Experimental evidence of ozone impacts on crop yield and crop quality in India

Dr. Madhoolika Agrawal
Professor in Botany
Department of Botany
Banaras Hindu University
Varanasi - 221 005
INDIA

Ground level Ozone

Ozone, a major secondary air pollutant

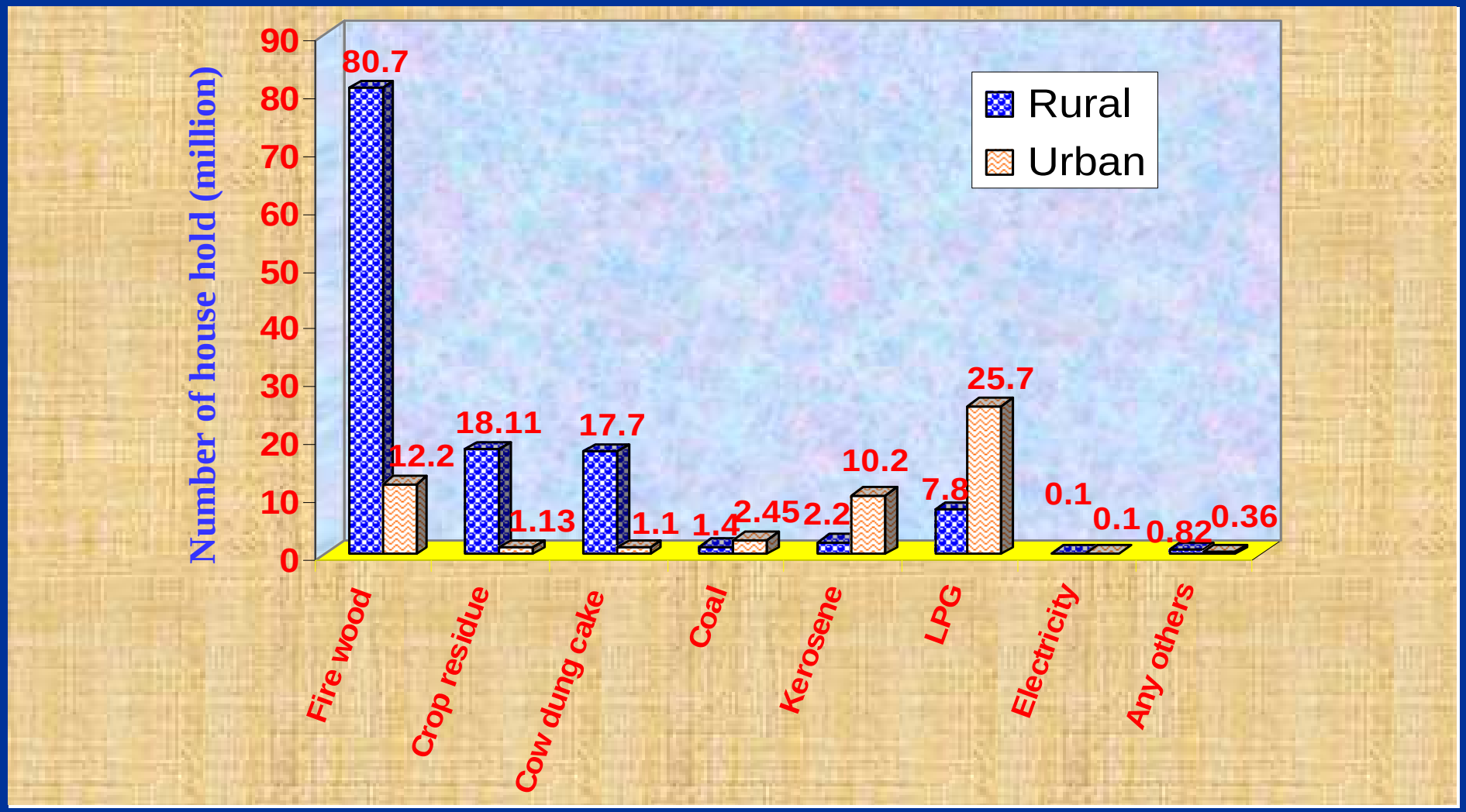
Meteorological conditions such as high temperature and high light intensity favor O_3 formation due to long range transport of precursors

Impact of ozone on plants

Higher levels of ozone cause:

- **Foliar injury**
- **Accelerate senescence**
- **Decrease plant growth**
- **Alter plant metabolism**
- **Reduce crop yield**

BIOMASS BASED FUELS KEEP RURAL INDIA ALIVE



RISING NUMBER OF VEHICLES

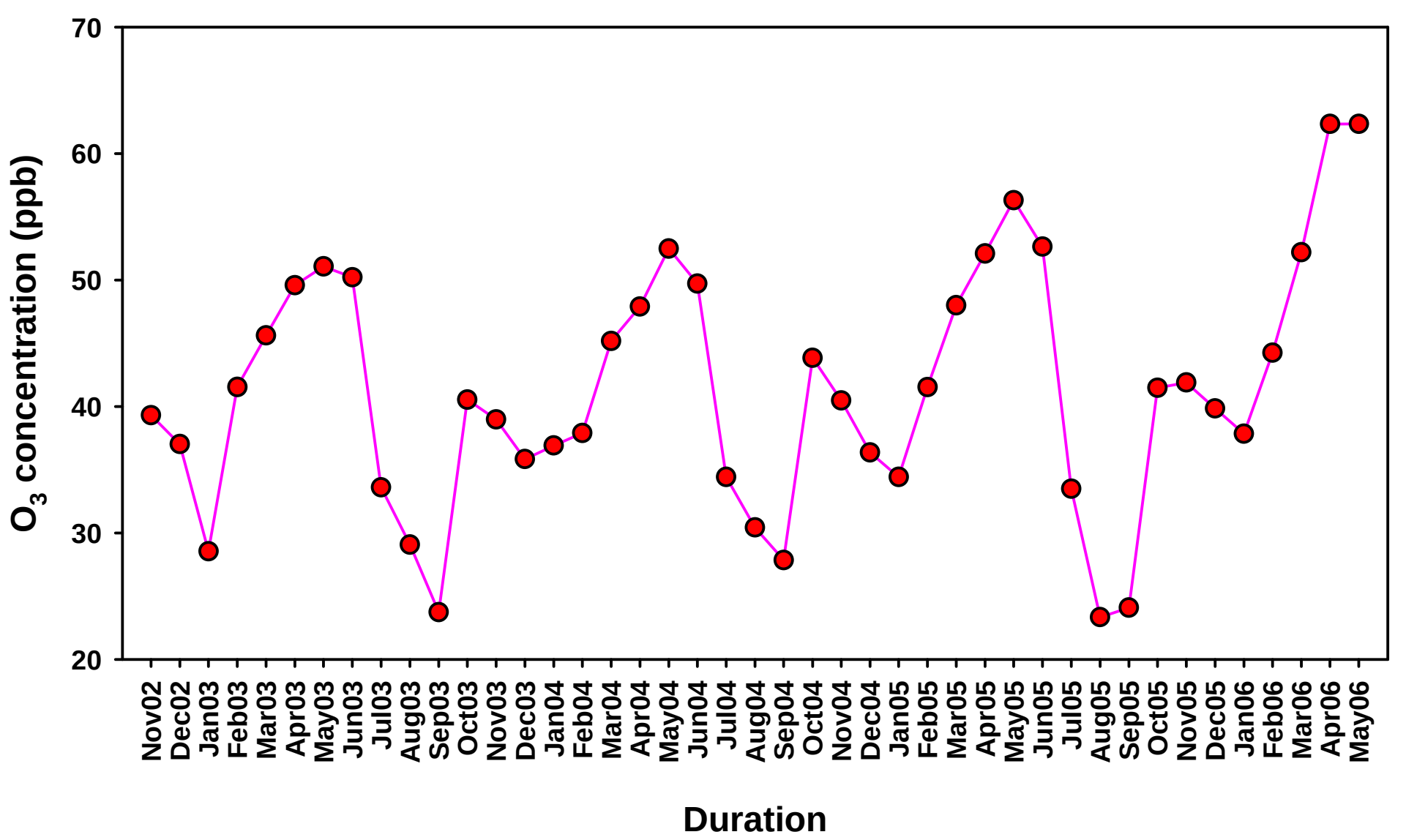
	1951	1961	1971	1981	1998	Rate of increase between 1981 and 1998
Number of vehicles (in thousand)*	306	665	1,865	5,391	40,939	659%
Urban population (in million)**	62	78	107	156	259	66%

* Motor transport statistics of India 1997-1998.

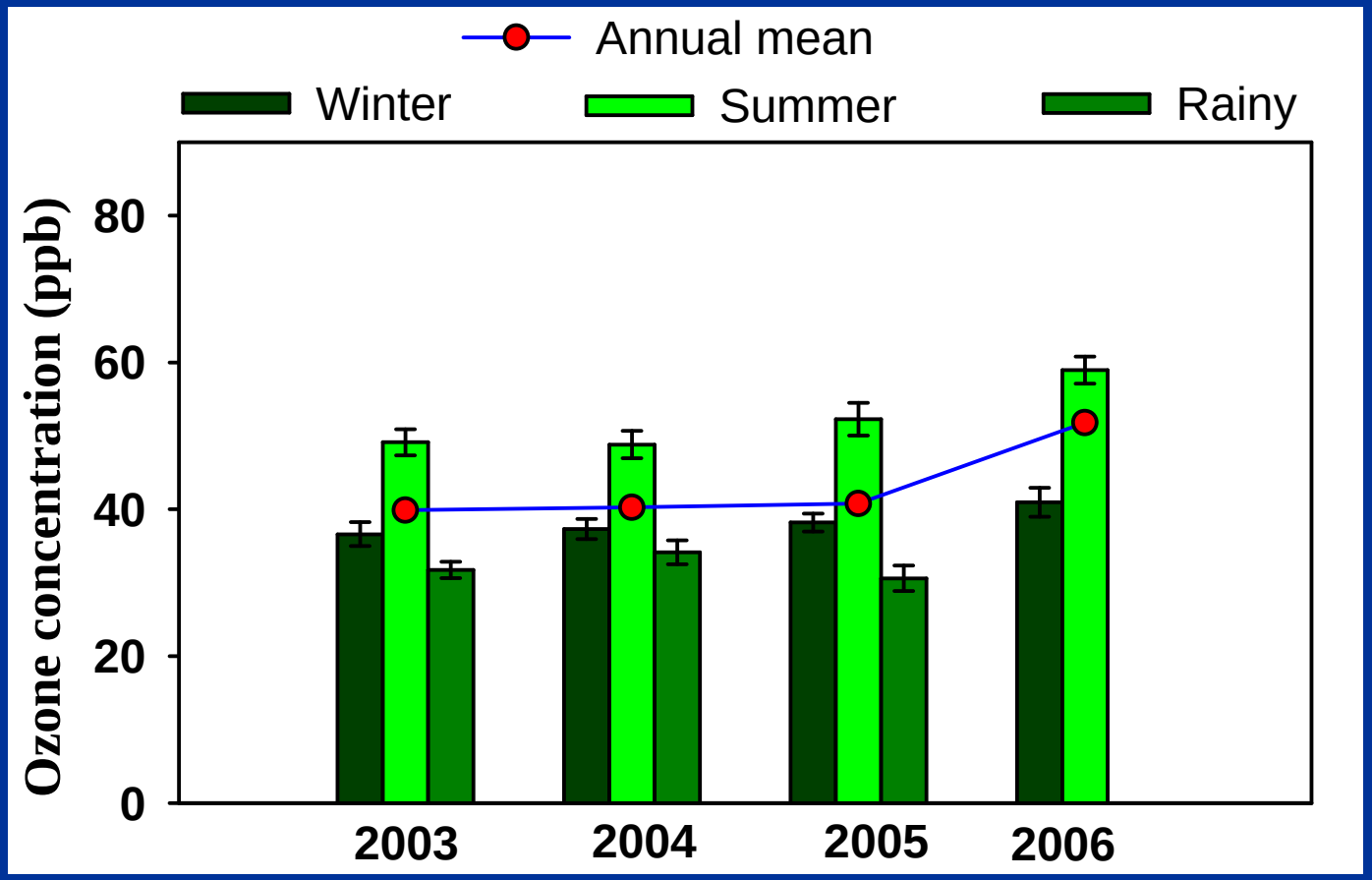
** Census data.

Long Term Field Studies

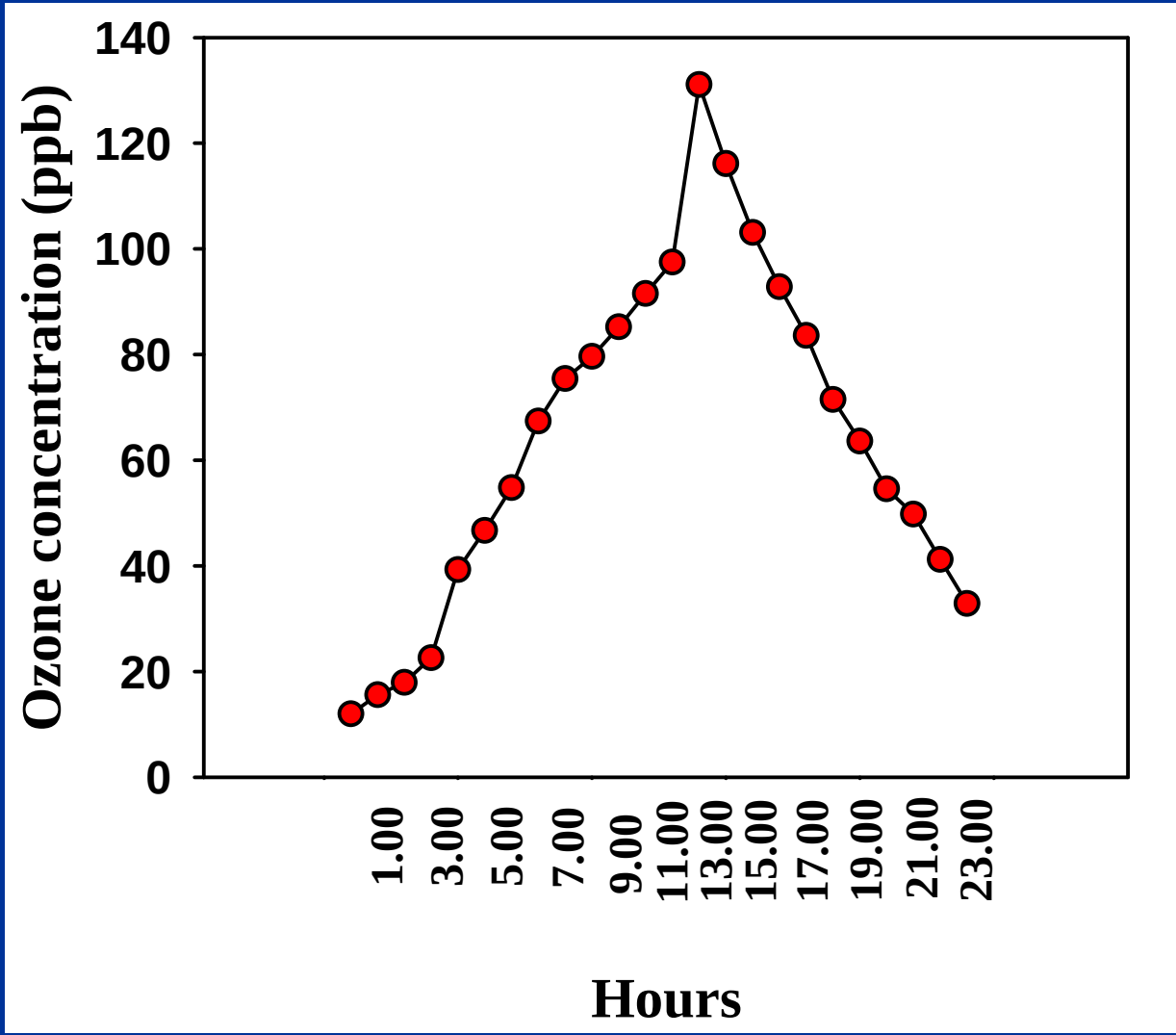
Annual variations in concentrations of Ozone from November 2002 to May 2006



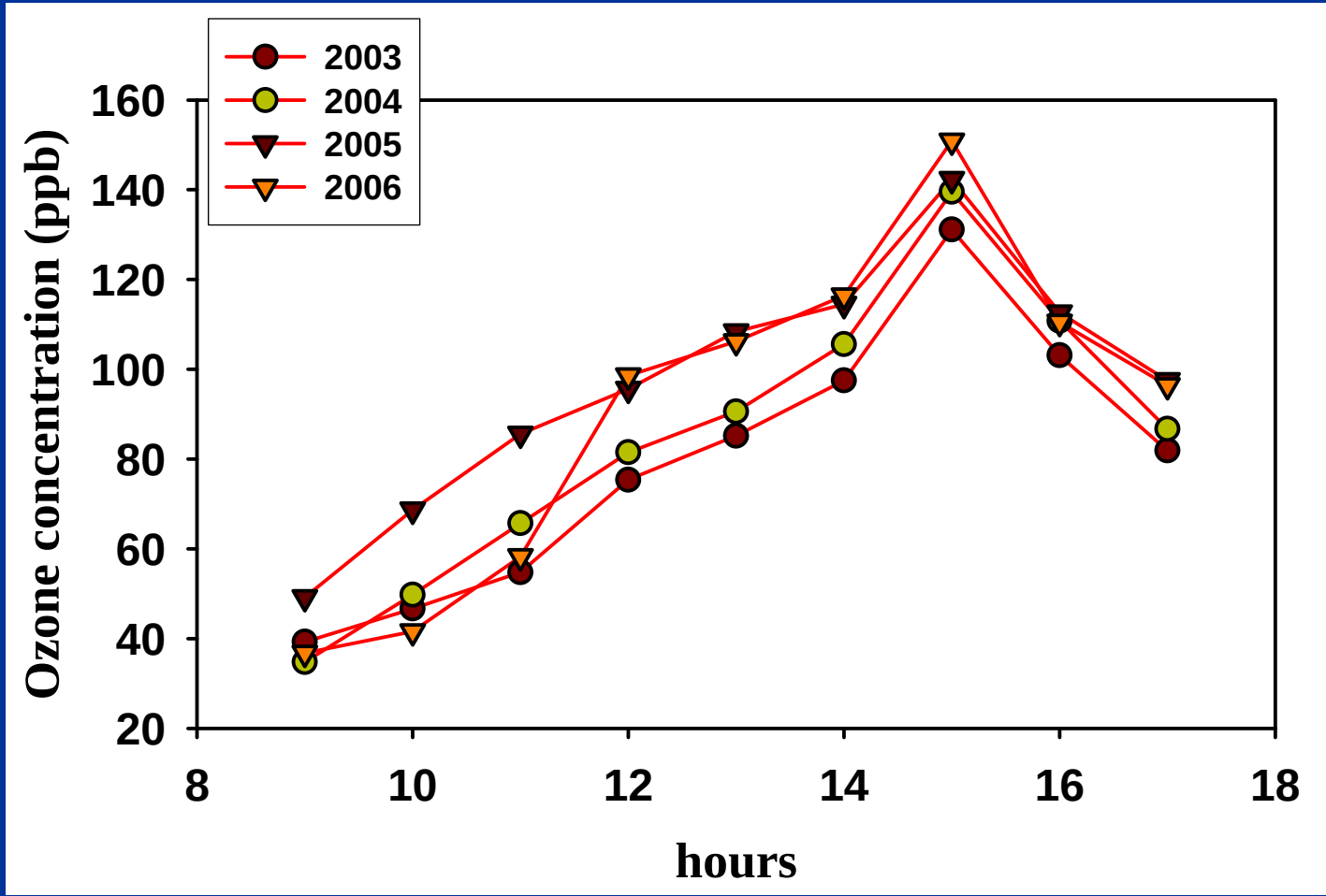
Seasonal and annual variations in ozone concentrations (ppb) from 2003 to 2006



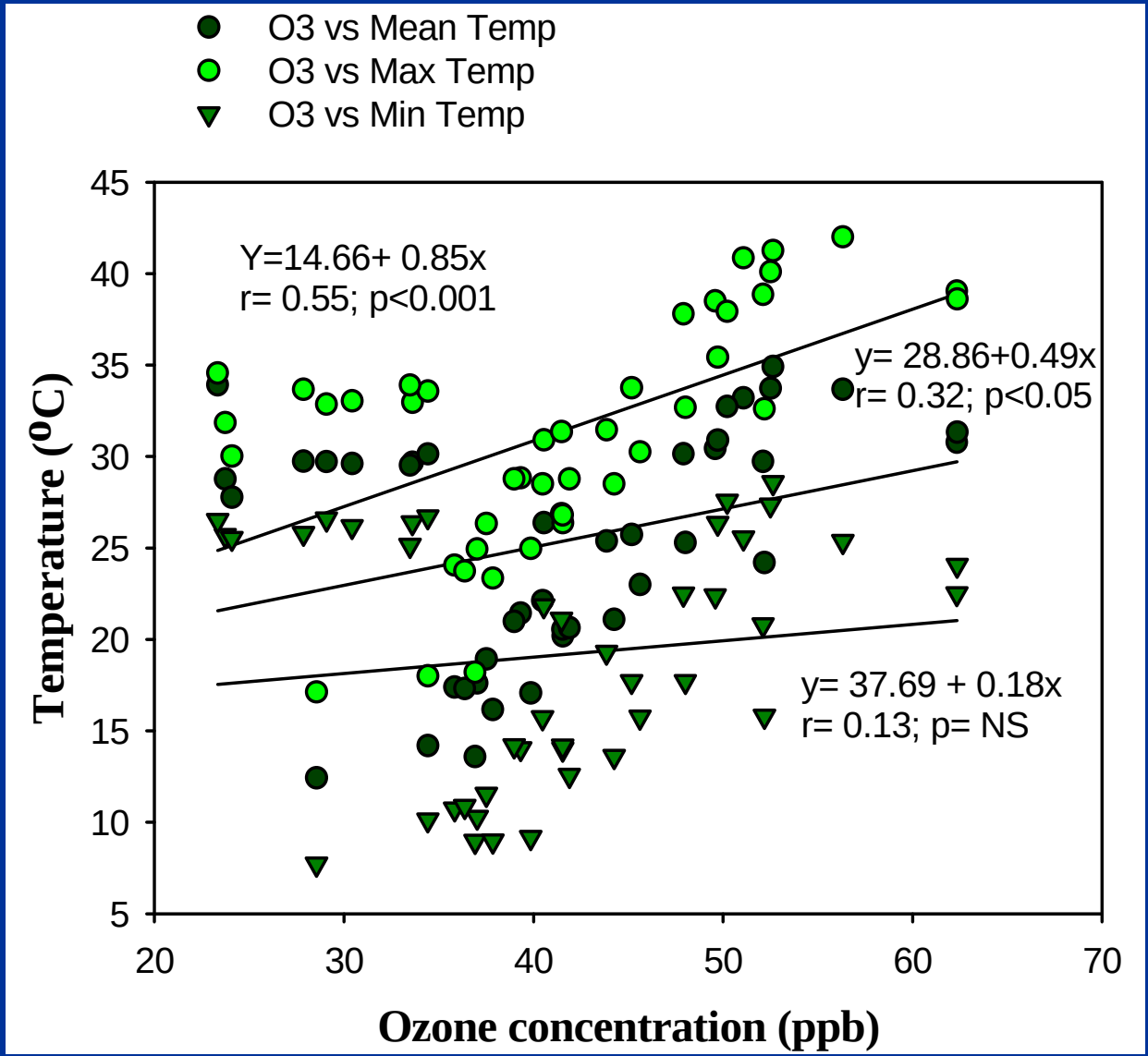
Diurnal variations in hourly O_3 concentrations during May, 2003



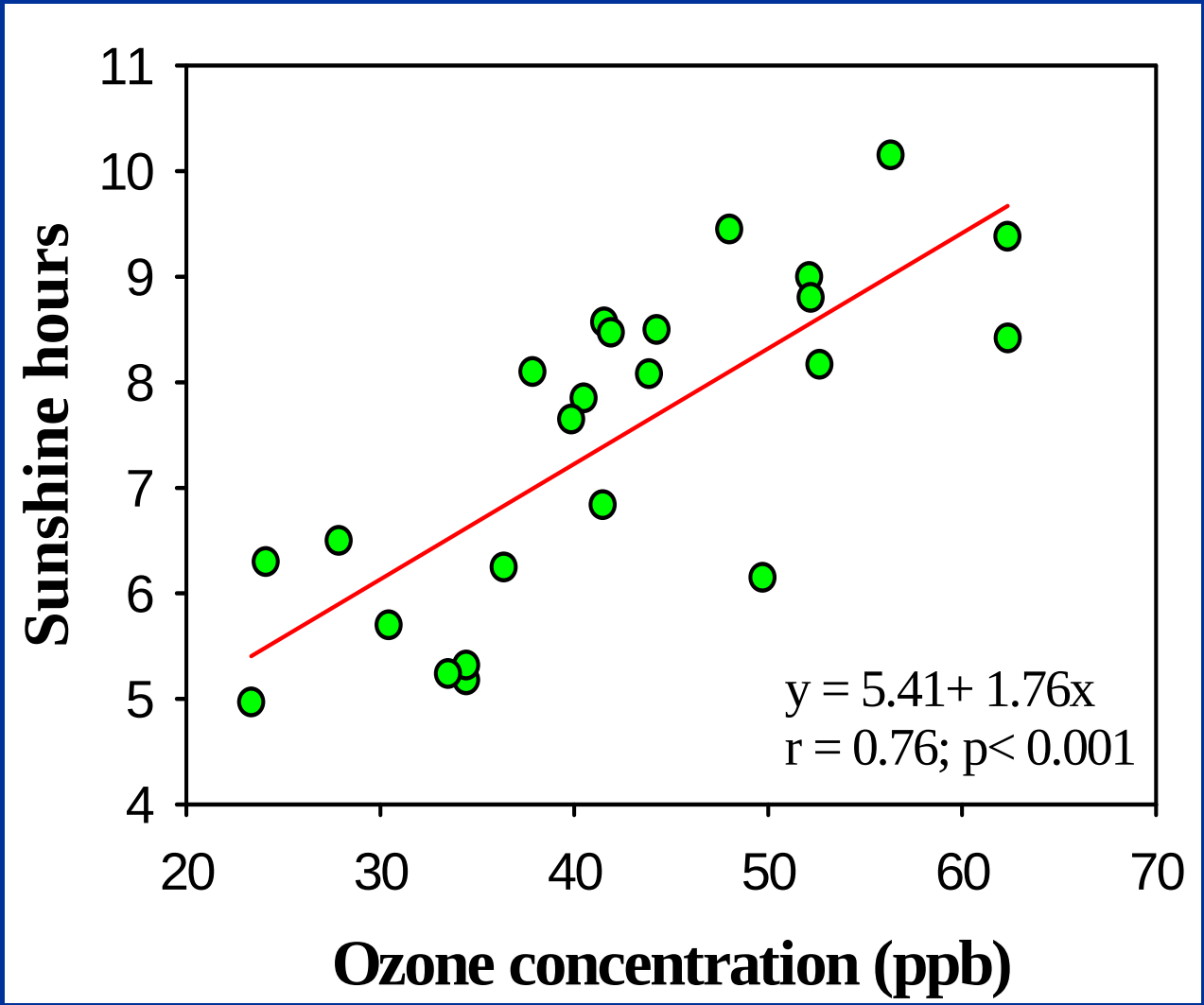
Hourly variations in ozone concentrations during day time on May 22, from 2003 to 2006

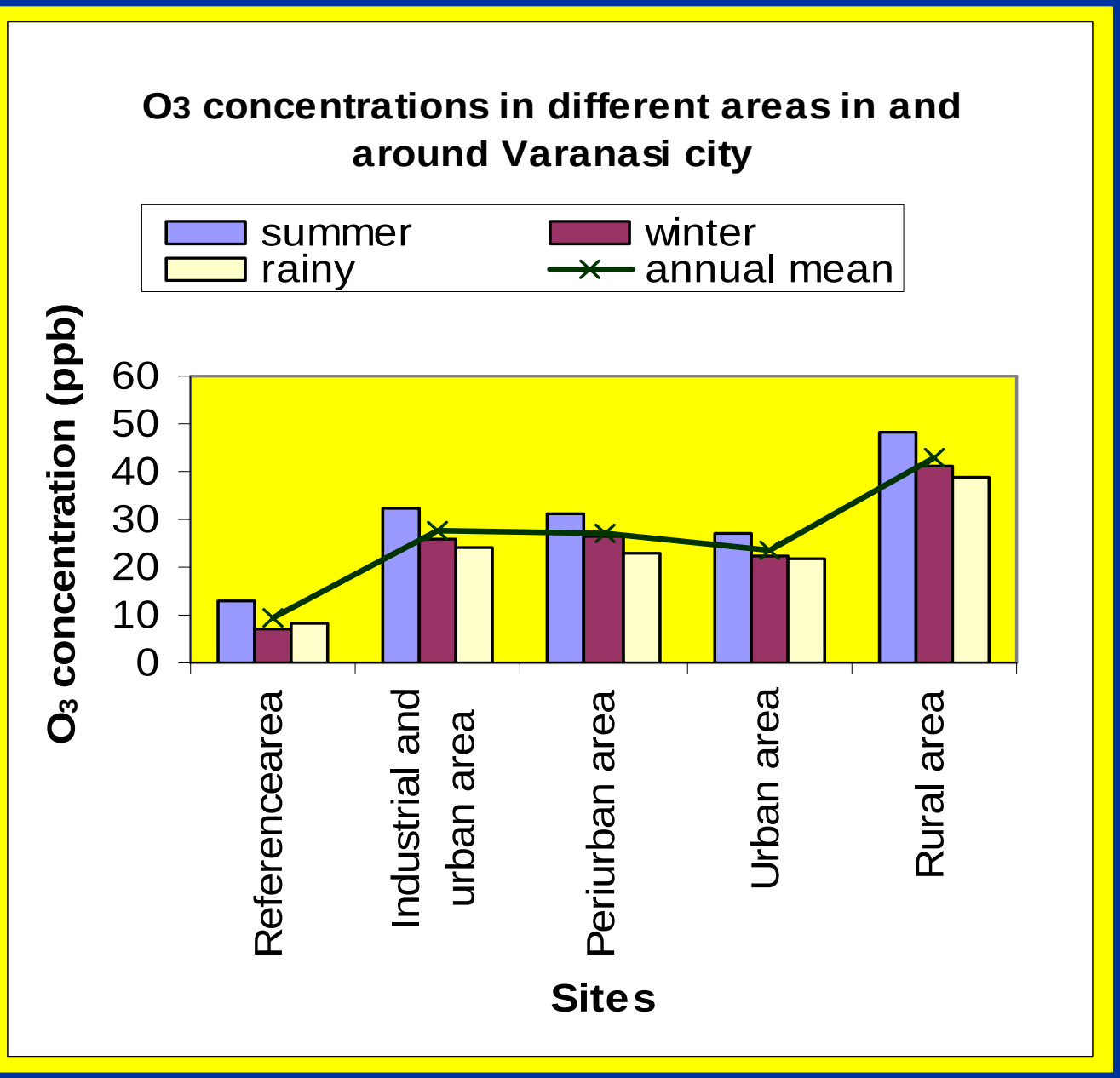


Correlations between mean monthly ozone concentrations and mean, maximum and minimum temperatures



Correlation between mean monthly sunshine hours and mean monthly ozone concentrations




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

Photosynthesis rate (μ mol $CO_2 m^{-2} s^{-1}$) 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
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$^{-1)}$ of 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
Periurban area	4.97 [b] ± 0.32	6.24 [c] ± 0.55	6.63 [c] ± 0.49	3.78 [c] ± 0.41
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
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

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

6 h mean concentrations

Air Exclusion Studies

OPEN TOP CHAMBER (OTC)

POLLUTANT CONCENTRATIONS AND CHANGES IN SELECTED PARAMETERS OF INDIAN SPINACH 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)	9^{a}	8.9^{a}	2.46^{b}
NO_2 (ppb)	15^{a}	16.90^{a}	$4..39^{b}$
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

Selected yield 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)
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)
Ozone (ppb)	43	5.1

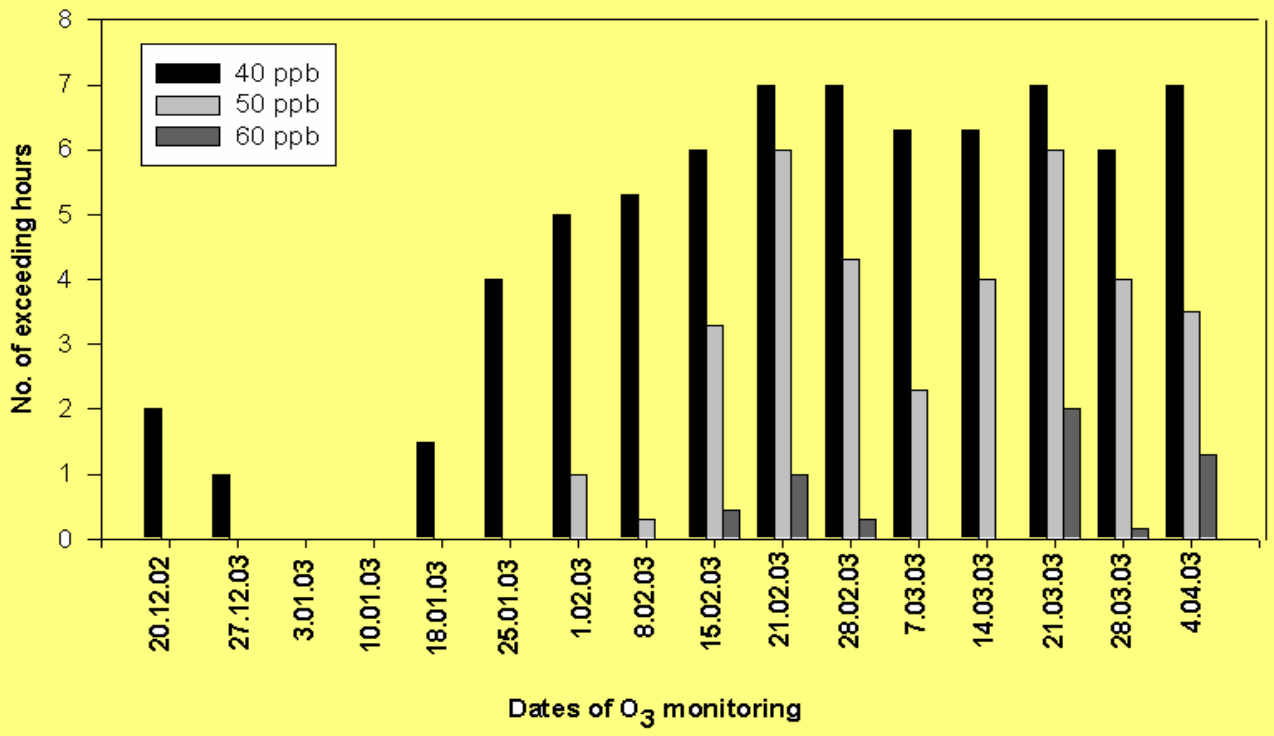
Values within parentheses show percent change from non filtered plants

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

Months	O_3	
	NF	F
December	35.33	3.83
January	35.48	3.26
February	37.14	3.75
March	52.09	5.16

12 h average (7.00- 19.00 h)

Ozone concentrations exceeding 40, 50 and 60 ppb



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

Mean concentrations of ozone (ppb) in non filtered chambers at a rural site during July - October 2005

Months	O_3
July	24.95
August	25.35
September	30.23
October	50.59

12h average (7.00- 19.00 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

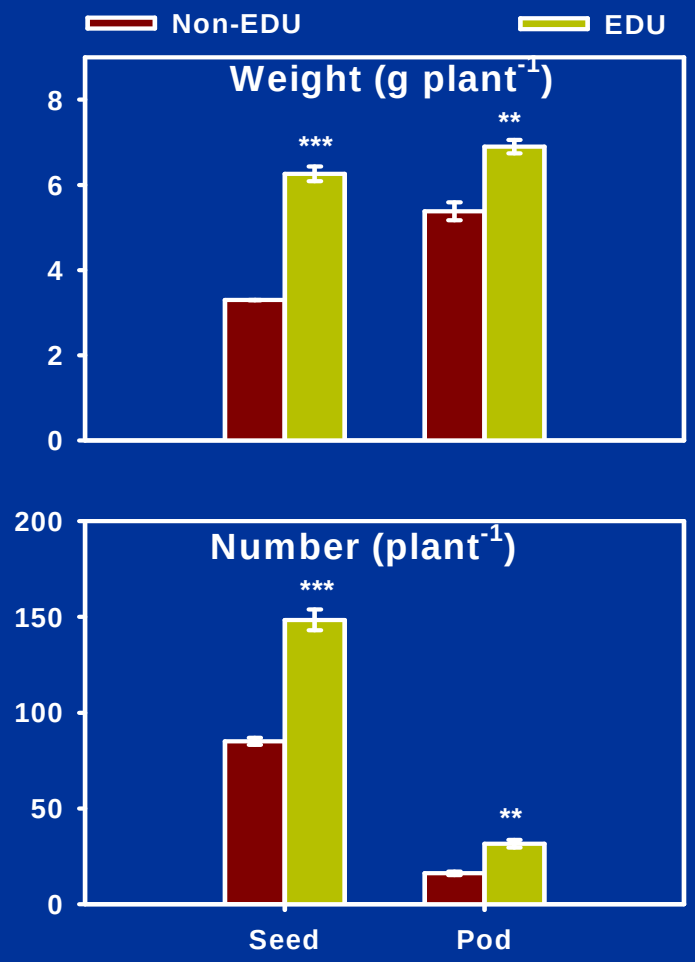
Per cent increments in yield (g plant^{-1}) of selected crops upon EDU treatment in ambient air

Site	Percent increment		
	Wheat	Mung	Pea
Reference area	0.2	0.6	0.5
Periurban area	14.2	14.0	18.8
Urban area	6.4	8.9	13.2
Rural area	18.9	19.2	29.8

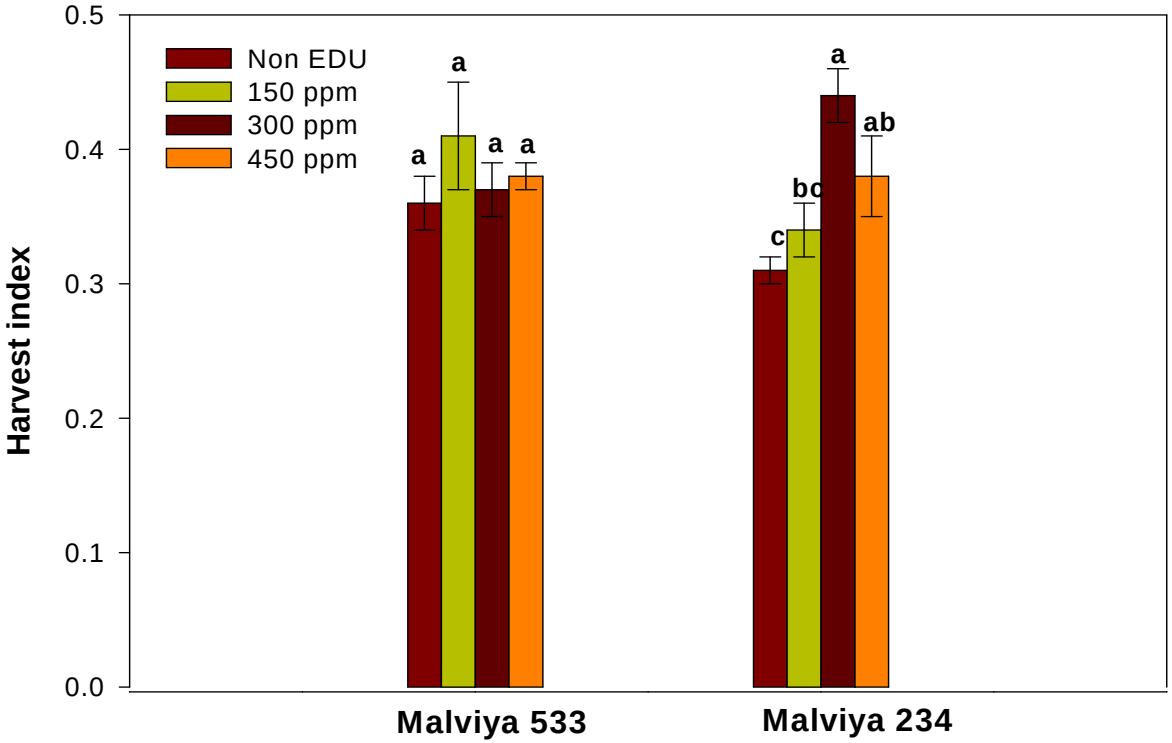
15/05/2006

Assessment of ozone effect using chemical protectant EDU

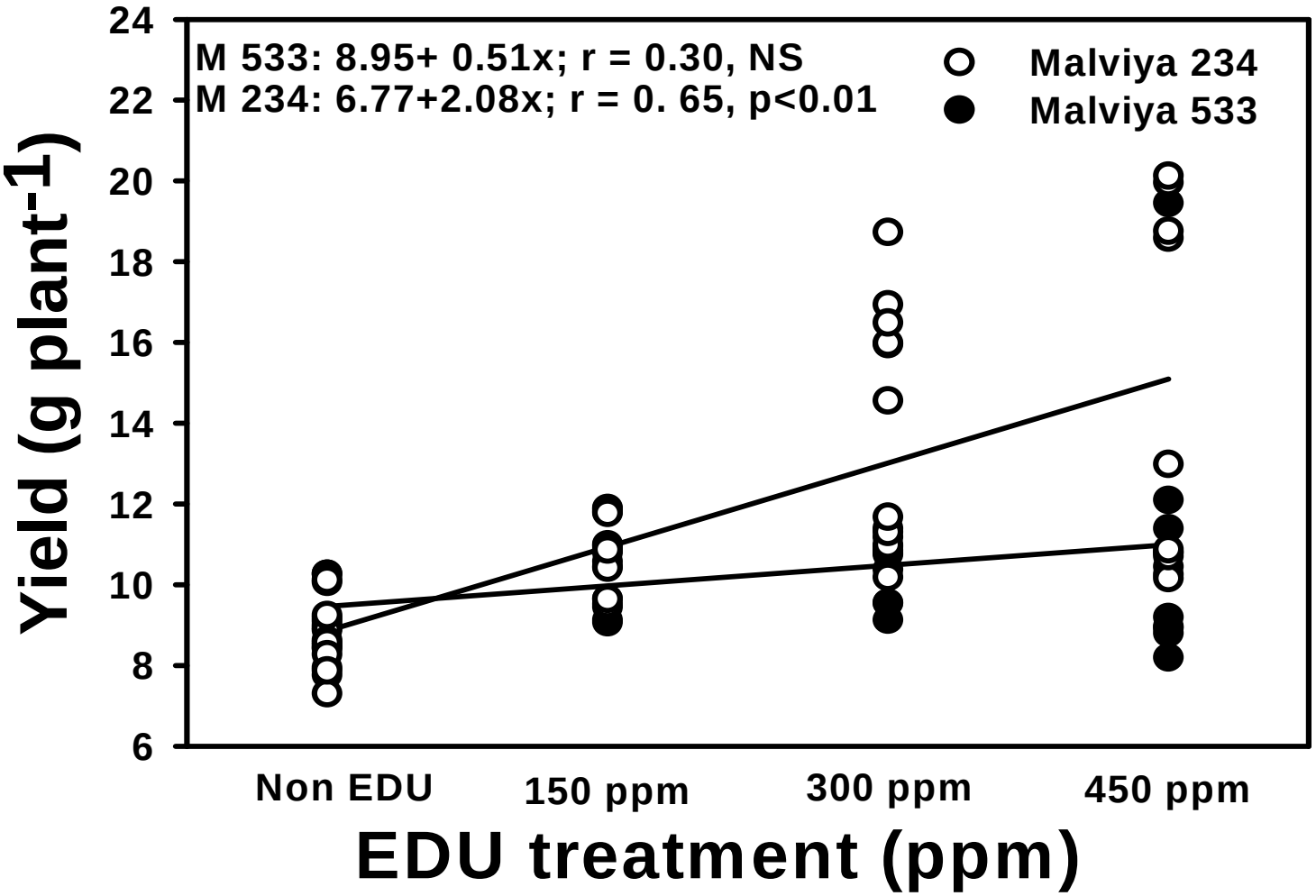
Effect of EDU treatment on weight and number of seeds and pods of mungbean plants



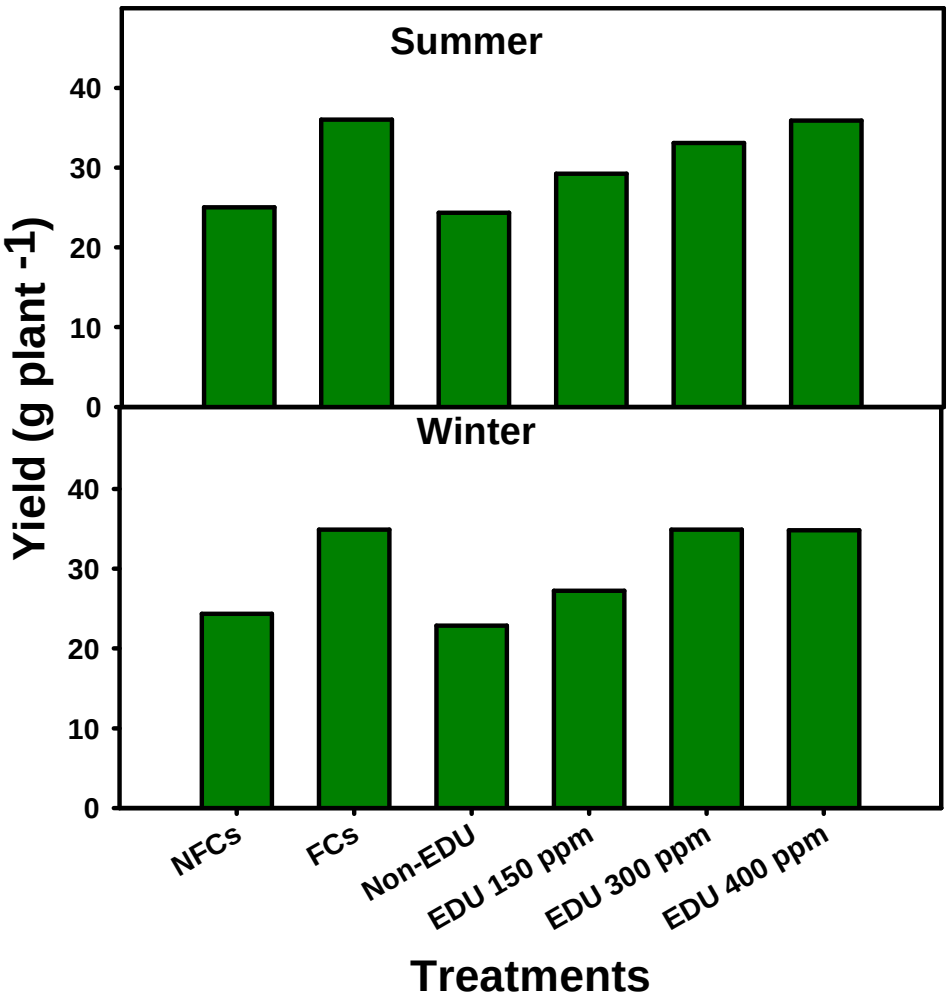
Variations in harvest index of two wheat cultivars at different EDU concentrations



Relationships between concentrations of EDU and yields of wheat cultivars



Comparison of yield of Indian spinach grown in filtered and non-filtered chambers and at different EDU treatments



Conclusions

- Ozone concentrations were higher in rural areas as compared to suburban and urban areas.
- High temperature, long sunshine hours and low humidity led to higher ozone concentrations during warmer months.
- Ozone negatively affected the yield and quality of crops.
- Sensitivity of crops differed among species and cultivars.
- Meteorological conditions during crop growing season affected ozone concentrations and the consequent magnitude of negative effects on growth and yield of crops.
- Ozone poses the greatest threat to agriculture during warmer months.
- EDU can be used as a tool in biomonitoring programme to map O_3 injury in plants especially in developing countries having major constraints of continuous electricity and monitoring equipments.

Recommendations

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

Thanks