Journal of Cereal Research

14(1): 26-36

Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Research Article

Effects of gradient ambient air pollutants on wheat cultivars (HD2967 and HD3086) in vicinity of thermal power plant

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Article history:
Received: 13, Dec., 2021
Revised: 17, Jan., 2022
Accepted: 29, Mar., 2022

Citation:
Kumar Y, U Mina, SN Kumar, B C, RC Harit, P Prakash and MC Garg. 2022. Effects of gradient ambient air pollutants on wheat cultivars (HD2967 and HD3086) in vicinity of thermal power plant. *Journal of Cereal Research* ***14(1):*** *26-36. http://doi.org/ 10.25174/2582-2675/2022/118406*

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Abstract

This study involves the effects of gradient ambient air pollutants on wheat cultivars (HD2967 and HD3086) that are grown on farmers' fields located in 8 villages, namely - Jamuha, Singanpur, Parwaha, Bahadurpur, Jawaharpur, Ghasa Ka Purwa, Hajiyapur, and Murhi which are present in the vicinity of the Thermal Power Plant (TPP) at Auraiya. The present study was carried out to observe the effects of Total Suspended Particulate Matter (TSPM), Nitrogen Dioxide (NO_2) and Ozone (O_3) air pollutants on growth and biochemical parameters viz. - pH, relative water content (RWC), ascorbic acid (AA), total chlorophyll (TC), and yield of wheat cultivars (HD2967 and HD3086) in a 10km radius of the TPP. The wheat cultivars were grown for two consecutive years on agricultural fields in the 8 villages chosen by this study. The range of selected ambient air pollutant observed at the selected experimental site was 139-189 µg/m^3 TSPM, 23-28 ppb NO_2, and 34-46 ppb O_3. The dust deposition on the flag leaves of wheat cultivars was maximum (3.4 mgcm^{-2}) in the 2-4 km area on the leeward side of the TPP while considerably lesser deposition was witnessed in the 7-9 km area on the windward side at Hajiyapur (2.5 mgcm^{-2}). Canopy area, growth, yield attributes, chlorophyll, relative water content, and yield were significantly ($P<0.05$) affected by SPM deposition. Due to air pollutants gradient, among the two cultivars of wheat, HD2967 was more adversely affected than HD3086.

Keyword: Chlorophyll, HD2967, HD3086, Nitrogen Dioxide, Ozone

1. Introduction

Wheat is the most cultivated cereal crop occupying 17% of the world's cultivated land; it is the staple food crop for 35% of the world population, providing more proteins to the world diet than any other food crop (Liu *et al.,* 2019; Foley *et al.,* 2011). It is also the staple food crop of India and its demand projected to increase to 73.5 million tonnes in 2020-21 from 57.4 million tonnes in 2004-05 (Leitch *et al.,* 2014). Wheat crop-based agroforestry systems are promoted in the northern Indo-Gangetic Plain (IGP) of India in order to enhance farmers' profits as well as maintain the sustainability of the agro-ecosystem (Singh *et al.,* 2016). In recent years, a rise in urbanization and industrialization in many developing countries has led to corresponding increases in atmospheric concentrations of primary and secondary air pollutants (Chauhan *et al.,* 2010). India and other developing countries have experienced a progressive degradation of air quality due to industrialization, urbanization, lack of awareness, number of motor vehicles, use of fuels with poor environmental performance, poorly-maintained roads, and ineffective environmental regulation (Agarwal *et al.,* 2003). Air pollution has become a serious threat to crops productivity over the last few decades (Mir *et al.,* 2019; Rai *et al.,* 2011). Currently, there are very limited reports on the qualitative as well as quantitative impact of air pollution caused by TPP on wheat crops in India (Duncan, 2013). Plants provide an enormous leaf area for impingement, absorption, and accumulation of air pollutants (Skinder *et al.,* 2014). The ability of each plant species to absorb and adsorb air pollutants through their foliar surface varies greatly. This ability depends on several biochemicals, physiological, and morphological characteristics (Singh *et al.,* 2007). Exposure of evergreen plants to air pollutants creates physiological and biochemical changes (Priyadarshini *et al.,* 2013).

Ambient levels of air pollution have been shown to affect stomata conductance, photosynthesis, and root morphology of a young plant (López *et al.,* 2021). The leaf is the part of the plant which is most sensitive and constantly exposed to the atmosphere (Watson, 2021). The adverse effects of dust and other air pollutants on plants with a reduction in photosynthetic ability and yield has been demonstrated by other research studies pertaining to diffèrent corps (Joshi *et al.,* 2009). Among secondary air pollutants, tropospheric ozone concentrations beyond 40 ppb are considered to phytotoxic for crops (Ghosh *et al.,* 2021). Studies have reported high surface O_3 concentration (>40ppb) over major agricultural regions in India, particularly the Indo-Gangetic Plains (IGP), one of the world's most important fertile agricultural lands (Singh *et al.,* 2017). Ozone concentrations are projected to increase further in the future (Feng *et al.,* 2019). The SO_2 and NO2 air pollutants visible foliar injuries in farmlands are largely confined to severely polluted locations or on occasions of large and accidental industrial releases (Mohamed *et al.,* 2021). In contrast, visible O_3 injuries are recorded more frequently across the world in the presence of an elevated level of this pollutant. Acute injuries caused by these pollutants vary with respect to necrotic lesions, ranging from a fine stipple to large patches of dead tissue with coloration ranging from white to brown black (Rai *et al.,* 2011).

The primary and secondary air pollutants alone, and in combination, can cause serious setbacks to the overall physiology of plants (Singh *et al.,* 2021). Therefore, the categorization of plants was carried out according to their susceptibility (whether sensitive or tolerant) to air pollutants con the basis of air pollution tolerance index (APTI). APTI is calculated using four biochemical parameters like AA, TC, leaf extract pH, and RWC of leaves (Sen *et al.,* 2017).

Monitoring air pollution impact on staple crops is important for identification of adaptation and mitigation options. With this background in the current study an assessment of air quality in vicinity of TPP as well as its impacts on growth, biochemical parameter, and yield of wheat cultivars within the established study area. The aim of the present study was (1) To quantify selected air pollutants present in the vicinity (within a 10 km radius) of a thermal power plant impact on wheat crop growth and yield attributes (2) To determine the variability in wheat cultivars air pollution tolerance

2. Materials and methods

2.1 Experimental site

The study was conducted in the vicinity of a thermal power plant (TPP), located in the Auraiya district of Utter Pradesh (26.4605°N, 79.5113°E) (Figure 1). The experiment was conducted during the rabi season consecutively for two years. Eight village sites around the TPP were selected according to dominant wind direction and distance from the thermal power plant. The Hajiyapur control site was selected in the opposite windward direction of the TPP. For the first year, the dominant wind direction throughout the crop period was in the south-west (SW) direction. Three villages were selected in the leeward direction (Parwaha, Jamuha and Murhi), two were selected perpendicular to the dominant wind direction (Hajiyapur and Jawaharpur), and one was chosen opposite to the direction of wind (Singanpur). For the second year, the dominant wind direction throughout the crop period was in the South-East (SE) direction. Three villages were selected in the Leeward direction (Jamuha, Ghasa ka purwa and Bahadurpur), two were selected perpendicular to the dominant wind direction (Parwaha and Singanpur), and one chosen opposite to the direction of wind (Singanpur). (Table1.), (Figure 2)

Figure 1. Geographical location of study area

Table 1. Selected Site, geographical location and wind direction from TPP

Village Name	Latitude (N)	Longitude (E)	Wind-Direction	Ariel-Distance(km) from TPP
Jamuha	26.6297	79.5398	SE	1-2
Singanpur	26.6445	79.5192	NW	2-3
Parwaha	26.6314	79.5050	SW	3-4
Bahadurpur	26.5949	79.5967	SE	4-5
Jawaharpur	26.6545	79.5774	NE	5-6
Ghasa ka purwa	26.6056	79.6136	SE	6-7
Hajiyapur	26.6832	79.5593	N	7-9
Murhi	26.5555	79.4704	SW	9-10

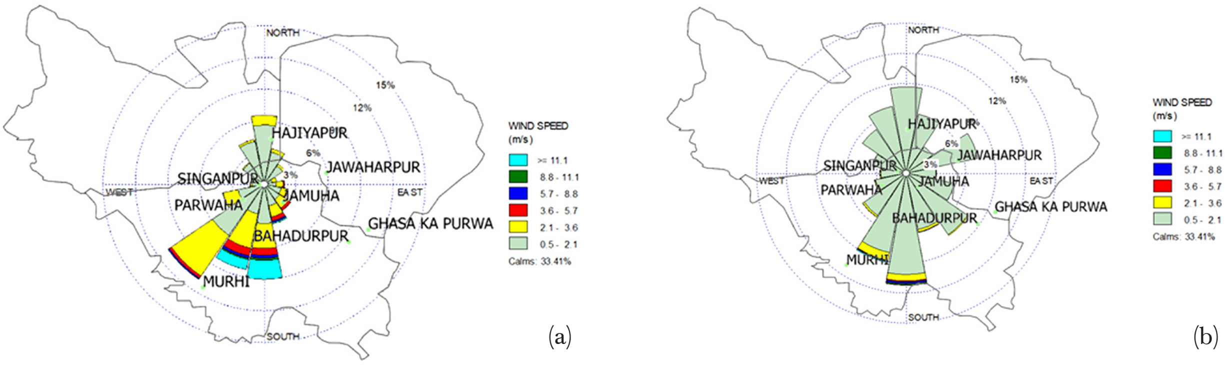

Figure 2. Wind Rose map during wheat crop period (a) 2015-16 and (b) 2016-17

2.2 Experimental crop cultivar

Wheat was grown from mid-November to April. The farmers primarily grew HD2967 and HD3086 wheat cultivars. The sowing of wheat seedlings was done in the month of November. Field visits were done at monthly intervals for the purpose of recording growth and yield of crop. The farm fields were also continuously monitored for evidence of any other threats like insect or pest infestations and diseases during the growing season.

2.3 Air pollutants monitoring and analysis

Ambient air pollutants - TSPM, NO_2, and O_3 - were monitored at all the chosen agricultural fields located in eight villages for the entire duration of the crop growth period. TSPM in ambient levels were collected by a respirable dust sampler (RDS) (Make – Envirotech, Model No - APM 460BL) on 20.3 × 25.4 cm glass fibre filter paper at an air flow rate of 1132 l/min. The concentration level of TSPM was determined by obtaining the difference in filter paper weights divided by the volume of total air sample passed through the filter paper. Air pollutants in ambient air (primary NO_2 and secondary O_3) are monitored calorimetrically in samples collected via the gaseous sampling unit attached to the respirable dust sampler (RDS) (Make – Envirotech, Model – APM 414). Ambient air passed through the impinger containing a 20 ml absorbing reagent solution made up of 4 g sodium hydroxide (NaOH) and 1 g sodium arsenite ($NaAsO_2$) dissolved in 1000 ml distilled water for NO_2 sampling, and passed through 10 ml potassium iodide (KI) (1%, pH-6.8) and neutral buffer (composed of Na_2HPO_4 and KH_2PO_4) solutions for O_3 sampling. The concentration of NO_2 in the sample is determined calorimetrically by reacting the sample containing NO_2 as nitrite ion with phosphoric acid, sulphanilamide, and N-(1-napthyl)-ethylenediamine di-hydrochloric (NEDA) while also measuring the absorbance of the highly coloured azo-dye at 540 nm using a spectrophotometer (Make – Systronic, Model - 2202). The concentration of O_3 in the sample, indicated by the iodine liberated in the absorbing solution, was determined spectrophotometrically by measuring the tri-iodide ion at 352 nm.

2.4 Suspended particulate matter deposition on wheat cultivar

The deposition of SPM on flag leaves of wheat was quantified as per the methodology iterated in Mina et al., (2018). Following equation (1) was used to quantify the dust load:

$$W = \frac{W2 - W1}{A} \tag{1}$$

where, W is the amount of SPM deposition load ($mgcm^{-2}$), W_1 is the initial weight of the beaker (gm) without dust; W_2 is the final weight of the beaker (gm) with dust; A is the total area of the flag leaf (cm^2).

2.5 Growth attribute

Leaf Area Index (LAI) values indicate the growth response of wheat cultivars. LAI of wheat cultivars was observed at each site during the vegetative, anthesis, and milking stages by using a canopy analyzer (Model- LAI-2000).

2.6 Biochemical parameter and APTI of wheat cultivars

After quantification of SPM deposition, flag leaves of wheat cultivars were analyzed for biochemical attributes namely – pH, AA, RWC, and TC.

AA content was determined as described in Balasubraminan (1973). The leaf sample (1 gm) was extracted in 4% oxalic acid (10 ml) (volume was made up to 50 ml with 4% oxalic acid), and was centrifuged at 5000 rpm for 20 minutes at 4 °C. The supernatant (5 ml) was collected through a pipette, 4% oxalic acid (10 ml) was added and titrated against the 2-6 dichlorophenol indophenol dye for ascorbic acid content estimation. For the estimation of chlorophyll content, 50 mg of flag leaves were cut into small pieces, and put into test tubes. 10 ml of Di-Methyl Sulphoxide (DMSO) was added to the leaves. The test tubes were kept in an oven for 4 hrs at 65°C for chlorophyll extraction. The absorbance of the solution was measured at 645 and 663 nm using a spectrophotometer. Leaf pH was estimated using filtrate of 5 g of the fresh flag leaves (crushed and homogenized in 50 ml deionized water) using calibrated pH meter. RWC was estimated on the basis of difference between fresh, saturated, and dry weight of flag leaf discs with 1 cm diameter.

2.7 Air Pollution Tolerance Index (APTI)

The biochemical data generated from the collected flag leaves samples was used to generate APTI value using the following equation (2) (Lakshmi *et al.,* 2009).

$$APTI = \frac{A(T+P)+RWC}{10} \tag{2}$$

Where, AA = Ascorbic Acid, T = Total chlorophyll of leaf, P = pH of leaf extract, RWC = Relative Water Content of leaves.

Estimation of grain yield

At the maturity stage, the wheat crop was harvested, dried for 3 days, weighed, and after threshing, the grain yield was recorded. The yield was expressed in gram per meter square (gm^{-2}).

2.8 Weather conditions at the study area

The climate of Auraiya was semi-arid and subtropical, its altitude was 137m above sea level, total rainfalls were recorded at 29.63 mm during the experimentation period in the study area. The value of maximum wind speed was 4.27 m/s and minimum value was 0.7 m/s, maximum temperature was 45.5 °C while minimum temperature was 4.1 °C, maximum humidity was 58.9 % and minimum humidity was 6.8% as observed and recorded during the study period in 2015-16. In 2016-17, total rainfalls were recorded at 29.44 mm during the study period and the maximum wind speed = 4.42 m/s, minimum wind speed = 0.64 m/s, maximum temperature = 45.7°C and minimum temperature = 2.6 °C, and maximum humidity = 68.6 % while minimum humidity = 8.0 % (Table 2).

Table 2. Weather Data during crop period

Month	2015-16						2016-17					
	Tmax. (°C)		Tmin. (°C)		RH (%)		Tmax. (°C)		Tmin. (°C)		RH (%)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
November	33.6	28.3	21.2	11.1	48	23.7	32.4	28	17.9	10.4	46.8	28.6
December	29.5	21.7	16.9	5.1	56.6	17.7	29.9	24.6	14.8	6.4	57.1	22.4
January	28.9	20.3	13.6	4.1	58.9	19.3	29.9	19	13.4	2.6	60.7	19.7
February	36.6	25.5	19.1	7.1	38.5	10.9	34.9	21.5	17	7.5	68.6	13.6
March	41	29.9	24	13.8	50.7	10.8	41.3	22.2	22.5	9.8	57.4	13.7
April	45.5	38	28.3	22.4	20.7	6.8	45.7	38.1	29.4	19.2	22.9	8.01

2.9 Statistical Analysis and Software

A statistical analysis was performed using Microsoft Excel - 2016. The data was presented as mean ± standard deviations. This study used WRPLOT View - Version 8.0.2 lakes environment for wind rose analysis.

3. Results and Discussion

3.1 Monitoring of air pollutants

The range of O_3 concentration at the chosen experimental site was 35 - 46 ppb, NO_2 concentration range was 23 – 29 ppb, and TSPM concentration range was 139-190 µg/m³ for the experimental period of 2015-2017. (Supplementary table 1). Out of the three air pollutants being monitored, TSPM levels were found to be above the National Ambient Air Quality Standard (NAAQS) limits. Therefore, it was observed that ambient air pollutant levels was high in the air shed at all study sites in 2016-17 as compared to 2015-16 with respect to TSPM. Furthermore, the ambient ozone level was also recorded to be more than the threshold limit for plants (i.e., > 40 ppb). However, NO_2 levels were found to be within the threshold limit. Results obtained by the study indicate the variability in TSPM, NO_2, and O_3 levels at the agricultural fields in eight villages which were located at different distances on the windward and leeward sides in the air shed of the study area. The fallout pattern of pollutants in the area was governed by the southwest and southeast prevailing winds in the years 2015-16 and 2016-17 respectively. This suggests that the air pollutants were present in the air shed of these two directions where the concentrations of the selected pollutants were higher than in any other direction. Out of all the agricultural fields chosen for study, those which were located within 1-3 kms of the TPP air shed along the leeward side were exposed to higher ambient levels of the air pollutants. Meanwhile, those fields which were located at 7-10 kms distance on the windward side were exposed to low ambient levels of air pollutants. This indicates that the probability of exposure of farm fields located within 10 km of the TPP air shed depends on meteorological conditions, especially wind direction and speed as well as vertical and horizontal thermal gradients prevailing in that area.

3.2 Effect of plant growth due to air pollution

3.2.1 Leaf Area Index (LAI)

LAI values observed for HD2967 and HD3086 from the vegetative to the milking stage were 1.2 - 4.7, 1.2 - 4.1 respectively (Figure 3, a, b, c, b). Maximum and minimum LAI for HD2967 and HD3086 was recorded at milking stage and vegetative growth stages at Bahadurpur and Parwaha site, respectively. The results obtained for cultivars, SPM deposition and LAI were negatively correlated in year 2015-16 and 2016-17. Reduction of LAI was observed in the study area due to the impact of dust deposition on wheat cultivars in leeward direction as compared to control sites. Similar trends were found by other studies (Bharti *et al.,* 2018; Yadav *et al.,* 2019).

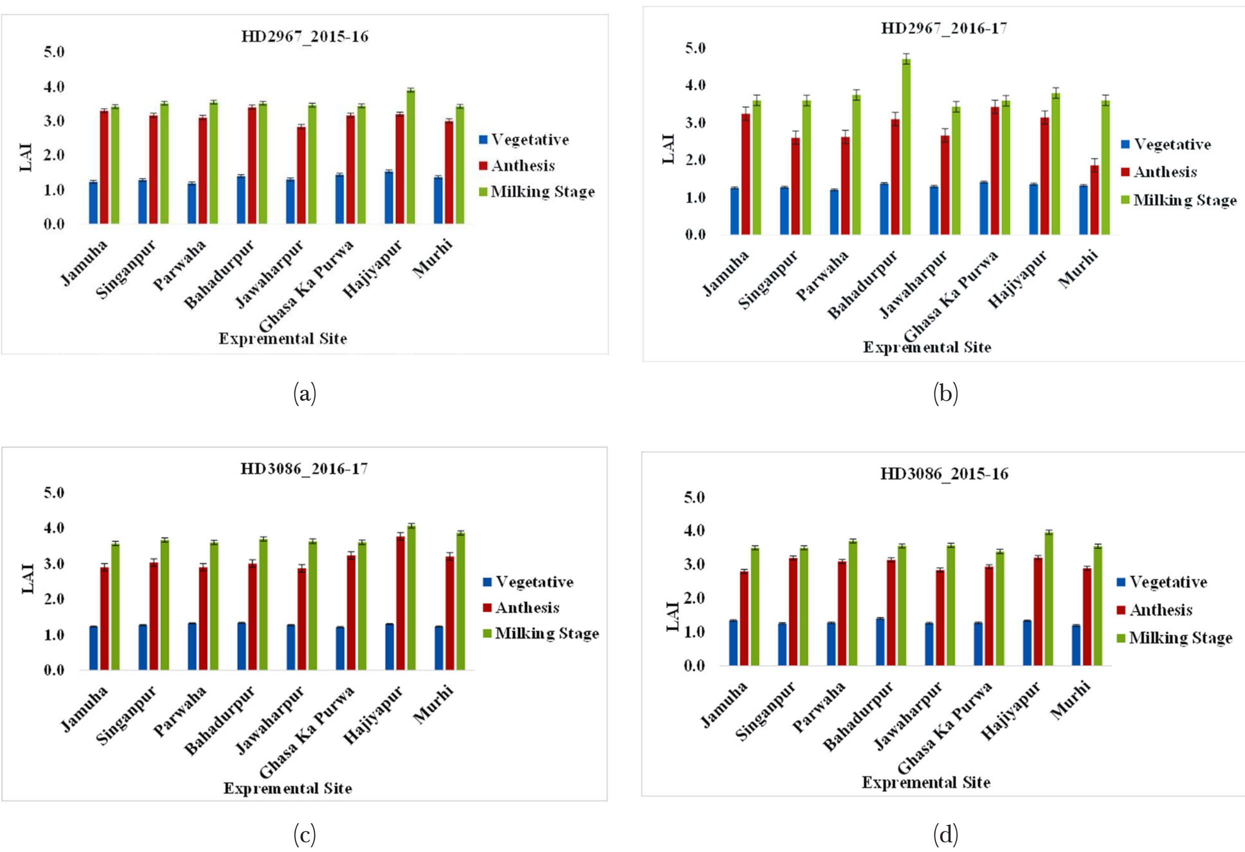

Figure 3. LAI of wheat cultivars HD2967 (a and b) and HD3086 (c and d) at the selected site during crop period 2015-16 and 2016-17 respectively

3.3 Impact of air pollution on the biochemical parameter and APTI

3.3.1 Ascorbic Acid (AA)

AA range observed for HD2967 and HD3086 was 57 – 68 mgg^{-1} and 54 – 65 mgg^{-1} respectively (Supplementary table 3 & 4). AA content of wheat cultivars on flag leaves was observed to be more at the exposed site of the air shed containing elevated ambient levels as compared to sites where the ambient levels of TSPM, NO_2 and O_3 pollutants were low. It indicates that, as the pollution load increases, ascorbic acid content in the crop leaf also increases in order to combat the stressed condition. Increased ascorbic acid content maintains cell division and cell membrane stability in plants by scavenging free radicles and reactive oxygen species (Bharti *et al.,* 2018; Sofia *et al.,* 2019). Plants with high ascorbic acid content are tolerant to any stress as compared to plants with low levels of ascorbic acid content (Prajapati *et al.,* 2012)

3.3.2 pH

pH values observed for HD2967 and HD3086 were in the range of 6.6 – 7.2 and 6.5 - 7.1 respectively (Supplementary table 3 & 4). Maximum and minimum pH values for HD2967 and HD3086 were recorded at the Jamuha and Murhi sites, respectively. Results of the present study show that the pH level significantly increased in the leeward wind direction within 2-5 km. pH is the indication of the sensitivity of the plant upon exposure to pollution (Lakshmi *et al.,* 2009; Rai and Panda, 2014). The findings of our study are in agreement with several other studies reporting basic pH of the leaf extracts near the pollution source while some also reported an inconsistent trend of variations with increasing distance away from the source (Khalid-Sofia, 2019).

3.3.3 Total Chlorophyll (TC)

TC range observed for HD2967 and HD3086 was 0.23 – 0.35 and 0.28 - 35 mgg^{-1} respectively (Supplementary table 3 & 4). Maximum and minimum TC for HD2967 and HD3086 was recorded at the Hajiyapur and Singanpur sites, respectively. The reduction in chlorophyll content of wheat cultivars is regarded as the index of productivity while also being suggestive of photosynthetic activity, growth, and biomass (Gangawane *et al.,* 2007). Chlorophyll is very sensitive to the exposure of pollutants and most liable to be damaged by pollution loads, variation of chlorophyll content in the plants that were studied might be due to the increased pollution level near the source (Khalid-Sofia, 2019).

3.3.4 Relative Water Content (RWC)

RWC range observed for HD2967 and HD3086 was 44 - 62 % and 53 - 62 % respectively (Supplementary table 3 & 4). Maximum and minimum RWC for HD2967 and HD3086 was recorded at the Ghasa ka purwa and Jamuha sites, respectively. The high relative water content in the presence of high pollution is an indication of greater tolerance shown by plants. The findings of the current study are supported by other studies which state that crops are adversely affected by air pollution (Seyyednejad *et al.,* 2017).

3.3.5 Air Pollution Tolerance Index (APTI)

APTI range for HD2967 and HD3086 was 47 - 64 and 56 -72 respectively (Supplementary table 3 & 4). APTI values indicates air pollution tolerance of HD3086 was more than that of HD2967. Several researchers have used the APTI to categorize plant species into three categories viz. sensitive, intermediate, and tolerant (Bharti *et al.,* 2018). Plants with APTI value ≤11 are considered to be sensitive while those with APTI values between 12 and 16 are classified as intermediate and finally, plants with APTI values ≥17 are known to be tolerant (Khalid-Sofia, 2019).

3.3.6 Dust deposition on flag leaves in wheat cultivars

The range of dust deposition in the flag leaves for HD2967 was 2.5 - 2.9 $mgcm^{-2}$ and HD3086 2.1 – 2.8 $mgcm^{-2}$ during the study period of 2015-2017 (Supplementary table 2). Crops growing in agricultural fields at the air shed constantly absorb, accumulate, and integrate pollutants impinging on their foliar surface. This is established in present study by recording PM deposition on wheat cultivars grown on the selected farm fields. dust deposition per unit area was high on HD2967 as compared to HD3086. On comparing agricultural fields, dust deposition was found to be more on the fields located at 0-4 km distance and less on fields located at 7-10 Km distance on the windward and leeward sides respectively. (Chaphekar *et al.,* 2021; Chakrabarti *et al.,* 2014) also reported a similar variation in dust deposition on vegetation and crops grown in the vicinities of the Mirzapur and Dadri TPPs, respectively.

3.3.7 Effect of selected air pollutants and dust deposition on grain yield of wheat cultivars

Average grain yield of HD2967 and HD3086 was 455.0 - 478.4 gm^{-2} and 450.5 - 497.8 gm^{-2} respectively (Table 3). It was more for HD3086 as compared to HD2967. Maximum and minimum yield for HD2967 and HD3086 was recorded at the Murhi and Jamuha sites, respectively. In our experiment, we found that dust deposition significantly affected the grain of the crops. Five villages surrounding the thermal power plant at the experimental area (Jamuha, Singanpur, Parwaha, Bahadurpur and Jawaharpur) witnessed a reduction in yield due to dust deposition. Reduction of HD2967 yield was recorded in Jamuha (6.5%, 4.0%), Singanpur (4.3%, 8.0%), Parwaha (5.6%, 4.9%), Bahadurpur (4.1%, 2.5%) and Jawaharpur (5.6%, 4.7%) whereas HD3086 yield reduction was observed at Jamuha (9.1%, 4.8%), Singanpur (4.8%, 7.4%), Parwaha (8.1%, 3.4%), Bahadurpur (3.5%, 2.0%), and Jawaharpur (3.4%, 2.4%) (Supplementery table 5) with respect to control site Haziyapur. High yield reduction with respect to both cultivars was recorded at Jamuha and Singanpur. (Chakrabarti *et al.,* 2014; Raja *et al.,* 2014) Studies have reported the highest yield reductions on the leeward side and lowest yield reductions on the windward side of the TPP.

Table 3. Grain yield of wheat cultivars HD2967 and HD3086

	HD2967		HD3086	
	2015-16	2016-17	2015-16	2016-17
Experimental Site	**Grain Yield (gm-2)**	**Grain Yield (gm-2)**	**Grain Yield (gm-2)**	**Grain Yield (gm-2)**
Jamuha	465.7±6.9	455.0±19.2	450.8±15.8	463.1±8.9
Singanpur	473.5±7.6	455.7±10.9	470.9±13.5	452.0±12.3
Parwaha	465.4±5.4	465.0±10.0	470.3±8.6	466.9±8.7
Bahadurpur	459.1±6.7	450.3±10.8	474.5±15.5	463.7±6.1
Jawaharpur	472.7±7.1	456.0±18.5	478.3±13.5	457.1±6.5
Ghasa ka purwa	468.1±6.5	455.4±18.8	487.8±6.2	474.9±13.5
Hajiyapur	483.9±11.2	468.5±19.0	496.9±5.7	458.7±4.5
Murhi	478.4±10.4	458.7±14.2	495.4±14.2	497.8±5.8

4. Conclusion

Air pollutants are a matter of serious concern due to its phytotoxicity leading to yield reductions and effects along biochemical parameters. Emission of air pollutants at the study area is due to industrial activity, automobiles, and a few bricks kilns. This study showed that the deposition of dust on leaves impact their biochemical parameters and affect yield reduction at the selected site which is nearer to the thermal power plant as compared to the control site. At this study area, phytotoxic air pollutants like Nitrogen Dioxide (NO_2) and Ozone (O_3) were found to be present under the threshold limit, these pollutants non-significantly impact biochemical parameters and yield. The impact of dust deposition on biochemical parameters and Leaf Area Index (LAI) was greater at those study sites which were around 2-4 km from the thermal power plant as the dust disposition was more in these areas in comparison with the control site. In view of rising air pollutants and dust deposition at the experimental site, a few mitigative steps should be taken for reducing air pollutants and dust deposition in these areas. This can be achieved by developing new pollution resistant varieties of wheat cultivars, and by adopting innovative agricultural management techniques in order to reduce the impact of dust deposition and phytotoxic air pollutants at the experimental area.

Abbreviations

TC: Total chlorophyll; AA; Ascorbic Acid; RWC: Relative water Content; APTI: Air Pollution tolerance Index; SPM: Suspended Particulate Matter; O3: Ozone; NO_2: Nitrogen Dioxide; LAI; Leaf Area Index; Pr: Photosynthetic Rate; TPP: thermal Power Plant;

Availability of data and materials

The data set used and/or analyzed during the current study are available from the corresponding author on reasonable request

Declaration

Conflict of Interest

The authors declare no conflict of interest

Consent for publications

All author agreed and approved the manuscript for publication in Physiology and Molecular Biology of Plants

5. References

1. Yadav A, S Kumar, V and B Singh. 2019. The effects of elevated CO2 and elevated O3 exposure on plant growth, yield and quality of grains of two wheat cultivars grown in north India. *Heliyon*, **5(8)**: https://doi.org/10.1016/j.heliyon.2019.e02317
2. Adrees M, M Ibrahim, AM Shah, F Abbas, F Saleem, M Rizwan, S Hina, F Jabeen and S Ali. 2016. Gaseous pollutants from brick kiln industry decreased the growth, photosynthesis, and yield of wheat (*Triticum aestivum* L.). *Environmental Monitoring and Assessment*, **188(5)**. https://doi.org/10.1007/s10661-016-5273-8
3. Aghajanzadeh T, MJ Hawkesford and LJ Dekok. 2016. Atmospheric H_2S and SO_2 as sulfur sources for *Brassica juncea* and *Brassica rapa*: Regulation of sulfur uptake and assimilation. *Environmental and Experimental Botany*, (**124**): 1-10.
4. Chaphekar SB, RP Madav and SS Ghate. 2021. Green Belts for Sustainable Improvement of Air Quality. *Handbook of Ecological and Ecosystem Engineering*, 423-435. https://doi.org/10.1002/9781119678595.ch23
5. Agrawal M, B Singh, M Rajput, F Marshall and JNB Bell. 2003. Effect of air pollution on peri-urban agriculture: a case study. *Environmental Pollution*, **126(3):** 323-329.
6. Balasubramaniam K, TMS Atukorala, S Wijesundera, AA Hoover and MAT DeSilva. 1973. Biochemical changes during germination of the coconut (*Cocos nucifera*). *Annals of Botany*, **37(3):** 439-445. https://doi.org/10.1093/oxfordjournals.aob.a084710
7. Bharti SK, A Trivedi and N Kumar. 2018. Air pollution tolerance index of plants growing near an industrial site. *Urban Climate*, **(24):** 820-829.
8. Chakrabarti B, R Singh, A Bhatia, SD Singh and B Singh. 2014. Impact of aerial deposition from thermal power plant on growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, **84(5):** 54–58.
9. Chauhan A. 2010. Effect of ambient air pollutants on wheat and mustard crops growing in the vicinity of urban and industrial areas. *New York Science Journal*, **3(2):** 52–60. http://www.sciencepub.net/newyork/ny0302/09_1234_Effect_ny0302
10. Duncan J. 2013. *Assessing the vulnerability of the rice-wheat production system in the north-west Indo-Gangetic Plains to climatic drivers* (Doctoral dissertation, University of Southampton). http://eprints.soton.ac.uk/id/eprint/365371
11. Feng Z, A DeMarco, A Anav, M Gualtieri, P Sicard, H Tian and E Paoletti E. 2019. Economic losses due to ozone impacts on human health, forest productivity and crop yield across China. *Environment International*, **131:** 104966.
12. Foley JA, N Ramamurthy, KA Brahman, ES Cassidy, JS Gerber, M Johnston and C Balzer. 2011. Solutions for a Cultivated Planet. *Nature*, **478:** 337-342.
13. Gangawane LV and VC Khilare. 2007. Sustainable Environmental Management: Dr. Jayashree Deshpande Festschrift Volume. *Daya Books*, 2007. https://doi.org/10.1002/2014GL060930.
14. Ghosh Annesha, M Agrawal and SB Agrawal. 2021. Examining the effectiveness of biomass-derived biochar for the amelioration of tropospheric ozone-induced phytotoxicity in the Indian wheat cultivar HD 2967. *Journal of Hazardous Materials*, **408:** 124968. https://doi.org/10.1016/j.jhazmat.2020.124968.
15. Joshi N, A Chauhan and PC Joshi. 2009. Impact of industrial air pollutants on some biochemical parameters and yield in wheat and mustard plants. *The Environmentalist*, **29(4):** 398-404. https://doi.org/10.1007/s10669-009-9218-4.
16. Khan T, M Mazid and F Mohammad F. 2011. A review of ascorbic acid potentialities against oxidative stress induced in plants. *Journal of Agrobiology*, **28(2):** 97. 10.2478/v10146-011-0011-x.
17. Khanoranga and S Khalid. 2019. Phytomonitoring of air pollution around brick kilns in Balochistan province Pakistan through air pollution index

and metal accumulation index. *Journal of Cleaner Production*, **229:** 727–738.

18. Lakshmi PS, KL Sravanti and N Srinivas. 2009. Air pollution tolerance index of various plant species growing in industrial areas. *The Ecoscan*, **2(2):** 203-206.

19. Liu B, P Martre, F Ewert, JR Porter, AJ Challinor, C **Müller,** AC Ruane, K Waha, PJ Thorburn, PK Aggarwal, M Ahmed, J Balkovi , B Basso, C Biernath, M Bindi, D Cammarano, G DeSanctis, B Dumont, M Espadafor and S Asseng. 2019. Global wheat production with 1.5 and 2.0°C above pre-industrial warming. *In Global Change Biology,* **25(4):** https://doi.org/10.1111/gcb.14542.

20. Leitch H, V Ahuja and M Jabbar. 2014. India's Livestock Sector: Demand Growth, Food Security and Public Investment–Issues and options. Prepared for the World Bank, Washington DC, USA.

21. López J, DA Way and W Sadok. 2021. Systemic effects of rising atmospheric vapor pressure deficit on plant physiology and productivity. *Global Change Biology*, **27(9):** 1704-1720.

22. Mir SA, JIA Bhat, F Lone, MU Rehman, N Nazir, AA Lone, T Ali and A Jehangir, A. 2021. Synergistic effects of vehicular emissions (NO2, SO2 and SPM) on progression of *Crocus sativus* L.in Saffron bowl Kashmir. *Environmental Advances*, **3(2):** 100033. https://doi.org/10.1016/j.envadv.2021.100033.

23. Mohamed AMO, MA Maraqa, FM Howari and EK Paleologos. 2021. Outdoor air pollutants: sources, characteristics, and impact on human health and the environment. *Pollution Assessment for Sustainable Practices in Applied Sciences and Engineering*, 491-554. https://doi.org/10.1016/B978-0-12-809582-9.00009-8.

24. Prajapati SK. 2012. Ecological effect of airborne particulate matter on plants. *Environ Skeptism Critism*, **1:** 12-22.

25. Priyadarshini P and C Sahu. 2019. Comparative assessment of biochemical parameters of plants in industrial and non-industrial areas of Western Odisha, India. *Nature Environment and Pollution Technology*, **18(4):** 1363–1368.

26. Raja R, AK Nayak, KS Rao, C Puree, M Shahid, BB Panda and B Lal. 2014. Effect of fly ash deposition on photosynthesis, growth and yield of rice. *Bulletin of Environmental Contamination and Toxicology*, **93(1):** 106-112. https://doi.org/10.35709/ory.2020.57.4.4.

27. Rai PK, LLS Panda, BM Chutia and M M Singh. 2013. Comparative assessment of air pollution tolerance index (APTI) in the industrial (Rourkela) and non industrial area (Aizawl) of India : An eco- management approach. *African Journal of Environmental Science and Technology*, **7:** 944–948. https://doi.org/10.5897/AJEST2013.1532.

28. Rai R, M Rajput, M Agrawal and SB Agrawal. 2011. Gaseous Air Pollutants : a Review on Current and Future Trends of Emissions and Impact on Agriculture. *Journal of Scientific Research*, **55(771):** 1.

29. Roy CA and DK Tripathi. 2019. *Molecular Plant Abiotic Stress.* Wiley. 10.1002/9781119463665.

30. Sen A, I Khan, D Kundu, K Das and JK Datta. 2017. Eco physiological evaluation of tree species for biomonitoring of air quality and identification of air pollution-tolerant species. *Environmental Monitoring and Assessment*, **189(6):** 262. 10.1007/s10661-017-5955-x.

31. Singh B, N Kaur, RIS Gill and JC Dagar. 2016. Agroforestry for crop diversification and carbon sequestration. *Agroforestry Research Developments*, **99.**

32. Singh T, A Biswal, S Mor, K Ravindra, V Singh and S Mor. 2020. A high-resolution emission inventory of air pollutants from primary crop residue burning over Northern India based on VIIRS thermal anomalies. *Environmental Pollution*, **266.** https://doi.org/10.1016/j.envpol.2020.115132.

33. Singh AA and SB Agrawal. 2017. Tropospheric ozone pollution in India: Effects on crop yield and product quality. *Environmental Science and Pollution Research,* **24(5):** 4367-4382. https://doi.org/10.1007/s11356-016-8178-8.

34. Skinder BM, AQ Sheikh, AK Pandit and BA Ganai. 2014. Brick kiln emissions and its environmental impact: A Review. *Journal of Ecology and The Natural Environment*, **6(1):** 1-11. https://doi.org/10.5897/JENE2013.0423.

35. Singh SN and A Verma. 2007. Phytoremediation of air pollutants: a review. *Environmental Bioremediation Technologies*, 293-314. https://doi.org/10.1007/978-3-540-34793-4_13.

36. Seyyednejad, M Seyyed, M Hossein and L Parinaz. 2017. Biochemical changes of *Conocarpus erectus* (combretaceae) in response to gas refinery air pollution as an air pollution indicator. *Pollution*, **3(2):** 185-190.

37. Singh S, B Pandey, LB Roy, S Shekhar and RK Singh. 2021. Tree responses to foliar dust deposition and gradient of air pollution around opencast coal mines of Jharia coalfield, India: gas exchange, antioxidative potential and tolerance level. *Environmental Science and Pollution Research*, **28(7):** 8637-8651. https://doi.org/10.1007/s11356-020-11088-1.

38. Mina U, TK Chandrashekara, SN Kumar, MC Meena, S Yadav, S Tiwari and R Kumar. 2018. Impact of particulate matter on basmati rice varieties grown in Indo-Gangetic Plains of India: Growth, biochemical, physiological and yield attributes. *Atmospheric Environment,* **188:** 174-184. https://doi.org/10.1016/j.atmosenv.2018.06.015.

39. Watson AS. 2021. Phytoremediation for urban landscaping and air pollution control - a case study in Trivandrum city, Kerala, India. *Environmental Science and Pollution Research*, **28(8):** 9979-9999.