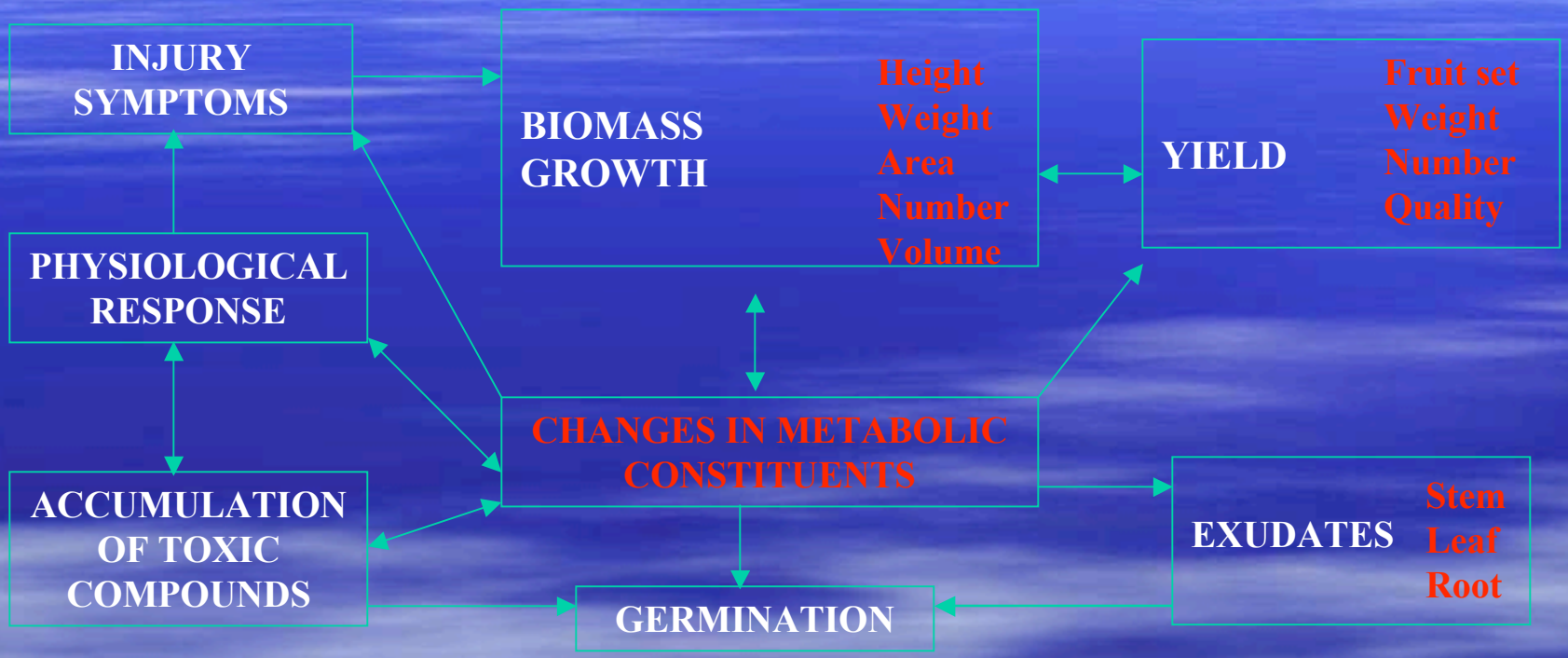
IMPACTS OF AIR POLLUTION ON CROPS IN SOUTH ASIA

Madhoolika Agrawal
DEPARTMENT OF BOTANY
BANARAS HINDU UNIVERSITY
VARANASI-221 005, INDIA

MEASURE OF EFFECTS
HOW THEY INTERRELATE?



AIR POLLUTION EFFECTS ON PLANTS INTERRELATIONSHIP

AIR POLLUTANTS

MOST IMPORTANT

O_3 | SO_2 | OXIDANT | NO_2

LEAST IMPORTANT
AG. CHEMICALS
TOXIC ELEMENTS

Impact singly and in combinations
[Acute & Chronic exposures]

BIOTIC FACTORS

PHYSIOLOGICAL FACTORS

Pathogens
Insects

Inter

LEAVES

STEM

PLANT

ROOTS

Relation

Climatic Factors
- Light
- Temperature
- Humidity
- Wind
- CO_2

AIR

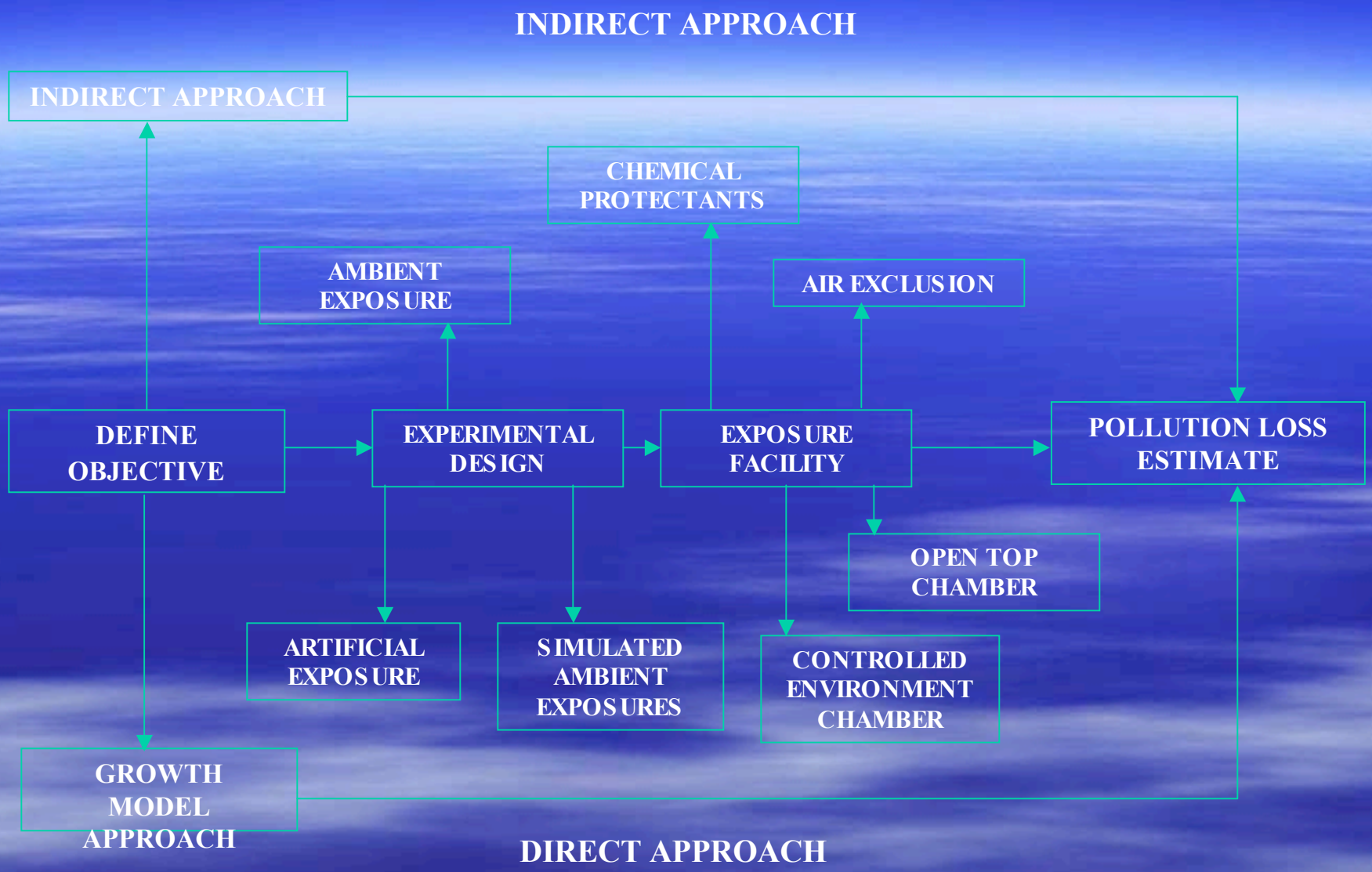
SOIL

Insects
Pathogens
Mycorrhiza
Nematodes
N_2 fixation
Competition

INTERACTION OF ABOVE

INTERACTION OF ABOVE

Temperature Moisture
Nutrition O_2/CO_2 tension
Soil Type



RESEARCH APPROACHES TO POLLUTION LOSS ASSESSMENT

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

Ambient air pollution effects on crops in selected countries of Asia

Country	Pollutant	Crop	Yield loss	References
Japan (Kantoh)	O_3 (40-60 ppb)	Rice	0- 7%	Kobayashi (1999)
China (7 provinces) (south west)	SO_2 and acid rain	Vegetables	7.8 %	Feng *et al.* (1999)
		Wheat	5.41 %	
		Soybean	5.73 %	
		Cotton	4.99 %	
	O_3 (ppb) (night 15 mid day max 75)	Green pepper	Sensitive	Zheng *et al.* (1998)
		Rice	"	
		Cauliflower	"	
		Aubergine		
Taiwan (S) Taipei Basin	O_3	Spinach	"	Sun (1993)
		Sweat potato	"	
China, Japan and South Korea	O_3 50- 55 ppb (1990)	Corn		
		Rice	1- 9 %	Wang and Mauzerall, 2004)*
		Wheat		
		Soybean	23- 27 %	
	60- 65 ppb (2020)	Corn		
		Rice	2- 16 %	"
		Wheat		
		Soybean	28- 35 %	

* MOZART - 3 O_3 exposure and yield relationship

Ambient air pollution effects on selected crops of Pakistan (Wahid, 2003)

Crops	Pollutant (ppb)		Yield losses (%)
	O_3 *	NO_2 **	
Wheat (6 varieties)	33 - 85	23 - 30	29 - 47
Rice (5 varieties)	35 - 60	13 - 25	28 - 42
Soybean (2 varieties)	64	29	37 - 46
Chickpea (3 varieties)	59	38	23 - 27
Mung bean (2 varieties)	66	31	26 - 34

* O_3 (6 h d^{-1} seasonal mean)

** NO_2 seasonal mean (weekly basis)

Long Term Field Studies

YIELD REDUCTIONS(%) IN DIFFERENT CROP PLANTS GROWING IN OBRA- RENUKOOT -SINGRAULI AREA

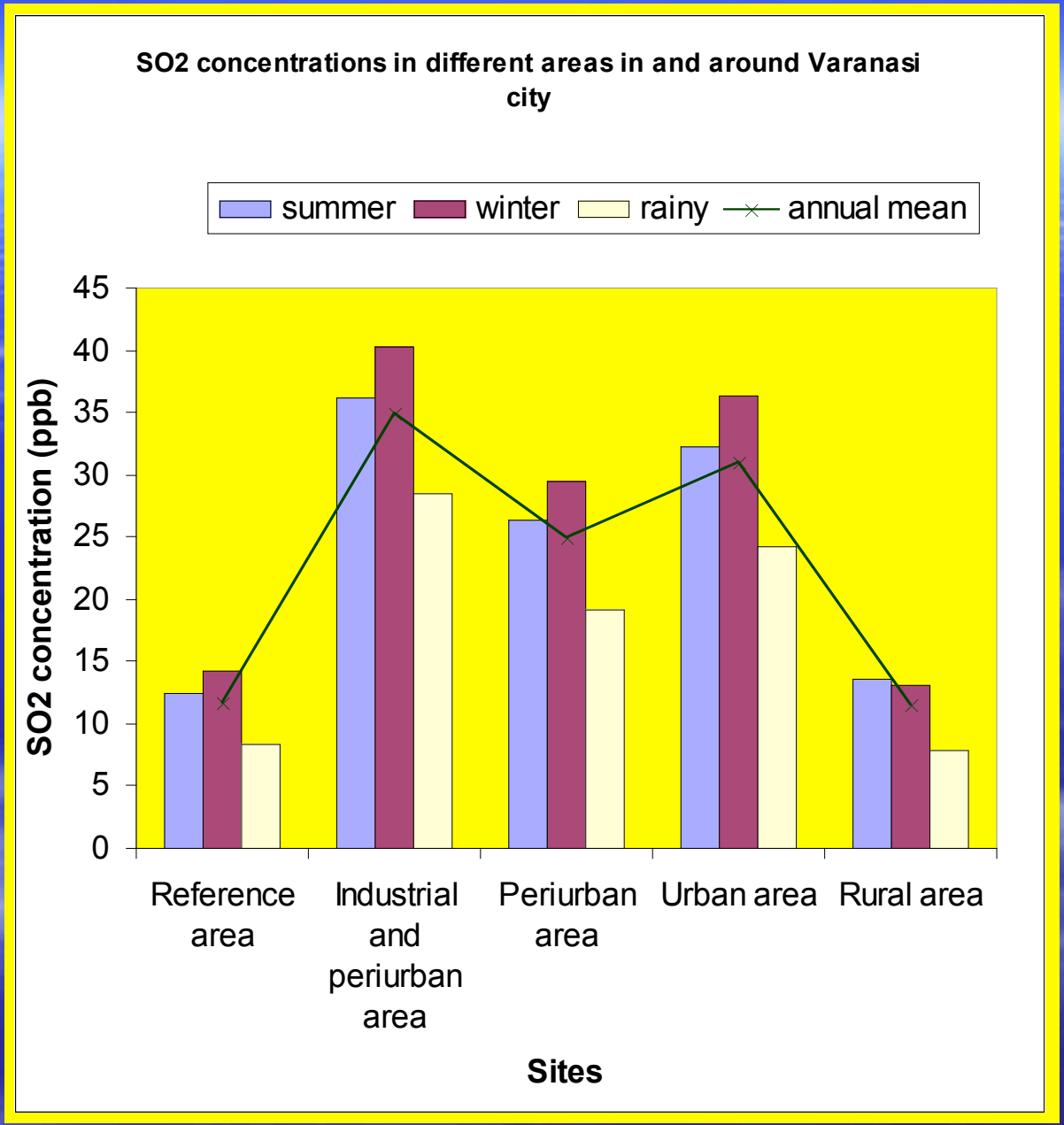
Crop		Range of reduction		Sensitivity range
		Minimum	Maximum	
Triticum aestivum	(Wheat)	30	50	S
Horedum vulgare	(Barley)	25	40	S
Cicer arietinum	(Gram)	10	15	R
Brassica campestris	(Mustard)	10	15	R
Pisum sativum	(Pea)	40	50	S
Zea mays	(Maize)	20	30	I
Phaseolus mungo	(Urd)	30	50	S
Oryza sativa	(Rice)	30	40	S
Cajanus cajan	(Arhar)	20	30	I
Sorghum vulgare	(Jowar)	15	20	R
Sesamum indicum	(Til)	10	15	R

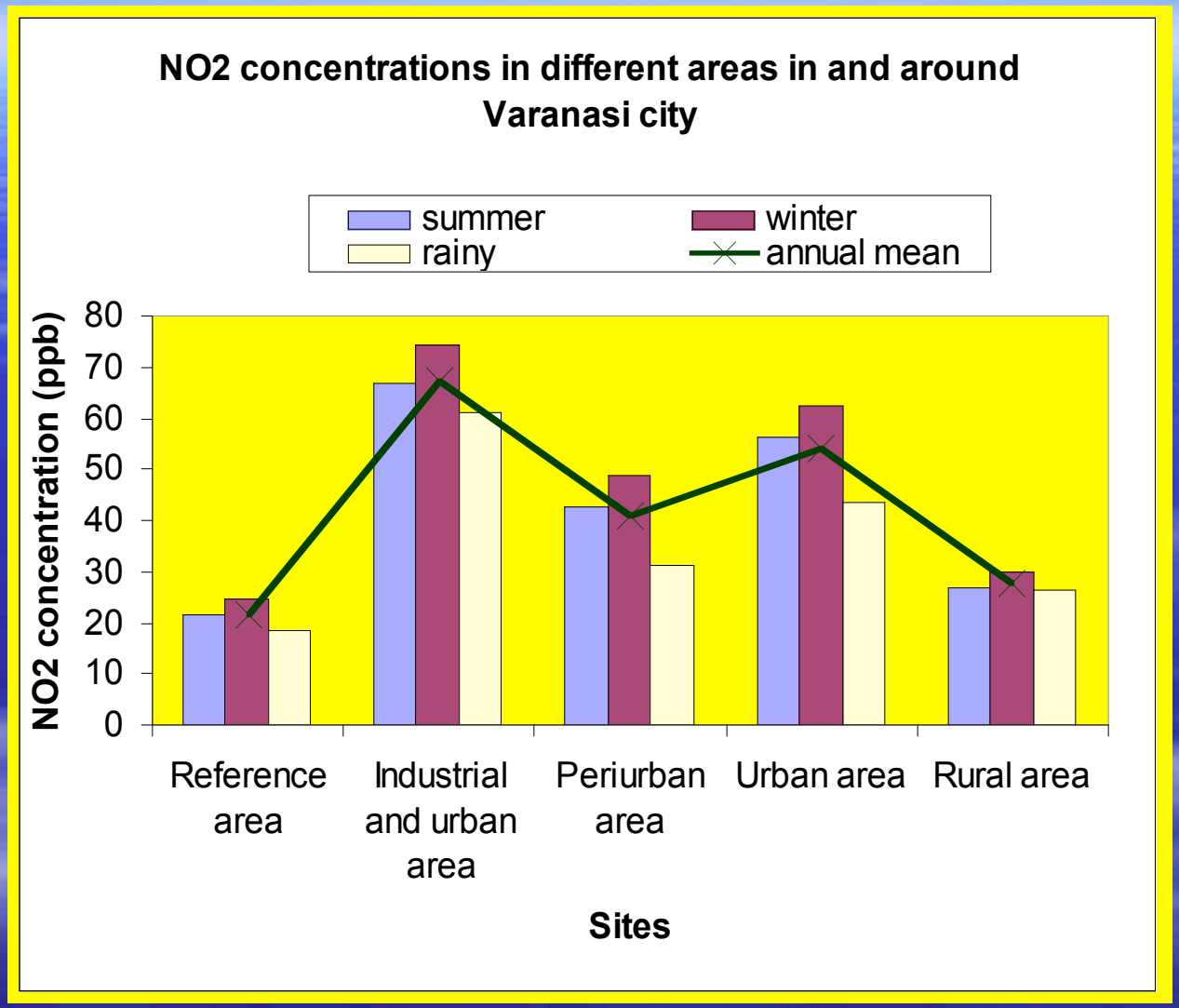
S: Sensitive (<30); I: Intermediate (15-30); R: Resistant (<15)

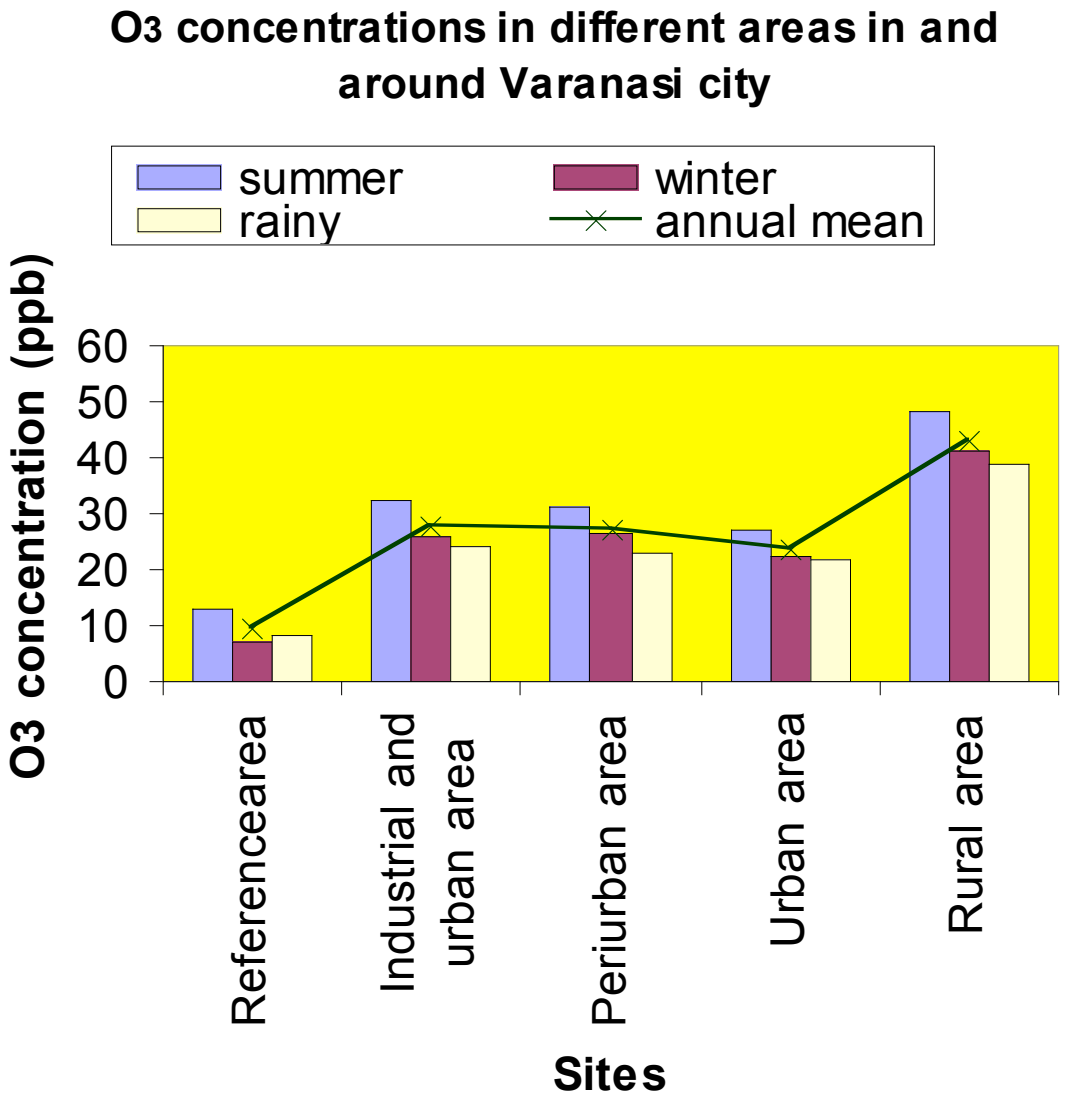
EFFECT OF THERMAL POWER PLANT EMISSION ON BIOMASS AND YIELD OF WHEAT (*Triticum aestivum* L.) PLANTS

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

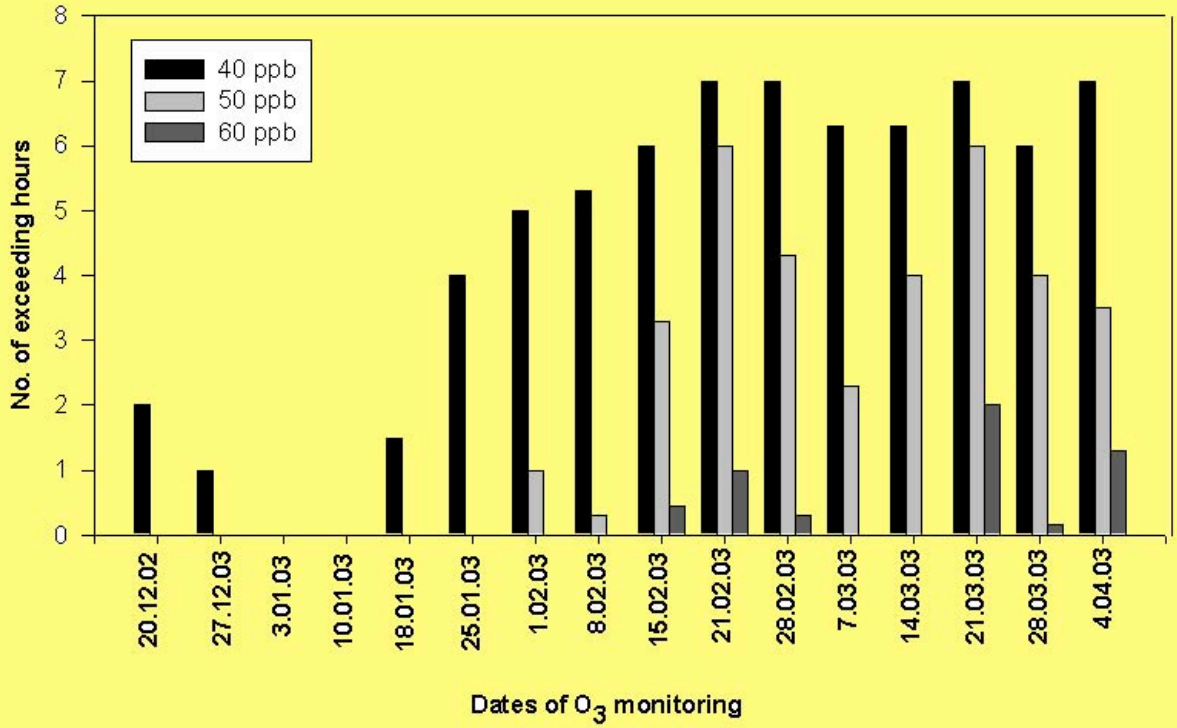
Values in parenthesis are reduction as compared to reference site


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

Ozone concentration exceeding 40,50 and 60 ppb during December 2003 – March 2004



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 $p < 0.05$

Yield (g plant^{-1}) in selected plants grown at different sites in and around Varanasi (Mean ± 1SE)

Site	Mustard	Wheat	Pea	Mung
Reference area	6.03 [a] ± 0.32	7.48 [a] ± 0.81	9.40 [a] ± 0.42	6.44 [a] ± 0.61
Industrial and urban area	4.51 [b] ± 0.21	5.57 [c] ± 0.39	5.85 [d] ± 0.35	1.71 [d] ± 0.22
Periurban area	4.97 [b] ± 0.32	6.24 [c] ± 0.55	6.63 [c] ± 0.49	3.78 [c] ± 0.4 1
Urban area	4.77 [b] ± 0.24	6.15 [c] ± 0.49	6.37 [c] ± 0.33	3.25 [c] ± 0.32
Rural area	5.67 [a] ± 0.41	6.44 [b] ± 0.62	7.10 [b] ± 0.49	4.23 [b] ± 0.45

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

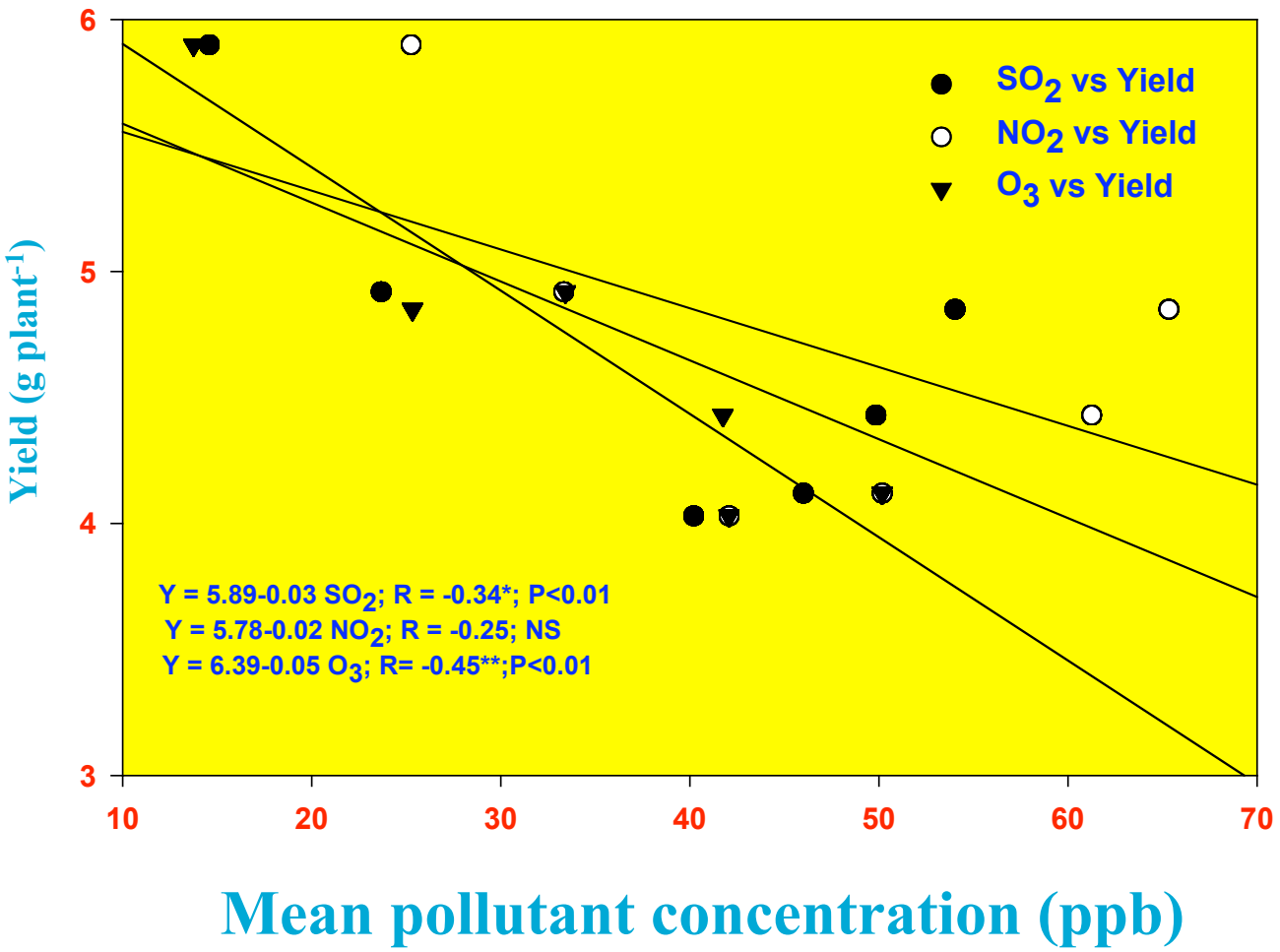
Energy (k cal g^{-1}) and protein (mg g^{-1} dw) contents in seeds of selected plants grown at different sites in and around Varanasi

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

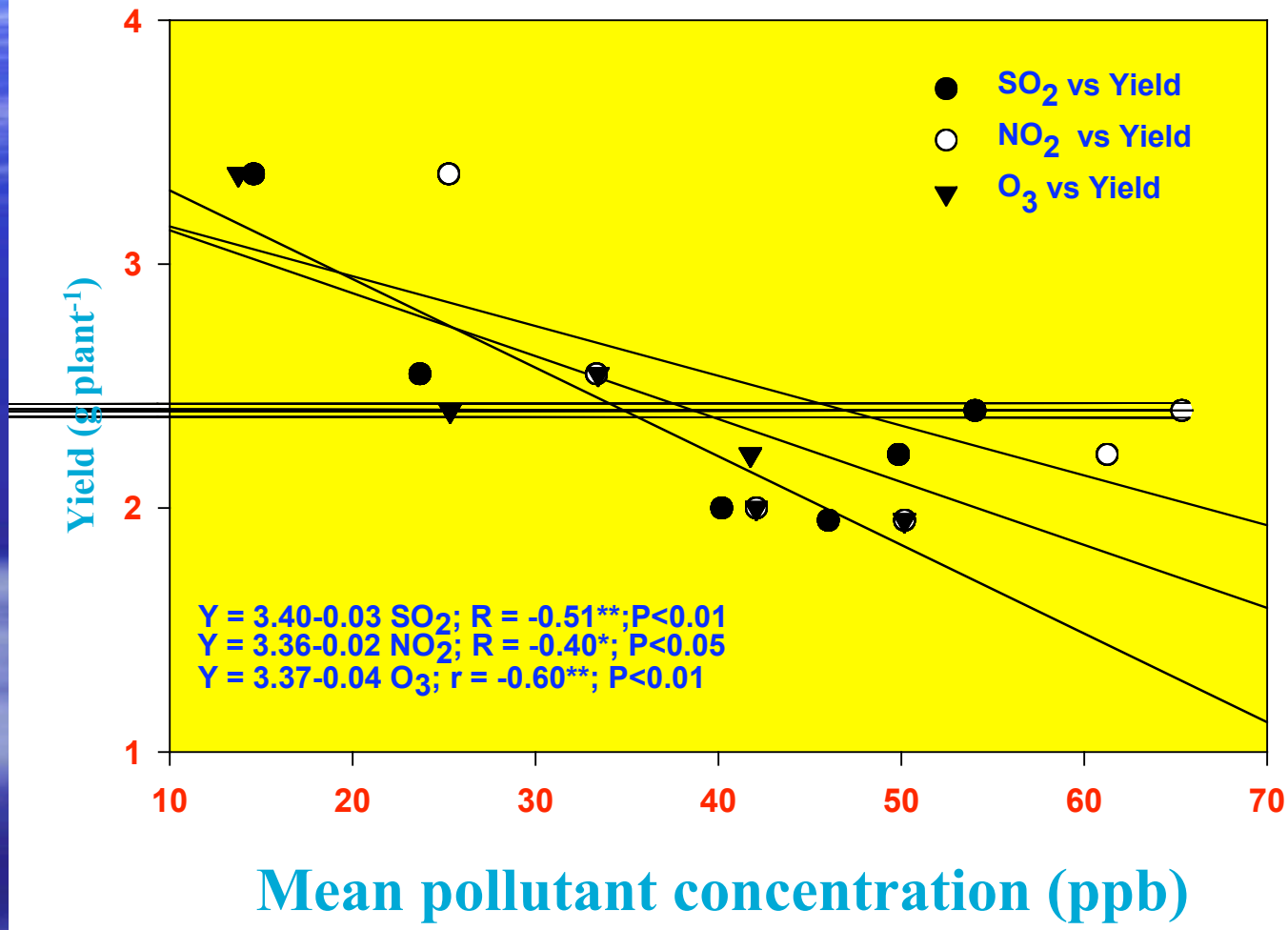
PRODUCTION, ECONOMIC VALUE AND % LOSS IN ECONOMIC VALUE OF YIELD AT DIFFERENT SITES AROUND VARANASI CITY

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 ar ea	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



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)	2.15 ^{a} (22)	2.39 ^{a} (17)	2.79 ^{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

Assessment of Ozone Injury using EDU

ROLE OF ETHYLENE DIUREA IN ASSESSING O_3 INJURY

- **EDU EXPERIMENTS**

One set of 10 days old plants were given 600 ml of EDU (+EDU) and another set were given equal amount of water (-EDU)
Treatments were repeated at ten days interval till maturity.

N-[2-(2-oxo-1-imidazolidinyl)ethyl-]-N-phenylurea

Percent increment in yield (g plant^{-1}) of selected crops upon EDU treatment in ambient air

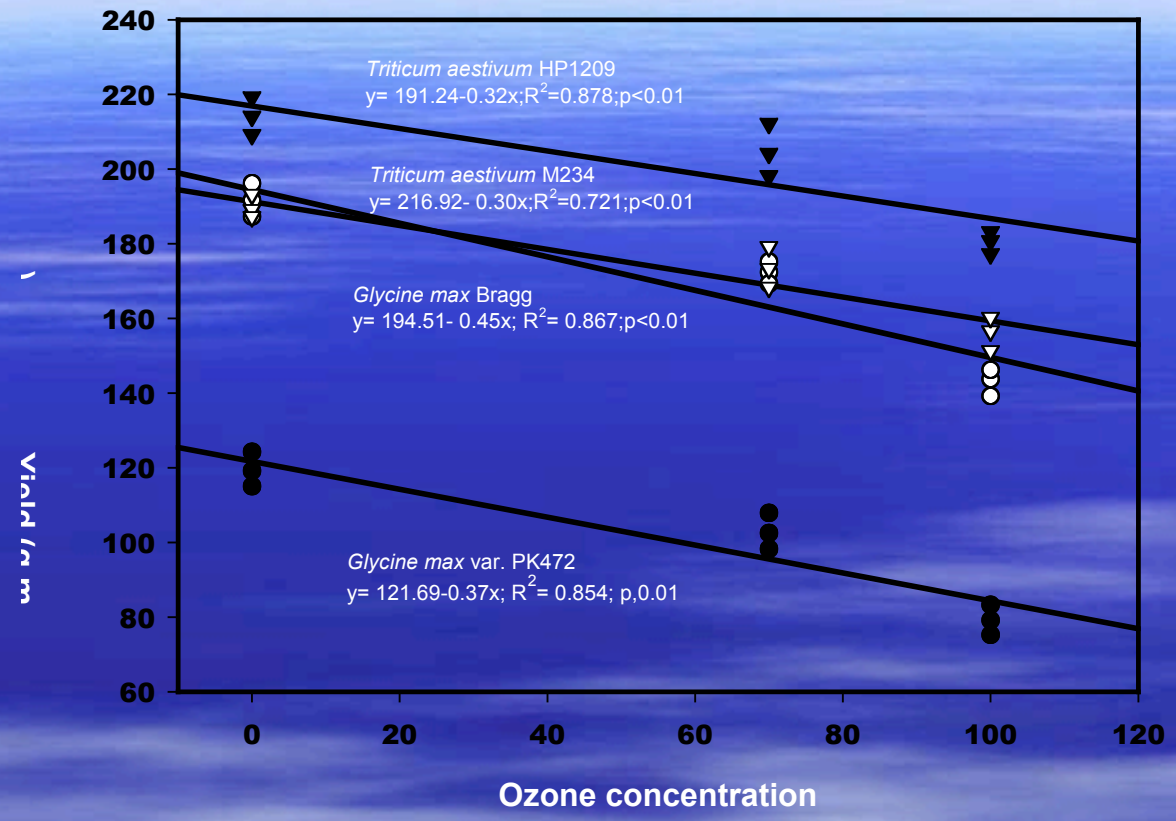
Site	Percent increment		
	Wheat	Mung	Pea
Reference area	0.2	0.6	0.5
Industrial and urban area	4.2	3.6	4.9
Periurban area	14.2	14.0	18.8
Urban area	6.4	8.9	13.2
Rural area	18.9	19.2	29.8

Artificial Exposure Studies using open top chambers

Percent reductions over control at 70 day age in selected characteristics of plants exposed to 70 (T1) and 100 (T2) ppb O_3 for 4 h daily from germination to maturity

Parameters	Soybean				Wheat			
	PK472		Bragg		HP1209		M234	
	T1	T2	T1	T2	T1	T2	T1	T2
Photosynthesis	19.8	40.4	25.6	32.4	29.0	41.0	36.0	43.0
Total chlorophyll content	26.6	34.1	11.5	36.9	19.8	42.1	15.0	20.9
Ascorbic acid content	15.0	15.0	1.1	4.0	5.8	19.6	24.9	34.6
Plant length	20.0	23.0	6.5	17	11.6	17.1	1.87	4.1
Leaf area	20.0	23.0	21.0	24.0	20.1	34.1	15.3	27.8
Total biomass	19.6	26.8	15.0	20.8	6.5	24.7	13.2	20.0
Wt of 1000 seeds*	3.0	21.0	3.0	18.0	14.0	16.0	3.3	14.4
Yield*	13.9	33.5	10.0	25.0	8.0	17.0	4.7	15.5

* At the time of harvest



Correlation between ozone concentration and yield of different varieties of wheat and soybean plants

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

THANKS