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Agricultural Production and Air Quality: An Emerging Challenge

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In the past decade we have witnessed an industrial revolution, an agricultural revolution and a population explosion unparalleled in the history of mankind. The first two of these significant events have provided society with many of the material things desired by man. For his benefits man has acted as the master and has treated nature as his subject. In this often strange relationship, life appears to have become a struggle of man against his environment, and not a joint venture for mutual benefits. The scientific technology that made these developments possible represents an array of unparalleled achievements. However, in reaching our goals for material things, the side effects of such technological developments on aesthetic values, and the quality of our environment have received little or no attention. Impact of human activities, especially in form of atmospheric pollution, is one of the important concerns throughout the world. *Air pollution is defined as any atmospheric condition in which substances are present at concentrations high enough above their normal ambient levels to produce a measurable effect on man, animals, vegetation, or materials.*

The problem of air pollution has attracted special attention in India due to tremendous increase in size of population, industrialization and urbanization since last few decades. Air pollutants emitted in varying forms adversely affect growth and yield of crops.

Sources and types of air pollutant

Pollutants are released into the air from different sources. Sources of pollutant can be classified as (A) Natural and anthropogenic (B) Combustion and Non-combustion (C) Stationary and Mobile (D) Point and Non-point sources.. Natural sources are volcanoes, coniferous forests, forest fires, pollens, spores, dust storms, hot springs. Man-made sources include fuel combustion, chemical plants, motor vehicles, power and heat generators, waste disposal sites and operation of internal-combustion engines. Pollutants released from natural sources have a minimal effect on environment when compared to that caused by emissions from man-made sources.

On the basis of its source pollutants can be classified as: (A) Primary and Secondary pollutants Many pollutants undergo chemical reactions when they encounter other pollutants in the air. The products of these chemical reactions are called secondary pollutants, as opposed to primary pollutants that are emitted directly into the atmosphere. Ground-level ozone (O_3) is an example of a secondary pollutant that forms when nitrogen dioxide (NO_2) and volatile organic compounds (VOCs) mix in the presence of sunlight.

Pollutants are also classified as criteria and non-criteria pollutants. Criteria pollutants are those air pollutants for which ambient air standards have been defined to protect human health and welfare. Non criteria pollutants are those for which ambient standards have not defined.

Units for measurement of air pollutant level in the atmosphere are $\mu g\ m^{-3}$ and ppm (parts per million) at 25°C temperature and 1atmospheric pressure.

Spatial and temporal dimension of air pollution

In the last few years there have been a growing recognition that transport of air pollutants can occur between continents, particularly in the northern hemisphere. This presents a challenge not only to the scientific community but also to the policy maker. Task Force on Hemispheric Air Pollution within the Convention on Long Range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe do accounting of long range transport of air pollutants. There is well-documented evidence for the intercontinental transport of ozone and their precursors, as well as mercury and some persistent organic pollutants. Emissions from one continent can influence air quality in another.

Temporal variation in atmospheric pollutant load is also observed. In night and early morning time pollutant load is less in atmosphere as compared to day time. Seasonally also during and after rainy season pollutant load is less in atmosphere as compared to other seasons (Mina *et al.*, 2010).

Air Quality and Agriculture

The term "air quality" means the relative state of the air around us. Good air quality refers to clean, clear, unpolluted air. On the basis of its location, air quality is defined as ambient or indoor air quality. Ambient air quality refers to the quality of outdoor air in our surrounding environment. It is typically measured near ground level, away from direct sources of pollution. The air quality in enclosed spaces, such as home, schools or workplaces, is known as indoor air quality. Both ambient and indoor air quality influence welfare of humans and vegetation.

Air quality index (AQI) is a number used by government agencies to communicate to the public how polluted the air is. Different countries also use different names for their indices such as Air Quality Health Index, Air Pollution Index and Pollutant Standards Index. In India Central Pollution Control Board (CPCB) has a developed threshold level for selected pollutants in ambient air (Table 1).

Table 1: National ambient air quality standards

Pollutant	Time weighted average	Concentration in ambient air			
		Industrial, residential, rural and other areas		Ecologically sensitive area	
		(µg m^{-3})	(ppb)	(µg m^{-3})	(ppb)
Sulphur dioxide(SO_2)	Annual*	50	19	20	8
	24 hours**	80	30.4	80	30.4
Nitrogen dioxide(NO_2)	Annual*	40	21.2	30	15.9
	24 hours**	80	42.4	80	42.4
Ozone(O_3)	Annual*	100	51	100	51
	1hours**	180	91.8	180	91.8

Source: CPCB, Annual report 2010

* Annual arithmetic mean of minimum 104 measurement taken in a year at a particular site twice a week, 24 hourly at uniform levels.

** 24 hourly or 1 hourly monitored values as applicable shall be complied with 98% of the time, 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Agricultural crops are affected by air pollutants. Air pollutants currently considered to be most important in causing direct damage to crops are sulphur dioxide (SO_2), nitrogen oxides (NOx), ozone (O_3), fluorine (F) and suspended particulate matter (SPM).

The urban and peri-urban areas of India have the unfortunate combination of being impacted by both the "traditional" pollutants (i.e. SO_2 and particulates), as well as the "new" pollutants in the form of NOx and ozone (O_3). Mixtures of both traditional and new pollutants result in combined adverse effects which is often greater than the sum of their individual effects. Agricultural crops can be injured when exposed to high concentrations of various air pollutants. Injury ranges from visible markings on the foliage, reduced growth and yield and premature death of the plant. Development and severity of the injury depends on pollutant concentration and number of other external factors. These factors include length of exposure to the pollutant, plant species and its stage of development. as well as other environmental factors conducive to a build-up of the pollutant and to the preconditioning of the plant, which make it either susceptible or resistant to injury (Mina and Varshney, 2008).

Experimental studies conducted at Varanasi situated in upper Indo-Gangetic Plains (IGP) of India have indicated significant losses of agricultural production at current ambient pollutant levels in urban, suburban and rural areas (Aggarwal *et. al*., 2005). The intensity of losses, however, depends upon the pollutant concentration, duration of exposure. climatic and edaphic factors, plant species and cultivars. Pollutants either affect the plants directly by causing visible injury or indirectly by growth or yield reductions. Reductions in leaf area, biomass, chlorophyll, ascorbic acid and N contents have often been observed for the crop species growing in polluted areas. Field transect studies have shown significant negative correlations between air pollutant concentrations and net photosynthesis, biomass accumulation as well as yield of crop plants. Monocot plants are found to be more resistant than dicot plants. Leguminous plants and leafy vegetables are most sensitive to air pollutants among the crop plants. Winter crops showed relatively lower magnitude of yield losses at different sites than summer crops. Quality of seeds also varied between urban, suburban and rural sites. Variations in nutrient, metabolite and energy contents of seeds directly corresponded to the levels of air pollutants at different sites. At urban and suburban sites, the magnitude of response involved all air pollutants, whereas at rural site ozone (O_3) had more influence than the others. Ozone seems to play a major role as maximum reductions in yield and seed quality were recorded at sites showing highest O_3 concentrations. Simulation experiments conducted in closed top or open top chambers have also confirmed the adverse impacts of individual pollutants on plants. National ambient air quality standards are mainly based on health impact; hence a revision of the same taking into account climatic conditions, type of vegetation and soil is urgently required to save crops from adverse impacts of air pollution. Economic evaluation of crop loss due to air pollution is an important need of the future to ensure food security for growing population of the country. Long-term studies are required all along the country to identify the high and low risk zones of air pollution in different regions to develop control policy for reducing adversities of air pollution on vegetation.

Ozone pollution and agriculture

Ozone in troposphere act as secondary pollutant. It is formed as a result of chemical reaction between NOx and VOCs which are primary air pollutants. Research studies conducted under research projects, predicted the impact of ozone pollution on wheat, rice, maize and soybean crops grown globally for the year 2030 by global air quality model, and compares the results to estimate losses in crop yields. In the year 2000, the global economic value of crop losses through surface ozone was estimated to be between US $14 and $26 billion, with 40 per cent of this cost occurring in China and India. Estimated losses for specific regions were: European (defined as EU25) - $0.9 to $1.1 billion, North America - $1.8 to $4 billion, India - $2.8 to $6.1 billion and China - $3 to $5.5 billion.

In comparison, climate change is estimated to cause global crop losses totaling approximately just US $5 billion per year. The study showed that soybean and wheat are especially sensitive to O_3. Greatest losses for wheat were in India and China, with India losing up to 28 % and China up to 19% of crop yields. Europe suffered the greatest relative yield loss for soybean (20 to 27%), followed by China (11 to 21 %). Across all four regions, maize was found to be the least affected crop with yield loss between 2 to 7%. Economic loss in different crops in India due to air pollution is given in Table 2.

(A) (B)

Figure: Ozone pollutant injury symptoms on (A) potato and its impact on growth of (B) Radish

Table 1: Yield loss in crops from O_3 pollution in India

Crop	O_3 concentration	Yield loss (%)	Reference
Spinach	196 and 98 µg/m^3	6.78-25.02	Varshney and Aggarwal, 1992
Brinjal	196 and 98 µg/m^3	87.33-93.80	Varshney and Aggarwal , 1992
Onion	196 and 98 µg/m^3	27.80-37.50	Varshney and Aggarwal , 1992
Tomato	Ambient O_3 conc.	7.38-24.94	Varshney and rout, 1998
Soyabean	Ambient O_3 conc.	29.73-46.98	Varshney and Rout, 1998
Wheat	Ambient O_3 conc.	40.97-30.68	Varshney, 1999
Mustard	Ambient O_3 conc.	9.34-9.25	Varshney, 1999
bean	Ambient O_3 conc.	2.32-42.3	Varshney, 1999

Table 2: Economic losses in different crops from air pollution in India

Crops/Cultivars	Economic loss (Rs ha^{-1})	Pollutant regime (ppb)			Studies approach
		SO_2	NO_2	O_3	
Wheat					
M 234	23846	8	40	42	OTCs
PBW 343	1620	11	20	45	OTCs
M 533	1641	11	20	45	OTCs
M 510	14040	-	-	47	OTCs
Sonalika	5389	-	-	47	OTCs
Lok-1	5055	6.1	13	48	OTCs
HD2329	12505-17995	18-45	28-47	10-15	FTS
M234	4156	-	-	44	EDU
M 468	11016	-	-	44	EDU
M 510	8964	-	-	44	EDU
PBW 343	1080	-	-	44	EDU
Sonalika	5724	-	-	44	EDU
HD 2329	13176	8.5	13.5	29	EDU
Rice					
NDR 97	4246	7.3	14.5	35	OTCs
Saurabh 950	1972	7.3	14.5	35	OTCs
Mustard					
Kranti	7481	6.1	13	48	OTCs
Aashirwaad	8445	6.1	13	48	OTCs
Vardan	3587	6.1	13	48	OTCs
Pusa Jaikisan	1208-5453	18-45	28-47	10-15	FTS
Urd					
Barkha	3096	-	-	51	EDU
Shekhar	1135	-	-	51	EDU
Soybean					
Pusa 9712	9907	-	-	52	EDU
Pusa 9814	7776	-	-	52	EDU

Pea					
Arkel	19012-30550	18-45	28-47	10-15	FTS
Mung					
Malviya Jagriti	7860-13244	13-32	12-80	10-58	FTS
Malviya	5972	9	17.5	59	EDU
Janpriya					

Source: Aggarwal (2005)

Approaches to assess impact of air pollution on agriculture

Identification of air polluted hot spots

Air polluted hot-spot areas across the country should be identified by modeling approach using data on air pollutant concentration and agricultural data. These data would be combined using prescribed Air Quality Guidelines (AQGs) that are recommended by CPCB. The areas across the region where thresholds and magnitude are exceeding would indicate locations where the agricultural crops may be at risk of damage from air pollution, and spatial distribution of relative risk respectively. The production of maps showing relative risk would form the basis to prioritise future work.

Air pollution risk assessment for crops

One of the key issues in making any kind of provisional risk assessment is to identify the receptor for which the assessment is being performed (i.e. the species or cultivars) and the length of time for which they may be exposed to air pollutant (i.e. the crop growing season or, ideally, the sensitive phenological period within the growing season). Important parameters for studying air pollution damage in crops include yield and its components, harvest index and nutritional quality (protein/nitrogen, sugar content and certain acids). There are number of protocols available for assessing air pollution risks on vegetation in developed countries. However, two methods have been identified as best in assessing real impacts of air pollutants on crops are:

- Bio-monitoring method: records pollutant specific visible injury and biomass loss
- Chemical protectant method: that allows quantification of yield losses

Additional methods that may be used include

- **Passive bio-monitoring methods:** these would require the development of a common photo-guide to identify air pollutant specific visible injury occurring in the field for key species of different regions. Development of such a passive bio-monitoring protocol would be a valuable tool in assessing air pollution injury.
- **Transect studies:** assess damage to selected crops (or active bio-monitors) along a pollution gradient (city, highway, industries etc.), to the rural sites.
- **Fumigation/filtration studies:** this involves establishment of filtration/fumigation facilities, to perform experimental investigations for derivation of dose-response relationships and then to screen sensitive and resistant cultivars.

Integration of modeling and crop monitoring field studies

Integration of the modelling and crop monitoring field campaigns will help in evaluating modelled information describing the magnitude and spatial extent of air pollution impacts to agriculture across the nation. This information will be useful for improving the modelling and mapping studies to define regional and crop specific air quality guidelines. Secondly, the information gained from the exercises described above will provide new evidence that can be combined with appropriate agricultural data to enable the socioeconomic aspects of air pollution related crop damage to be investigated.

Conclusion

India is very much dependent on agriculture. Agricultural production determines the livelihood security as well as economic development of the country. Reduction in crop yield and consequently the economic losses caused air pollutants have major social, economic and environmental consequences. Sulphur dioxide, nitrogen oxides, ozone and suspended particulate matter are some of the important air pollutants causing yield loss in crops. Soybean and wheat crops were found to be sensitive to ozone. Air pollution risk assessment of Indian crops will bring together experts and specialists on air pollution, to discuss the likely impacts of air pollution on agricultural production. It will help the decision makers to formulate necessary policy options to reduce the vulnerability of crops to air pollution.

References:

Agarwal, M (2005) Effects of air pollution on agriculture: An issue of national concern. National Academy Science Letters (India) 28, 93-106.

Mina, U,– Kumar, P and Varshney, CK (2010) Effect of ozone stress on different growth stages of Potato (*Solanum tuberosum*). Phyton. 49(2), 253-266.

Mina, U and Varshney, C.K. (2008). Response of Indian crops to ozone phytotoxicity. Environment and ecology, 26(2), 700-703.

Varshney, C.K. and Aggarwal, M. (1992). Ozone levels in the urban atmosphere of Delhi. Atmos. Environ., 26B, 291-294.

Varshney, C.K. and Rout, C. (1998). .Ethylene Diurea (EDU) protection against ozone injury in tomato plants at Delhi. Bulletin of Environmental Contamination and Toxicology. 61(2), 181-193. –

Varshney, C.K. (1999). Effect of air pollution on Peri-Urban crops (Part-I- Summer crops, May- July 1998). Project report submitted to Centre of Sciences and Technology, Imperial College of Sciences and Technology.