IMPACT OF AIR POLLUTION ON AGRICULTURE

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1. Why “Agriculture” should care about Air pollution?
2. Air quality research - An Advantage to AgrMet
3. WHO - Pilot Project for AQ, Agriculture & Health
4. Assessing air Pollution Injury to plants, crops:
   (a) Modeling Research; (b) Experimental Work
5. WHAT DO WE DO?
6. Recommendations to CAgM Community
AIR POLLUTANTS AND ITS AGRICULTURAL CONSEQUENCES

AIR POLLUTANTS

DIRECT DAMAGE ON LEAVES

DEATH
- Damage to crop crown
- Early leaf fall
- Growth disturbance
- Reduced photosynthesis
- Increased susceptibility to frost and pests
- Water deficit
- Nutrient deficiency
- Disturbance in nutrient & water uptake

INCREASED OR DECREASED TRANSPIRATION

DISTURBANCE OF STOMATAL ACTIVITY

DISTURBANCE OF NUTRIENT RELEASE

EFFECT ON SOIL ORGANISM

SOIL
- Acidification
- Leaching of nutrients

DAMAGE TO FINE ROOTS

RELEASE OF TOXIC ELEMENTS
Impacts of Ozone on Plants

- Tropospheric ozone is an oxidant that damages agriculture, ecosystems, and materials.

- Ozone destroy rubisco, an enzyme crucial for photosynthesis.

- O3 effects on vegetation occur when stomatal gas exchange is active.

- It is also known to make leaves age faster.
Response of O₃ exposure to yield of (a) rice, (b) corn, (c) spring and (d) winter wheat
## Ambient Air Pollution Effects on Crop

### SOME KNOWN STUDY AROUND ASIA

<table>
<thead>
<tr>
<th>Country</th>
<th>Pollutant</th>
<th>Crop</th>
<th>Yield loss</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Japan</strong> (Kantoh)</td>
<td>O$_3$ (40-60 ppb)</td>
<td>Rice</td>
<td>0- 7%</td>
<td>Kobayashi (1999)</td>
</tr>
<tr>
<td><strong>China</strong> (7 provinces)</td>
<td>SO$_2$ and acid rain</td>
<td>Vegetables</td>
<td>7.8 %</td>
<td>Feng <em>et al.</em> (1999)</td>
</tr>
<tr>
<td>(south west)</td>
<td><strong>O$_3$ (ppb)</strong></td>
<td>Wheat</td>
<td>5.41 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(night 15 mid day max 75)</td>
<td>Soybean</td>
<td>5.73 %</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Cotton</td>
<td>4.99 %</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Green pepper</td>
<td>Sensitive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rice</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cauliflower</td>
<td>&quot;</td>
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<tr>
<td></td>
<td></td>
<td>Aubergine</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td><strong>Taiwan (S)</strong></td>
<td>O$_3$</td>
<td>Spinach</td>
<td>&quot;</td>
<td>Sun (1993)</td>
</tr>
<tr>
<td><strong>Taipei Basin</strong></td>
<td></td>
<td>Sweat potato</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td><strong>China, Japan and South</strong></td>
<td>O$_3$</td>
<td>Corn</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Korea</strong></td>
<td>50- 55 ppb (1990)</td>
<td>Rice</td>
<td>1- 9 %</td>
<td>Wang and Mauzerall, 2004)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wheat</td>
<td>23- 27 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soybean</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Corn</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rice</td>
<td>2- 16 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wheat</td>
<td>28- 35 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soybean</td>
<td></td>
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</tr>
</tbody>
</table>
METROPOLITAN ADVISORIES FOR CITIES FOR SPORTS & TOURISM IN INDIA

Gufran Beig
Indian Institute of Tropical Meteorology, Pune
Indian Ministry of Earth Sciences

System of Air Quality Weather Forecasting & Research (SAFAR-Metro)
http://safar.tropmet.res.in/ ;; Toll Free: 1800-180-1717
Promises
Baseline data validation
Bringing together AQ, Weather and Health researchers to harmonize data and impact study

Monitoring
- O3, NOx, CO, BTX
- PM2.5, PM10, BC, OC
- All Weather Parameters

SAFAR FOR INDIAN MEGA CITIES

(A10 in 1 city)

AQMS Network of IITM (MAPAN)

(1 in 1 city)
SAFAR

- Predict Air Quality
- Translate Data to Information
- Help Prepare Public
- Protect Health & Agriculture
MAPAN - India

8 hr avg Ozone (ppb)

(01 Jan 2010 to 30 Nov 2011)

- Udaipur
- Pune
- Hyderabad
- Jabalpur
- 30 per. Mov. Avg. (Udaipur)
- 30 per. Mov. Avg. (Hyderabad)
- 30 per. Mov. Avg. (Jabalpur)
- 30 per. Mov. Avg. (Pune)
WHO Sponsored Heritage Budhdha Lumbini Project

PM10 (24 hr) - Lumbini - Nepal

PM2.5 (24 hr) - Lumbini - Nepal
Lumbin
2. DELHI POISONING EVENT

October’ 26-November’ 9, 2012
A debate on the issue “Whether the Air quality in Delhi is worse than Beijing?”, triggered by “New York Times news paper” published on 26th January 2014

The New York Times

Beijing’s Bad Air Would Be Step Up for Smoggy Delhi
By GARDINER HARRIS  JAN. 25, 2014
http://www.nytimes.com/2014/01/26/world/asia/beijings-air-would-be-step-up-for-smoggy-delhi.html?_r=0

NEW DELHI — In mid-January, air pollution in Beijing was so bad that the government issued urgent health warnings and closed four major highways, prompting the panicked buying of air filters and donning ………..
Question needing answer?

Then, Why there is attention and discomfort?

SAFAR-Scientists ANSWERS

Capital recording more ‘extreme pollution events’

Jayashree Nandi | TNN

New Delhi: Though there is no clear pattern of increase or decrease in levels of PM2.5—fine...
A CASE STUDY:

Reductions in India’s crop yield due to surface OZONE

OBJECTIVE:

A MODELING STUDY using satellite data, emission inventories and crop production, quantifies, impact on cotton, soybeans, rice and wheat crops in India for the first decade of the 21st century.
O$_3$-induced crop production loss
(in kilotons/grid box)

Wheat

Rice

Cotton

Soyabean
Conclusions of Indian Pilot Study

• No doubt that long-term exposure to high concentration of surface O3 damages vegetation with substantial reduction in crop yields and crop quality.

• Major concern for developing countries (like India) where expanding economy led to rapid increases in gases like NOx, CO & VOCs which increases ozone.

• Climate change can further exacerbate the situation since it has been shown to increase O3 in many regions of the world.
• **Wheat** is the most impacted crop with losses of $3.5+_0.8$ Mt, followed by **Rice** at $2.1+_0.8$ Mt.

• The nationally aggregated yield loss is sufficient to feed **94 million people** living below poverty line.

• Model Sensitivity studies identify **NOx** as the key pollutant causing as much as 93% of the crop loss.

Thus offering a *critical mitigation pathway* to protect *food security* in India which may be applicable in many tropical countries whether developed or developing.
**EXPERIMENTAL WORK**

Crop Yield (g plant$^{-1}$) of selected plants grown at different sites in & around an Indian City (Mean ± 1SE)

<table>
<thead>
<tr>
<th>Site</th>
<th>Mustard</th>
<th>Wheat</th>
<th>Pea</th>
<th>Mung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference area</td>
<td>6.03 $^a$</td>
<td>7.48 $^a$</td>
<td>9.40 $^a$</td>
<td>6.44 $^a$</td>
</tr>
<tr>
<td></td>
<td>± 0.32</td>
<td>± 0.81</td>
<td>± 0.42</td>
<td>± 0.61</td>
</tr>
<tr>
<td>Semi-urban</td>
<td>4.97 $^b$</td>
<td>6.24 $^c$</td>
<td>6.63 $^c$</td>
<td>3.78 $^c$</td>
</tr>
<tr>
<td></td>
<td>± 0.32</td>
<td>± 0.55</td>
<td>± 0.49</td>
<td>± 0.41</td>
</tr>
<tr>
<td>Urban area</td>
<td>4.77 $^b$</td>
<td>6.15 $^c$</td>
<td>6.37 $^c$</td>
<td>3.25 $^c$</td>
</tr>
<tr>
<td></td>
<td>± 0.24</td>
<td>± 0.49</td>
<td>± 0.33</td>
<td>± 0.32</td>
</tr>
<tr>
<td>Rural area</td>
<td>5.67 $^a$</td>
<td>6.44 $^b$</td>
<td>7.10 $^b$</td>
<td>4.23 $^b$</td>
</tr>
<tr>
<td></td>
<td>± 0.41</td>
<td>± 0.62</td>
<td>± 0.49</td>
<td>± 0.45</td>
</tr>
</tbody>
</table>
## PRODUCTION, ECONOMIC VALUE AND % LOSS IN ECONOMIC VALUE OF YIELD AT DIFFERENT SITES AROUND PUNE CITY

<table>
<thead>
<tr>
<th>Sites/Plants</th>
<th>Production (q ha⁻¹)</th>
<th>Economic value (Rs.)</th>
<th>% loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference area</td>
<td>29.50</td>
<td>17995.0</td>
<td></td>
</tr>
<tr>
<td>Rural area</td>
<td>24.25</td>
<td>14792.5</td>
<td>17.80</td>
</tr>
<tr>
<td>Periurban area</td>
<td>22.15</td>
<td>13511.5</td>
<td>24.91</td>
</tr>
<tr>
<td>Urban area</td>
<td>20.60</td>
<td>12566.0</td>
<td>30.17</td>
</tr>
<tr>
<td>Industrial and</td>
<td>20.50</td>
<td>12505.0</td>
<td>30.50</td>
</tr>
<tr>
<td>Urban area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mung</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference area</td>
<td>10.11</td>
<td>13244.0</td>
<td></td>
</tr>
<tr>
<td>Rural area</td>
<td>7.20</td>
<td>9432.0</td>
<td>28.78</td>
</tr>
<tr>
<td>Periurban area</td>
<td>6.66</td>
<td>8724.6</td>
<td>34.12</td>
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<tr>
<td>Urban area</td>
<td>5.85</td>
<td>7663.0</td>
<td>42.14</td>
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<tr>
<td>Industrial and</td>
<td>6.00</td>
<td>7860.0</td>
<td>40.65</td>
</tr>
<tr>
<td>Urban area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference area</td>
<td>23.50</td>
<td>30550.0</td>
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<tr>
<td>Rural area</td>
<td>17.75</td>
<td>23075.0</td>
<td>24.47</td>
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<tr>
<td>Periurban area</td>
<td>16.57</td>
<td>21541.0</td>
<td>29.49</td>
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<tr>
<td>Urban area</td>
<td>15.92</td>
<td>20702.5</td>
<td>32.23</td>
</tr>
<tr>
<td>Industrial and</td>
<td>14.62</td>
<td>19012.5</td>
<td>37.76</td>
</tr>
<tr>
<td>Urban area</td>
<td></td>
<td></td>
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</tbody>
</table>
Experimental set of open top chambers
A Sensitivity Experiment
Assessment of O$_3$ injury on plants using EDU

- **EDU** = A Synthetic Chemical =
  
  Ethylene-di-urea (N-[2-(2-oxo-1-imidazolidinyl)ethyl]-N' phenyl-urea)

  Provides protection to wide range of plants from ozone injury without confounding effects of its own.

- Allows assessment of yield losses
Effect of 400 ppm EDU treatment on yield of potato plants

![Bar graph showing the yield (g plant$^{-1}$) of potato plants with and without 400 ppm EDU treatment. The graph indicates a significant increase in yield for the EDU-treated plants compared to the non-EDU (Non EDU) plants.](image-url)
Percent increment in yield (g plant\(^{-1}\)) of selected crops upon EDU treatment in ambient air

<table>
<thead>
<tr>
<th>Site</th>
<th>Percent increment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wheat</td>
</tr>
<tr>
<td>Reference area</td>
<td>0.2</td>
</tr>
<tr>
<td>Industrial and urban area</td>
<td>4.2</td>
</tr>
<tr>
<td>Periurban area</td>
<td>14.2</td>
</tr>
<tr>
<td>Urban area</td>
<td>6.4</td>
</tr>
<tr>
<td>Rural area</td>
<td>18.9</td>
</tr>
</tbody>
</table>
‘EDU’ CASE STUDY FOR O₃ INJURY

- One set of 10 days old plants were given 600 ml of EDU and another set were given equal amount of water (-EDU)

- Treatments were repeated at ten days interval till maturity.
Injury obtained in non-EDU treated plants.

Water soaked area

Pigmentation

Tip burning
What Do We Do?

1. Learn to live with these levels of pollutants – *Adaptation Policies*

1. Minimize emissions of pollutants and precursors – *Mitigation policies*

2. Protect agriculture with Geo-engineering talent - *Technological Intervention*
Adaptation Options

- Technological developments (e.g., new crop varieties, water management innovations etc.)
- Government program and insurance
- Farm production practices (e.g., crop diversification, irrigation).
- Farm financial management (e.g., crop shares, income stabilization programs).
- Other measures (For example, reduce the emissions of precursors, and or change the time they are emitted to miss the peak sunshine and heat).
Assess feasibility and economic practicality of adaptation options

Examine the capacity of producers to undertake adaptation

Study the affordability of adaptive measures, access to technology, and other constraints
Charaterize the economic losses from current (and projected) levels of air pollution

Suggest market-based approaches and technological changes

Emphasize the long term benefits of the mitigation policies
CONCLUSIONS

- Air pollution negatively affects the yield and quality of crops
- Sensitivity of crops differs among species and cultivars
- Meteorological conditions during crop growing season affect the degree of negative effects on growth and yield of crops
- Ozone poses the greatest threat to agriculture
- Plants also differ in their response to different air pollutant combinations
The plants which utilized more photosynthates for neutralizing the damaging impact of pollutants could not translocate efficiently to developing ears and hence showed greater reductions in yield.

Slow growing and low yielding cultivars were more resistant than fast growing and high yielding cultivars.

Higher magnitude of protection provided by EDU to yield as compared to growth parameters (high concentration of O<sub>3</sub> during anthesis period).

Higher magnitude of protection to sensitive as against resistant cultivar.
RECOMMENDATIONS & FUTURE NEEDS

- Expand air pollutant monitoring networks into agricultural and forested areas
- Need to establish yield response relationships applicable to different environmental conditions to project future yield losses at increasing ozone concentrations
- Develop bio-indicator protocols for impact evaluation
- Interactive effects of increased concentrations of CO₂ and O₃ on plants along with temperature/ drought.
- Establish realistic air quality guidelines for protecting vegetation including crops – CAgM?