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Impact of aerial deposition from thermal power plant on growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*)

B CHAKRABARTI[1], R SINGH[2], A BHATIA[3], S D SINGH[4] and B SINGH[5]

Centre for Environment Science and Climate Resilient Agriculture, Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

Thermal power plants (TPP) are a major source of air pollutants particularly suspended particulate matter (SPM) which either remains suspended in air or gets deposited onto soil surface and crop canopy in adjoining areas thereby affecting the growth and productivity of crops. Keeping this in view, a study was undertaken near Dadri TPP situated at NTPC Dadri, Uttar Pradesh, to assess the impact of aerial deposition on crops grown in adjoining areas. Eight different locations situated in different villages located at varying distance within 1-10 km radius were selected for study. Rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) fields were identified in the selected villages and their growth and yield parameters were recorded during the entire crop duration. Aerial deposition load on crop canopy was also quantified. Results showed that rice and wheat crops grown nearer to the TPP were most affected in terms of reduction in growth and yield as compared to fields located at far off distances. This was attributed to the deposition of SPM on rice and wheat leaves, which reduced photosynthesis rate leading to lower leaf area index, biological and grain yield of both the crops. In wheat crop, aerial deposition load on leaves was found to be more than rice at all stages. Reduction in grain yield in rice within10 km radius were 13.5% and 20.4%, while in wheat reduction were 21.9% and 19.1% in first and second year of study, respectively. The zone of 1 to 3 km radius from the TPP was found to be most vulnerable in terms of yield loss both in rice and wheat crops. In this zone some more resistant alternative crops can be grown which will help farmers to increase their productivity and income.

Key words: Aerial deposition, Rice, Thermal power plant and Wheat

Impact of anthropogenic activities, especially in form of atmospheric pollution, is one of the important concerns throughout the world (Hindy and Farag 1983, Raoof and Al-Shahhaf 1992). Aerial deposition emitted from varying sources adversely affect growth and yield of crops. Effects of air pollutants have been described in terms of inhibition in physiological processes (Agrawal *et al.* 2003, Verma *et al.* 2000), alteration in metabolic functions and enzyme activities (Loewus *et al.* 1990), nutrient uptake (Agrawal and Verma 1997) and suppression of growth and yield (Agrawal *et al.* 2003). During recent years, anthropogenic activities have dramatically increased the atmospheric deposition of pollutant elements even in areas far away from direct human influence (Pandey 2005). Current pollutant concentrations experienced in many developing countries, particularly Asia can result in severe damage to vegetation (Emberson *et al.* 2001). A study conducted by Rajput and Agrawal (2005) also showed that wheat plants are negatively affected by the ambient levels of air pollutants. Suspended particulate matter (SPM), emitted from various sources remain in the air for varying length of time. Those larger than 10 µm in size settle under forces of gravity on surfaces of vegetations and soil but the smaller ones remain suspended in air for longer periods of time, get dispersed and diffused by the wind, and eventually deposited on various surfaces including foliar ones (Rao 1985). Considerable amount of damage is caused to vegetation by the particulate matter showing physical damage of leaves as a result of dust deposition, inhibition of photosynthetic activities and protein synthesis as well as susceptibility to injuries caused by microorganisms and insects (Saha and Padhy 2011). Dusts effects on vegetation may be connected with the decrease in light available for photosynthesis, an increase in leaf temperature due to changed surface optical properties, and interference with the diffusion of gases into and out of leaves (Prajapati 2012).

In order to meet the industrial, domestic and agricultural electricity requirements of a very large population, number of new thermal power plants (TPPs) and capacities of existing TPPs are being increased in recent past in the

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[1]Senior Scienctist (e mail: bidisha2@yahoo.com), [2]Scienctist (e mail: renu_icar@yahoo.com), [3]Principal Scientist (e mail: abensc@gmail.com), [4]Head (e mail: sdsingh16b@yahoo.in), [5]Principal Scientist (e mail: bhupindersingh@hotmail.com)

country (Sharma and Tripathi 2009). Thermal power plants (TPP) are a major source of air pollutants particularly SPM which remains suspended in air and also gets deposited in adjoining areas. Reports have shown, that air and soil quality around Indian thermal power plants are deteriorating at measurable rate (Sharma and Tripathi 2008a, b). Agricultural fields located near TPP get affected by this air borne deposits which affect crop growth and yield. Field transect studies have highlighted adverse plant responses to dust. Purushothamanan *et al.* (1996) found that spatial variation in foliar dust deposition and yield were correlated. Singh *et al.* (1991) have shown yield reductions in several field grown crops in the vicinity of Obra thermal power plant in Obra- Renukoot- Singrauli area of the Sonbhadra district in India. In situ experiments have advantage of being performed under natural condition for quantifying the measurable impacts of pollutants on plants growing in their natural habitats (Pandey and Pandey 1994). The following study was undertaken to assess the impact of aerial deposition released from TPP on growth and yield of rice and wheat crop.

MATERIALS AND METHODS

The study area was selected near Dadri TPP situated in western Uttar Pradesh, India. The study was conducted for two consecutive years, i.e. 2010 and 2011. Eight different locations situated in different villages located at varying distance within 1-10 km radius were selected for the study. Initial soil samples were collected from the fields located at varying distances from the TPP. Soil samples were analyzed for pH, N, P, K, and soil organic carbon content. Soils were found to be alkaline with pH ranging from 7.7-9.0. Total nitrogen content of soils ranged from 0.06 to 0.07%, available phosphorus (P_2O_5) was 21.2 to 24.5 kg/ha and available potassium (K_2O) ranged from 143.2 to 156.7 kg/ ha. Soil organic carbon content was 0.35 to 0.4%.

During the months of July to October rice crop was grown in the study area while wheat crop was grown during November to April. Farmers were mainly growing Pusa 1121 variety of rice and PBW 343 variety of wheat crop. Transplanting of rice seedlings was done during second fortnight of July. Rice was grown as irrigated crop and fields were flooded to maintain standing water of 4-5 cm. Wheat sowing was done in the second week of November. Nitrogen was mostly applied as urea (120 kg N/ha) in both the crops. Three to four farmers' fields were identified in each village growing same crop variety and following almost similar crop management practices. Fields were visited at monthly interval for recording growth, and yield parameters of rice and wheat plants. Photosynthesis rate was recorded at vegetative and flowering stages using portable Infra Red Gas Analyzer (IRGA) (LI6400, LICOR, USA). Leaf samples were collected at flowering stage for determination of leaf area index (LAI). In each plot five hills were selected and leaves were collected from each hill. Length (L) and maximum width (W) of leaves was determined for each leaf. Leaf area was then calculated as:

Leaf area = L × W × K, where K is 0.75 (Bhan and Pande 1966, Palaniswamy and Gomez 1974).

LAI was calculated by dividing total area by the area covered by leaves of rice and wheat plants. During harvesting of rice and wheat in the month of October and April respectively, plant samples were collected from three representative locations of 1 m^2 area in each farmers' field. Biomass as well as grain weight were recorded and yield of both the crops was calculated.

Deposition of dust on crop canopy was also quantified by collecting dust load on plant leaves and measuring the amount as per the methodology of Prusty *et al.* (2005). Leaf samples from different heights were randomly collected in a beaker and washed thoroughly by a hairbrush with distilled water. The water in the beaker was completely evaporated in an oven at 100°C and weighed.

Dust load was quantified by the following equation:

$$W = (w_2 - w_1) / A$$

where W, amount of dust load (mg/cm^2)' w_1, initial weight of beaker with dust; w_2, final weight of the beaker with dust; A, total area of the leaf (cm^2).

RESULTS AND DISCUSSION

Effect of aerial deposition on photosynthesis

Results showed that photosynthesis rate was affected markedly by air pollution. Crops grown nearer to the TPP showed lower photosynthesis rate than crops grown far off. At both vegetative and flowering stages similar trend in photosynthesis rate was observed. At vegetative stage photosynthesis rate of rice crop was maximum (10.3 and 11.8 $\mu mol/m^2/s$) at 8 km and 10 km respectively in first and second year of the study, while it was lowest at 1 km distance from TPP (Fig 1a). Similar trend was observed at flowering stage when photosynthesis rate was maximum (19.0 and 18.1 $\mu mol/m^2/s$) at 10 km distance in both the years (Fig 1b). Photosynthesis in wheat crop was also more at 10 km than at 1 km distance (Fig 2a and 2b). Reduction in photosynthesis was more in 1 to 3 km zone for both the crops. Crops grown up to 3 km distance from TPP had significantly lower photosynthesis rate than crops grown at a larger distance. Reduction in photosynthesis was attributed to deposition of air pollutants on crop canopy. In case of both the crops aerial deposition load on crop canopy was higher in locations nearer to the TPP. In rice crop aerial deposition on leaves at vegetative stage were 0.44 and 0.52 mg/cm^2 at 1 km distance while at 10 km distance it was 0.08 and 0.02 mg/cm^2 in first and second year of study respectively (Fig 1a). Similar trend in aerial deposition on rice leaves was also observed at flowering stage. In wheat crop aerial deposition load on leaves was found to be more than rice at both the stages. This is due to the fact that wheat is grown in the winter months when rainfall is much less than the *kharif* season when rice is grown. Higher rainfall in *kharif* might have washed out some of the deposition on rice leaves. In wheat crop deposition was more at nearer

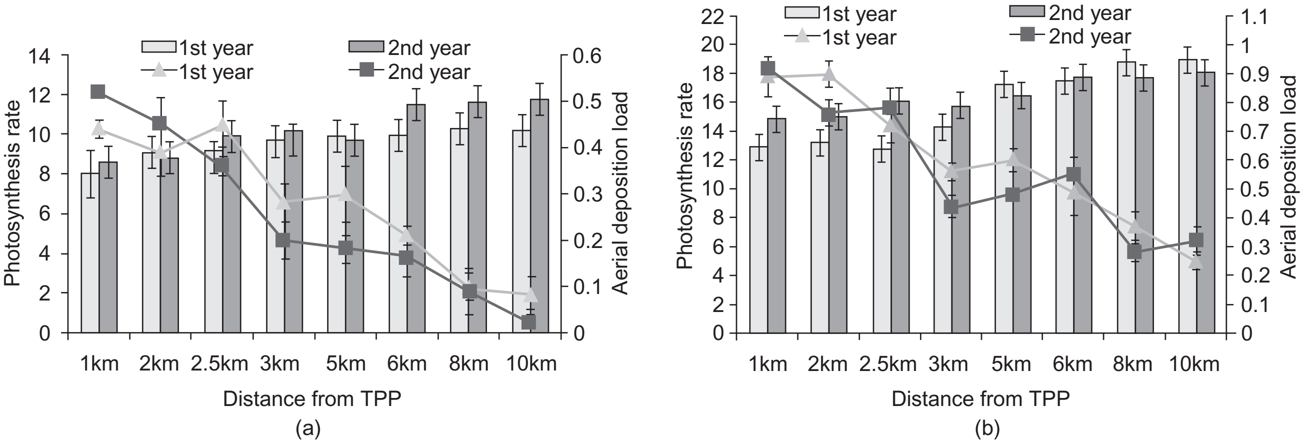

Fig 1 Aerial deposition load (mg/cm^2) on crop canopy and photosynthesis rate (μmol/m^2/s) of rice crop at (a) vegetative and (b) flowering stages

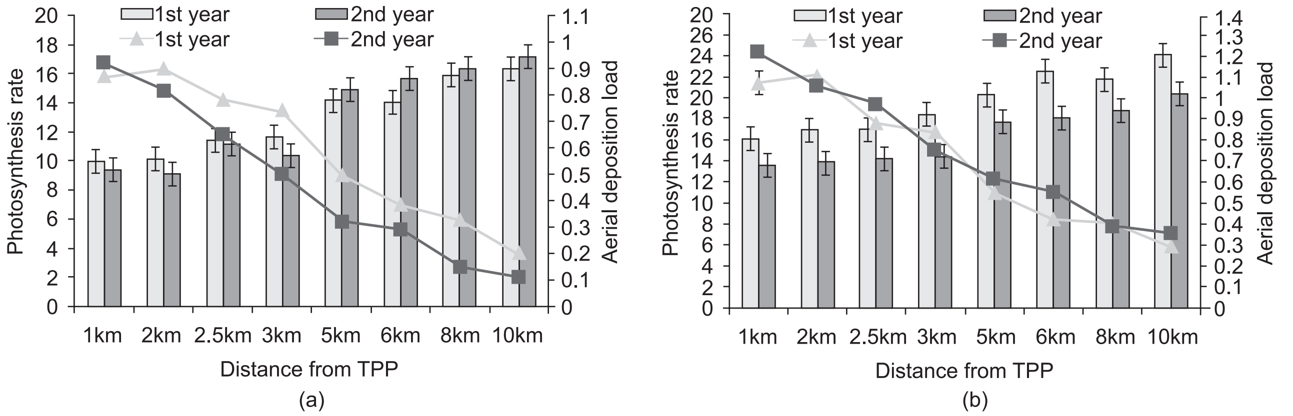

Fig 2 Aerial deposition load (mg/cm^2) on crop canopy and photosynthesis rate (μmol/m^2/s) of wheat crop at (a) vegetative and (b) flowering stages

distance. At flowering stage of wheat crop, deposition load on leaves was 1.07 and 1.22 mg/cm^2 at 1 km distance from TPP in first and second year of study respectively (Fig 2b). These deposited particles prevented free air exchange between plant leaves and the atmosphere, thereby suppressing the rate of photosynthesis. According to Prajapati (2012), dust accumulating on leaf surfaces of trees may interfere with gas diffusion between leaf and air. Dust deposited on leaf surface also alters its optical properties, particularly the surface reflectance in the visible and short wave infrared radiation range (Eller 1977, Keller and Lamprecht 1995) and the amount of light available for photosynthesis gets decreased. Higher aerial deposition rate in wheat growing season might be attributed to the fact that less rainfall events during the winter months has led to more aerial deposition load on crop canopy. In case of rice crop more frequent rainfall during the *kharif* season might have washed out some of the deposited particles leading to less deposition load on rice leaves.

Effect of aerial deposition on Leaf Area Index

Reduction in photosynthesis rate was reflected in growth and leaf area of both rice and wheat crops. At flowering stage maximum Leaf Area Index (LAI) of rice plants was recorded to be 3.5 and 3.28 at 10 km distance from TPP. At nearer locations LAI was much less in both the years. In wheat crop LAI was 4.1 at 10 km distance during the first year, while at 2 km distance it was 2.1. During second year LAI of wheat was maximum (3.9) at 8 km distance. This showed that plants grown at a larger distance from the TPP had better growth in terms of leaf area.

Effect of aerial deposition on biomass and yield

Higher photosynthesis rate and larger leaf area of crops led to more biomass accumulation. This was reflected in the data on biological yield of rice and wheat crop. In rice, biological yield was maximum (7 400 kg/ha) at 10 km distance, while it was minimum (6 100 kg/ha) at 1 km distance during the first year of study (Table 1). In the second year rice biomass was highest (7 450 kg/ha) at 8 km distance, while least biomass (5 580 kg/ha) was recorded in fields located at 2 km distance from the TPP (Table 1). Overall there was 17.6% and 23.7% reduction in biological yield of rice between fields located at 1 km and 10 km distance in the first and second year respectively. In wheat biological yield was maximum (9 200 and 10 100 kg/ha) at

Table 1 Biological and grain yield of rice and wheat crops grown in villages adjacent to TPP

Distance from TPP (km)	Biological yield (kg/ha)				Grain yield (kg/ha)			
	1st Year		2nd Year		1st Year		2nd Year	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
1	6 100	6 950	5 640	8 000	2 810	3 320	2 460	3 720
2	6 330	7 200	5 580	7 860	2 800	3 390	2 500	3 770
2.5	6 300	7 290	5 960	7 990	2 820	3 510	2 820	3 860
3	6 550	7 500	6 130	8 400	2 980	3 490	2 760	3 870
5	6 780	8 560	6 850	9 010	2 990	3 800	3 040	4 180
6	7 400	9 200	7 050	9 500	3 290	3 850	3 110	4 380
8	7 250	9 000	7 450	9 560	3 280	4 050	3 120	4 580
10	7 400	9 200	7 390	10 100	3 250	4 250	3 090	4 600
LSD (P = 0.05)	300	370	280	340	120	210	160	200

10 km distance in first and second year respectively. In case of wheat reduction in biological yield was 24.5% and 20.8% respectively in the two years of study.

Grain yield was also found to be less in locations nearer to the TPP in both the crops. Grain yield of rice was found to be minimum (2 800 and 2 460 kg/ha) at 1-2 km distance from TPP in first and second year respectively (Table 1). Reduction in grain yield with 10 km distance was 13.5% and 20.4% in first and second year respectively. In wheat also grain yield was lowest (3 320 and 3 720 kg/ha) at 1 km distance in both the years (Table 1). There was reduction in wheat grain yield by 21.9% and 19.1% with increase in distance by 10 km in first and second year respectively. Results showed that yield reduction in both the crops was recorded to be highest in 1 to 3 km zone of TPP indicating the zone near the TPP is most vulnerable for growing crops.

Field transect studies conducted by Purushothaman *et al.* (1996) also found that spatial variation in foliar dust deposition and yield were correlated. Similar results were reported by earlier workers. In a gradient study, yield losses of 30 to 50% were recorded in wheat, depending upon the distance from coal fired power plants where the main pollutant was SO_2 (Agrawal 2005). Singh *et al.* (1991) studied growth of rice crops growing at different locations around Dala cement factory and found that vegetative and reproductive parts accumulated significantly lower biomass (44 and 60% respectively) at sites 1 km from the factory receiving high dust load.

Table 2 Correlation between different plant characteristics and aerial deposition load in rice and wheat crop

Plant characteristics	Correlation coefficient	
	Deposition load in rice leaves	Deposition load in wheat leaves
Photosynthesis rate	–0.81	–0.84
LAI	–0.85	–0.93
Biological yield	–0.80	–0.87
Grain yield	–0.74	–0.78

In the present study deposition of aerial pollutants on crop canopy was found to be the main reason for yield decline in both rice and wheat crops. Plant characteristics like photosynthesis rate, LAI, biological yield and grain yield were found to be negatively correlated with aerial deposition load on plant leaves. Correlation coefficient (r) between deposition load and photosynthesis rate was –0.81 and –0.84 in rice and wheat crops respectively (Table 2). Maximum negative correlation (r= –0.93) was observed between aerial deposition load and LAI of wheat crop suggesting that leaf area in wheat crop was most affected by the deposition of air pollutants. Grain yield of rice and wheat had correlation coefficient of –0.74 and –0.78 respectively with aerial deposition.

CONCLUSIONS

Air pollutants released from TPP are of major concern. Agricultural fields located in areas adjacent to TPP get affected severely by the emission. Following study was aimed to quantify the impact of air pollutants released from TPP on rice and wheat crops. Results showed that growth, yield and physiological processes of rice and wheat plants were harmfully affected due to the aerial deposition of air pollutants on crop canopy. A zone of 1 to 3 km radius from the TPP is most vulnerable in terms of yield loss of rice and wheat crops. In this zone some alternative crops can be grown which are more resistant to aerial deposition. This can help farmers of those areas to increase their productivity and income.

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