Effect Of Ambient Air Pollutants On Wheat and Mustard Crops Growing In The Vicinity Of Urban and Industrial Areas

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Abstract: The study aimed to appraise the effect of different air pollutants viz. SO_2, NO_x, SPM and RSPM on bio-physiological as well as yield characteristics of wheat and mustard plants grown at different sites in the urban and industrial areas of Haridwar City. The ambient levels of air pollutants were lowest at site 2 and 4 and hence these sites were treated as control sites for comparing the response pattern observed at site 1 and 3, respectively. The wheat and mustard plants grown at polluted sites (1 and 3) showed significant reduction in total chlorophyll, carotenoid, ascorbic acid, plant height, shoot fresh weight, root fresh weight and yield. The study indicated that parameters reductions in wheat and mustard grown at polluted sited correlated directly with the gaseous and particulate pollutants, which led to lower yield at polluted sites experiencing higher levels of pollutants. [New York Science Journal. 2010;3(2):52-60]. (ISSN: 1554-0200).

Key words: Ambient air pollution, total chlorophyll, ascorbic acid, carotenoid, yield

Introduction

Increased urbanization and industrialisation in recent years in many developing countries have led to corresponding increases in atmospheric concentrations of primary and secondary pollutants (WHO/UNEP, 1992; Slanina *et al.,* 1995; Mage *et al.,* 1996). 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 regulation (Joshi and Chauhan, 2008). Ambient air pollution in several large cities of India is amongst the highest in the world. Apart from local effects, air pollutants can travel long distances and cause impacts far from its source (Agrawal, 2005). Indian cities are facing serious problem of airborne particulate matter (Agarwal *et al.,* 1999) and the United Nations estimated that over 600 million people in urban areas worldwide were exposed to dangerous levels of traffic generated air pollutants (Cacciola *et al.,* 2002).

Air pollution has become a serious environmental stress to crop plants due to increasing industrialization and urbanization during last few decades (Rajput and Agrawal, 2004). The particulates and gaseous pollutants, alone and in combination, can cause serious setbacks to the overall physiology of plants (Ashenden and Williams, 1980; Mejstrik, 1980; Anda, 1986). Of all plant parts, the leaf is the most sensitive part to the air pollutants and several other such external factors (Lal and Singh, 1990). Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollutant level in the air environment (Warren, 1973; Shannigrahi *et al.,* 2004).

Some workers have reported the adverse effect of air pollution on wheat crops (Murray and Wilson, 1988; Wilson and Murray, 1990; Rajput and Agrawal, 2005; Agrawal *et al.,* 2003; Agrawal, 2005; Singh and Rao, 1981; Maggs *et al.,* 1995; Agrawal and Deepak 2003) and mustard crops (Shukla *et al.,* 1990; Agrawal *et al.,* 2003). Work have been done in the direction to study the sensitivity of plants based on the selected parameters such as ascorbic acid content (Keller and Schwangar, 1977; Rajput and Agrawal, 2005, Chauhan, 2008), relative moisture content (Falla *et al.,* 2000; Joshi and Chauhan, 2008), chlorophyll content (Bell and Mudd, 1976; Prasad and Inamdar, 1990; Sabratnam and Gupta, 1988; Rajput and Agrawal, 2005; Petkovšek *et al.,* 2008, Chauhan and Sanjeev, 2008, Chauhan and Joshi, 2008), leaf extract pH (Chaudhary and Rao, 1977; Joshi and Chauhan, 2008, Chauhan and Joshi, 2008). APTI of some plants have been calculated by Karthiyayini *et al.,* 2005; Dwivedi and Tripathi, 2007, Chauhan and Joshi, 2008).

The present investigation has been undertaken to study the effect of ambient particulates and gaseous pollutants on total chlorophyll, carotenoid, ascorbic acid, plant height, stem fresh weight, root fresh weight and yield of wheat and mustard, most important staple and edible oil yielding in India, respectively and hence a great economic value.

Material and Methods:

Study area

The present study was conducted in district Haridwar of Uttarakhand state in India, which is situated between 29° 30' to 30° 15' latitude and 78°43' to 78°20' longitude. It is about 60 kms in length from east to west and about 80 kms in width from north to south. Total area of district Haridwar is 2,360 km^2 at an altitude of 294.7 meters with a population of 14, 44,213 (according to 2001 census) (Joshi and Swami, 2007), which must have increased during last seven years because of the creation of New state of Uttarakhand in the month of November 2000 .The four distinct season's autumn, winter, spring and summer can be seen here. The climate of the area is relatively temperate with an average rainfall of about 1127.2 mm which is chiefly confined to monsoon months. There exist a highest temperature recorded was 15.5^0C-40.9 ^{0}C during summer season whereas lowest temperature of 4.0^0C-16.6^0C during winter. It receives millions of tourists every month, sometimes just in a day.

Study sites

Four sites were selected for the study in urban and industrial area with their control sites. Site 1 (Shivalik Nagar is an urban area) is very close to the newly developed state industrial belt. The roads of this area bear a very heavy traffic load, including large trucks, loaded trucks, mini trucks, private buses, very high number of cars, three wheelers, scooters, bikes etc. Site 2 (Jhamlpur-Bahadrabad, an agricultural land) about 5 km away from site-1, connected to the main road by an unpaved road, with a nil to very low vehicular density. It located south-east of the Shivalik Nagar. Site 3 (SIDCUL, an industrial area) a massive industrial area, spread over 2034 acres which is the newly developed state industrial belt and about 360 industries already started functioning and some 400 are yet to arrive. The roads of this area bear a very heavy traffic load, including four wheelers like large trucks, loaded trucks, mini trucks, private buses, vans, cars, etc. three wheelers like vikram, loaded tempo etc. two wheelers like scooters, bikes etc. Site 4 (Roshnabad, an industrial area), located south-east and about 5 km away from SIDCUL.

Air pollution monitoring

The concentration of different air pollutants viz. NO_x, SO_2, SPM and RSPM monitored in the ambient air at the selected with the help of RDS APM 460 by sucking air into appropriate reagent for 24 hours. The apparatus was kept at a height of 2 m from the surface of the ground. Once the sampling was over, the samples were brought to the laboratory and concentration of different pollutants was determined. The concentration of SPM and RSPM was determined using filter paper methods. The concentration of NO_x was measured with standard method of Modified Jacobs- Hochheiser method (1958), SO_2 was measured by Modified West and Geake method (1956).

Plant sampling and analysis

The studies were conducted on wheat (*Triticum aestivum*, Var., PBW 343) and mustard (*Brassica campestris* L.) crops growing under field conditions. Crop samples were analyzed at every 30 days of intervals. The samples (in ten replicates of wheat and mustard plants) were collected from selected sites.

The concentrations of chlorophyll '*a*' and '*b*' (mg/g^{-1} fresh leaf) were obtained using the following formula given by Maclachlan and Zalik (1963). Carotenoid was determined by the method of Duxbury and Yentsch (1956). Ascorbic acid was determined by the method of Sadashivam and Manikam (1991). Relative water content was determined by method proposed by Weatherly (1965). 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 (1983). The present investigation has been undertaken to study the effect of ambient particulates and gaseous pollutant on total chlorophyll, carotenoid, ascorbic acid, plant height, stem fresh weight, root fresh weight and yield of wheat and mustard, most important staple and edible oil yielding in India and hence a great economic value. Agriculture crops in these fields grown include wheat and mustard during December to April.

Statistical analysis

Data from the four selected sites for the plant materials were subjected to a two-way-analysis of variance (ANOVA). Using ANOVA the comparison made between site 1 and 2 as well between site 3 and 4. Least Significance Difference was calculated at 0.05%, 0.01% and 0.001% level as per standard method of Gomez and Gomez (1984).

Results and discussion

Pollutant concentrations

The air pollutant monitoring data from the four selected sites are summarized in Table 1. The concentration of NO_x during winter recorded as 17.38, 2.42, 23.71 and 2.13 µg/m^{-3} at site 1, 2, 3 and 4, respectively, whereas during summer it was recorded as 15.27, 2.38, 22.93 and 2.82 µg/m^{-3} at site 1, 2, 3 and 4, respectively. SO_2 concentration during winter was recorded as 11.75, 1.87, 17.90 and 2.23 µg/m^{-3} at site 1, 2, 3 and 4, respectively, however during summer the SO_2 concentration was recorded as 11.03, 1.79, 18.56 and 1.91 µg/m^{-3} at site 1, 2, 3 and 4, respectively. SPM concentration during winter was recorded as 412.04, 109.08, 512.28 and 121.62 µg/m^{-3} at site 1, 2, 3 and 4, respectively, while during summer it was recorded as 400.84, 102.42, 508.30 and 122.92 µg/m^{-3} at site 1, 2, 3 and 4, respectively. During the winter concentration of RSPM was recorded as 126.38, 23.92, 177.26 and 45.73µg/m^{-3} at site 1, 2, 3 and 4, respectively while during summer it was recorded as 123.74, 24.40, 173.70 and 55.62 at site 1, 2, 3 and 4, respectively.

Air monitoring conducted in Haridwar has shown that site 3 had maximum level of all four pollutants, whereas site 2 showed minimum levels of all the over winter and summer. Site 2 and 4 were treated as control site for site 1 and 3, respectively, for comparing the levels of changes in various parameters.

Effect of air pollutants on photosynthetic pigments and antioxidant property

Total chlorophyll content decreased significantly in response to air pollutants at site 1 and 3 for wheat and mustard plants (Table 2). Ascorbic acid and carotenoid contents also decreased significantly in response to air pollutant at site 1 and 3 for wheat and mustard plants are summarized in Table 3 & 4.

Effects on plant growth and morphology

The plant height of wheat and mustard plant at four sites are shown in Table (5). ANOVA test showed significant variations in plant height at site 1 and 3 in comparison with their control sites namely site 2 and 4, respectively, due to elevated air pollutants. Stem fresh weight of wheat and mustard plants growing at site1 and 3 showed significant variation as compared to their control site 2 and 4, respectively (Table 6), whereas for root fresh weight also showed significant variation at polluted site 1 and 3 as compared to their control site 2 and 4, respectively.

Effect on yield

At the time of harvest, number of grains per plant, grains weight per plant and weight of 100/ 1000 grains showed significant reduction between site 1 and 2 as well as between site 3 and 4 for wheat plants. In mustard plants a similar pattern was observed.

Monitoring of air quality carried out at different four sites in Haridwar region showed spatial and seasonal variations for SO_2, NO_x, SPM and RSPM concentrations. The site 3 showed the maximum pollutant concentrations, which may be due to the presence of many large and small scale industries in this area. Large traffic volume in this area also may cause increased air pollutants concentration. Site 2 present in agricultural belt, which may have absorbed a portion of the pollutants, had the lowest concentrations of all four pollutants.

Joshi and Chauhan (2008) have also observed higher levels of SO_2, NO_x, SPM and RSPM at SIDCUL, Haridwar, Uttarakhand State, India. The level of SO_2, NO_x, SPM and RSPM observed in the present study are similar to that of Joshi and Swami (2007), who carried out air quality monitoring in Haridwar region. Air monitoring conducted in Allahabad city, U.P. State of India has shown that SO_2 concentration varied from 10.60 to 65.00 µg/m^{-3} and NO_2 from 2.5 to 42.5 µg/m^{-3} during the study period at different selected sites (Singh et al., 2005).

Changes in total chlorophyll, ascorbic acid, carotenoid, pH, plant height, stem fresh weight, stem fresh weight and yield of wheat and mustard plants grown at different sites reflected varying levels of ambient air pollution experienced at different sites in Haridwar city. Reduction in total chlorophyll content of wheat and mustard plants at site 1 and 3 as compared to site 2 and 4, respectively provide further evidence that site 3 and 4 during winter and summer were exposed to higher level of pollutants concentrations.

Pollutants have been shown reduce the synthesis of chlorophyll and enhance degradation of chlorophyll (Sandelius et al., 1995). Reductions in chlorophyll content of a variety of crop plants due to NO_2, SO_2 and O_3 exposure have also been reported by Agrawal et al., (2003). Chlorophyll content is essentials for the photosynthetic activity and reduction in chlorophyll content has been used as an indicator of air pollution (Pawar and Dubey, 1985; Gillbert (1968). Photosynthetic pigments are fairly sensitive to air pollutants and their sensitivity may determine the response of plants to pollutants. Lerman (1972) has suggested that continuous application of cement dust clog the stomata, so interfering with gaseous exchange. Carotenoids protect from photoxidation destruction hence their reduction would have serious consequence on chlorophyll pigments (Sifermann-Harms, 1987). Joshi and Swami (2007) also reported significant reduction in carotenoid content of different plants grown at polluted sites. Reduction in ascorbic acid further provide evidence that site 1 and 3 are receives higher concentration of pollutant levels as compared to site 2 and 4. The reduction in ascorbic acid may be ascribed to its consumption for scavenging cytotoxic free radicals generated during the chain reaction after the absorption of pollutants into the foliage. The physiological condition of plants is very well indicated by their pigment content (Petkovšek et al., 2008). Ascorbic acid, a natural antioxidant in plants has been shown to play an important role in pollution tolerance (Chen et al., 1990).

In this study the plants were maintained at similar edaphic and climate conditions and thus observed differences in plant growth performance may be attributed to atmospheric pollutants. Plant height of wheat and mustard found to be decreased significantly grown at site 1 and 3 as compared to site 2 and 4, respectively, because site 1 and 3 receiving higher concentrations of SO_2, NO_2, SPM and RSPM. Agrawal et al., 2003 have reported reductions in height of wheat, mustard, mung and palak under varying levels of air pollution stress in the urban environment of Varansi. Ashmore et al., (1988) concluded from study on growth along a gradient of ambient air pollution that the air pollutants were a major factor influencing plant growth in and around London during the mid 1980s.

Some regional scale gradient studies have also reported indicated similar trend, such that of Young and Mathew (1981), Agrawal et al., 2003. Murray and Wilson (1988) found that continuous exposure of SO_2 had no significant negative effect on the growth of wheat cv. Halberd, but shoot dry weight was reduced significantly. Davieson et al., (1990) reported that exposure of wheat cv. Eradu to 0.10µl/litre-1 reduced dry weight of shoots, ears and grains by approximately 25%. Wilson and Murray (1990) reported exposure of different concentrations of SO_2 to wheat plants adversely affected and reduced the shoot weight.

Reduction in stem fresh weight and stem dry weight may be attributed to the inhibition of chlorophyll formation and damage of leaf tissue which in turn the not photosynthetic grains. Lalman and Singh (1990) concluded that the SO_2 fumigated plants undergo several reversible and irreversible physiological and biochemical changes as reflected by foliar injury reduced leaf area and biomass. Decreased photosynthetic activity and poor plant growth apparently reduced the dry matter and yield (Khan and Khan, 1993). SO_2 decreases the chlorophyll and dry matter production (Mandloi and Dubey, 1988: Rao and Dubey, 1988: Katiyar and Dubey, 2000). Low NO_2 dose is also believed to be toxic or inhibitory to some plants.

Significant reductions in yield have also been observed as a result of SO_2 pollution in many cereals and pulses by Thomas (1961); Singh and Rao, (1982). Ozone, SO_2 and NO_2 individually and in combination are known to reduce the yield of many crop plants (Renaurd et al., 1997, Heggested and Lesser, 1990; Agrwal et al., 2006). Yield losses have often been attributed to reductions in photosynthetic activity and assimilate supplies to support reproductive development and seed growth (Krupa and Lickert, 1989). Agrawal et al., (2003) have reported significant yield reduction in wheat, mung bean and mustard plants growing along a gradient of air pollution. Agrawal et al., (2005) also reported significant reduction in number of ears plant-1, number of seeds plant-1 and yield of wheat plants grown at polluted sites.

Table 1: Twenty Four Hour Mean Pollutant Concentration (μg/m^{-3}) During Winter and Summer Seasons At Different Sites Of Haridwar Region

Sites	RSPM		NOx		SO_2		SPM	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1	17.38	15.27	11.75	11.03	412.04	400.84	126.38	123.74
2	2.42	2.38	1.87	1.79	109.08	102.42	23.92	24.40
3	23.71	22.93	17.90	18.56	512.28	508.30	177.26	173.70
4	2.13	2.82	2.23	1.91	121.62	122.92	45.73	55.62

Where: RSPM = Respirable suspended particulate matter, SPM= Suspended particulate matter.

Table 2: Changes In Total Chlorophyll Contents (mg g^{-1} dry weight) Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Sites	Wheat (days)			Mustard (days)		
	30	60	90	30	60	90
1	2.46±0.17***	5.03±0.27***	3.83±0.18***	2.32±0.05***	2.89±0.09***	2.55±0.07***
2	3.00±0.22	4.40±0.22	4.43±0.20	2.64±0.06	3.42±0.04	2.93±0.06
3	2.43±0.08***	4.32±0.22***	3.41±0.18***	2.07±0.09***	2.73±0.08***	2.42±0.09***
4	3.02±0.06	4.92±0.11	4.13±0.13	2.33±0.12	3.20±0.10	2.77±0.09

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Table 3: Changes In Ascorbic Acid Content (mg 100g^{-1}) Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Sites	Wheat (days)			Mustard (days)		
	30	60	90	30	60	90
1	1.14±0.14***	1.22±0.17***	1.19±0.08***	1.17±0.04***	1.39±0.04***	1.28±0.08***
2	1.72±0.17	1.93±0.23	1.80±0.18	1.30±0.05	1.57±0.06	1.40±0.07
3	1.32±0.13***	1.38±0.17***	1.21±0.13***	1.10±0.06***	1.32±0.07***	1.25±0.11***
4	1.80±0.06	2.17±0.11	1.91±0.09	1.24±0.08	1.47±0.09	1.36±0.12

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Table 4: Changes In Carotenoid Content (mg g^{-1}) Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Sites	Wheat (days)			Mustard (days)		
	30	60	90	30	60	90
1	1.10±0.03***	1.20±0.08***	1.18±0.08***	0.88±0.03***	1.31±0.05***	1.15±0.08***
2	1.30±0.03	1.42±0.11	1.34±0.06	1.10±0.03	1.47±0.06	1.32±0.09
3	1.01±0.05***	1.49±0.09***	0.95±0.08***	0.89±0.05***	1.25±0.12***	1.04±0.08***
4	1.14±0.05	1.69±0.08	1.19±0.11	1.08±0.06	1.39±0.11	1.18±0.09

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Table 5: Changes In Plant Height (cm) Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Sites	Wheat (days)			Mustard (days)		
	30	60	90	30	60	90
1	33.50±0.92**	69.90±0.91***	86.20±0.42***	41.60±1.32***	91.00±1.59***	187.70±1.13***
2	37.00±0.89	73.80±1.10	90.60±0.49	46.70±1.18	98.00±1.47	194.90±1.55
3	24.80±0.86***	58.20±1.13***	82.60±1.52***	42.00±1.14***	83.50±1.61***	160.00±2.12***
4	27.40±0.90	62.30±1.06	87.50±1.64	47.80±1.18	89.40±1.52	167.50±2.01

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Table 6: Changes In Stem Fresh Weight (g) Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Sites	Wheat (days)			Mustard (days)		
	30	60	90	30	60	90
1	0.98±0.02**	50.20±0.12***	60.42±2.32***	11.17±0.39 ns	93.12±3.78 ns	127.5±3.10**
2	1.27±0.04	55.21±0.59	66.89±2.36	11.92±0.28	95.89±2.90	132.53±3.04
3	0.75±0.09**	46.89±0.88***	61.98±1.24***	5.59±0.34 ns	77.94±3.12 ns	117.04±3.40*
4	1.07±0.07	50.47±0.76	68.18±1.18	6.12±0.20	80.14±3.01	121.40±3.56

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Table 7: Changes In Root Fresh Weight (g) Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Sites	Wheat (days)			Mustard (days)		
	30	60	90	30	60	90
1	0.32±0.02 ns	20.52±0.47***	26.56±0.36***	4.63±0.09 ns	19.52±1.30**	24.34±1.80***
2	0.45±0.03	24.98±0.72	29.17±0.42	5.14±0.06	20.63±1.14	26.12±1.69
3	0.33±0.05 ns	19.34±0.57***	27.80±0.86***	4.14±0.14 ns	13.69±1.20**	18.04±1.32***
4	0.38±0.03	24.24±0.49	31.24±0.98	4.44±0.14	14.87±0.86	19.98±1.41

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Table 8: Changes In Yield Parameters Of Wheat and Mustard Plants Growing At Different Sites Of Haridwar Region

Plats/parameters	Site 1	Site 2	Site 3	Site 4
Wheat (120) days				
Number of grains per plant	152.50±3.66***	162.3±4.55	145.0±6.04***	155.2±5.12
Grains weight per plant	11.08±0.61**	12.36±0.58	9.83±0.32***	10.96±0.67
Weight of 100 grains	6.30±0.16*	7.02±0.23	6.38±0.27**	7.11±0.22
Mustard (120 days)				
Number of grains per plant	1100.00±8.40***	1186.3±9.29	1101.7±8.87***	1189.8±9.88
Grains weight per plant	4.09±0.19*	4.79±0.11	3.96±0.14*	4.65±0.13
Weight of 1000 grains	0.37±0.02 ns	0.43±0.09	0.33±0.04 ns	0.39±0.08

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, ns = non significant

Conclusion:

Our result shows that changes in morphological characteristics, photosynthetic pigment and yield of wheat and mustard plants. The study clearly show that gaseous (NO_x and SO_2) and particulate pollutants such as SPM and RSPM have detrimental effects on wheat and mustard crops. Changes in morphological characteristics, photosynthetic pigment and yield of wheat and mustard plants directly corresponded to the levels of air pollution at different sites. The study elucidates that air pollution emitted from urban and industries adversely affecting the ambient air and agricultural production. It is very clear that urban and industrial air pollution has become a serious threat to agricultural production grown adjacent to urban and industrial areas. More research is, however, necessary to evaluate the contribution of individual and in combination of air pollutant on crop production and its losses.

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