Response of air pollution load on biomass, yield and calorific value of two wheat cultivars

Manderia Krishna[1]* and Manderia Sushil[2]
1 Department of Botany, PMB Gujarati Science College, Indore (M.P.) India
2 SS in Environment Management, Vikram University, Ujjain (M.P.) India
* krishnaharyani@gmail.com or krishnaharyani@yahoo.com

Abstract
The study was conducted for the assessing the effect of air pollutants for the common wheat cultivars CV 147 and CV Lok-1 at five different location covering crop lands in South West part of India for three years. Study was done at various distances from source of pollution load in up wind and prevailing wind direction extending up to 5 kms. The pollutant measured were suspended particulate matter (SPM), sulphur di-oxide (SO_2), oxide of nitrogen (NOx) and ground level ozone (O_3). Air monitoring data showed that mean concentrations of annual SPM loads in the regions ranged between 204 - 459 g/m^3 at about 1km and 79- 154 g/m^3 at 5km while SO_2, the annual average is between 5-44 g/m^3 with a minimum concentration in cement zone i.e. 5 g/m^3 at 1km in prevailing wind direction. Also, NOx levels ranges between 17- 52 g/m^3 and O_3 concentration 9 to 32 g/m^3. The concentration of SO_2, NO_2 and SPM were higher during winter season, whereas O_3 during summer season. Results indicated that air pollutants significantly reduced above-ground biomass by 35%, and yield by 45% and calorific value by 10% in CV Lok1 as comparison with CV 147 plants, suggesting that air pollutants reduces growth and yield under current ambient conditions. Proline was another indicator of air pollution stress or others. It was clear from results that increase in proline content (21-33%) being maximum in wheat CV Lok-1 than CV 147. The study depicts that significant loss in the grains of both the cultivars of wheat at different sites occurred.
Key words: Air Pollution Load (APL), Ground Level Ozone, Total Gaseous Level (TGL), Total Particulate Load (TPL), Calorific Value.

1. Introduction

Ambient concentration of the pollutant was known to decrease the productivity of a wide range of crops in many parts of developing Worlds (Wahid et.al. 1995; Fuhrer et.al. 1997; Fuhrer and Booker, 2003; Morgan et al.,2003; Ashmore, 2005; Wahid,2006a, b; Feng et al., 2008; Booker et al., 2009; Emberson et al., 2009; Feng and Kobayashi, 2009; Wittig et al., 2009 Mills et al., 2010; Feng et.al 2010). In the USA, the NCLAN (National Crop Loss Assessment Network) study has produced estimates of economic losses on crops in excess of $ $3x10^9$ per year (Gelang et.al., 2001). Wheat (*Triticum aestivum* L.) constitutes the India's most important cereals crops occupying 34% of the total land planted with cereals, an area amounting to 38 million ha and total loss due to air pollution in yield and corresponding loss in terms of money may be 2,789,831 tonnes and 10,044 lakh rupee respectively in India (ODA, report, 1997).Yield reduction studies have been reported in wheat in glass house or open top chamber with relation to individual air pollutants i.e. SO_2, NOx, O_3, HF or cement dust, fly ash etc. (Ollerenshaw et.al. 1998). Some of the negative effects induced by air pollutants specially ozone include decreased chlorophyll contents, decline in photosynthesis and stomatal conductance, altered antioxidant levels, accelerated leaf senescence, and reductions in total plant biomass and nutritive yield (Morgan et al., 2003; Feng et al., 2008; Piikki et al., 2008b; Booker et al., 2009; Feng and Kobayashi, 2009; Wittig et al., 2007, 2009). The present study was focused on different biomass, yield allocation strategies adapted by the crop growing in different areas with significant variations in ambient air concentrations.

2. Materials and Methods

2.1 Area and Sampling fields

The industrial area selected for the study were Dewas, Pithampur, Nagda, Nayagaon-Khor in Madhya Pradesh and Nimbaheda in Rajasthan.

The wind direction and deflection ranges largely get confined between West-North-East. Since it is well-established fact that maximum load of pollutants occur in vicinity of the source i.e.0.5 to 1.5 km area. This criteria was effectively applied in the selection of sites. After visual survey sampling fields were marked in upwind direction at about 1-1.5 km as reference zone (RZ) and in the prevailing wind direction at 1-1.5 km as host zone (HZ) , 2-2.5 km as moderately affected zone (MAZ) and 4.5-5 km as least affected zone (LAZ) respectively at each industrial area.

2.2 Ambient Air Quality Monitoring

Sampling schedule was prepared by standard protocol i.e. for suspended particulate matter (SPM) was 24 hrs. average/day with two days per week in a month by High Volume Sampler (Kimoto-120, Japan), and gaseous analysis one day/week with 4 observations per day with 2 hrs. Intervals with Toxic Gas Monitor- 555 (CEA, USA) for Oxides of Sulphur (SO_2,West and Gaeke,1956) and Oxides of Nitrogen (NOx, Griess and Saltzman,1954) instantaneously and Ozone ($O_{3,}$ Byers and Saltzman, 1958) by Portable gas sampler (Netel NPM-PS-1, India) & analysis with UV-VIS Spectrophotometer.

2.3 Yield and Biomass

At each areas, seeds of wheat cultivars (*Triticum aestivum* L. CV Lok-1 and CV 147) were collected, their quality and weight was recorded. Plant samples were collected on monthly basis till harvest with standard protocol for biomass and grain yield. The harvest plot size was 10x10m and result was computed on hectare basis. The calorific value of seeds was estimated with Digital Bomb Calorimeter by following the methods of AOAC, 1954 and proline content by Bates *et al*. (1973).

2.4 Statistical Analysis

Sampling, monitoring and analysis of air and plant were done for three consecutive years. All statistical analysis was performed using STATISTICA® 6.0.

3. Results and Discussion

Individually, ambient SO_2 and NOx were quite below the standard limits 120 g/m^3 for SO_2 and NOx and 500 g/m^3 for particulate matter prescribed by Ministry of Environment or Central Pollution Control Board, New Delhi, for industrial areas. It has been noted that no ambient limits for ground level ozone have been prescribed in India.

Decentralisation and dispersion of industry to rural areas and long range transport of air pollutants have serious consequences for crop plants. The results of ambient air quality at study areas corresponds inversely with the pollutant concentration vis a vis distance i.e. at about 4 to 5 kms the total load decreases and almost touches to normal levels. At host zone which lies near to source, the gaseous levels are in range of 48 g/m^3 (Nayagaon-Khor) to 123 g/m^3 (Nagda) but the particulate load is maximum at the cement zone, Nimbaheda (458 g/m^3) followed by Dewas (335 g/m^3) and minimum at Nagda (204 g/m^3). At moderately affected zone the gaseous levels ranges between 68 - 92 g/m^3, with maximum at Dewas and minimum at Nayagoan - Khor and particulate loads in range of 155- 347 g/m^3, maximum at Nimbaheda followed by Dewas (305 g/m^3) and minimum at Nagda.

The area average of particulates / gaseous concentration shows that particulate levels are more at all zones then gaseous concentration. Nimbaheda air appears to be seriously loaded with SPM and Dewas with gaseous pollutant.

A perusal for the total cumulative pollution load picture exhibits that the total load in the host zone & moderately affected zone in winter season is higher then summer season i.e. 4 times then reference zone during winter and 3.4 times during summer season.

Since the standard limits of particulate is more then gaseous pollutant, the same trend is observed at study areas i.e. particulate concentration is more than gaseous concentration. The standard limits ratio is approximately 2:1 (500 g/m^3 SPM : 240 g/m^3 SO_2 + NOx).

The fig.1 indicates the scenario of particulate and gaseous loads at different areas. In cement producing areas the particulate load is higher and ratio lies between 3 to 7 at Nayagaon-Khor and Nimbaheda. While at gaseous polluted areas like Nagda, Pithampur and Dewas, where particulate load is not dominant the average ratio is nearly same as standard limit ratio.

The productivity of CV Lok-1 and CV 147 the most commonly grown winter wheat in the area was found to be significantly decreased in the field at all zones. The cumulative pollution load appears to be responsible for this marked reduction as the fertiliser and irrigation inputs were kept same in these years. In terms of economic loss, the decrease in grain yield of 1.2 to 1.6 tonnes ha^{-1} induced by cumulative pollution load.

The decrease in grain number subsequently results in loss of yield per spike, which exhibits the direct effects of ozone on reproductive structure (Bosac et.al. 1993, 1994; Stewart et.al. 1996) and accelerate leaf senescence (Ojanpera et.al. 1998). Biomass and yield loss has been significant among crops (Booker et al., 2009; Fuhrer, 2009; Wittig et al., 2009) and also assessed through a comprehensive program in US (NCLAN). Wahid et.al. (1995) and Feng and Kobayashi (2009) proved that yield of wheat cultivars was much affected due to air pollution.

It was observed that effect of cumulative pollution load i.e. SPM + SO_2+ NOx + O_3 on the yield, biomass and calorific value is statistically significant and highly correlatable (Rai et.al. 2007; Tiwari et.al. 2010). It has been noted that the with higher pollution load the biomass and yield reduction touches to level of 35% and 40% in wheat CV 147 and CV Lok-1 respectively in fig 2 & 3. The data further establishes that at lower cumulative pollution load the loss in these parameters nears to 10%. Singh, P. et.al (2009) reported loss in oil crop due to air pollution. The calorific value which provides a more relevant information, rather gives a more precise picture of the crop quality in terms of energy. Results of calorific value showed that the range of loss at HZ was 13-24%, at MAZ, the loss ranged between 8-24%, and at LAZ i.e. 3-4% in wheat CV Lok-1 than CV 147 (Fig 4).

Rai et al. (2007) recorded reductions of 20.7% in yield and 14.5% in number of grains plant of wheat cv. HUW 234 at mean concentration of 40.1 ppb O_3. Proline content is a indicator of stress whether it is air pollution stress or others. This is clear from results that at HZ where cumulative pollution load was more, increase in proline content occurred i.e. 21-33 % being maximum in wheat CV Lok-1. But at LAZ, where the cumulative pollution load was less, proline content showed a little increase i.e. 7-9 %. The increase in proline content is directly correlated with cumulative pollution load.

Due to ambient air pollution load loss in quantity and quality of cereals occurred which can be improved by applying EDU under ambient conditions reported by Tiwari et al. (2005). A higher nutrient amendment may also sustain high ambient air pollution concentrations. Further research is needed with other cereal crops.

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Table. 1 : Suspended Particulate Matter (g/m^3) at different study areas

S.N	Area	Distances				
		RZ	HZ	MAZ	LAZ	Area Av.
1	Dewas	85.83	335.16	305.00	170.16	224.04
2	Pithampur	59.67	249.00	161.84	104.50	143.75
3	Nagda	56.83	204.34	155.00	119.34	133.88
4	Nayagaon-Khor	84.50	254.67	186.84	123.34	162.34
5	Nimbaheda	125.83	458.50	347.50	227.83	289.92

Table 2 : Sulphur di oxide concentration (g/m^3) at different study areas

S.N	Area	Distances				
		RZ	HZ	MAZ	LAZ	Area Av.
1	Dewas	4.00	44.50	29.50	18.28	24.07
2	Pithampur	5.00	36.17	24.67	10.17	19.00
3	Nagda	3.50	37.50	22.67	14.34	19.50
4	Nayagaon-Khor	0.75	5.17	7.00	5.84	4.69
5	Nimbaheda	3.50	5.84	3.33	5.59	4.57

Table 3 : Concentration of oxide of Nitrogen (g/m^3) at different study areas

S.N	Area	Distances				
		RZ	HZ	MAZ	LAZ	Area Av.
1	Dewas	11.00	58.50	41.16	25.16	33.96
2	Pithampur	11.34	45.34	36.67	21.50	28.71
3	Nagda	8.67	55.00	39.50	22.00	31.29
4	Nayagaon-Khor	17.84	30.34	38.50	20.64	26.83
5	Nimbaheda	18.83	45.50	40.83	31.17	34.08

Table 4 : Ground level ozone concentration (g/m^3) at different study areas

S.N	Area	Distances				
		RZ	HZ	MAZ	LAZ	Area Av.
1	Dewas	7.17	18.83	19.17	12.00	14.29
2	Pithampur	9.33	18.17	19.33	11.83	14.67
3	Nagda	9.83	31.00	26.67	18.50	21.50
4	Nayagaon-Khor	9.33	18.34	22.17	17.00	16.71
5	Nimbaheda	7.67	27.34	25.34	22.84	20.80

RZ= Reference Zone, HZ= Host Zone, MAZ= Moderately Affected Zone, LAZ= Least Affected Zone, Area Av. = Area Average

Table. 5 : Air Pollution Load (g/m^3) at different study areas

S.No.	Area	Pollutant	Sampling fields				
			RZ	**HZ**	**MAZ**	**LAZ**	**Area Av.**
1	Dewas	TGL	22.17	121.83	92.00	55.51	72.88
		TPL	85.86	335.16	305.00	170.16	224.05
		CPL	**108.03**	**456.99**	**397.00**	**225.67**	**296.92**
2	Pithampur	TGL	25.66	99.66	76.49	43.50	61.33
		TPL	59.67	249.00	161.84	104.50	143.75
		CPL	**85.33**	**348.66**	**238.33**	**148.00**	**205.08**
3	Nagda	TGL	22.00	123.49	88.83	54.82	72.29
		TPL	56.83	204.67	155.00	119.34	133.96
		CPL	**78.83**	**327.83**	**243.83**	**174.16**	**206.16**
4	Nayagaon-Khor	TGL	23.02	47.83	67.65	43.49	45.50
		TPL	84.50	254.67	186.84	123.34	162.34
		CPL	**107.52**	**302.50**	**254.49**	**166.83**	**207.84**
5	Nimbaheda	TGL	28.00	78.66	69.50	30.75	51.73
		TPL	125.83	458.50	347.50	227.83	289.92
		CPL	**153.83**	**537.16**	**417.00**	**258.58**	**341.64**

Note : TGL = Total Gaseous Load (sum of SO_2 + NOx + O_3), TPL = Total Particulate Load, CPL = Cumulative Pollution Load (sum of TGL + TPL)
RZ= Reference Zone, HZ= Host Zone, MAZ= Moderately Affected Zone, LAZ= Least Affected Zone, Area Av. = Area Average

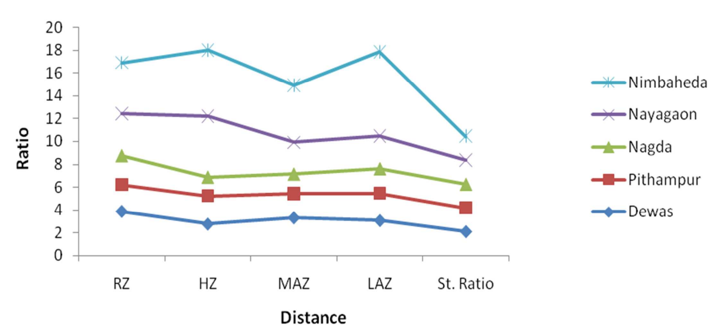

Fig.1 Ratio of Particulate vs Gaseous pollutant

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Fig. 2 Cumulative Pollution Load vs Biomass of two Wheat Cultivars

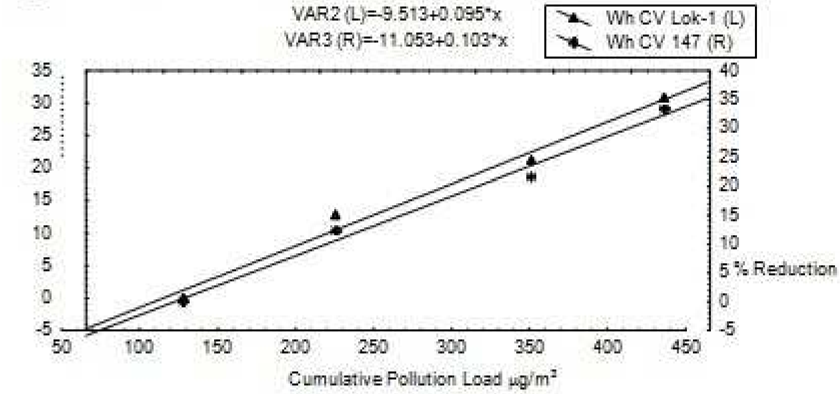

Fig. 3 Cumulative Pollution Load vs Yield reduction in two wheat cultivars

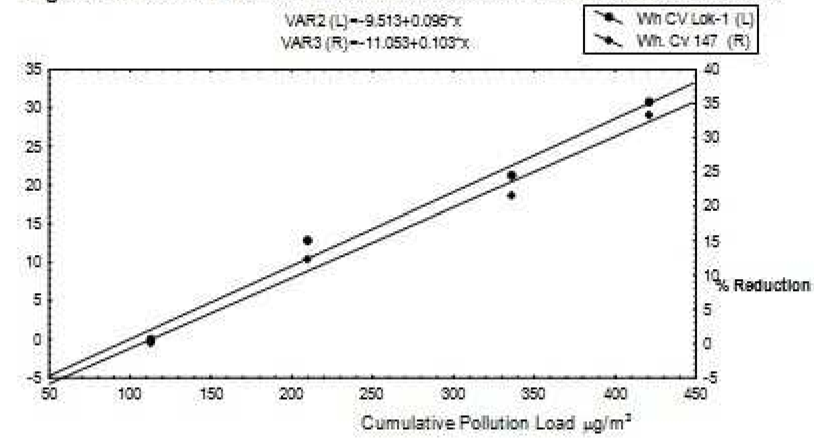

Fig. 4 Cumulative Pollution Load vs Calorific value of two wheat cultivars