Nature Environment and Pollution Technology An International Quarterly Scientific Journal	Vol. 9	No. 1	pp. 13-18	2010

Original Research Paper

Effect of Emission from Thermal Power Stations on Growth and Yield of Rice Crop at Selected Rural Sites in Cuddalore District of Tamil Nadu

B. Kumaravel, S. Palanivelraja and K. Sivakumar*
Department of Civil Engineering, Annamalai University, Annamalainagar-608 002, T.N., India
*Department of Botany (DDE), Annamalai University, Annamalainagar-608 002, T.N., India

Nat. Env. Poll. Tech.
ISSN: 0972-6268
www.neptjournal.com

Key Words:
Air pollution
Thermal power stations
Oryza sativa L.
Growth and yield of rice
Effects of SO_2

ABSTRACT

Emission from coal fired thermal power stations discharges numerous types of gases as pollutant in the ambient air environment, which is causing potential threats to crop production. This study deals with the effects of sulphur dioxide on rice crop (*Oryza sativa* L.), and yield responses at selected rural sites adjacent to the power station. Eight hour averaged SO_2 concentrations were measured at the two stations during the crop period. Physicochemical parameters of the soil and water samples were observed in the crop fields in pre-flowering, flowering as well as post-flowering phases. The uncontrolled area was located by determining the predominant wind direction with the help of wind rose using the meteorological frequency data whereas the controlled area was located upwind to predominant wind direction. The data were constructed and related with the yield responses. There was only a slight reduction in yield of rice crop because of the thermal power plants.

INTRODUCTION

Gaseous pollutants from thermal power stations exert a tremendous pressure on fauna and flora in the vicinity of industrial complexes (Yunus & Iqbal 1996, Iqbal et al. 2000). Leaves experience the maximum brunt of exposure and accordingly undergo structural and functional alterations with changes in the air environments. Ambient air pollution has been shown to reduce the growth and economic yield of a wide range of major crop species in US (Heck et al. 1988), Switzerland (Fuhrer et al. 1989), Germany (Adaros et al. 1990), Sweden (Pleijel et al. 1991), Pakistan (Wahid et al. 1995), Malaysia (Ishii et al. 2004), Thailand (Ariyaphanphitak et al. 2005) and China (Wang et al. 2007). Considerable knowledge about the rapidly increasing levels of air pollutants in the industrial complexes of developing countries has been generated, but their possible consequence on agricultural production have scarcely been explored (Agarwal et al. 2003).

Rice is one of the important food grain crops in the world, particularly in India, but there is only a little knowledge about its responses under ambient air pollution levels. Although visible injury to rice plants caused by photochemical oxidants is well documented (Heck et al. 1988, UNECE ICP Vegetation 2001, Agarwal 2003), there have been few studies, which have examined effects of air pollutants on rice over the whole growth season under realistic environmental conditions. These studies, in general, indicate that rice is not among the most sensitive crops to pollutants such as ozone (O_3) and sulphur dioxide (SO_2). However, emissions of air pollution are rising rapidly in many countries of south and south Asia, and given the importance of rice in the region, it is essential that the responses of the locally-grown cultivars to these and other pollutants are properly assessed under the characteristic climatic conditions (Wahid et al. 1995). Sulphur dioxide injury symptoms on rice consist of initial chlorotic areas, which became bleached after several days (Valenzona et al. 1978).

Agricultural crops near thermal power stations (TPS) in Cuddalore district have also not received due attention. Hence, the present study was made to know influence of emissions from thermal power stations on rice crop yields in selected rural sites in Cuddalore district of Tamil Nadu.

MATERIALS AND METHODS

Study area: The study was conducted in the rural environment of Neyveli, which is the super thermal power station in south India, located in the latitude of 11°28' and 11°37' N and longitude of 79°25' and 79°33'E of Cauvery delta region in India. The field experiments were conducted during summer crop season of 2008. Two sites were selected along a transect from west to south-east in rural locations of Neyveli power stations, which represented a gradient of air pollution. Site 2 (Kammapuram) is an agricultural area of the power station, 6.5 km radial south-west from the source complex. Site 1 (Muthanai) is in the north-west of the source complex, which is in upwind direction to the gradient of air pollution in an agricultural area. Site 1 is taken as the controlled open field plot (COFP) and site 2 is taken as the uncontrolled open field plot (UOFP). There is no change in climatic conditions between these two sites. Soil and water samples were collected and tested in the Govt. of Tamil Nadu Agricultural Soil Testing Laboratory, Cuddalore.

Experimental setup: Rice (*Oryza sativa* L.) cultivar ADT 36, grown widely in the tail end of Cauvery delta region by farmers having small as well as large land holdings, was selected as test plant. The ADT 36 rice has a life span of 105 to 110 days. Initially, the nursery was prepared by sowing seeds in large pots filled with well manured garden soil. The soil was prepared at one place by mixing garden soil and farm yard manure in 3:1 ratio. After 20 days of germination, seedlings (3 each) were transplanted into each 30 cm diameter pot of 12.5cm apart in rows by hand. Sowing was carried out on 18 June 2008, and seedlings were transferred to the open field on 8 July 2008. They were kept in a well watered condition in order to maintain constant soil moisture.

Air quality analysis: Chemical wet monitoring was conducted for gaseous pollutants. Air quality monitoring was carried out at all sites by using high volume samplers at ground level for 6 h daily from 8.30 to 21.30 hrs thrice in alternate days. Sulphur dioxide and other gases were scrubbed separately in tetrachloromercurate, NaOH (0.1 N) and buffered KI (0.1N), respectively. The absorbing solutions were analysed colourimetrically for SO_2.

Morphometric analysis: Plant growth and development were monitored throughout the crop period by weekly measurements of plants height and number of tillers, and number of live and senescent leaves. A single destructive harvest was performed at crop maturity on 12 October 2008, with the measurements of panicles per plant, grains per plant, and the number of fertile and infertile spikelet per panicle. Grain, straw and root dry weights were determined for each plant. The statistical analyses were carried out on final harvest data based on mean value.

RESULTS AND DISCUSSION

Air quality monitoring: During the summer crop season the maximum mean monthly temperature ranged from 29.4°C to 41.1°C with minimum from 23.3° to 30.6°C, and during the winter season maximum temperature ranged from 23.3° to 35.6°C and minimum from 17.8° to 27.8°C. The average maximum relative humidity vary from 49.93% to 71.72% during summer, and 63.37% to 80.85% during winter, with minimum from 23% to 51% during summer and from 29% to 56% during winter

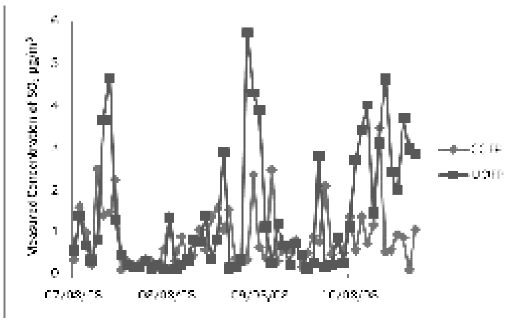

Fig. 1: Sulphur dioxide concentration (µg/m^3) in Controlled (COFP) and Uncontrolled (UOFP) plots.

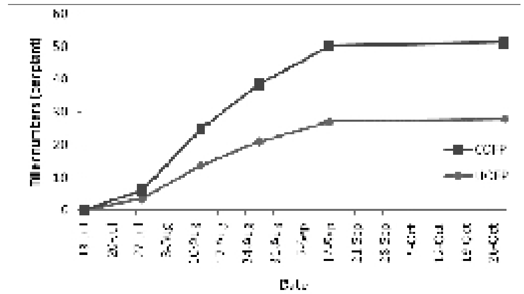

Fig. 2: Effect of treatment on tiller development.

Fig. 3: 40 DAT in COFP.

Fig. 4: 40 DAT in UOFP.

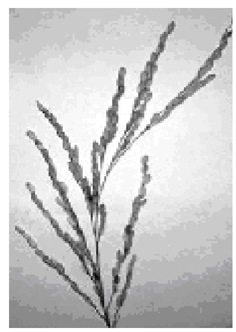

Fig. 5: Panicle in COFP.

Fig. 6: Panicle in UOFP.

(Table 1). Wind speed varied from 2-18 km/hr during the summer and from 0.2 to 20 km/hr during the winter season. The wind direction was predominantly easterly and north easterly during the summer, and westerly and north-westerly during winter.

Ambient air quality monitoring data showed higher concentration of SO_2 in uncontrolled open field plot as compared to controlled open field plot (Fig. 1). During month of the growing period of rice, maximum variations were found with SO_2 concentration which increased for a mean concentration of 0.63 µg/m^3 in July to mean concentrations of 2.37 µg/m^3 in October 2008. There was a significant difference in the concentration of SO_2 between UOFP and COFP.

Morphological growth: Plants developed in COFP showed an increase in growth parameters

Table 1: Meteorological data of the experimental site during the study period.

Month/year	Rainfall (mm)	Mean temperature (°C)		Relative humidity (%)		Sunshine (h)
		Max	Min	Max	Min	
July 2008	96.4	35.97	27.02	84.00	38.00	5.4
August 2008	149.8	34.60	26.23	77.00	55.77	5.1
September 2008	155.0	33.98	25.49	76.23	54.16	5.6
October 2008	181.6	31.53	24.06	86.36	68.23	6.3

Table 2: Characteristics of water used for irrigation.

S. No.	Details	COFP	UOFP
1.	pH	8.0	7.7
2.	Electrical Conductivity (EC) dSm^{-1}	0.60	1.06
3.	Carbonate (CO_3) meq/L	Nil	Nil
4.	Bicarbonate (HCO_3) meq/L	3.4	4.8
5.	Chloride (Cl) meq/L	2.5	5.8
6.	Sulphate (SO_4) meq/L	0.1	0.1
7.	Sodium (Na) meq/L	2.4	4.10
8.	Potassium (K) meq/L	0.18	0.32
9.	Calcium (Ca) meq/L	2.2	3.9
10.	Magnesium (Mg) meq/L	1.2	2.3
11.	Sodium Adsorption Ratio (SAR)	1.84	2.33
12.	Percentile of magnesium & calcium	0.55	0.59
13.	Category of irrigation water	$C_1S_1R_1$	$C_2S_1R_1$
14.	Geochemical	NaCl	NaCl

compared to those grown in UOFP. There was a slightly significant effect of treatment on tiller production in COFP and UOFP (Table 4, Fig. 2). There were no differences in tiller number until early August; after this time no tiller production was showed in UOFP but in COFP it continued at same rate through to end of August. Final tiller numbers were significantly reduced by 13.87% in UOFP compared to COFP. There was also an accelerated rate of leaf senescence in UOFP when compared to COFP (Figs. 3 and 4), which became apparent in early August.

Yield responses: The final results after harvest show significant effect of the treatment. Yield was more in COFP compared to the UOFP (Table 5) with total grain weight per plant showing increments of 10-15%. Increments in straw weight were slightly lower than the increments in total grain weight (15-23%), with significant increment in root biomass (20-25%). A substantial part of the yield reduction was due to reduction in the number of panicles per plant of 18-20% with UOFP (Figs. 5 and 6). The number of filled grains per panicle was reduced by 3-5%. The reduction of filled grain per panicle was largely due to as increase of sterilities in UOFP. The increased sterilities also affect the straw and root dry weight in UOFP.

The present study clearly showed negative effects of the ambient air pollution from TPS on morphometric analysis of rice. Similar observation was also made on Rai & Agarwal (2008). UOFP clearly showed significant adverse effect of ambient air pollutant (SO_2) on rice plants growing in the rural area of Cuddalore district. The air quality monitoring data clearly show that SO_2 being low in concentration may not have major impacts in the area. However, yield response show marked variation in decreased growth parameters in UOFP, which may be due to exposure of SO_2 concentration.

The environmental parameters and chemical analysis of rice field in water and soil are given in Tables 2 and 3 respectively. As this is only a primary study, the results presented are those of a one time study. Since the study has been undertaken with water and soil of the same place, in all pots hydrologically they are almost similar. The pH of natural water above the level of 8 is probably due to photosynthetic activity that demands CO_2 as shown by Wani & Subla (1990), Jayakumar & Karpagam (2005). In the present investigation this could be the reason for alkaline range of pH in the rice fields. The chlorine content of rice field water in UOFP showed 5.8 meq/L, which may be due to various factors.

Many researchers used the open top chambers with charcoal filter to determine the effect of ambient air pollutants on crops along with suitable arrange-

Table 3: Characteristics of soil sample.

S. No.	Details	COFP	UOFP
1.	pH	7.7	8.1
2.	Electrical conductivity (EC), dSm^{-1}	0.23	0.26
3.	Carbonate (CO_3)	Nil	Nil
4.	Nitrogen (N) content, g/kg of soil	0.065	0.035
5.	Phosphorus (P), g/kg of soil	0.005	0.0015
6.	Exchangeable potassium, g/kg of soil	0.125	0.0325
7.	Soil type	Silt clay loam	Silt loam

Table 4: Age-wise changes in morphological parameters of rice in controlled open field plots (COFP) and uncontrolled open field plots.

Parameter	25 Day After Transplantation		40 Day After Transplantation		75 Day After Transplantation	
	COFP	UOFP	COFP	UOFP	COFP	UOFP
Root length (cm)	3.2 ± 0.5	2.9 ± 0.5	7.1 ± 0.62	6.05 ± 0.76	9.7 ± 0.52	8.9 ± 0.43
Shoot length (cm)	-	-	15.57 ± 1.8	13.90 ± 2.1	41.6 ± 0.9	38.4 ± 1.15
No. of tillers	14.5 ± 1.2	11.9 ± 0.75	26 ± 1.80	23 ± 2.5	27 ± 0.6	23 ± 1.2
No. of leaves	3 ± 1.2	3 ± 1.2	3.5 ± 2.2	2.9 ± 1.5	3.2 ± 1.8	2.3 ± 1.3
Leaf area (3 leaves)	14.4 ± 1.6	12.5 ± 1.1	36.6 ± .8	22.3 ± 1.7	35.3 ± 1.5	21.5 ± 0.6
Percentile leaf injury	0.40 ± 0.25	0.56 ± .70	0.90 ± 1.0	1.8 ± 1.4	0.7 ± .50	1.2 ± 0.90
Number of panicles	-	-	7 ± 1.5	5 ± 2.1	8.7 ± 0.6	6.3 ± 1.4

Values are expressed as the mean ± SD; n = 3.

Table 5: Final harvest parameters of rice in controlled open field plots (COFP) and uncontrolled open field plots.

Harvest Parameter	COFP	UOFP
Total number of panicles per plant	9 ± 2.9	7 ± 1.7
Total number of spikelet per panicle	4.6 ± 1.8	2.7 ± 2.3
Total number of grains per plant	128 ± 3.56	101 ± 2.31
Total filled grain dry weight per plant (g)	3.7 ± 1.30	2.9 ± 1.1
Average grain weight per panicle (g)	4.2 ± 0.6	3.65 ± 0.8
Average number of filled grains per panicle	142.6 ± 1.5	135 ± 2.0
Average number of unfilled grains per panicle	12.1 ± 1.2	18.6 ± 2.4
1000 grain weight (g)	28.60 ± 0.1	24.6 ± 0.2
Total straw dry weight (g)	98.7 ± 3.8	59.5 ± 4.1
Root dry weight (g)	57.4 ± 1.9	42.5 ± 2.3
Root/Shoot ratio	0.18 ± 0.016	0.2 ± 0.019
Harvest Index	1.02 ± 0.09	1.67 ± 0.10

Values are expressed as the mean ± SD; n = 3

ments for ventilation. Comparison study of filtered chamber and non-filtered chamber shows the differences occurred in both. Although the use of open top chambers represents a good state of the art, a better approach would be to conduct the research in a pollutant free area and use of a zonal air pollution system in which SO_2 could be emitted upwind and allow measured levels of the pollutants to be carried over the field grown crop (Gerrit Kats et al. 1985). Therefore, this study was carried out under field condition, and sites also selected with respect to the source emission. Morphometric analysis such as root length, shoot length, number of leaves and leaf area did not vary significantly, however, number of tillers in 45 and 75 days have shown significant variation in tiller growth in COFP. Anyhow, a larger increase in the rate of leaf senescence was made by Wahid et al. (1995). The similar observations are also shown in the present study.

Yield was comparatively lesser by 10-15% at Kammapuram (UOFP) compared to Muthanai (COFP). However, the reduction was not significantly different between the two sites. This reduction may be due to that the SO_2 and NO_2 concentrations were relatively low compared to O_3 concentration in the atmosphere. Based on this observation in rice crop, there is not much difference in morphological characteristics, but differences in yield response between COFP and UOFP may be due to exposure of SO_2 air pollutant in the downwind direction.

REFERENCES

Adaros, G., Weigel, H.J. and Jager, H.J. 1990. Effects of incremental ozone concentrations on the yield of bush beans (*Phaseolus vulgaris* var. Nanus (L.) Aschers). Gartenbauwissenschaft, 55: 162-167.

Agarwal, M. 2005. Effects of air pollution on agriculture: An issue of national concern. Nat. Acad. Sci. Lett., 28: 93-106.

Agarwal, M., Singh, B., Rajput, M., Marshall, F. and Bell, J.N.B. 2003. Effect of air pollution on peri-urban agriculture: A case study. Environ. Poll., 126: 323-329.

Ariyaphanphitak, W., Chidthaisong, A., Sarobol, E., Bashkin, V.N. and Towprayoon, S. 2005. Effects of elevated ozone concentrations on Thai jasmine rice cultivars (*Oryza sativa* L.). Water Air Soil Poll., 179-200.

Fuhrer, J., Egger, A., Lehnherr, B., Grandjean, A. and Tschannen, W. 1989. Effects of ozone on the yield of spring wheat (*Triticum aestivum* L., cv. Albis) grown in open-top field chambers. Environ. Poll., 60: 273-289.

Gerrit Kats, Philip J. Dawson, Anderzej Bytnerowicz, Joanne W. Wolf, C. Roy Thompson and David M. Olszy 1985. Effects of ozone and sulphur dioxide on growth and yield of rice. Agriculture, Ecosys. Environ., 14: 103-117.

Heck, W.W., Taylor, O.C. and Tingey, D.T. 1988. Assessment of Crop Loss from Air Pollutants. Elsevier Applied Science, New York.

Iqbal, M., Srivastava, P.S. and Siddiqi, T.O. 2000. Anthropogenic stresses in the environment and their consequences. In: Iqbal, M., Srivastava, P.S. and Siddiqi, T.O. (ed.): Environmental Hazards: Plants and People. pp 1-37. CBS Publishers, New Delhi.

Ishii, S., Marshall, F.M. and Bell, J.N.B. 2004. Physiological and morphological responses of locally grown Malaysian rice cultivars (*Oryza sativa* L.) to different ozone concentrations. Water Air Soil Poll., 205-221.

Jayakumar, S. and Karpagam, S. 2005. Factors affecting productivity of phytoplankton in a reservoir of Cuddalore, Tamilnadu. Ind. Hydrobiol., 8(2): 187-192.

Pleijel, H., Skarby, L., Wallin, G. and Sellden, G. 1991. Yield and grain quality of spring wheat (*Triticum aestivum* (L.) cv. Drabant) exposed to different concentrations of ozone in open-top chambers. Environ. Poll., 69: 151-168.

Rai, R. and Agarwal, M. 2008. Evaluation of physiological and biochemical responses of two rice (*Oryza sativa* L.) cultivars to ambient air pollution using open top chambers at a rural site in India. Science of the Total Environment 407: 679-693.

UNECE, ICP 2001. Vegetation. Air Pollution and Vegetation: Annual report. National Environment Research Council (NERC), Bangor, Centre for Ecology and Hydrology.

Valenzona, F.V., Saladaga, F.A. and Silva, N.L. 1978. Threshold limits and effects of sulfur dioxide on 22 rice varieties, NSDB Technol. J., 3: 35-42.

Wahid, A., Maggs, A., Shamsi, A.R.S., Bell, B.N.J. and Ashmore, R.M. 1995. Effects of air pollution on rice yield in the Pakistan, Panjab. Environ. Poll., 90(3): 323-329.

Wang, X., Zheng, O., Yao, F., Chen, Z., Feng, Z. and Manning, W.J. 2007. Assessing the impact of ambient ozone on growth and yield of rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) cultivar grown in the Yangtze Delta, China using three rates of application of ethylene diurea (EDU). Environ. Poll., 148: 390-395.

Wani, I.A and Subla, B.A. 1990. Physico-chemical features of two shallow Himalayan lakes. Bull. Environ. Sci., 8: 33-40.

Yunus, M. and Iqbal, M. 1996. Plant Response to Air Pollution. John Wiley, Chichester.