7.74 (2.88%)**	**7.86**	**7.70 (2.03%)**	**7.84**	**7.68 (2.04%)**

Note: % in parenthesis indicates % reduction in APTI value in comparison to control

Table 3(b). Variations in the studied parameters of Soybean Sector-2 vs. Control.

Month	July		August		September		October	
parameter	Control	Sector-1	Control	Sector-1	Control	Sector-1	Control	Sector-1
Total photosynthetic Pigment(mg/gm)	2.85±0.03	2.80±0.03 (1.75%)	2.80±0.05	2.74±0.03 (2.14%)	2.77±0.04	2.71±0.03 (2.16%)	2.74±0.04	2.68±0.02 (2.18%)
Ascorbic acid(mg/gm)	1.50±0.03	1.44±0.01 (4.00%)	1.49±0.02	1.43±0.01 (4.02%)	1.48±0.02	1.41±0.01 (4.72%)	1.47±0.02	1.40±0.01 (4.76%)
Relative water content	66.19±1.00	65.31±1.00 (1.32%)	66.18±0.99	65.27±0.99 (1.37%)	65.17±2.52	65.26±1.03 (0.13%) Increased	65.16±2.50	65.25±1.02 (0.13%) Increased
Leaf extract pH	6.32±0.01	6.27±0.01	6.30±0.04	6.26±0.01	6.29±0.01	6.25±0.01	6.28±0.01	6.24±0.01
APTI	7.99	7.83 (2.00%)	7.97	7.81 (2.00%)	7.86	7.78 (1.01 %)	7.84	7.77 (0.89%)

Note: % in parenthesis indicates % reduction in APTI value in comparison to contro

Table 3(c). Variations in the studied parameters of Soybean Sector-3 vs. control.

Month	July		August		September		October	
parameter	Control	Sector -3	Control	Sector -3	Control	Sector -3	Control	Sector-3
Total photosynthetic Pigment(mg/gm)	2.85±0.03	2.65±0.02 (7.01%)	2.80±0.05	2.62±0.03 (6.42%)	2.77±0.04	2.61±0.01 (5.77%)	2.74±0.04	2.58±0.02 (5.83%)
Ascorbic acid(mg/gm)	1.50±0.03	1.32±0.03 (12.00%)	1.49±0.02	1.31±0.03 (12.08%)	1.48±0.02	1.30±0.02 (12.16 %)	1.47±0.02	1.38±0.01 (6.12%)
Relative water content	66.19±1.00	64.67±1.0(2.29%)1	66.18±0.99	64.66±1.0(2.29%)2	65.17±2.52	64.30±1.40 (1.33%)	65.16±2.50	64.27±1.03 (1.36%)
Leaf extract pH	6.32±0.01	6.20±0.01	6.30±0.04	6.19±0.01	6.29±0.01	6.18±0.01	6.28±0.01	6.17±0.01
APTI	7.99	7.63 (4.50%)	7.97	7.62 (4.39%)	7.86	7.57 (3. 68%)	7.84	7.54 (3.82%)

Note: % in parenthesis indicates % reduction in APTI value in comparison to control

Table 3(d) Variations in the studied parameters of Maize Sector-1 vs. control.

Month	July		August		September		October	
parameter	Control	Sector-1	Control	Sector-1	Control	Sector-1	Control	Sector-2
Total photosynthetic Pigment(mg/gm)	3.01±0.01	2.86±0.02 (4.98%)	2.98±0.02	2.83±0.02 (5.03%)	2.95±0.02	2.80±0.02 (5.08%)	2.91±0.02	2.77±0.02 (4.81%)
Ascorbic acid(mg/gm)	2.01±0.04	1.89±0.02 (5.90%)	1.99±0.03	1.88±0.02 (5.52%)	1.98±0.02	1.87±0.01 (5.55%)	1.97±0.03	1.85±0.02 (6.09%)
Relative water content	67.95±0.96	67.86±0.9 (0.13%) 0	67.93±0.96	67.85±1.05 (0.11%)	67.92±0.96	67.83±1.02 (0.13%)	67.91±0.97	67.82±1.03 (0.13%)
Leaf extract pH	7.57±0.01	7.45±0.02	7.55±0.01	7.44±0.01	7.53±0.02	7.43±0.01	7.52±0.02	7.42±0.01
APTI	8.92	8.73 (2.13%)	8.88	8.71 (1.91%)	8.86	8.69 (1.91%)	8.84	8.66 (2.03%)

Note: % in parenthesis indicates % reduction in APTI value in comparison to control

Table 3 (e). Variations in the studied parameters of Maize Sector-2 vs. control.

Month	July		August		September		October	
parameter	Control	Sector-2	Control	Sector-2	Control	Sector-2	Control	Sector-2
Total photosynthetic Pigment(mg/gm)	3.01±0.01	2.95±0.01 (1.99%)	2.98±0.02	2.92±0.01 (2.01%)	2.95±0.02	2.89±0.01 (2.03%)	2.91±0.02	2.86±0.02 (1.71%)
Ascorbic acid(mg/gm)	2.01±0.04	1.93±0.03 (3.98%)	1.99±0.03	1.92±0.01 (3.51%)	1.98±0.02	1.91±0.01 (3.53%)	1.97±0.03	1.90±0.02 (3.55%)
Relative water content	67.95±0.96	67.90±0.95 (0.07%)	67.93±0.96	67.89±0.96 (0.05%)	67.92±0.96	67.88±0.89 (0.05%)	67.91±0.97	67.87±0.89 (0.05%)
Leaf extract pH	7.57±0.01	7.50±0.01	7.55±0.01	7.49±0.01	7.53±0.02	7.47±0.01	7.52±0.02	7.46±0.01
APTI	8.92	8.80 (1.34%)	8.88	8.78 (1.12%)	8.86	8.76 (1.12%)	8.84	8.74 (1.13%)

Note: % in parenthesis indicates % reduction in APTI value in comparison to control

Table 3 (f) Variations in the studied parameters of Maize Sector-3 vs. control.

Month	July		August		September		October	
parameter	Control	Sector -3	Control	Sector -3	Control	Sector -3	Control	Sector-3
Total photosynthetic Pigment(mg/gm)	3.01±0.01	2.76±0.03 (8.30%)	2.98±0.02	2.74±0.03 (8.05%)	2.95±0.02	2.70±0.03 (8.47%)	2.91±0.02	2.67±0.03 (8.24%)
Ascorbic acid(mg/gm)	2.01±0.04	1.84±0.02 (8.45%)	1.99±0.03	1.83±0.03 (8.04%)	1.98±0.02	1.82±0.02 (8.08%)	1.97±0.03	1.81±0.02 (8.12%)
Relative water content	67.95±0.96	67.81±1.00 (0.20%)	67.93±0.96	67.80±0.99 (0.19%)	67.92±0.96	67.79±1.00 (0.19%)	67.91±0.97	67.78±1.01 (0.19%)
Leaf extract pH	7.57±0.01	7.41±0.01	7.55±0.01	7.40±0.01	7.53±0.02	7.39±0.02	7.52±0.02	7.38±0.02 (%)
APTI	8.92	8.65 (3.02%)	8.88	8.63 (2.81%)	8.86	8.61 (2.82%)	8.84	8.59 (2.82%)

Note: % in parenthesis indicates % reduction in APTI value in comparison to control

Table 3 (g) Variations in the studied parameters of Gram Sector-1 vs. control.

Month	December		January		February		March	
Parameter	Control	Sector-1	Control	Sector-1	Control	Sector-1	Control	Sector-1
Total photosynthetic Pigment(mg/gm)	2.43±0.10	2.19±0.05 (9.87%)	2.29±0.07	2.16±0.04 (5.67%)	2.28±0.07	2.12±0.03 (7.01%)	2.20±0.06	2.08±0.04 (5.45%)
Ascorbic acid(mg/gm)	1.43±0.03	1.42±0.04 (0.69%)	1.41±0.02	1.41±0.04 (0%)	1.40±0.02	1.40±0.04 (0%)	1.39±0.02	1.38±0.04 (0.71%)
Relative water content	55.41±1.05	54.49±0.83 (1.66%)	55.39±1.05	54.47±0.83 (1.66%)	55.36±1.05	54.45±0.83 (1.64%)	55.33±1.04	54.42±0.43 (1.64%)
Leaf extract pH	4.66±0.01	4.52±0.01 (%)	4.65±0.01	4.51±0.01	4.64±0.01	4.50±0.01	4.60±0.01	4.47±0.01
APTI	6.55	6.40 (2.29%)	6.51	6.38 (1.99%)	6.50	6.37 (2.00%)	6.47	6.34 (2.00%)

Table 3(h) Variations in the studied parameters of Gram Sector-2 vs. control.

Month	December		January		February		March	
parameter	Control	Sector-2	Control	Sector-2	Control	Sector-2	Control	Sector-2
Total photosynthetic Pigment(mg/gm)	2.43±0.10	2.38±0.09 (2.05%)	2.29±0.07	2.25±0.07 (1.74%)	2.28±0.07	2.22±0.07 (2.63%)	2.20±0.06	2.14±0.04 (2.72%)
Ascorbic acid(mg/gm)	1.43±0.03	1.40±0.04 (2.09%)	1.41±0.02	1.39±0.04 (1.41%)	1.40±0.02	1.37±0.04 (2.14%)	1.39±0.02	1.35±0.04 (2.87%)
Relative water content	55.41±1.05	54.73±0.44 (1.22%)	55.39±1.05	54.72±0.42 (1.20%)	55.36±1.05	54.70±0.43 (1.19%)	55.33±1.04	54.69±0.42 (1.15%)
Leaf extract pH	4.66±0.01	4.59±0.01	4.65±0.01	4.58±0.01	4.64±0.01	4.56±0.01	4.60±0.01	4.54±0.01
APTI	6.55	6.44 (1.67%)	6.51	6.42 (1.38%)	6.50	6.39 (1.69%)	6.47	6.37 (1.54%)

Table 3(i) Variations in the studied parameters of Gram Sector-3 vs. control.

Month	December		January		February		March	
parameter	Control	Sector-3	Control	Sector-3	Control	Sector3	Control	Sector3
Total photosynthetic Pigment(mg/gm)	2.43±0.10	2.10±0.04 (13.58%)	2.29±0.07	2.07±0.04 (9.60%)	2.28±0.07	2.05±0.04 (10.08%)	2.20±0.06	2.02±0.03 (8.18%)
Ascorbic acid(mg/gm)	1.43±0.03	1.37±0.04 (4.19%)	1.41±0.02	1.36±0.04 (3.54%)	1.40±0.02	1.34±0.04 (4.28%)	1.39±0.02	1.32±0.04 (5.03%)
Relative water content	55.41±1.05	54.39±0.44 (1.84%)	55.39±1.05	54.37±0.44 (1.84%)	55.36±1.05	54.32±0.43 (1.87%)	55.33±1.04	54.30±0.42 (1.86%)
Leaf extract pH	4.66±0.01	4.48±0.01	4.65±0.01	4.46±0.01	4.64±0.01	4.40±0.01	4.60±0.01	4.39±0.01
APTI	6.55	6.34 (3.20%)	6.51	6.32 (2.91%)	6.50	6.29 (3.23%)	6.47	6.27 (3.09%)

Table 3(j). Variations in the studied parameters of Wheat Sector-1 vs. control.

Month	December		January		February		March	
parameter	Control	Sector-1	Control	Sector-1	Control	Sector-1	Control	Sector-1
Total photosynthetic Pigment(mg/gm)	2.32±0.07	2.16±0.07 (6.89%)	2.29±0.08	2.09±0.05 (8.73%)	2.23±0.10	2.06±0.04 (7.62%)	2.20±0.11	2.03±0.05 (7.72%)
Ascorbic acid(mg/gm)	1.06±0.07	0.97±0.03 (8.49%)	1.05±0.07	0.96±0.04 (8.57%)	1.04±0.04	0.95±0.05 (8.65%)	1.03±0.04	0.94±0.04 (8.73%)
Relative water content	65.88±1.44	65.70±1.32 (0.27%)	65.87±1.41	65.69±1.32(0.27%)	65.79±1.34	65.68±1.32 (0.16%)	65.78±1.34	65.67±1.31 (0.16%)
Leaf extract pH	5.99±0.01	5.90±0.02	5.98±0.01	5.89±0.02	5.96±0.01	5.88±0.02	5.95±0.01	5.87±0.02
APTI	7.46	7.35 (1.47%)	7.45	7.33 (1.61%)	7.43	7.32 (1.48%)	7.41	7.30 (1.48%)

Table 3(k). Variations in the studied parameters of Wheat Sector-2 vs. control.

Month	December		January		February		March	
parameter	Control	Sector-2	Control	Sector-2	Control	Sector-1	Control	Sector-2
Total photosynthetic Pigment(mg/gm)	2.32±0.07	2.24±0.06 (3.44%)	2.29±0.08	2.21±0.05 (3.49%)	2.23±0.10	2.14±0.09 (4.03%)	2.20±0.11	2.12±0.05 (3.63%)
Ascorbic acid(mg/gm)	1.06±0.07	1.02±0.04 (3.77%)	1.05±0.07	1.01±0.03 (3.80%)	1.04±0.04	0.99±0.01 (4.80%)	1.03±0.04	0.98±0.01 (4.85%)
Relative water content	65.88±1.44	65.77±0.94 (0.16%)	65.87±1.41 (	65.75±1.34 (0.18%)	65.79±1.34	65.74±1.33 (0.07%)	65.78±1.34	65.72±1.33 (0.09%)
Leaf extract pH	5.99±0.01	5.94±0.02	5.98±0.01	5.93±0.02	5.96±0.01	5.92±0.02	5.95±0.01	5.91±0.03
APTI	7.46	7.41 (0.67%)	7.45	7.39 (0.80%)	7.43	7.37 (0.80%)	7.41	7.35 (0.80%)

Table 3(l) Variations in the studied parameters of Wheat Sector-3 vs. control.

Month	December		January		February		March	
parameter	Control	Sector-3	Control	Sector-3	Control	Sector-3	Control	Sector-3
Total photosynthetic Pigment(mg/gm)	2.32±0.07	2.09±0.04 (9.91%)	2.29±0.08	2.06±0.04 (10.04%)	2.23±0.10	2.03±0.06 (8.96%)	2.20±0.11	2.00±0.04 (9.09%)
Ascorbic acid(mg/gm)	1.06±0.07	0.93±0.04 (12.26%)	1.05±0.07	0.92±0.03 (12.38%)	1.04±0.04	0.91±0.03 (12.50%)	1.03±0.04	0.90±0.04 (12.62%)
Relative water content	65.88±1.44	65.65±1.40 (0.34%)	65.87±1.41	65.63±1.33(0.36%)	65.79±1.34	65.62±1.55 (0.25%)	65.78±1.34	65.61±1.33 (0.25%)
Leaf extract pH	5.99±0.01	5.86±0.02	5.98±0.01	5.87±0.02	5.96±0.01	5.86±0.02	5.95±0.01	5.85±0.02
APTI	7.46	7.30 (2.14%)	7.45	7.29 (2.14%)	7.43	7.27 (2.15%)	7.41	7.26 (2.02%)

Table 3(m) Monthly Variations in APTI in Soybean.

Month	July		August		September		October	
	Control	polluted	Control	polluted	Control	polluted	Control	Polluted
Sector-1	7.99	7.76 (2.87%)	7.97	7.74 (2.88%)	7.86	7.70 (2.03%)	7.84	7.68 (2.04%)
Sector-2	7.99	7.83 (2.00%)	7.97	7.81 (2.00%)	7.86	7.78 (1.01%)	7.84	7.77 (0.89%)
Sector-3	7.99	7.63 (4.50%)	7.97	7.62 (4.39%)	7.86	7.57 (3.68%)	7.84	7.54 (3.82%)
Control Vs. Polluted	P <0.006		P<0.005		P<0.022		P<0.028	

Statistical analysis : P value , <0.05 significant, <0.01 highly significant

Table 3(n) Monthly Variations in APTI in Maize.

Month	July		August		September		October	
	Control	polluted	Control	polluted	Control	polluted	Control	Polluted
Sector-1	8.92	8.73 (2.13%)	8.88	8.71 (1.91%)	8.86	8.69 (1.91%)	8.84	8.66 (2.03%)
Sector-2	8.92	8.80 (1.34%)	8.88	8.78 (1.12%)	8.86	8.76 (1.12%)	8.84	8.74 (1.13%)
Sector-3	8.92	8.65 (3.02%)	8.88	8.63 (2.81%)	8.86	8.61 (2.82%)	8.84	8.59 (2.82%)
Control Vs. Polluted	P<0.005		P<0.008		P<0.008		P<0.007	

Statistical analysis : P value , <0.05 significant, <0.01 highly significant

Table 3(o) Monthly Variations in APTI in Gram.

Month	December		January		February		March	
	Control	polluted	Control	polluted	Control	polluted	Control	Polluted
Sector-1	6.55	6.40 (2.29%)	6.51	6.38 (1.99%)	6.50	6.37 (2.00%)	6.47	6.34 (2.00%)
Sector-2	6.55	6.44 (1.67%)	6.51	6.42 (1.38%)	6.50	6.39 (1.69%)	6.47	6.37 (1.54%)
Sector-3	6.55	6.34 (3.20%)	6.51	6.32 (2.91%)	6.50	6.29 (3.23%)	6.47	6.27 (3.09%)
Control vs. Polluted	P<0.002		P<0.004		P<0.003		P<0.004	

Statistical analysis : P value , <0.05 significant, <0.01 highly significant

Table 3(p) Monthly Variations in APTI in Wheat.

Month	December		January		February		March	
	Control	polluted	Control	polluted	Control	polluted	Control	Polluted
Sector-1	7.46	7.35 (1.47%)	7.45	7.33 (1.61%)	7.43	7.32 (1.48%)	7.41	7.30 (1.48%)
Sector-2	7.46	7.41 (0.67%)	7.45	7.39 (0.80%)	7.43	7.37 (0.80%)	7.41	7.35 (0.80%)
Sector-3	7.46	7.30 (2.14%)	7.45	7.29 (2.14%)	7.43	7.27 (2.15%)	7.41	7.26 (2.02%)
Control vs.Polluted	P<0.014		P<0.008		P<0.009		P<0.007	

Statistical analysis : P value , <0.05 significant, <0.01 highly significant

Table 3(q) Correlation coefficient of ascorbic acid, pH, relative water content and total chlorophyll, with APTI for Soybean in sector-1, 2 & 3.

Soybean	APTI versus pH	APTIversus RWC	APTI versus Ascorbic acid	APTIversus Photosynthetic pigment	
Sector-1	0.95088	0.90341	0.903393	0.872968	APTI
Sector-2	0.971928	0.880473	0.950215	0.938471	
Sector-3	0.990621	0.963759	0.910042	0.990333	

Table 3(r) Correlation coefficient of ascorbic acid, pH, relative water content and total chlorophyll, with APTI for Maize in sector-1, 2 & 3.

Maize	APTI versus PH	APTIversus RWC	APTI versus Ascorbic acid	APTIversus Photosynthetic pigment	
Sector-1	0.99643	-0.60526	0.99326	0.904	APTI
Sector-2	0.997606	0.997921	0.99839	0.987333	
Sector-3	0.900282	0.890447	0.884772	0.886862	

Table 3(s) Correlation coefficient of ascorbic acid, pH, relative water content and total chlorophyll, with APTI for Soybean in sector-1, 2 & 3.

Gram	PH	RWC	Ascorbic acid	Photosynthetic pigment	
Sector-1	0.985496	0.909242	0.929669	0.702205	APTI
Sector-2	0.991713	0.955276	0.496919	0.943678	
Sector-3	0.993077	0.979019	0.965696	0.966778	

Table 3(t) Correlation coefficient of ascorbic acid, pH, relative water content and total chlorophyll, with APTI for Wheat in sector-1, 2 & 3.

Wheat	APTI versus PH	APTIversus RWC	APTI versus Ascorbic acid	APTIversus Photosynthetic pigment	
Sector-1	0.985652	0.944134	0.992335	0.963448	APTI
Sector-2	0.998067	0.972719	0.965126	0.981086	
Sector-3	0.993859	0.987036	0.998234	0.988386	

Figure 1. Showing % reduction in APTI value in comparison to control in Pithampur industrial area sector 1, 2 & 3.

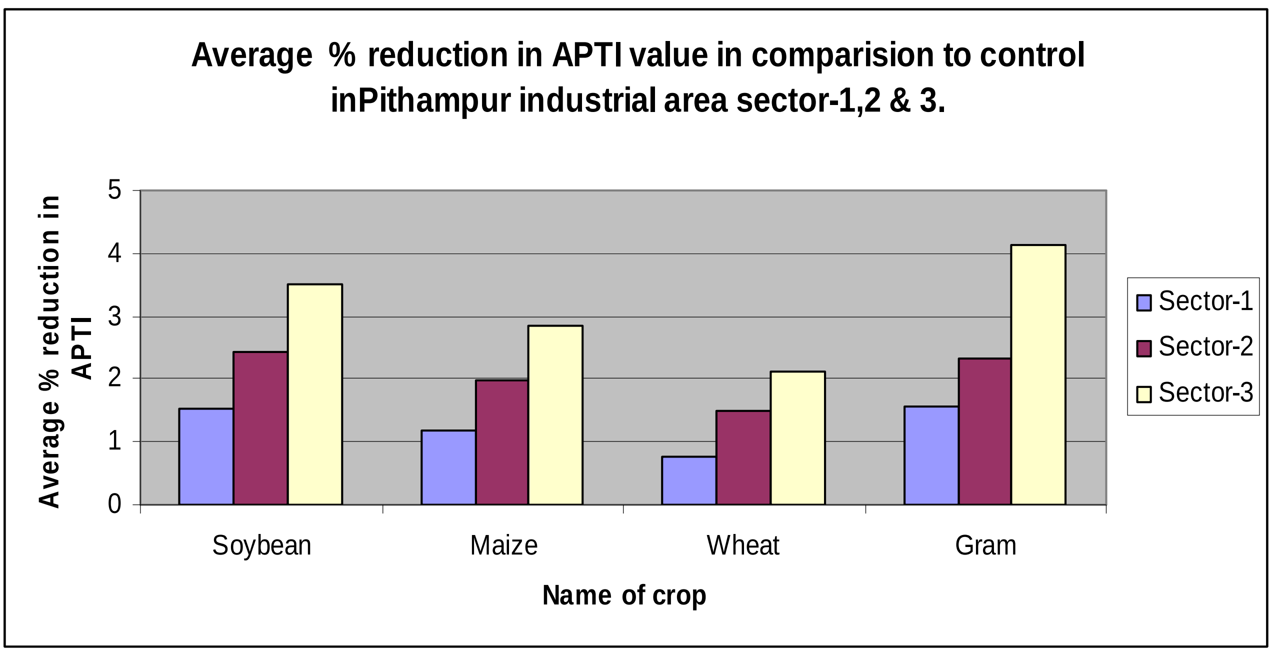
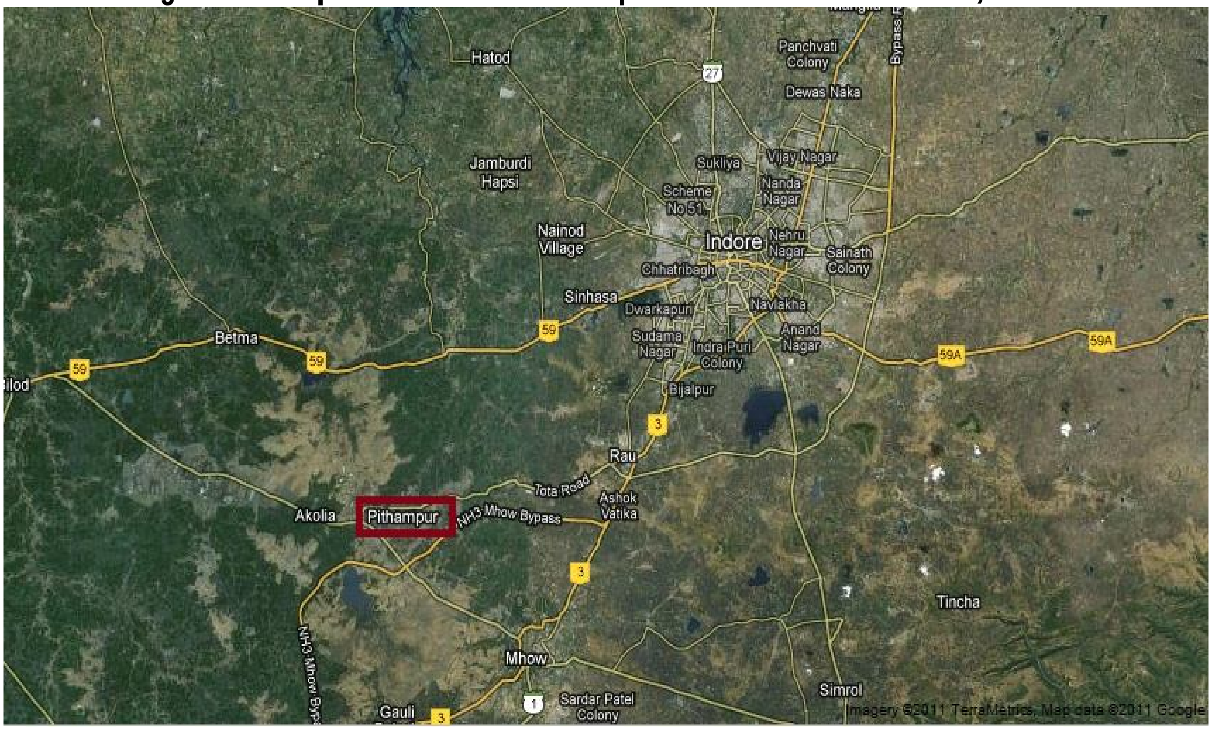


Figure 2. Site plan of studied Pithampur industrial area sector 1, 2 & 3.



Air Pollution Tolerance Index(APTI): All the crop selected for the present study were sensitive to industrial air pollution since APTI value of all the studied crop were reported less than 10. (Sing and Rao 1983) states that APTI is an index, which determines capability of a plant to fight against air pollution. Plants which have higher index value are tolerant to air pollution and can be used as sink to mitigate pollution, while plants having low index value show less tolerance and can be used as bio-indicator of air pollution. More sensitive plants act as biological indicators of air pollution and the response of plants to air pollution at physiological and biochemical levels can be used as mitigators of pollutants (Sharma and Tripathi *et al.,* 2009). It is suggested, for some species, the biggest effects of pollution treatments are associated with the early stages of the life cycle (Honour et al., 2009). The long term, low-concentration exposures of air pollution produces harmful impacts on plant leaves without visible injury (Joshi et al., 2009). In summary, plant adaptation to changing environmental factors involves both short-term physiological responses and long-term physiological, structural and morphological modifications. These changes help plants minimize stress and maximize use of internal and external resources (Dineva, 2004). At higher concentration plants are reported to exhibit symptoms (visible injury) and at lower concentrations, plants are reported to exhibit certain physiological and biochemical changes (invisible injury**).**The present study hypothesis also supporting the hypothesis of P. Padmavathi, Jyotsna Cherukuri, M. Anji Reddy,(2013) they found that both paddy and cotton crops are sensitive towards air pollution due to their close vicinity of thermal power plant.

Another study is also supported by the study of Joshi and Chauhan, (2008), found that air pollutants such as suspended particulate matter (SPM), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) emitted from automobiles were adversely affected the plants chlorophyll, carotenoid, ascorbic acid, pH, relative moisture content, and air pollution tolerance index (APTI) of *Oryza sativa L*.

CONCLUSION

Air Pollution Tolerance Index (APTI value): Due to urbanization and industrialization, there is an immense loss to the yield and in turn to the economy of the region. Hence APTI determination to various crops provides information regarding the tolerance capacity of them to industrial air pollutants and such crops may be recommended to the farmers in industrialized urban and peri-urban areas. In the present study (APTI) of wheat and gram (rabi crop) maize and soya bean (kharif crop) were calculated. The highest value of APTI was observed in maize i.e. Highest among all four studied crops grown in control area. Thus it may be suggested that maize is tolerant crop than soya bean, wheat and gram. The highly significant reduction was observed in all four crops in APTI due to industrial air pollutants i.e. in maize (3.02%), wheat (2.15%) gram 3.23 %, and Soya bean 4.50%. Soya bean crop of sector-3 was shown highest reduction in APTI i.e. .4.50% which was resultant of higher concentration of air pollution due to presence of large no. of industries in this sector. This reduction in APTI and sensitivity of crop was also affected by higher traffic density in that area. Lowest reduction in APTI was observed in wheat (2.02 %) in sector -3 indicating highest resistant capacity of wheat (Lok-1) towards industrial air pollutants. From the present study it was concluded that wheat was least affected (ravi crop) and monocots were resistant as compared to dicots by industrial air pollution. Hence they can be cultivated near industrial area.

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