Performance of locally grown rice plants (*Oryza sativa* L.) exposed to air pollutants in a rapidly growing industrial area of district Haridwar, Uttarakhand, India

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Abstract

The different physiological parameters of rice plants exposed to ambient air pollution were determined at a site very close to an industrial area as well as at a site far from the industrial belt. Reduction in chlorophyll *a*, chlorophyll *b*, total chlorophyll content, ascorbic acid, carotenoid, pH, relative water content and APTI was recorded in the leaf samples of locally grown rice (*Oryza sativa*) plants collected from polluted area when compared with samples from control area. Highest reduction in total chlorophyll content (14.38%) was recorded during October, whereas, lowest reduction (7.38%) was recorded during July. In case of carotenoid content, highest reduction (13.39%) was observed during July, whereas lowest reduction was observed during August (9.29%). Number of grains per plant of rice was 6.15% less at polluted site as compared to control site, whereas grains per plant and weight of 1000 grains was 10.31% and 10.86% less at polluted site respectively, as compared to control site confirming the adverse impact of pollutants on the performance of the rice plants. [Life Science Journal. 2008; 5(3): 57 – 61] (ISSN: 1097 – 8135).

Keywords: pollution; rice plant; chlorophyll; yield

1 Introduction

Changes in the gaseous composition of earth's atmosphere due to human activities have become a prime concern for today's world. India and other developing countries have experienced a progressive degradation in air quality due to industrialization, urbanization, lack of awareness, number of motor vehicles, use of fuels with poor environmental performance, badly maintained poor roads and ineffective environmental regulations. The devastating effects of air pollutants inducing significant variations in the normal morphology and physiology of several sensitive plants have been reported by different workers[1–7]. 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)[8]. Chlorophyll is found in the chloroplasts of green plants and is called a photoreceptor. Chlorophyll itself is actually not a single molecule but a family of related molecules, designated as chlorophyll a, b, c, and d. Chlorophyll a is the molecule found in all plant cells and, therefore, its concentration is what is reported during chlorophyll analysis. Accessory pigments absorb energy that chlorophyll a does not absorb. Accessory pigments include chlorophyll b, xanthophylls and carotenoid. Carotenoids are a class of natural fat-soluble pigments found principally in plants, algae, and photosynthetic bacteria, where they play a critical role in the process of photosynthesis. Some 600 different carotenoids are known to occur naturally[9] and new carotenoids continued to be identified[10]. Ascorbic acid, a natural antioxidant in plants plays an important role in pollution tolerance[11].

Rice is undoubtedly the most important crop in Asia as its production accounts for more than 90% to total world output, to which over 99% was in South, Southeast and East Asia in 2000[12]. Despite differences in methodologies adopted, adverse impacts on rice growth and yield have been commonly observed in response to air pollut-

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ants in other Asian countries such as India[13–16], Japan[17,18], Malaysia[19] and Pakistan[20,21]. The present investigation has been undertaken to study the effect of different gaseous and dust pollutants on photosynthetic pigments and yield of locally grown rice (*Oryza sativa* L.), which is an important staple food crop of India and hence of great economic value.

2 Materials and Methods

2.1 Study area

The present study has been conducted in a rapidly expanding district of newly carved State of India, the Uttarakhand, and known as Haridwar. The district Haridwar extends between latitude 29º 58' in the north to longitude 78º 13' in the east. It is about 60 kms in length from east to west and about 80 kms in width from north to south. A massive industrial area, spread over 2034 acres, has been developed by State Industrial Development Corporation of Uttarakhand Limited (SIDCUL), a state government body and very big enterprises are working and functioning in SIDCUL, which is 3 km away from the Delhi-Hardwar National Highway. Sites selected for the present study were located near industrial area of SIDCUL (referred to as pollutes site) and near agricultural land (referred to as control site) about 4 km far from SIDCUL, Haridwar.

2.2 Monitoring of air pollutants

The concentration of NO_x and SO_2 was measured with standard methods[22,23]. SPM and respirable suspended particulate matter (RSPM) were determined using filter paper methods. Rice plant samples were analyzed at every 30 days of intervals. The samples (in ten replicates) were collected arbitrarily from control and polluted sites. The concentrations of chlorophyll a and b (mg/g fresh leaf) and caratenoids and ascorbic acid were determined by the standard method[24–26]. Relative water content was determined by method proposed by Weatherly[27]. pH of leaf extract was measured with a digital pH meter. Air pollution tolerance index (APTI) was estimated using the method of Singh and Rao[28]. For the plant materials two-way-analysis of variance (ANOVA) was performed. Least Significance Difference was calculated at 0.05%, 0.01% and 0.001% level using the standard method[29].

3 Results and Discussion

3.1 Concentration of primary pollutants

The 24 hours mean concentration of primary pollutants recorded during rice season has been presented in Table 1. Concentration of RSPM at polluted site was 160.67 μg/m^3, 171.18 μg/m^3 and 167.90 μg/m^3 during winter, monsoon and summer, respectively, whereas the standard limit prescribed by Central Pollution Control Board (CPCB) of India for RSPM is 150 μg/m^3, 100 μg/m^3, and 75 μg/m^3 for industrial, residential and sensitive areas, respectively. SPM at polluted site was 500.85 μg/m^3, 487.28 μg/m^3, and 483.65 μg/m^3 during winter, monsoon and summer seasons, respectively, whereas the standard limit prescribed by CPCB of India is 500 μg/m^3, 200 μg/m^3, and 100 μg/m^3 for industrial, residential and sensitive areas, respectively.

The highest concentration (18.10 μg/m^3) of SO_2 was recorded during monsoon season at polluted site, which was 92.45% higher as compared to control site. Similarly highest concentration (22.43 μg/m^3) of NO_x was recorded during winter season at polluted site, which was 89.43% higher as compared to control site.

3.2 Photosynthetic pigments of rice plants

Variations in the different parameters have been presented in Table 2. Chlorophyll a content of rice plants was recorded as 0.87 mg/g ± 0.09 mg/g, 1.34 mg/g ± 0.27 mg/g, 2.18 mg/g ± 0.12 mg/g and 1.64 mg/g ± 0.20 mg/g at control site during the months of July, August, September and October, respectively, whereas at polluted site it was recorded as 0.80 mg/g ± 0.11 mg/g, 1.19 mg/g ± 0.25 mg/g, 1.94 mg/g ± 0.19 mg/g and 1.38 mg/g ± 0.17 mg/g during the same months, respectively. Thus a reduction

Table 1. Primary air pollutants recorded from control and polluted sites during the study period

Site	RSPM (μg/m^3)			SPM (μg/m^3)			NO_x (μg/m^3)			SO_2 (μg/m^3)		
	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer
Polluted	160.67	171.18	167.90	500.85	487.28	483.65	22.43	21.70	20.81	15.01	18.10	14.29
Control	31.31	22.71	31.40	102.83	103.32	106.31	2.39	2.26	2.20	1.65	1.45	1.44
%	80.51	86.73	81.30	79.47	78.80	78.06	89.43	89.59	89.43	89.01	92.45	89.92
CPCB, standards (24 hours)	150.00			500.00			120.00			120.00		

CPCB: Central Pollution Control Board, New Delhi, India.

Table 2. Variations in the studied parameters of rice plants during 2006 (Mean of 10 replicates ± SE).

Months	July		August		September		October	
Parameters	Control	Polluted	Control	Polluted	Control	Polluted	Control	Polluted
Chlorophyll *a* (mg/g)	0.87 ± 0.09	0.80 ± 0.11***	1.34 ± 0.27	1.19 ± 0.25***	2.18 ± 0.12	1.94 ± 0.19***	1.64 ± 0.20	1.38 ± 0.17
Chlorophyll *b* (mg/g)	0.62 ± 0.11	0.58 ± 0.13**	1.08 ± 0.13	0.93 ± 0.12***	1.56 ± 0.23	1.42 ± 0.27***	1.28 ± 0.18	1.12 ± 0.20
Total chlorophyll (mg/g)	1.49 ± 0.20	1.38 ± 0.26***	2.42 ± 0.23	2.12 ± 0.18***	3.74 ± 0.31	3.36 ± 0.33***	2.92 ± 0.27	2.50 ± 0.38
Carotenoid (mg/g)	1.27 ± 0.08	1.10 ± 0.06***	1.40 ± 0.13	1.27 ± 0.10***	1.59 ± 0.22	1.40 ± 0.23***	1.47 ± 0.25	1.31 ± 0.21
Ascorbic acid (mg/100 g)	1.18 ± 0.06	1.11 ± 0.08***	1.30 ± 0.07	1.18 ± 0.09***	1.52 ± 0.12	1.35 ± 0.11***	1.36 ± 0.11	1.20 ± 0.14
Relative moisture content %	64.89 ± 0.20	61.39 ± 0.33ns	66.12 ± 0.44	63.00 ± 0.40ns	64.12 ± 0.49	60.88 ±0.33ns	66.81 ± 0.52	62.06 ± 0.56*
pH	4.21 ± 0.11	3.86 ± 0.08***	4.47 ± 0.18	4.03 ± 0.19***	5.86 ± 0.22	5.68 ± 0.24***	5.23 ± 0.29	5.01 ± 0.26
APTI	7.16 ± 0.22	6.72 ± 0.26***	7.51 ± 0.16	7.03 ± 0.15***	7.71 ± 0.20	7.31 ± 0.27***	7.80 ± 0.39	7.11 ± 0.28

Significant at: $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, ns = not significant

of 8.05%, 11.19%, 11.01% and 15.85% in chlorophyll *a* content was recorded in the samples from polluted area in comparison to control area. Chlorophyll *b* content of rice plants was recorded as 0.62 mg/g ± 0.11 mg/g, 1.08 mg/g ± 0.13 mg/g, 1.56 mg/g ± 0.23 mg/g and 1.2 8 mg/g ± 0.18 mg/g at control site during July, August, September and October, respectively, whereas at polluted site it was recorded as 0.58 mg/g ± 0.13 mg/g, 0.93 mg/g ± 0.12 mg/g, 1.42 mg/g ± 0.27 mg/g and 1.12 mg/g ± 0.20 mg/g during July, August, September and October, respectively, with a reduction of 6.45%, 13.89%, 8.97% and 12.50% in the samples from polluted area in comparison to control area, during July, August, September and October, respectively. Total chlorophyll was 7.38%, 12.40%, 10.16% and 14.38% less at polluted site as compared to control site during July, August, September and October, respectively. Ascorbic acid content was 5.93%, 9.23%, 11.18% and 11.76% less at polluted site as compared to control site during July, August, September and October, respectively. Carotenoid content of rice plants was recorded as 1.27 mg/g ± 0.08 mg/g and 1.10 mg/g ± 0.06 mg/g at control and polluted sites, respectively during July, while during October it was recorded as 1.47 mg/g ± 0.25 mg/g and 1.31 mg/g ± 0.21 mg/g at control and polluted sites, respectively. pH of leaves of rice plants was recorded as 8.31%, 9.84%, 3.07% and 4.21% less at polluted site as compared to control site during July, August, September and October, respectively. Relative water content was 5.39%, 4.72%, 5.05% and 7.02% less at polluted site as compared to control site during July, August, September and October, respectively. APTI of rice plants was 7.16 ± 0.22, 7.51 ± 0.16, 7.71 ± 0.20 and 7.80 ± 0.39 at control site during July, August, September and October, respectively, whereas at polluted site it was recorded as 6.72 ± 0.26, 7.03 ± 0.15, 7.31 ± 0.27 and 7.11 ± 0.28 during July, August, September and October, respectively.

3.3 Yield of rice plants during the study period

Data on yield have been shown in Table 3. Number of grains per plant of rice was reported as 3496.6 ± 12.21 and 3305.8 ± 10.24 at control and polluted sites, respectively, with a reduction of 6.15% during the final harvest in the month of November 2006. Grain weight per plant of rice plants was reported as 58.47 g ± 4.11 g and 52.44 g ± 3.87 g at control and polluted sites, respectively, with a reduction of 10.31%. The weight of 1000 grains of rice plants during November were reported as 16.73 g ± 0.66 g and 14.96 g ± 0.57 g at control and polluted site, respectively, with a reduction of 10.86%.

Rice is a staple food for over 2 billion people in Asia alone who derive their 60 – 70 percent caloric value from

Table 3. The yield of rice plants at the final harvest during the month of November 2006 (Mean of 10 replicates ± SE).

Yield parameters	Rice plants		
Site	Control	Polluted	% R
Number of grains per plant	3496.6 ± 12.21	3305.8 ± 10.24***	6.15
Grains weight per plant (g)	58.47 ± 4.11	52.44 ± 3.87***	10.31
Weight of 1000 grains per plant (g)	16.73 ± 0.66	14.96 ± 0.57**	10.86

Significant at: $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, ns = not significant, % R = reduction percentage.

the grain and its derivatives. Studies have shown that SO_2 induced reduction in plant growth and alteration of physiological and biochemical processes are not accompanied with visible foliar symptoms[30]. Reduction in yield is also reported without visible symptoms when plants are treated with low concentration of SO_2 for long duration[31]. The cement dust deposited on leaves have been found responsible for the reduced chlorophyll content and growth in maize plants[32–34]. Some workers have also reported reduction of chlorophyll content brought by acidic pollutants like SO_2 which causes phaeophytin formation by acidification of chlorophyll[35]. Reductions in chlorophyll contents of a variety of crop plants due to SO_2 and O_3 exposure have also been reported[36]. Dusted or encrusted leaf surface is responsible for reduced photosynthesis and thereby causing reduction in chlorophyll content[37]. In the present study, one way ANOVA shows that the changes in the values of all the parameters studied, except relative moisture content, were significant at 0.001 level. Crop plants have the ability to take up atmospheric gases without active metabolism and therefore, vegetation serve as a natural sink for air pollutants by providing expanded leaves for the absorption and setting of gases and particulate matter. The SO_2 and NO_2 gases reduced growth and yield of crops[38]. Sulphur dioxide is one of the most prevalent phytotoxic air-pollutants and causes substantial damage to green plants[39]. It is known that SO_2 alters the metabolic processes of plants[40,41], decreases their photosynthetic activity[42,43] and yield[44]. In the recent studies it has been reported that ambient air pollution from automobiles has adversely affected and reduced the plants chlorophyll, carotenoid, ascorbic acid, pH, relative moisture content and APTI[45] and SO_2 and NO_x gases have been found most destructive[46]. In a similar study on effects of ambient air pollution on wheat and rice yield in Pakistan a significant yield reduction has been reported in two successive seasons which ranged from 33% to 46% in wheat and from 37% to 51% in rice[20]. These results are very significant in terms of the maintenance of agricultural yields because there is a continuous industrial growth not only in India but in the entire south and south-east Asia.

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