Review Article

Impact of Gaseous Air Pollutants on Agricultural Crops in Developing Countries: A review

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Received: 21 March 2020; **Accepted:** 01April 2020; **Published:** 27 May 2020

Citation: Satesh Kumar Devrajani, Mehran Qureshi, Uzma Imran, Tamat Ul Nisa. Impact of Gaseous Air Pollutants on Agricultural Crops in Developing Countries: A review. Journal of Environmental Science and Public Health 4 (2020): 71-82.

Abstract

This review provides knowledge about air pollution and its impact on agriculture crop yield and quality in developing countries. The need of increasing agriculture production has been very important for the increasing of population. Air pollutants pose risks on yield of crops depending on the emission pattern, atmospheric transport and leaf uptake and on the plant’s biochemical defence capacity. In the recent research it is identified that the agriculture production is being affected by air pollution, the impact of air pollution is caused by number of air pollutants (sulphur dioxide (SO2), Nitrogen oxides (NOx), and Ozone (O3). Air pollutants produce reactive oxygen species (ROS), which adversely affect biochemical processes of plants and reduce their tolerance capacity to other stresses also. Several vital physiological processes such as photosynthetic CO2 fixation and energy metabolism are also affected negatively by air pollutants. An adverse effect caused by air pollutants depends not only upon its concentration, but also on the duration and combination of air pollutants. Ozone is the most phytotoxic of the common air pollutants. It is concluded that the continuous increasing concentration of pollutants will pose a critical threat to future world food security.

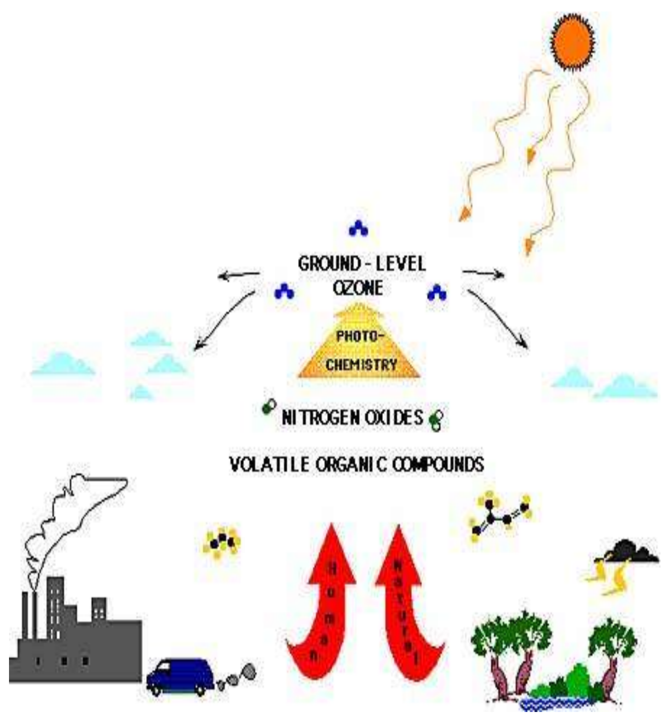
Keywords: Air pollution; Agriculture; SO2; NO2; O3

1. Introduction

Developmental activities are the seeds of environmental damage which are necessary for the needs and greed of man. The various activities like manufacturing, processing, consumption and transportation not only depleting the stock of natural resources but also destroy the environmental system. The productivity of the economic system of the countries depends upon the supply and quality of environmental and natural resources. Air, water, soil and noise pollution are the by-products of economic development. The word pollution is derived from the Latin word 'pollutioneum' which means to make dirty. According to National Environmental Research Council, "Pollution is viewed as the release of substances and energy as waste products of human activities, which result in harmful changes within the natural environment". The concentration and duration of one or more contaminant like dust, gas, mist, odour, smoke, smog and harmful gases in the outdoor atmosphere is injurious to human beings, animal and plants life. The developed and developing countries have always aimed to minimize the constraints to the maximum production of crop yield. These constraints can also be abiotic, consisting of nutrient deficiency, metallic toxicity, salinity, low and high temperatures, wind and waterlogging. there are also numerous biotic constraints: invertebrates and vertebrates pests; fungal, viral and bacterial pathogens and trampling. The vast amount of money is being spent in order to overcome these issues and increase agriculture yield. Another constraint which is less noticeable but with the proof it is identified that the air pollution is a widespread threat to agricultural production.

Some countries are aware of the effects of air pollution on crops and they are practicing reducing the effects of air pollutants on crops and increase the yield of crops, but some countries are just striving increasing the crop yield for rapidly expanding population. Air pollution has become a serious problem and adversely affect health, vegetation, aquatic ecosystem and materials. Rapid urbanization, industrialization, and energy consumption are taking place in many developing countries with poor emission controls. The motor vehicles are growing at a high rate in the developing countries, mostly poor and old maintained vehicles that play a vital role in the deterioration of air quality. Thus, SO2 and NOx are increasing rapidly in developing countries. We know less about the pollutant O3 because in most countries very little attention has been paid. However, it is clear that the concentration of O3 in developing countries is phytotoxic [1, 2]. The ozone which is component of photochemical smog was first observed around Los Angeles in the 1940s. It was noticed after the research into this new smog that this phenomenon not only had adverse effect but that the main culprit is O3. Photochemical reactions on NOx and volatile organic compounds (VOCs) produce ozone. SO2 is one of the major pollutants emitted mainly from coal and fuel oil combustion, the emissions are increasing with a rapid increase in energy demand in many developing countries. In China, coal burning alone accounted for 72% of total energy consumption in 1998, causing more than half of the country's SO2 emissions [3]. China is now the leading emitter of SO2 in the world. Due to low sulphur content in the fuel the thermal powerplants, old and poorly maintained vehicles in developing countries, the road traffic is minor contributor of SO2. Thermal power stations and automobiles` are also major sources of NOx emission, with nitric oxides being the primary pollutant but oxidized to NO2. NOx is predicted in the developing countries to cause widespread increases in O3 levels.

In the (Table 1), it is shown the concentration of exposure and effects of the pollutants on plants indicates that what kind of problems occurs in plants with this.



Ground-level ozone causes more damage to plants than all other air pollutants combined. Ozone is formed in the troposphere when sunlight causes complex photochemical reactions involving nitrogen oxides (NOx), volatile organic hydrocarbons (VOC) and carbon monoxide that mainly from gasoline engines and other fossil fuels combustion. Woody vegetation is another major source of VOCs. NOx and VOCs can be transported long distances by regional weather patterns before they react to create ozone in the atmosphere, where it can persist for several weeks. Through a complex series of photochemical reactions involving both NOx and volatile organic compounds (VOCs), ozone levels can be elevated above the natural background of about 40 ppb. Motor vehicles, particularly inefficient and poorly tuned engines characteristic of developing countries, are the major source of VOCs. In addition, ozone production is encouraged by the high temperatures and high light intensity characteristics of many developing country cites. Although the precursors for ozone are produced in cities, the levels of this secondary pollutant are often higher on the outskirts of the city, due to local destruction by NO at ground level within the city [4]. Ozone is a cause for concern because elevated ozone levels can be widespread over rural agricultural areas, particularly downwind of cities [4]. There have been very little coordinated ozone monitoring levels in rural areas of developing countries, but the limited data available are consistent with this, indicating phytotoxic levels in several important agricultural areas [5].

Pollutant	Level (ppm) and exposure	Effects
SO2	• 0.3 to 0.5 for several days	• Bleached spots, Chlorosis, Chronic injury to Spinach and other leafy vegetables
NO2	• 0.25 for 8 months • 0.5 for 10-12 days • 3.5 for 21 hours • 25 for 1 hour	• Increased Abscission and reduced yield in citrus plants • Suppressed growth of tomatoes • Spots of mild Necrosis on cotton and bean plants • Acute leaf injury
Ozone	• 0.03 for 8 hours, time effect reduces if low level SO2 is also present	• Fleck on upper surface; • Necrosis and bleaching; damage to tobacco leaves at O3 = 0.24 ppm after 2 hours of exposure

Table 1: Effects of air pollutants on vegetation.

Diffusion which is governed by micro-meteorological conditions (radiation, temperature, wind, etc.) transfers gaseous atmospheric compounds from the atmosphere to plant canopies. Penetration of gases through plant is generally of minor importanc (Lendzian and Kerstiens, 1991), although some pollutants such as SO2 can affect the plants and gain entry into the internal leaf tissue to some extent (Wellburn, 1994). Aerosols and sedimenting particles containing nutrients and pollutants (e.g., heavy metals) are deposited directly on plant surfaces or on soil surfaces; matter deposited on plant surfaces indirectly can be transmitted indirectly to the soil by run-off or by plant debris or litter. For agriculture, persistent effects of air pollutants such as O3 are of particular concern, because they are due to exposures for weeks, months, or over the entire crop’s lifecycle. It is well known that increasing levels of O3 cause a decrease in the yield of many crop species, such as wheat, rice, soybean and cotton (Ashmore, 2005). Considering the information that urban pollution can pose a serious threat to agricultural productivity in areas around urban centers and there exist variations in pattern of pollutants due to interactions during transport.

2. Trends in Air Pollutant- Concentrations and Distributions

Increasing energy demands associated with economic growth and industrialization in Asia, Africa and Latin America have resulted in dramatic increases in air pollution emissions. Problems are exacerbated by rapid and poorly planned industrial growth in developing countries, the close proximity of industrial complexes and thermal power plants to residential areas [6] and the fact that regulation air pollution control in developing countries is often insufficient for technical and economic reasons. Air pollution kills more than 2.7 million people each year, with over 90% of these deaths in developing countries and two-thirds of them in Asia [7]. Thus, it is not surprising that most attention to date has concentrated on the direct impact of these industrial and urban emissions on human health. Nonetheless, very little is known about pollutant concentrations in many suburban and rural areas, whereas through decreased crop yields, food quality and income there may be significant indirect impacts of air pollution on human health.

One of the major phytotoxic primary pollutants, sulphur dioxide is emitted mainly from the coal and fuel oil combustion, with increased emissions associated with the rapidly increasing energy demands in many developing countries. For example, Asian energy demand doubles every 12 years, and burning fossil fuels, mainly coal meets 80% of demand [8]. As a result, SO2 emission in Asia is predicted to increase from 34 x 106tonnes in 1990 to 110 x 106tonnes by 2020 [8]. In China, coal burning alone accounted for 72 percent of total energy consumption in 1998, causing more than half of the country's SO2 emissions [3]. China is now the leading emitter of SO2 in the world. Coal-based power generation has also greatly increased in India over the last decade and now accounts for 64 percent of electricity generation [9]. Smelters are another important, but more localized source of sulphur dioxide.

Traffic also plays an important in NOx emissions, with nitric oxide as the principal primary pollutant but being rapidly oxidized to NO2. All combustion processes at high temperatures produce NOx emissions, with thermal power plants being the other main source. A global increase in NOx emissions from 40 x 106tonnes in the mid-1980s to 55-66 x 106tonnes per year by 2025 has been predicted [10], with substantially higher percentage increases in some developing countries, such as China. It is anticipated that these increases in NOx lead to large increases in O3 levels in developing countries.

Ozone levels can be about 40 ppb above natural background due to a series of complex photochemical reactions involving both NOx and volatile organic compounds (VOCs). The main source of VOC is automobiles, especially ineffective and faulty tin engines, characteristic of developing countries. In addition, significant temperatures and high light intensities support ozone generation in many cities in developing countries. Although the precursors for ozone are produced in cities, the levels of this secondary pollutant are often higher on the outskirts of the city, due to local destruction by NO at ground level within the city [4]. Ozone is a significant cause of concern because ozone levels can be high in rural areas of agriculture, especially in the lower cities [4]. There is little integrated monitoring of ozone levels in the rural areas of developing countries, but available data are in accordance with this, indicating phytotoxic levels in many important agricultural areas [5].

3. Agriculture in the Developing Countries

While in developing countries, in particular, the effects of air pollution on ozone have been observed. Here is the social and economic importance of the impact of air pollution on agriculture can be enormous to maintain leading food security and exchange on the importance of national agricultural production. However, the fight against air pollution is usually discussed due to limited resources and a general desire to promote industrial development.

4. Impacts of Air Pollution on Agricultural Crops in Developing Countries

4.1 Ozone

Direct effects of O3 on crop yields have been studied in Pakistan and India (Tables 2, 3, 4). These studies include the use of leaf antioxidants. Chamber filtration systems are more expensive and easier to use this way. Wahid et al. [11] conducted an experiment in Pakistan. Here, the protective effect of EDU against soybeans (Glycine max) was assessed during the growing rainy season in suburban areas, remote rural areas and rural road areas around Lahore. Seed weight of untreated plants decreased by 53 percent, 65 percent and 74 percent at remote suburban, rural and rural road locations compared to untreated plants. The concentration of oxidants is also high in rural areas. The results suggest that ozone can have a significant impact on crop production in Pakistan, which is a major agricultural area of Pakistan (Table 4).

Very limited open-top filtration studies have been conducted in developing countries. The most important series of experiments was again conducted in the outskirts of Lahore, Pakistan, in which two local crops of winter wheat, rice and mung beans were used for two consecutive years [19, 20, 24, 25] (Tables 1, 2, 3). The grains were grown in open top chambers, they were aerated by air or coal filtered air, and they were subjected to local planting methods. In all four experiments, partial air treatment significantly reduced production compared to filtering air, which varied from 34 to 46 percent. The concentration of sulfur dioxide in this area was very low, but a series of fumigation studies were performed in the chamber to estimate the contribution of ozone and nitrogen dioxide to the observed decrease in production [26]. These studies showed that the use of a single cultivar did not show an effect associated with NO2 or O3, and that the reduction in yields recorded in Lahore was only related to O3. Subsequent studies using EDUs containing soy confirmed these results [11].

Reference	Study site	Experimental type (growth period)–field/pot –O_3 monitoring method	Cultivator (No. of data points)	SO_2 and NO_2 concs. (ppb)	O_3 concs. (ppb) averaging period	Yield response (parameter, rel. yield%)
Agarwal (2005) [12]	India, Varanasi	Fu (Dec-March) – field – wet chemistry	Winter wheat: Malviya 234 (2). HP1209 (2)	–	70; 100: 4-h mean	Yield plant^{-1} (95%-83%)
Ambasht and Agarwal (2003) [13, 14]	India, Varanasi	Fu (Nov-April) – field – wet chemistry	Winter wheat: Malviya 234 (1).	–	70; 4-h mean	Yield plant^{-1} (91%)
Rai et al. (2007) [15]	India, Varanasi	Fi (Dec-March) – field – UV absorption	Winter wheat: Malviya 234 (1).	SO_2 8, 4; NO_2 39.9	40; 8-h mean	Yield plant^{-1} (79%)
Tiwari et al. (2005) [16]	India, Varanasi	EDU (300 ppm) (Dec-March) – field – UV absorption	Winter wheat: Malviya 533 (1). Malviya 234 (1)	–	41; 8-h mean	Yield plant^{-1} (87%-81)
Wahid (2006) [17]	Pakistan Lahore	Fi (Dec-March) – pot – UV absorption	Spring wheat: Inqlab – 91 (1). Punjab-96 (1). Pasban-90 (1)	SO_2 16; NO_2 30	72; 8-h mean	Yield plant^{-1} (82%-57%)
Wahid and Maggs (1999) [18]	Pakistan Lahore	Fi (Dec-March) – field – wet chemistry	spring wheat: Rawal-87 (1). Punjab-85 (1)	No data	70; 8-h mean	Yield plant^{-1} (64%-52%)

Fu: Fumigation; Fi: Filtration; EDU: Ethylenediurea

Table 2: Describing the data collated about wheat yield response to ozone.

Reference	Study site	Experimental type (growth period)– ield/pot – O_3 monitoring method	Cultivator (No. of data points)	SO_2 and NO_2 concs. (ppb)	O_3 concs. (ppb) averaging period	Yield response (parameter, rel. yield%)
Maggs et al. (1995) [19]	Pakistan Lahore	Fu (May/June to Oct/Nov) – pot – wet chemistry	Basmati 385 (1). IRRI 6 (1)	SO2 no data; NO2 22.5	60; 6-h mean of 3 days/week	Yield plant–1 (63%-53%)
Wahid et al. (1995) [20]	Pakistan Lahore	Fi (July-Nov) – pot – wet chemistry	Basmati 385 (1). IRRI 6 (1)	SO2 no data; NO2 12.6	36; 6-h mean of 3 days/week	Yield plant–1 (63%-58%)
Wahid et al. (1997) [21]	Pakistan Lahore	Fi (July-Nov) – pot – wet chemistry	Basmati 370 (1). Basmati Pak (1)	No data	57; 8-h mean	Yield plant–1 (71%-55%)

Fu: Fumigation; Fi: Filtration

Table 3: Describing the data collated about rice yield response to ozone.

Reference	Study site	Experimental type (growth period)–field/pot – O_3 monitoring method	Species and cultivator (No. of data points)	Control treatment	O_3 concs. (ppb) averaging period	Yield response (parameter, rel. yield%)
Agarwal (2005) [12]	India, Allahabad	Fu (July-Oct) – field – wet chemistry	Soybean: PK472 (2) Bragg (2)	–	70; 100: 4-h mean	Yield plant^{-1} (95%-66%)
Agarwal et al. (2005) [22]	India, Varanasi	EDU (500 ppm) (July-Sept) – field – wet chemistry	Mungbean: Malviya Jyoti (1).	–	33; 8-h mean of 1 day/week	Yield plant^{-1} 70%
Ambasht and Agarwal (2003) [13, 14]	India, Varanasi	Fu (Nov-March) – field – wet chemistry	Soybean: Punjab 1 (1).	–	70; 4-h mean	Yield plant^{-1} 89%
Bajwa et al. (1997)]23]	Pakistan, Lahore	Fi (March-June) – pot – wet chemistry	Mungbean M-28 (1)	No data	61; 8-h mean	Yield plant^{-1} 50%
Wahid et al. (2001) [11]	Pakistan Lahore	EDU (400 ppm) (Aug-Oct and Feb-May) – pot – wet chemistry	Soybean NARC-1 (4)	–	40-75; 6-h mean	Yield plant^{-1} (68%-35%)
Ahmed (2007) [24]	Pakistan Lahore	OTCs (March-June) – pot – wet chemistry	Mungbean NM-92 and NM-51 (2)	–	62; 8-h mean	Yield plant^{-1} 55%

Fu: Fumigation; Fi: Filtration; EDU: Ethylenediurea

Table 4: Describing the data collated about various legumes yield response to ozone.

4.2 Sulphur dioxide

Several chamber and field studies were carried out to investigate the impact of sulfur dioxide on growing crops, especially in India. Wheat, which seems to be particularly susceptible to other major crop plants, has been studied a lot. However, most of these studies cover chamber fog with an unusually large number of SO2s, with a limited number of smokes using pollution levels. Field trials are often studied with prospective resources that are widely adopted in developed countries due to the complex and expensive nature of open-air smoking systems. In these communication studies, plant material is usually grown on standard soils and vessels and exposed to all or part of the growing season on the contaminated slope. The results can be complicated by the presence of other pollutants, especially NOx. A main study by Transect was by [27] Local wheat was grown in a coal-fired power plant in Uttar Pradesh, India. Despite evidence of increased SO2 emissions in developing countries, empirical data show that phytotoxic effects in agriculture mostly identify sources and affect the area closest to industrial companies in those areas. Will In rural areas, however, this ignores the problem of urban and suburban agriculture, which in many places is exposed to high levels of SO2 and other pollution. Cities and urban agriculture, which are often overlooked by decision makers and planners, play a vital role in developing countries to rapidly feed the urban population. There is evidence of this. It is essential for the nutrition of the urban poor [28].

4.3 Nitrogen dioxide

There is little research on the impact of nitrogen dioxide on agricultural production in developing countries. Although the study by Magazine et al. (1995) indicated that NOx had no environmental impact on wheat and rice production in the suburbs of Lahore, which may be significant in urban and adjoining areas. The above study also examined the effects of NOx, which studied the effects of SO2 on four crops in Delhi and Varanasi. In winter, wheat yield was significantly negatively correlated ($p < 0.05$) with NO2 concentrations ranging from 31 to 105 µg m-3 [29]. In Delhi the yields of both mustard and wheat were negatively correlated with NO, which ranged from 79 and 197 µg m-3 [29]. The transect study in Varanasi also raised the possibility that urban air pollution was having an impact on the nutritional quality, in addition to the yield of crops. The results showed significant negative relationships with SO2 and NO2 for carbohydrate and energy content, as well as for beans and wheat (Table 1).

5. Conclusion

This paper summarize that the air pollution concentrations are high enough to cause adverse impacts to crops. The continuous increasing concentration of pollutants will pose a critical threat to future world food security. Developing countries such as India, Pakistan, and China use low quality of fuel in Powerplants and in automobiles that tend to the emit SO2, NO2, O3 and Particulate matters in the atmosphere that have both direct and indirect effects on humans, plants and animals. The limited field experimental data described above clearly indicate that there may be significant crop losses in a number of important agricultural areas in the developing countries, with ozone the main cause for concern. However, this issue is little recognized and resources available to investigate it are limited. Therefore, in order to target further research efforts, it is important to be able to identify and illustrate geographical areas where there is a high risk of major crop losses. Due to various forms of air pollutants in developing countries, the proper work could have been done in detecting crop diseases.

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