AIR POLLUTION AND AGRICULTURE : AN INDIAN SCENARIO

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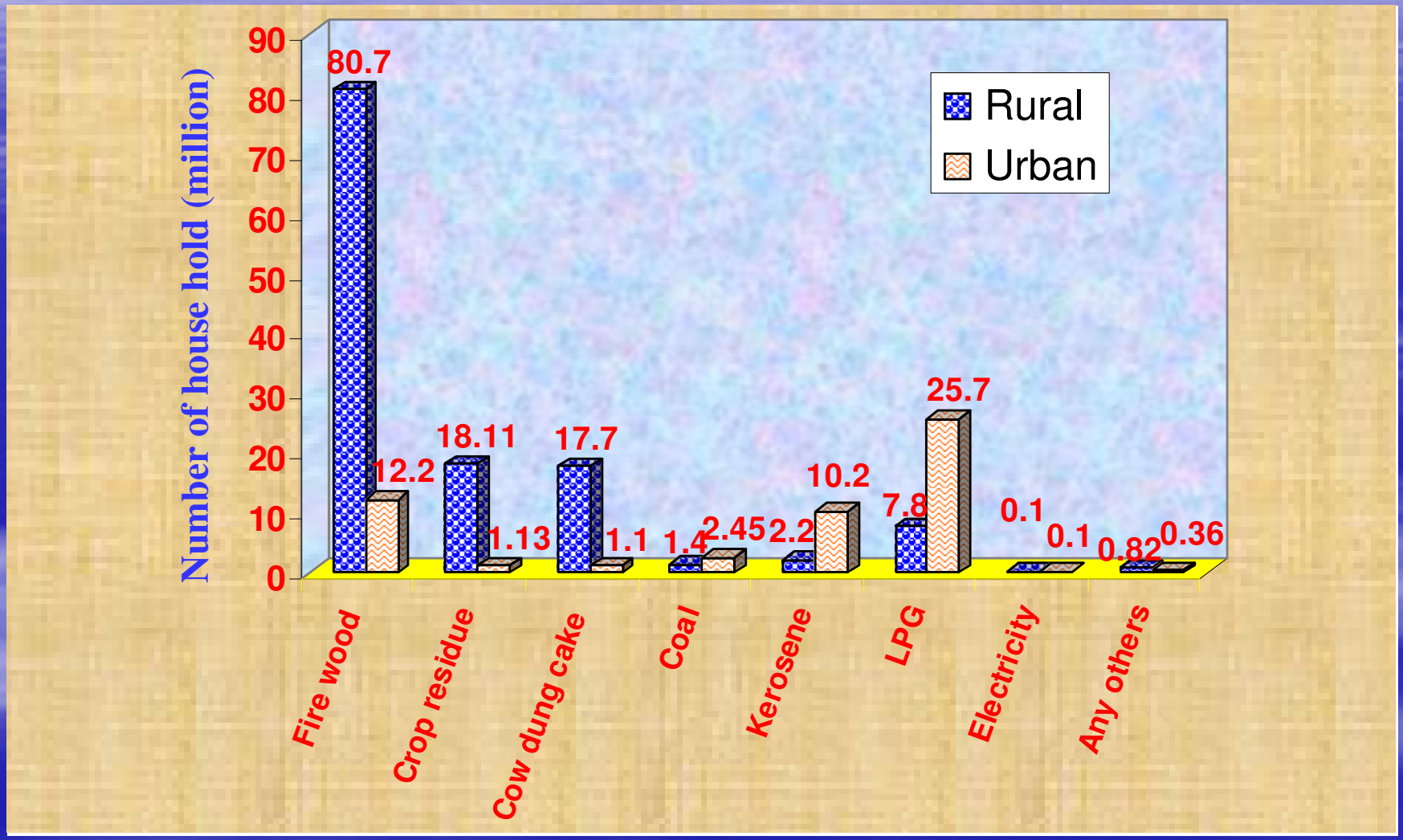
SOURCES OF AIR POLLUTION

- Thermal Power Plants
- Industries
- Transportation
- Biomass burning
- Forest Fire
- Domestic uses

MAJOR AIR POLLUTANTS

- Particulate matter
  - Suspended particulate matter
  - Settled dust
- Ozone
- Sulphur dioxide
- Nitrogen dioxide
- Heavy metal contamination
- Hydrogen fluoride

BIOMASS BASED FUELS KEEP RURAL INDIA ALIVE



RISING NUMBER OF VEHICLES

	1951	1961	1971	1981	1998	Rate of increase between 1981 and 1998
Number of vehicles (in thousand)*	306	665	1,865	5,391	40,939	659%
Urban population (in million)**	62	78	107	156	259	66%

* Motor transport statistics of India 1997-1998.

** Census data.

TRENDS IN AIR POLLUTANT CONCENTRATIONS (mg m^{-3}) IN INDIA (Agrawal *et al.*, 1999)

	Northern	Western	Southern	Eastern
SO_2	10–60 (Delhi 60)	10–-50 (Industrial 70)	10–40	10–50 (Industrial 85)
NO_x	30–90	30–80	20–70	30–70
SPM	200–400	200–400	100–200	200–350
O_3	20–273 (Delhi)	54 (Pune)	30 (Nilgiri forest)	48 (Varanasi)

MAJOR APPROACHES TO AIR POLLUTION RESEARCHES

SURVEY ORIENTED FIELD STUDIES

- Injury pattern
- Bioindicator/biomonitor plants

LONG TERM FIELD STUDIES

- Spatial & temporal variations in air pollutants
- Field transect studies
- Air exclusion studies
- Changes in biomass and yield of economically important plants
- Assessment of injury using chemical protectant

ARTIFICIAL EXPOSURE STUDIES

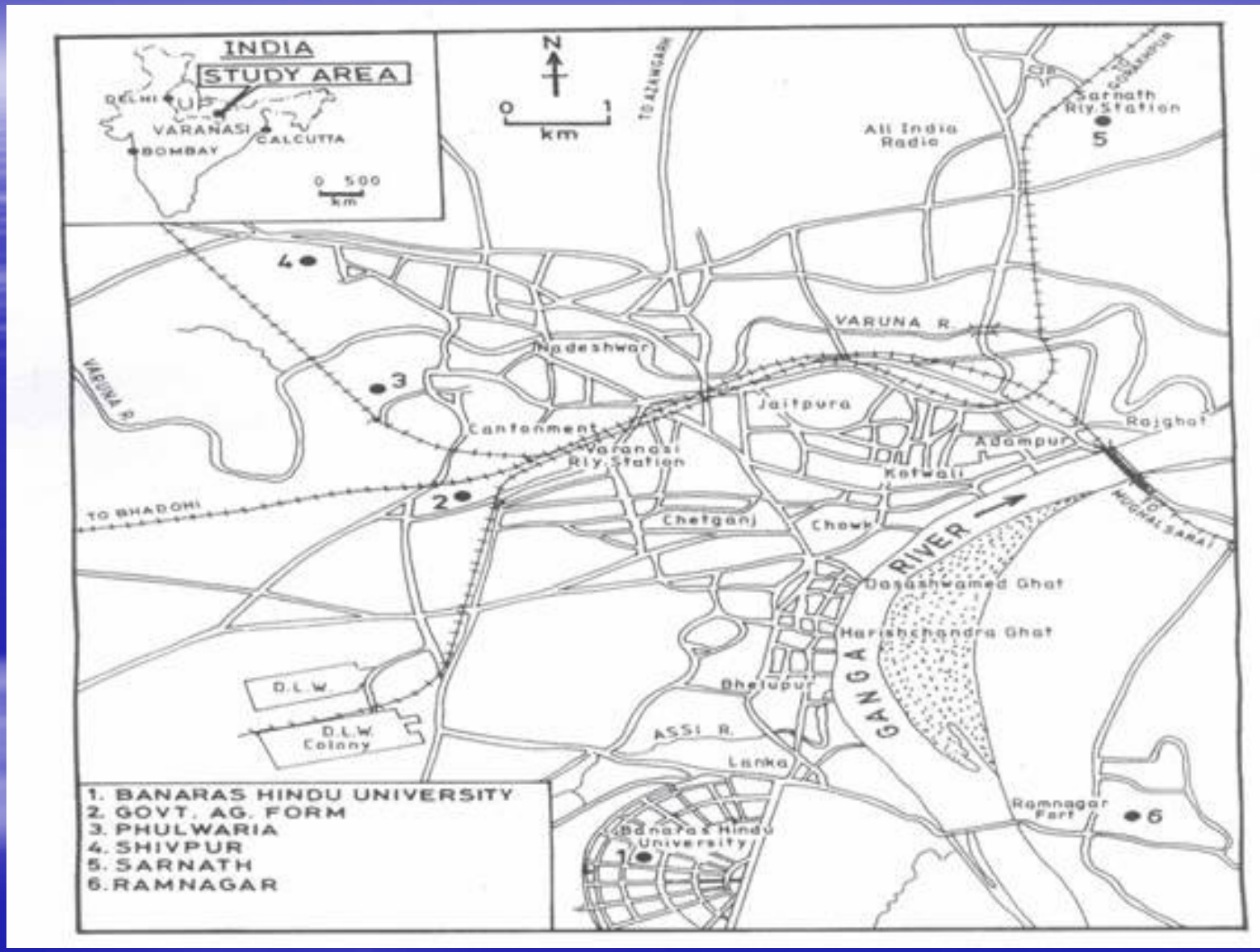
- Closed top chamber studies
- Open top chamber studies
- Responses to pollutant combinations

Long Term Field Studies

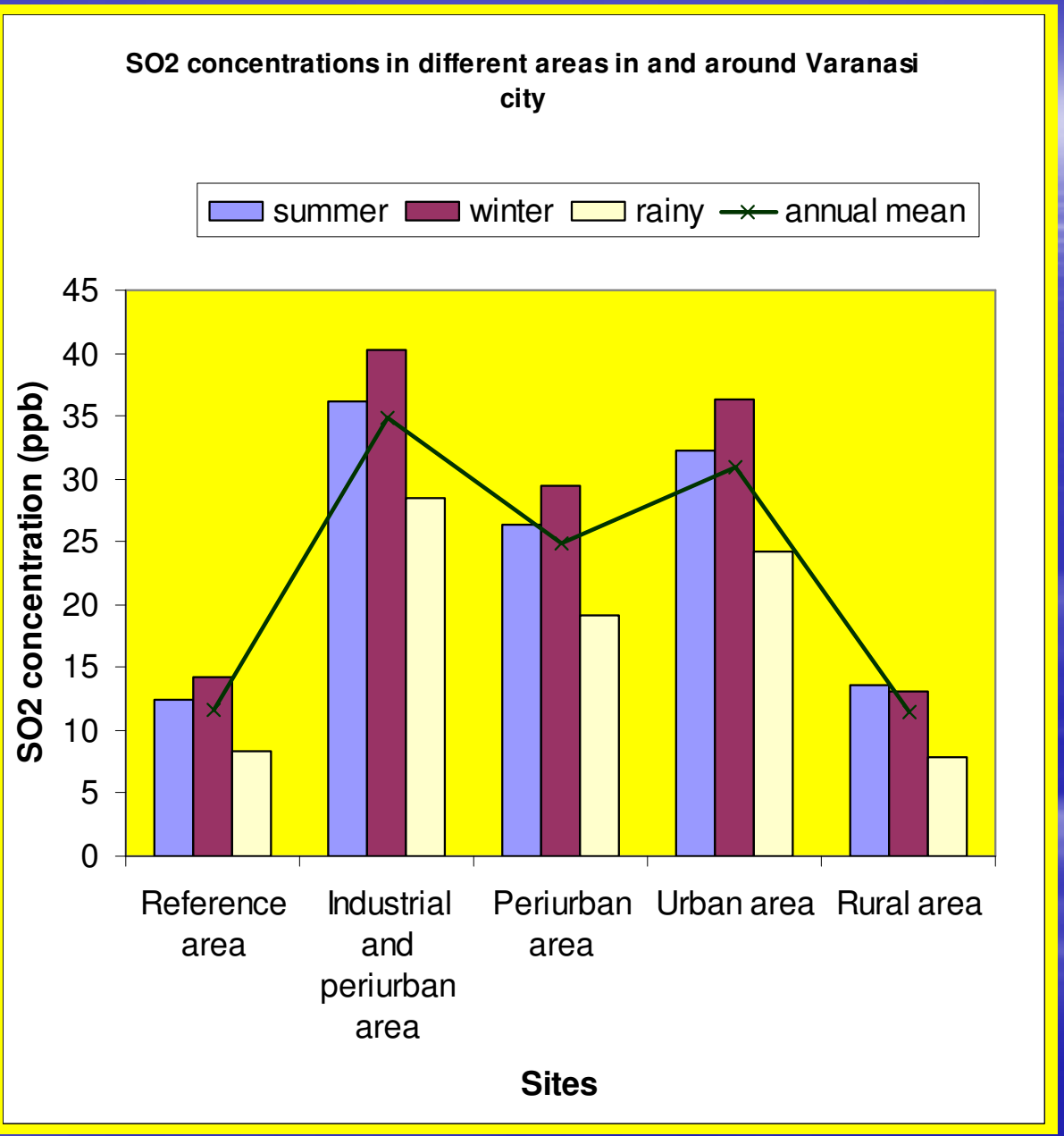
EFFECT OF THERMAL POWER PLANT EMISSION ON BIOMASS AND YIELD OF WHEAT (*Triticum aestivum* L.) PLANTS

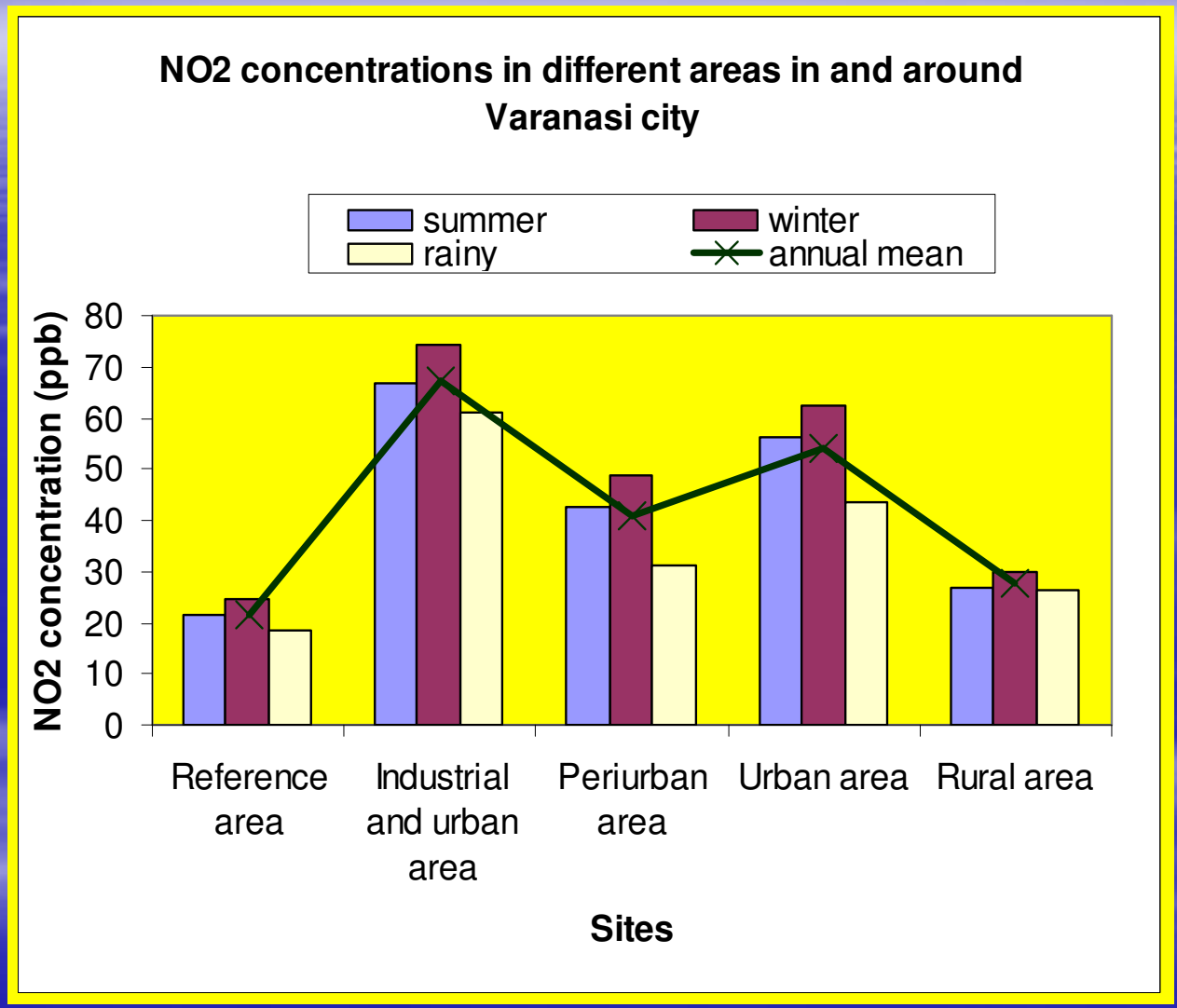
Parameters	Distance (km) and direction from source				
	1.5 SE	3.0 SE	5.0SE	8.0SE	22.0 N (Reference site)
SO_2 µg m^{-3} ppb	139 52.8	100 38	76 28.8	56 21.8	20 7.6
NO_2 µg m^{-3} ppb	11.0 58.3	76 40.3	69 36.6	42 22.3	12 6.4
TSP µg m^3	764	385	275	152	42
Biomass g $plant^{-1}$	1.45 (72%)	2.3 (55.1%)	3.1 (40%)	3.6 (31%)	5.2
Yield g m^{-2}	205 (47%)	220 (43%)	259 (33%)	274 (29%)	386

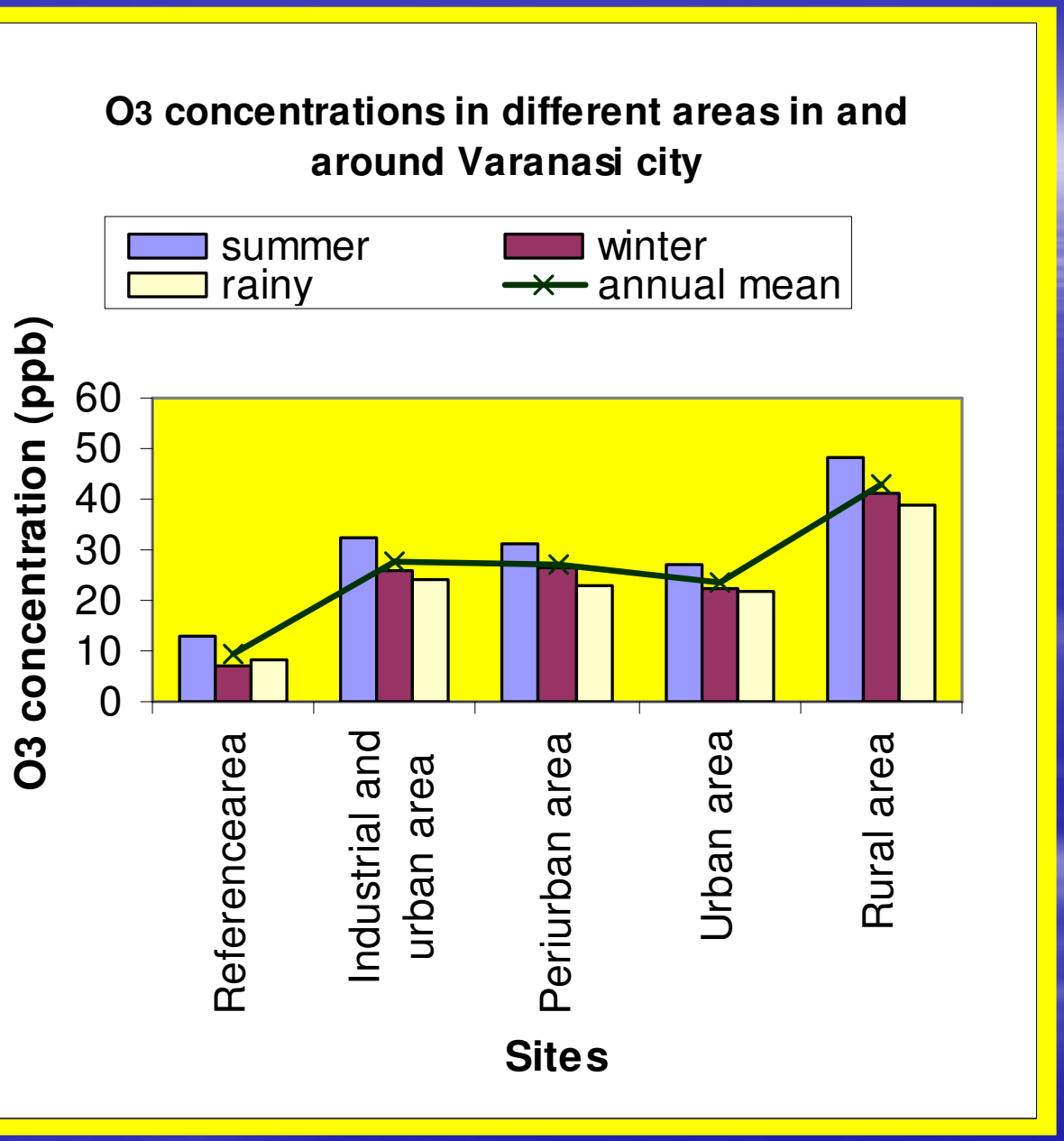
Values in parenthesis are reduction as compared to reference site



Map of Varanasi


SO2 concentrations in different areas in and around Varanasi city
summer
winter
rainy
annual mean
SO2 concentration (ppb)
45
40
35
30
25
20
15
10
5
0
Reference area
Industrial and periurban area
Periurban area
Urban area
Rural area
Sites


NO2 concentrations in different areas in and around Varanasi city
summer
winter
rainy
annual mean
NO2 concentration (ppb)
80
70
60
50
40
30
20
10
0
Reference area
Industrial and urban area
Periurban area
Urban area
Rural area
Sites


O3 concentrations in different areas in and around Varanasi city
summer
winter
rainy
annual mean
O3 concentration (ppb)
60
50
40
30
20
10
0
Referencearea
Industrial and urban area
Periurban area
Urban area
Rural area
Sites

NATIONAL AIR QUALITY STANDARDS FOR SO_2 AND NO_2 (8 HOURS MEAN)

Pollutants	Sensitive area	Rural, residential and other areas	Industrial area
SO_2			
$\mu g\ m^{-3}$	30	80	120
ppb	11.4	30.4	45.6
NO_2			
$\mu g\ m^{-3}$	30	80	120
ppb	15.9	42.4	63.6

Photosynthesis rate (μ mol $CO_2 m^{-1} s^{-1}$) in selected plants grown at different sites in and around Varanasi (Mean ± 1SE)

Site	Mustard	Wheat	Pea	Mung
Reference area	13.75 [a] ± 0.3	20.7 [a] ± 0.31	11.51 [a] ± 0.41	10.03 [a] ± 0.28
Industrial and urban area	7.24 [c] ± 0.35	13.9 [c] ± 0.67	4.56 [d] ± 0.64	5.26 [d] ± 0.26
Periurban area	11.65 [b] ± 0.34	15.2 [c] ± 0.42	5.68 [c] ± 0.38	8.11 [b] ± 0.14
Urban area	10.21 [b] ± 0.49	14.2 [c] ± 0.50	4.96 [d] ± 0.19	7.29 [c] ± 0.32
Rural area	13.55 [a] ± 0.26	18.0 [b] ± 0.52	7.62 [b] ± 0.09	8.34 [b] ± 0.11

Within each plants values not followed by the same letter are significantly different at $p < 0.05$

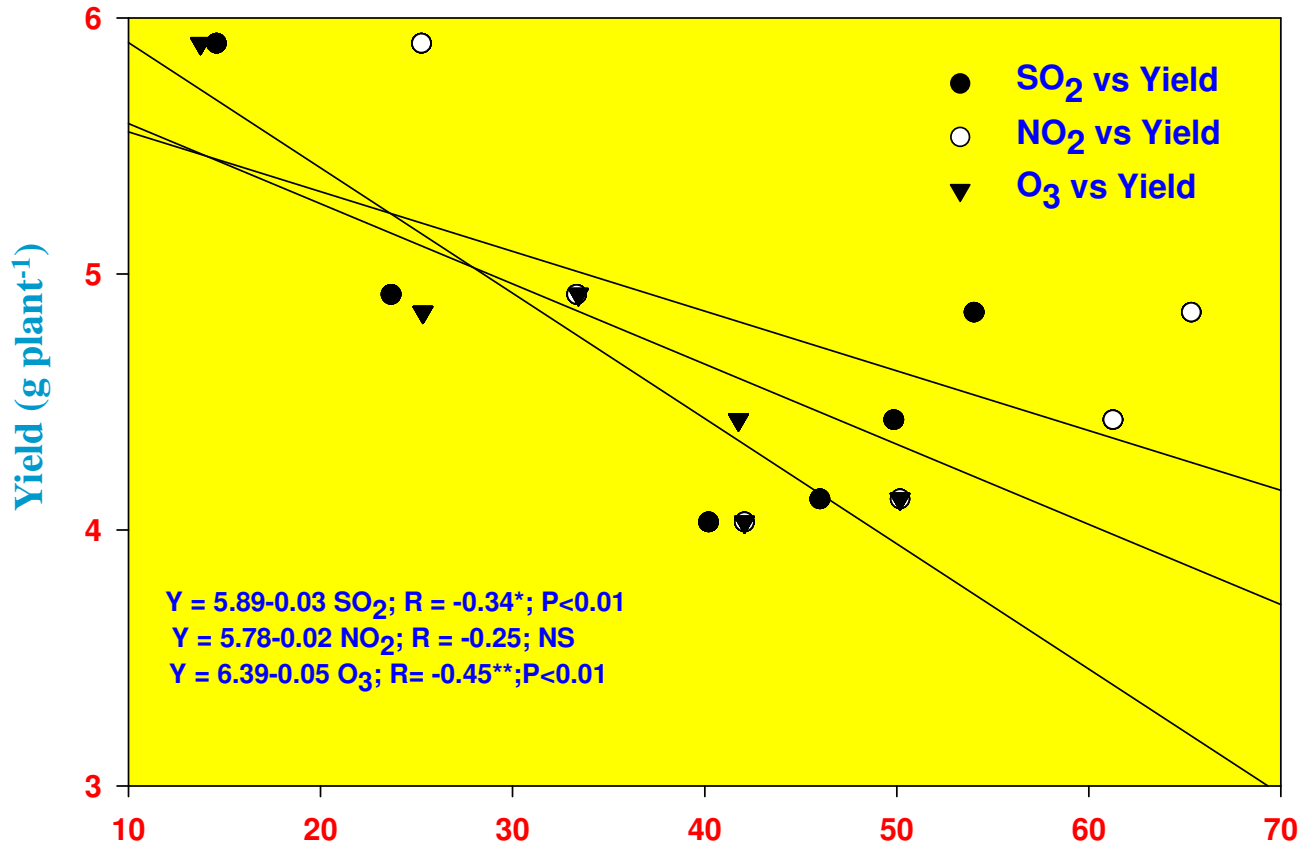
Energy (k cal g^{-1}) and protein (mg g^{-1} dw) contents in seeds of selected plants grown at different sites in and around Varanasi

Site	Wheat		Mung		Pea	
	Energy	Protein	Energy	protein	Energy	protein
Reference area	4.32	291.58	3.80	262.00	3.90	287.60
Industrial and urban area	3.50	234.87	1.90	186.60	2.30	217.00
Periurban area	3.86	245.03	2.90	210.50	3.10	233.00
Urban area	3.66	243.43	2.80	208.60	3.00	225.30
Rural area	4.01	277.13	3.10	218.00	3.30	247.60

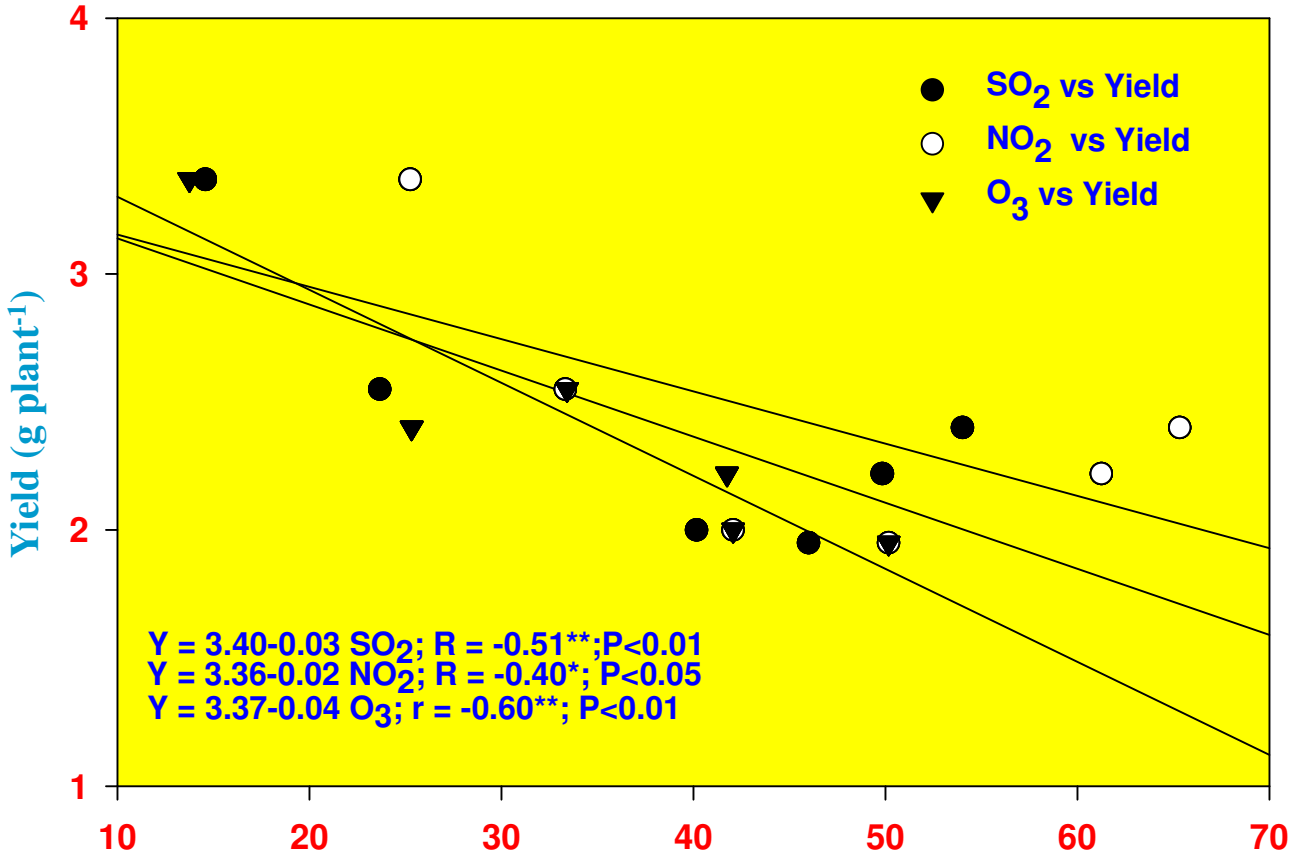
PRODUCTION, ECONOMIC VALUE AND % LOSS IN ECONOMIC VALUE OF YIELD AT DIFFERENT SITES AROUND VARANASI CITY

Sites/Plants	Production ($q\ ha^{-1}$)	Economic value (Rs.)	%loss
Wheat			
Reference area	29.50	17995.0	
Rural area	24.25	14792.5	17.80
Periurban area	22.15	13511.5	24.91
Urban area	20.60	12566.0	30.17
Industrial and Urban area	20.50	12505.0	30.50
Mung			
Reference area	10.11	13244.0	
Rural area	7.20	9432.0	28.78
Periurban area	6.66	8724.6	34.12
Urban area	5.85	7663.0	42.14
Industrial and Urban area	6.00	7860.0	40.65
Pea			
Reference area	23.50	30550.0	
Rural area	17.75	23075.0	24.47
Periurban area	16.57	21541.0	29.49
Urban area	15.92	20702.5	32.23
Industrial and Urban area	14.62	19012.5	37.76

CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS BETWEEN INDIVIDUAL POLLUTANTS AND YIELD OF WHEAT PLANTS



CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS BETWEEN INDIVIDUAL POLLUTANTS AND YIELD OF MUNG PLANTS



Mean pollutant concentration (ppb)

Pollutant concentrations (ppb) and associated leaf injury indices obtained using tobacco Bel W3 plants

Site	Pollutant concentration (ppb)		Leaf injury (%)
	NO_2*	O_3**	
Urban area	58	34	8
Periurban area	27	52	20
Rural area	10	66	31

* Weekly mean

** 6 h mean concentration (10.00- 16.00 h) once $week^{-1}$

Air Exclusion Studies

OPEN TOP CHAMBER (OTC)

POLLUTANT CONCENTRATIONS AND CHANGES IN SELECTED PARAMETERS OF PALAK GROWN UNDER FILTERED AND NON-FILTERED CONDITIONS

Parameters	Open plots	Non filtered	Filtered
Plant height (cm plant^{-1})	15.58^{a} (47)	16.52^{a} (38)	22.88^{b}
Leaf area (cm^{2} plant^{-1})	123.68^{a} (36)	127.57^{a} (32)	167.77^{b}
Number of leaf (plant^{-1})	18.00^{b} (22)	19.00^{a} (16)	22.00^{b}
Biomass (g plant^{-1})	3.59^{a} (35)	4.24^{a} (27)	5.40^{b}
N (mg g^{-1} dw)	9.45^{a} (33)	8.94^{a} (40)	12.55^{b}
Ca (mg g^{-1} dw)	7.08^{a} (18)	7.58^{a} (10)	8.35^{b}
Fe (mg g^{-1} dw)	1.85^{a} (51)	2.39^{a} (17)	2.79^{b}
SO_2 (ppb)	35.09^{a}	34.79^{a}	4.46^{b}
NO_2 (ppb)	38.60^{a}	38.90^{a}	8.39^{b}
O_3 (ppb)	36.95^{a}	38.15^{a}	4.01^{b}

Within each grouping, values not followed by the same letter are significant different at $p < 0.05$
Values in parenthesis represent percent increment due to filtration

Concentration of pollutants (ppb) in filtered (F) and non filtered (NF) chambers at a rural site during winter

Months	SO_2*		NO_2*		O_3**	
	NF	F	NF	F	NF	F
December	40.3	4.5	47.5	5.5	33.9	3.8
January	39.3	4.6	49.5	6.9	29.2	3.2
February	36.5	4.7	43.2	6.9	38.9	3.7
March	33.6	3.8	35.7	5.0	43.7	5.1

* 12 h average (7.00- 19.00 h)
** 8 h average (9.00- 16.00 h)

Selected parameters of carrot plants grown in filtered and non-filtered chambers at a rural site

Parameters	Non- filtered	Filtered
Yield (g plant^{-1})	1.52	2.78 (+82.8)
Nitrogen (mg g^{-1})	1.09	0.95 (- 12.8)
Phosphorus (mg g^{-1})	0.09	0.21 (+133.3)
Sulphates (mg g^{-1})	0.73	0.17 (-76.7)
Energy (k cal g^{-1})	39	51 (+30.7)
Total carotene (µg g^{-1})	71.20	89.30 (+25.42)
Beta Carotene (µg g^{-1})	52.36	64.79 (+23.73)
Thiamine (µg g^{-1})	0.1	0.4 (+300)

Values within parentheses show percent change from non filtered plants

Concentration of pollutants (ppb) in filtered (F) and non filtered chambers (NF) at a rural site during December 2004- March 2005

Months	NO_2		SO_2		O_3	
	NF	F	NF	F	NF	F
December	31.36	6.19	8.65	3.28	35.33	3.83
January	30.36	6.09	8.55	3.08	35.48	3.26
February	24.97	4.80	5.94	2.63	37.14	3.75
March	20.57	3.65	3.91	1.42	52.09	5.16

8 h average (8.00- 16.00 h)

Selected yield parameters of wheat cultivars grown in filtered and non-filtered chambers at a rural site

	HUW -234		PBW- 343	
	FCs	NFCs	FCs	NFCs
No. of ears (plant^{-1})	14.5± 0.42	11.66± 0.66	16.9± 0.525	12.8± 0.48
Wt of ears (g plant^{-1})	29.66± 0.88	23.16± 1.01	34.8± 0.72	25.6± 0.37
No. of grains (plant^{-1})	568± 14.26	485.8± 18.89	674.5± 4.23	568.2± 4.02
Wt of grains (g plant^{-1})	27.16± 1.02	21.55± 0.85	31.81± 0.27	27.65± 0.22
Yield (g m^{-2})	977.88± 36.76	775.8± 30.92 (21%)	1145.16± 10.04	995.4± 8.07 (13%)
HI (g g^{-1})	0.39± 0.01	0.36± 0.01	0.41± 0.006	0.38± 0.002

Concentration of pollutants (ppb) in non filtered chambers at a rural site during July - October 2005

Months	SO_2	NO_2	O_3
July	5.25	11.59	24.95
August	5.53	12.05	25.35
September	4.60	14.17	30.23
October	8.25	16.96	50.59

8 h average (8.00- 16.00 h)

Selected yield parameters of rice (Saurabh- 950) plants grown in filtered and non-filtered chambers at a rural site

Parameters	Filtered	Non Filtered
No. of Ears (per plant)	13.2 ± 0.46	9.4 ± 0.30***
Wt. of Ears (g /plant)	9.74 ± 0.28	8.09 ± 0.45*
No. of Grains (per plant)	741.5 ± 11.61	656.71 ± 6.20***
Wt. of Grains (g /plant)	8.86 ± 0.23	7.96 ± .26*
Yield (g /m^2)	319.14 ± 8.41	286.56 ± 9.63* (10 %)
Wt. of 1000 Grains (g)	2.50 ± 0.10	2.14 ± 0.01**
Harvest Index	0.259 ± 0.01	0.255 ± 0.01***

Significant levels*** p< 0.001; ** p< 0.01; * p< 0.05; NS; not significant

Conclusion

- 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

Recommendations

- Expand air pollutant monitoring networks into agricultural and forested areas
- Need to establish yield response relationships applicable to different environmental conditions
- Develop bioindicator protocols for impact evaluation
- Explore high and low risk zones of air pollution impact in different regions
- Establish realistic air quality guidelines for protecting vegetation including crops

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