E N V I S NEWSLETTER

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Indian Institute of Tropical Meteorology, Pune

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Acid Rain & Atmospheric Pollution

CONTENTS

EDITORIAL

Editor's Desk:

The previous newsletters of ENVIS-IITM, so far, covered the topics related to different pollutants, measurement of pollutant levels and the effects of pollutants on human beings. However the pollution topic still remains unfinished if we leave out the most important aspect "Effect of Air Pollution on Plants and Agriculture". It is observed that surface ozone levels over Delhi are high enough to exceed the "critical levels" which are considered to be safe for human health, but from agricultural point of view the ozone levels have surpassed the critical levels for vegetation and forests. It is now known worldwide that, ozone accounts for roughly 90% of the plant injury and losses to air pollutants. The current ENVIS Newsletter (Volume: 8, Issue: 3) therefore mainly focuses on the aforementioned topic along with some other details related to our ENVIS Centre.

Readers are invited to contribute articles, review papers, successful case studies or news items relevant to Acid Rain & Atmospheric Pollution Issues for publishing in the next edition of Newsletter of IITM, ENVIS Centre.

Effect of Air pollution on agriculture

Air pollution not only damages the air but it also damage the environment on Earth's surface and harm its inhabitants viz. human beings, trees, lakes, crops, animals etc.

Plants are more severely affected by air pollution than any other entity, as they are immobile and hence fully exposed to polluted air in most cases.

There are two ways by which air pollution can affect the plants:

- Visible
- Non Visible

Visible symptoms include:

- loss of color,
- necrosis,
- chlorosis and stippling
- early senescence or leaf drop,
- elongated or misshapen stem and leaf structures and decreased yield.

Whereas **Non visible effects include:**

- reduced plant growth &
- alteration of physiological and biochemical processes

In agricultural activities, the crops are injured when exposed to high concentrations of various air pollutants. The development and severity of the injury depends not only on the concentration of the particular pollutant, but also on a number of other factors. These factors include the length of exposure to the pollutant, the plant species, its stage of development as well as the environmental factors conducive to a build-up of the pollutant.

Air pollution injury to plants can be tracked from various symptoms. Injury to foliage is visible in a short time and appear as necrotic lesions (dead tissue), or it may develop slowly as a yellowing or chlorosis of the leaf. There may be a reduction in growth of various portions of a plant. Plants may be killed outright; usually air pollution weakens the plants by damaging their leaves.

Pollutants which affect crops

The Principal air pollutants of major interest to agriculture are: sulphur dioxide, fluorine compounds and smog. The last is the complex mixture. There are two types of smog: One is mixture of coal smog and fog with enough sulphur dioxide whereas the other type is highly oxidizing, which usually contains neither coal smoke nor fog but rather is a mixture of ozone and pre oxidized organic compounds formed by photochemical reactions between oxides of nitrogen and innocuous organic compounds such as

ethylene, DDT, and some heterocyclic bases are known to have powerful phyto-toxicity.

Ozone

Ozone, a major smog constituent, inhibits the ability of plants to open the microscopic pores on their leaves and breathe, (according to research published in *Proceedings of the National Academy of Sciences).*

Ozone effects on plants are most pronounced when soil moisture and nutrients are adequate and ozone concentration is high. Under good soil moisture and favorable conditions the ozone enters through opening into leaf and damages the cells that produce the food for the plants. Once the ozone is absorbed into the leaf, some plants spend energy to produce bio-chemicals that can neutralize a toxic effect while other will suffer from a

Fig1.These blackberry plants near Shining Rock Wilderness had severe Ozone symptoms present in mid-August

toxic effect and growth loss and/or visible symptoms may occur. The presence of the ozone in an area can be detected when consistence and known symptoms are observed.

Sulfur Dioxide

Sulfur dioxide (SO_2) was formerly viewed as the most important phytotoxic pollutant. Major sources of sulfur dioxide are coal-burning operations, especially those providing electric power and space heating. Its emissions can also result from the burning of petroleum and the smelting of sulfur containing ores.

Fig 2. Acute sulfur dioxide injury to raspberry. Note that the injury occurs between the veins and that the tissue nearest the vein remains healthy.

Sulfur dioxide penetrates into leaves primarily in gaseous form through the stomata, (microscopic openings) and the resultant injury is classified as either acute or chronic. Acute injury (*Fig* 2) is caused by absorption of high concentrations of sulfur dioxide in a relatively short time.

The symptoms appear as 2-sided (bifacial) lesions that usually occur between the veins and occasionally along the margins of the leaves. High concentrations of sulfur dioxide can produce acute injury in the form of foliar necrosis.

The color of the necrotic area can vary from a light tan or near white to an orange-red or brown depending on the time of year, the plant species affected and weather conditions. Usually newly expanded leaves are the most sensitive to acute sulfur dioxide injury, while oldest being somewhat more resistant.

Fluoride

Fluoride is toxic in high concentrations to plants. Industrial activities plays major role for fluoride pollution. Fluorides are discharged into the atmosphere from the combustion of coal; the production of brick, tile, enamel frit, ceramics, and glass; the manufacture of aluminum and steel; and the production of hydrofluoric acid, and phosphate chemicals. Fluorides are released into the air in both a gaseous state (as hydrogen fluoride and silicon tetra fluoride) and in solid particles. Gaseous fluoride enters the leaf through the stomata (=pores) then it dissolves in the water permeating the cell walls. Carried by the water, the fluoride concentrates in the margins and tip, so it is these areas that generally are the first to show visible injury. Clearly, this concentration mechanism is one reason why fluoride can be so toxic to plants.

Fig 3. Fluoride injury to plum foliage. The fluoride enters the leaf through the stomata and is moved to the margins where it accumulates and causes tissue injury

The injury (*Fig 3*) starts as a gray or light-green water-soaked lesion, which turns tan to reddish-brown. With continued exposure the necrotic areas increase in size, spreading inward to the midrib on broad leaves and downward on monocotyledonous leaves.

Ammonia

Nitrogen is an essential nutrient that is required by all plants and animals for the formation of amino acids.

Although ammonia is a source of plant nitrogen, still high concentrations of ammonia are work as phytotoxic. Due to high concentration of ammonia plants may die overnight. However lower level typically cause burning on

the margins of young leaves. Ammonia injury to vegetation has been observed frequently in Ontario in recent years due to the involvement of storage, transportation or application of anhydrous and aqua ammonia fertilizers.

Fig 4. Severe ammonia injury to apple foliage and subsequent recovery through the production of new leaves following the fumigation

- Grasses often show reddish, interveinal necrotic streaking or dark upper surface discoloration.
- Flowers, fruit and woody tissues usually are not affected, and in the case of severe injury to fruit trees, recovery through the production of new leaves can occur (*Fig4*).
- Sensitive species include apple, barley, beans, clover, radish, raspberry and soybean. Resistant species include alfalfa, beet, carrot, corn, cucumber, eggplant, onion, peach, rhubarb and tomato.

Release of large quantities of ammonia into the atmosphere for brief periods of time causes severe injury to vegetation in the surroundings.

Impact of Ozone on Crops: Indian Study

High surface ozone arising from photochemical formation and accumulation is now a major environmental concern in many regions of the world. It is now well known that high amounts of volatile organic compounds (VOCs) from industrial and traffic emission lead to fairly high concentration of surface ozone in the industrial cities. However, this ozone not only deteriorates air quality near the region of emission, but is likely to have far-reaching impacts at remote places also. Thus the current article imparts the knowledge about effects of ozone on agricultural crops in India. For this it is first necessary to know about “Ozone exposure” and AOT40 which is used for predicting the vegetation.

What is AOT40?

AOT40 (Accumulation exposure over threshold of 40 ppb) is an exposure-plant response

$$\text{AOT 40} = \sum_{i=1}^{n} ([O_3] - 40)_i \quad \text{for } [O_3] > 40 \text{ ppb}$$

An AOT 40 value of 10,000 ppb h for daylight hours (radiation > 50 W m-2)

over a 6 month period has been established as a critical level for the protection of forests. Whereas, for the protection of agricultural crops of 5% loss in yield, an AOT 40 value of 3000 Ppb h for daylight hours over 3 months growing season has been established as the critical level (WHO, 1996).

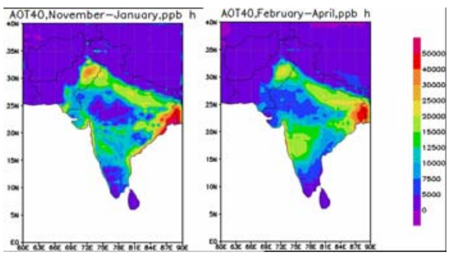

Fig 5.AOT-40 values for winter and summer seasons over Indian region

From Fig 5 it is observed that the model simulated AOT40 values are above the critical level in major parts of India with maximum values reaching as high as 13000 ppb*h over the eastern parts of the Indo-Gangetic plains region which is an alarming signal.

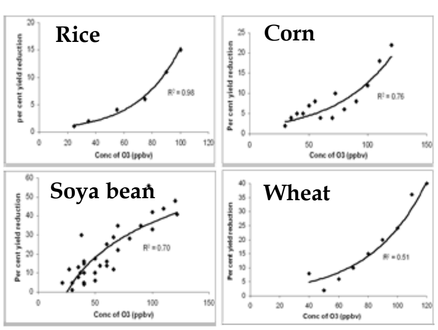

Fig 6. Impact of Ozone Exposure to Crop Yield

Fig 6. depict the crop yield reduction on exposure to ozone. In case of Rice, Corn, wheat and soyabean an exponential increase in the percent yield reduction is observed with increasing concentration of ozone which reveals that an increase in ozone concentration leads to reduction in crop yield through several mechanism such as growth of crops, productivity, etc.

The AOT40 (3000 ppb*h) target and WHO threshold for the protection of vegetation is a factor of 1.7 during pre-monsoon, 6.5 during winter, and 5.3 during pre-monsoon when compared to the AOT40 critical limit for the protection of vegetation.

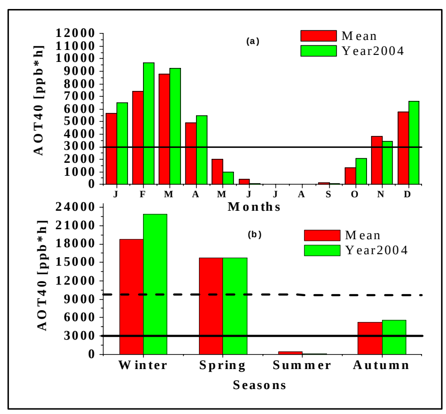

Fig7. Seasonal and monthly variations in AOT40 for the year 2004 and mean of several years (Taken from Beig, et al., *Geophys. Res. Lett.*, *35*, L02802, doi:10.1029/2007GL031434, 2008).

Thus in conclusion, it is found that the current ozone concentrations at the tropical Indian suburban site are high enough to exceed 'Critical Levels' for the protection of human health, vegetation and forest.

Honorable Minister Shri Prithvirajji Chavan visit ENVIS Centre

Honorable Minister of Earth Sciences, **Shri Prithvirajji Chavan** visited IITM, Pune, on 23 December 2009. During this visit he was briefed about the ongoing research activities at IITM. He inaugurated the HPC (High Performance Computing) System which will be used to simulate several types of sophisticated multi dimensional climate models. This system will also run the models related to the atmospheric pollution which lies in the interest of the thematic area of IITM-ENVIS center. On this occasion, the Minister also paid a visit to the ENVIS centre. During this official visit, Minister was briefed about the thematic area and the related work carried out at ENVIS center of IITM. A brief dynamic presentation was also imparted by the ENVIS team members.

The work of IITM-ENVIS Centre was highly appreciated by the Minister who also shared his valuable suggestions.

Dr. Beig providing information

Sr. Programme Officer, ENVIS briefing the activities

Research Team associated with ENVIS related scientific research with Shri. Prithvirajji Chavan

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