Use of ethylenediurea (EDU) as a research tool in assessing the impact of ambient ozone on plants

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Troposphere 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**

Formation of tropospheric Ozone

Ozone from NO_x

NO_x + radiations (380 nm) ⟶ NO + O

O + O_2 ⟶ O_3

Ozone from carbon monoxide

CO + $2O_2$ + $h\nu$ ⟶ CO_2 + O_3

Ozone from methane

CH_4 + $4O_2$ + $2h\nu$ ⟶ HCHO + H_2O + $2O_3$

HCHO + $h\nu$ ⟶ H + HCO ($\lambda < 330$nm)

HCO + $h\nu$ ⟶ H + CO ($\lambda < 360$nm)

CO + $2O_2$ + $h\nu$ ⟶ CO_2 + O_3

Ozone from methane hydrocarbons

RH + $4O_2$ + $2h\nu$ ⟶ RCHO + H_2O + $2O_3$

Impact of ozone on plants

Higher levels of ozone cause:

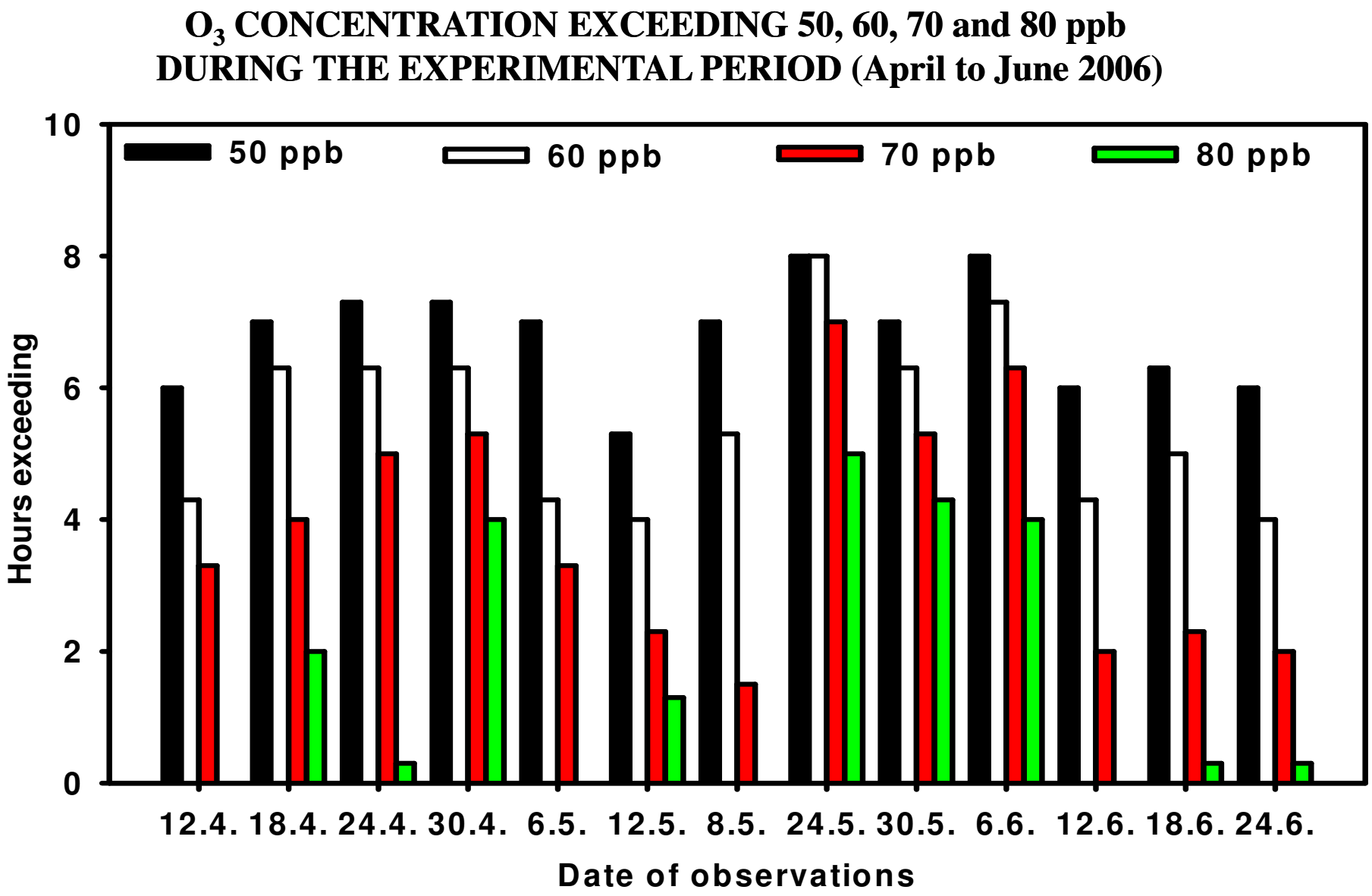
- **Foliar injury**
- **Accelerate senescence**
- **Decrease plant growth**
- **Alter plant metabolism**
- **Reduce crop yield**

Assessment of O_3 injury on plants using EDU

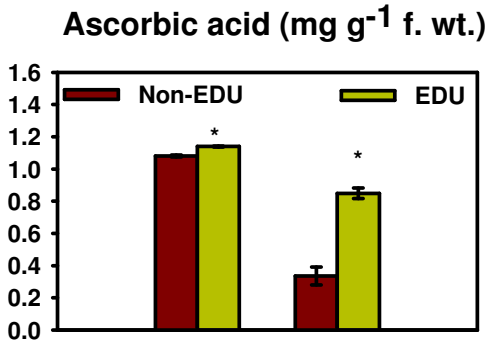
- **Ethylenediurea (N-[2-(2-oxo-1-imidazolidinyl) ethyl]- N' phenylurea; EDU)**
- **Synthetic chemical**
- **Provides protection to wide range of plants from O_3 injury without confounding effects of its own**
- **Allows assessment of yield losses**

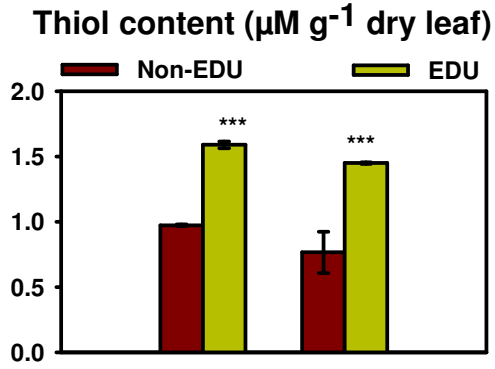
EDU as a tool to assess ozone injury on mungbean plants

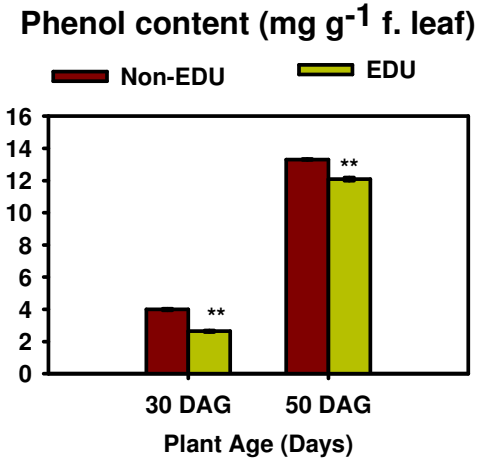
- **EDU solution (400 ppm) @ 100 ml plant^{-1} as soil drench, one week after seedling emergence, at interval of 10 days up to 70 days**
- **Mean ozone concentration 60 ppb**

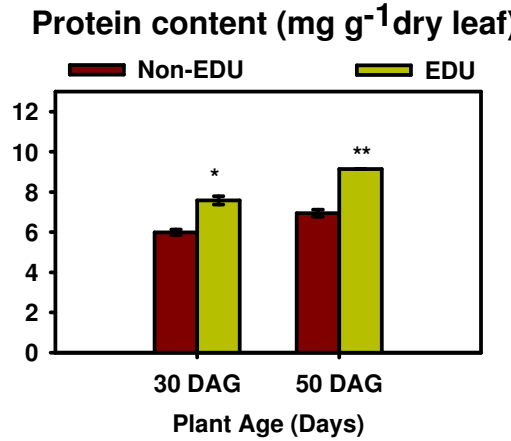

O_3 CONCENTRATION EXCEEDING 50, 60, 70 and 80 ppb
DURING THE EXPERIMENTAL PERIOD (April to June 2006)
50 ppb
60 ppb
70 ppb
80 ppb
Hours exceeding
0
2
4
6
8
10
12.4.
18.4.
24.4.
30.4.
6.5.
12.5.
8.5.
24.5.
30.5.
6.6.
12.6.
18.6.
24.6.
Date of observations

Effect of EDU treatment on ascorbic acid, phenol, thiol and protein contents of mungbean plants

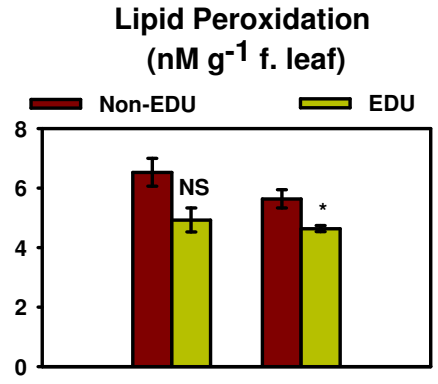


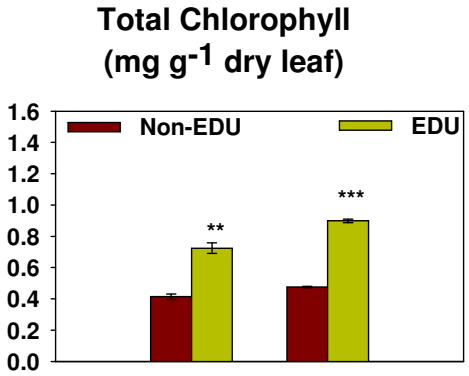


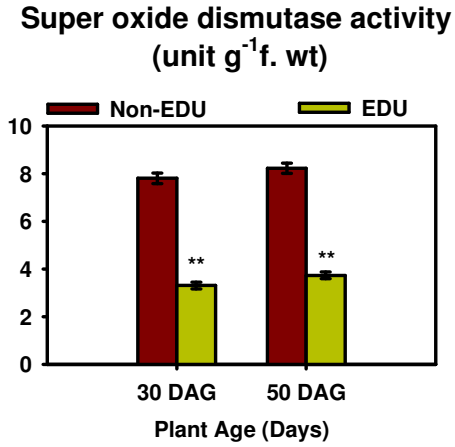


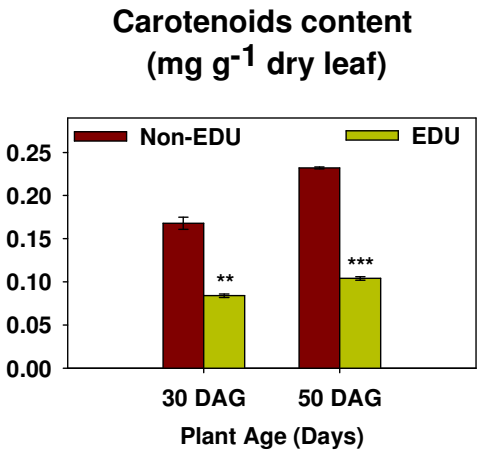


Effect of EDU treatment on LPO, SOD and photosynthetic pigments of mungbean plants

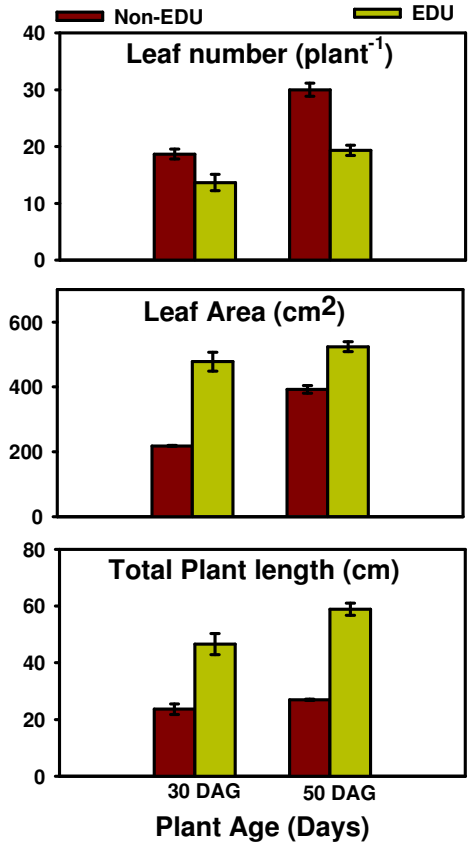




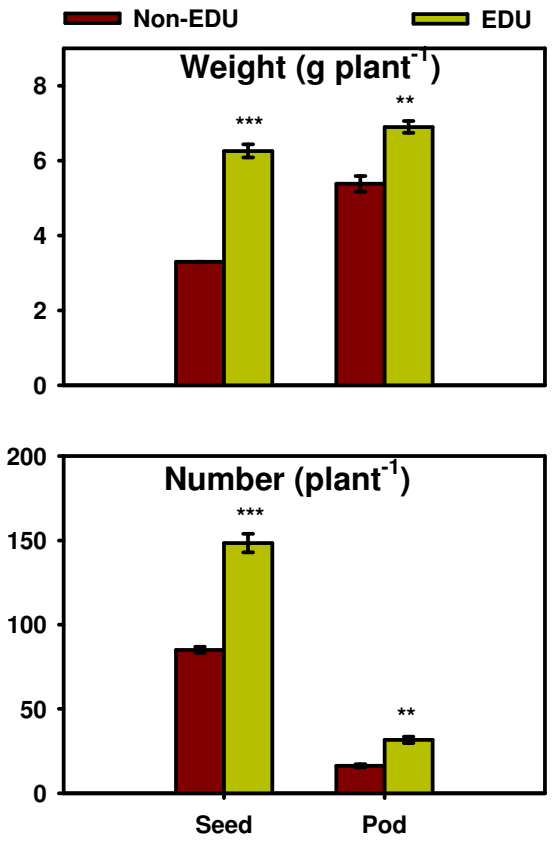




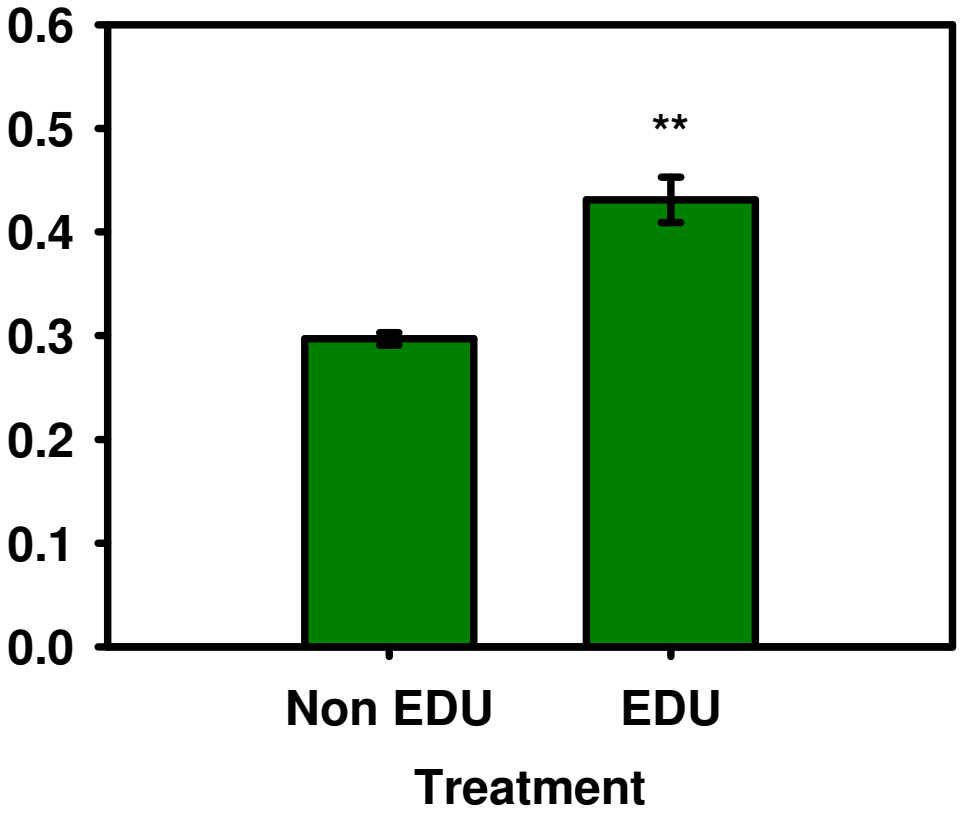
Effect of EDU treatment on Leaf number, leaf area and total plant length of mungbean plants



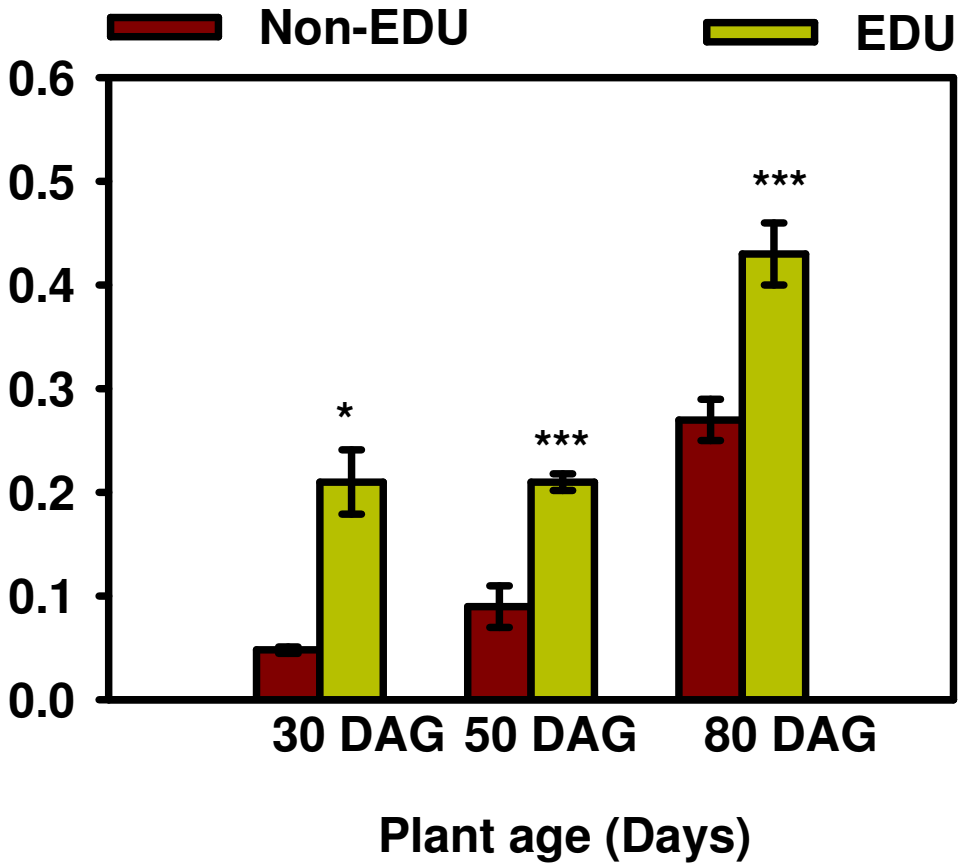
Effect of EDU treatment on weight and number of seeds and pods of mungbean plants



Effect of EDU treatment on harvest index (g g^{-1}) of mungbean plants



Age wise effect of EDU treatment on root shoot ratio (g g^{-1})of mungbean plants



Effect of EDU treatment on yield parameters of mungbean plants

Parameter	Non – EDU	EDU
Seed wt. (g plant^{-1})	3.30	6.26 (47%)
Pod wt. (g plant^{-1})	5.38	6.90 (22%)
No. of seeds (plant^{-1})	85	148 (42%)
No. of pods (plant^{-1})	16	31 (48%)
Yield (g m^{-2})	223.12	432.65 (48%)


15/05/2006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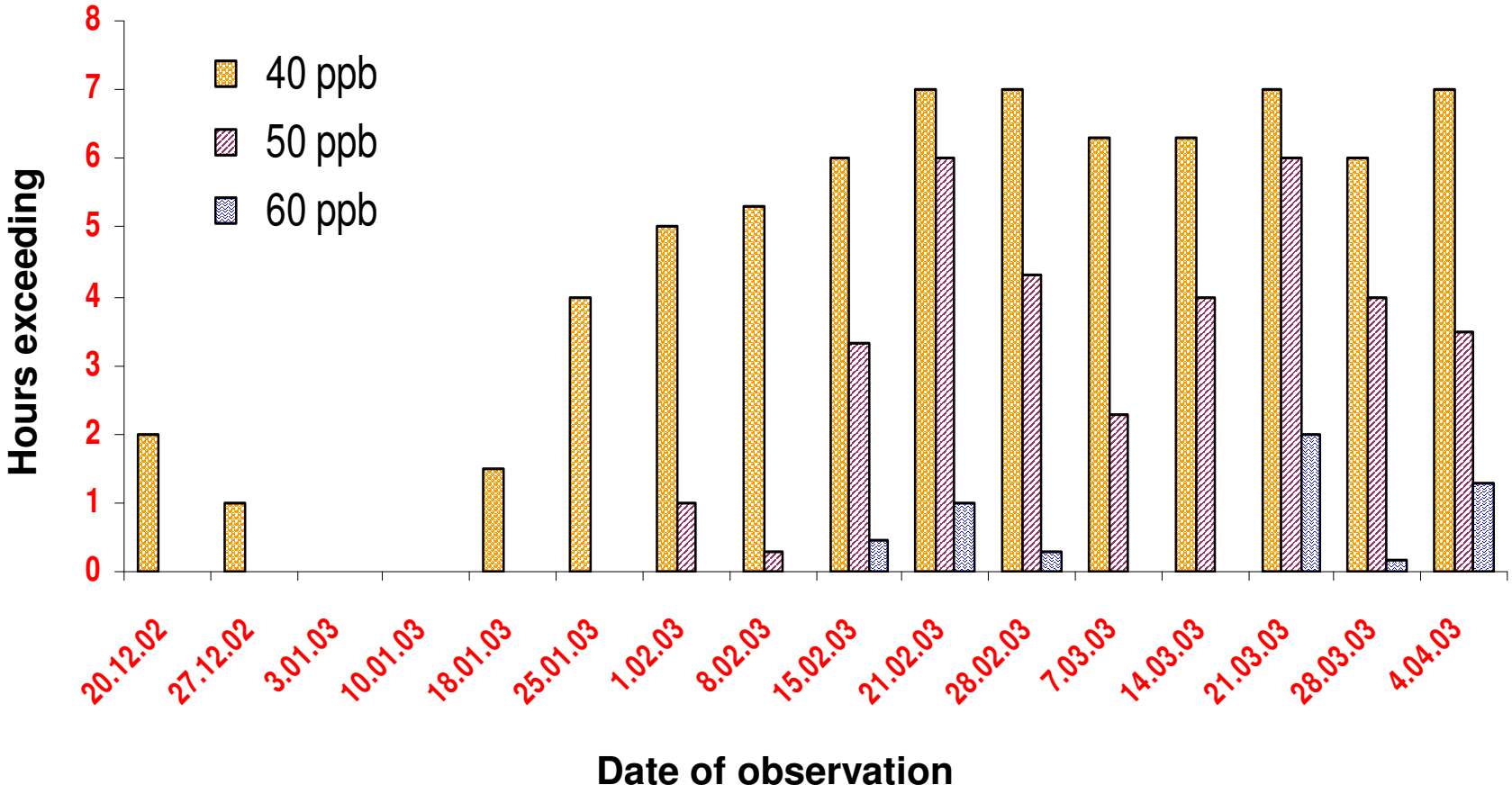
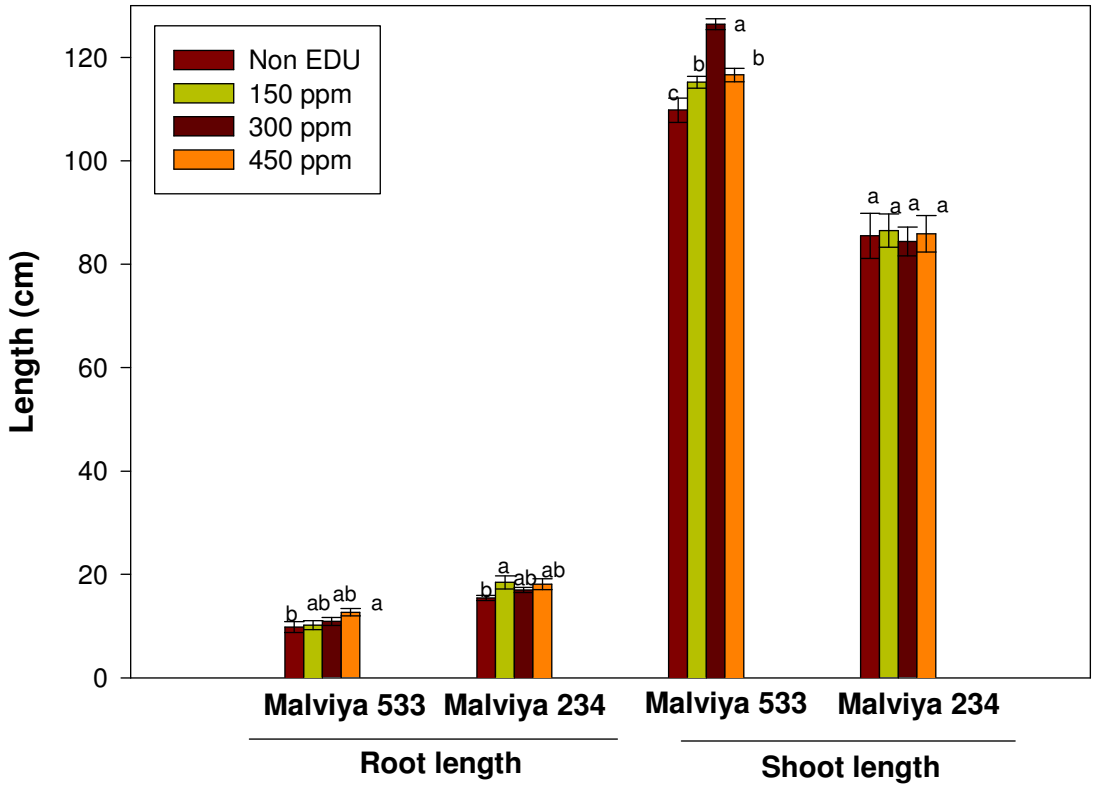
EDU as a tool to assess ozone injury on wheat plants

- **EDU (150, 300 and 450 ppm) at 10 days interval after germination up to 100 days age**
- **Mean ozone concentration 43 ppb**

O_3 CONCENTRATIONS EXCEEDING 40, 50 AND 60 ppb DURING THE EXPERIMENTAL PERIOD



Variations in root and shoot length of two wheat cultivars at different levels of EDU treatments at 60 days age



Selected morphological characteristics of two cultivars of wheat at different EDU treatments at 60 DAG (Mean ±1SE)

Cultivars/ treatment	No of tillers (plant^{-1})	No of leaves (plant^{-1})	No of standing dead (plant^{-1})	Leaf area (cm^2)
		Malviya 533		
Control	9.00 ^{b} ± 0.31	13.40 ^{a} ± 2.50	47.80 ^{a} ± 2.35	44.05 ^{a} ±3.10
EDU 150 ppm	13.6 ^{a} ± 1.40	16.20 ^{a} ± 1.15	42.80 ^{b} ± 3.36	53.77 ^{a} ± 3.99
EDU 300 ppm	10.4 ^{ab} ± 2.31	16.40 ^{a} ± 1.56	35.20 ^{c} ± 5.35	55.78 ^{a} ± 4.04
EDU 450 ppm	14.4 ^{a} ± 0.81	12.20 ^{a} ± 3.91	31.0 ^{c} ± 2.42	54.18 ^{a} ± 2.46
		Malviya 234		
Control	7.20 ^{b} ± 1.06	11.60 ^{a} ± 1.43	37.40 ^{a} ± 7.63	43.24 ^{a} ± 3.10
EDU 150 ppm	12.6 ^{a} ± 1.80	17.00 ^{a} ± 2.75	20.00 ^{c} ± 2.84	46.69 ^{a} ± 0.86
EDU 300 ppm	10.8 ^{ab} ± 1.98	19.00 ^{a} ± 2.36	31.80 ^{b} ± 3.90	47.00 ^{a} ± 2.60
EDU 450 ppm	9.20 ^{ab} ± 1.24	15.40 ^{a} ± 2.40	15.80 ^{c} ± 1.39	42.12 ^{a} ± 1.81

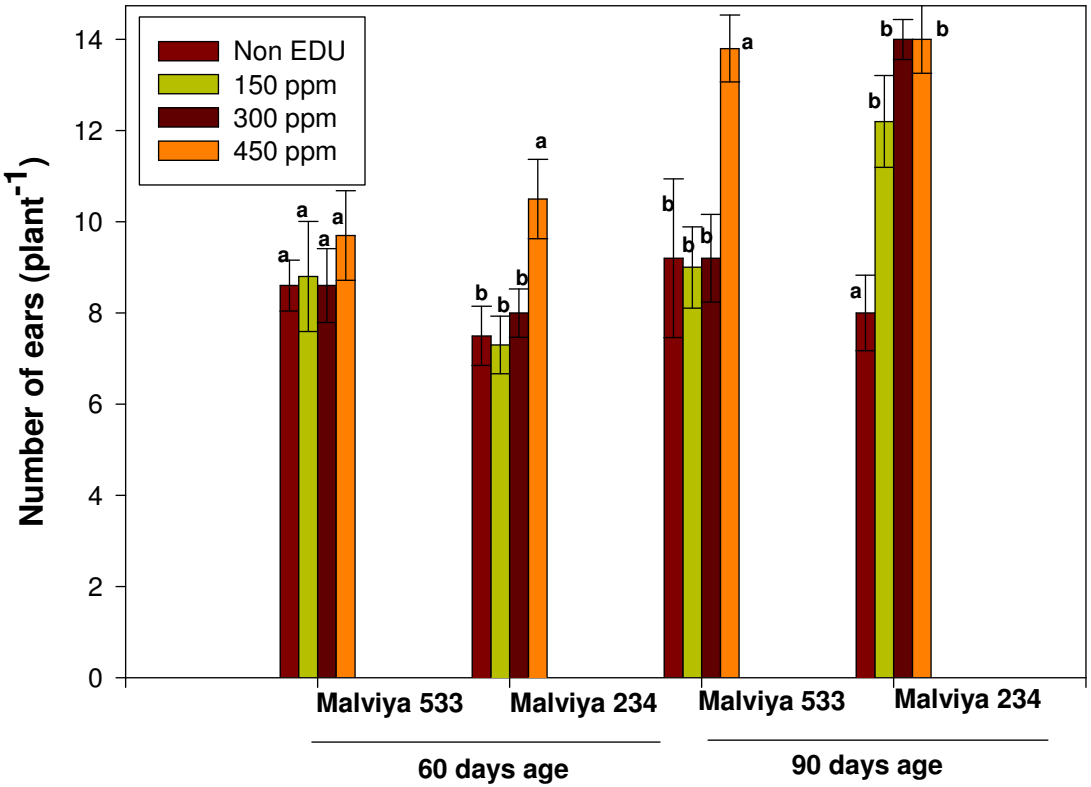
Within each grouping, values not followed by same letter are significantly different at $p < 0.05$

Component wise biomass accumulation (g plant^{-1}) of two wheat cultivars at different EDU treatments at 60 DAG (Mean ± 1SE)

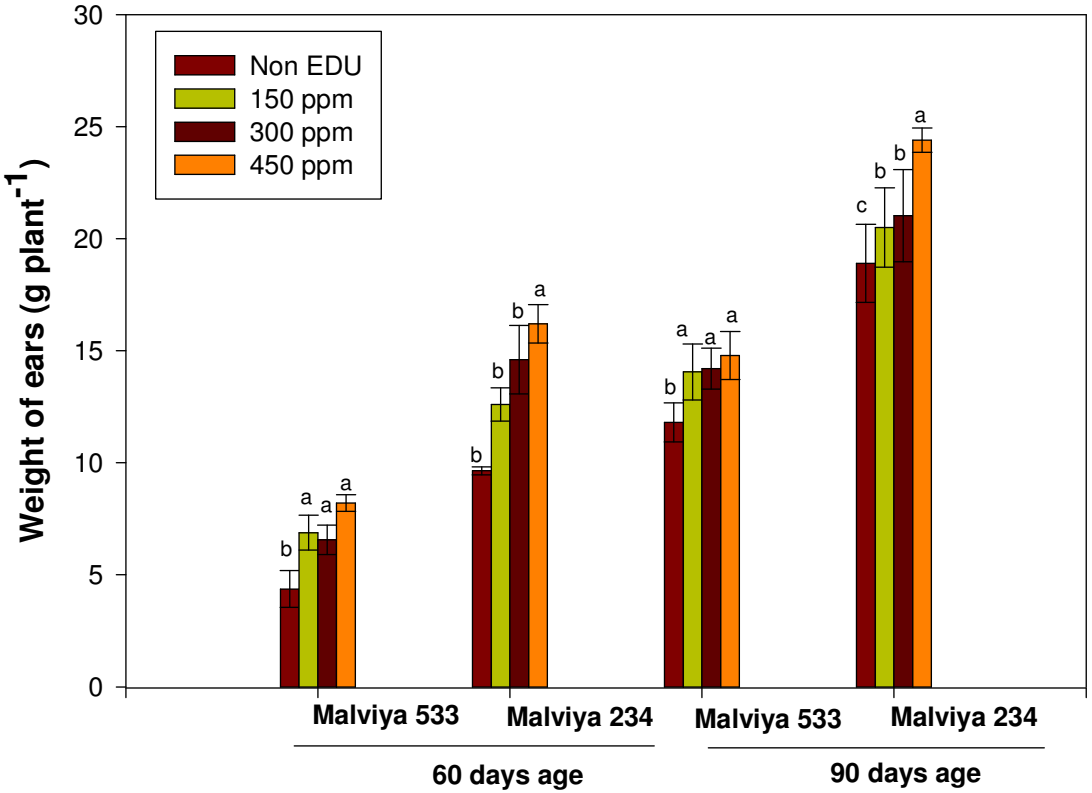
Cultivar / treatment	Root	Shoot	Leaf	Standing dead	Ear	Total
Malviya 533						
Control	5.45 ^{b} ± 0.46	12.05 ^{b} ± 1.78	1.39 ^{b} ± 0.24	3.96 ^{a} ± 2.01	4.37 ^{b} ± 0.82	25.58 ^{a} ± 2.30
EDU 150 ppm	6.31 ^{b} ± 0.72	14.40 ^{ab} ± 0.81	2.19 ^{a} ± 0.35	2.32 ^{a} ± 0.18	6.88 ^{a} ± 0.78	32.12 ^{ab} ± 2.21
EDU 300 ppm	6.71 ^{b} ± 0.59	18.20 ^{a} ± 2.39	2.41 ^{a} ± 0.10	2.04 ^{a} ± 0.30	6.56 ^{a} ± 0.65	35.92 ^{bc} ± 3.64
EDU 450 ppm	8.71 ^{a} ± 0.70	18.99 ^{a} ± 2.15	2.03 ^{a} ± 0.18	3.12 ^{a} ± 0.41	8.20 ^{a} ± 0.37	41.08 ^{c} ± 2.23
Malviya 234						
Control	2.83 ^{b} ± 0.53	9.54 ^{b} ± 0.29	1.46 ^{a} ± 0.07	2.51 ^{a} ± 0.52	9.64 ^{c} ± 0.18	25.10 ^{a} ± 0.82
EDU 150 ppm	5.55 ^{a} ± 0.43	14.40 ^{a} ± 0.97	2.12 ^{a} ± 0.25	2.14 ^{ab} ± 0.13	12.60 ^{b} ± 0.74	37.19 ^{b} ± 1.92
EDU 300 ppm	3.63 ^{b} ± 0.31	14.10 ^{a} ± 1.66	1.83 ^{a} ± 0.24	1.62 ^{a} ± 0.12	14.60^{a} ± 1.53	36.31 ^{b} ± 0.88
EDU 450 ppm	5.35 ^{a} ± 0.56	15.92 ^{a} ± 1.41	1.86 ^{a} ± 0.31	1.46 ^{b} ± 0.11	16.20 ^{a} ± 0.86	40.85 ^{b} ± 2.00

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

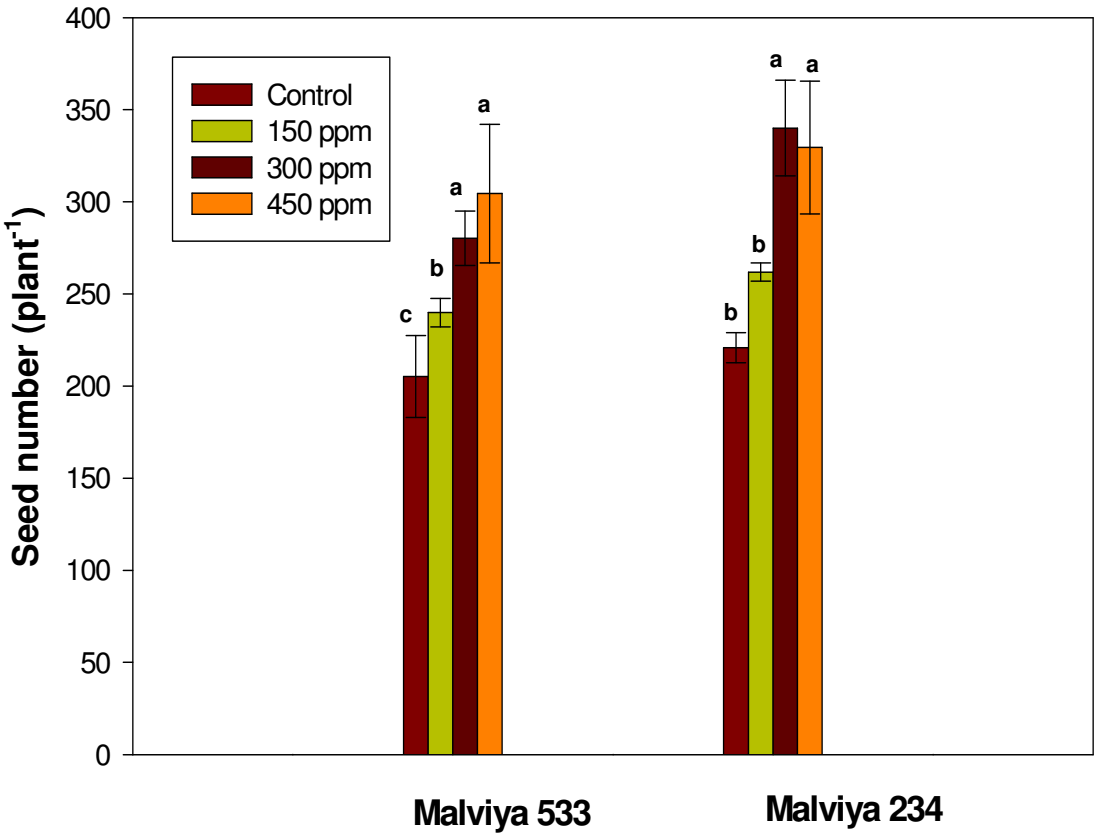
Agewise changes in the ear number of two wheat cultivars at different levels of EDU treatments



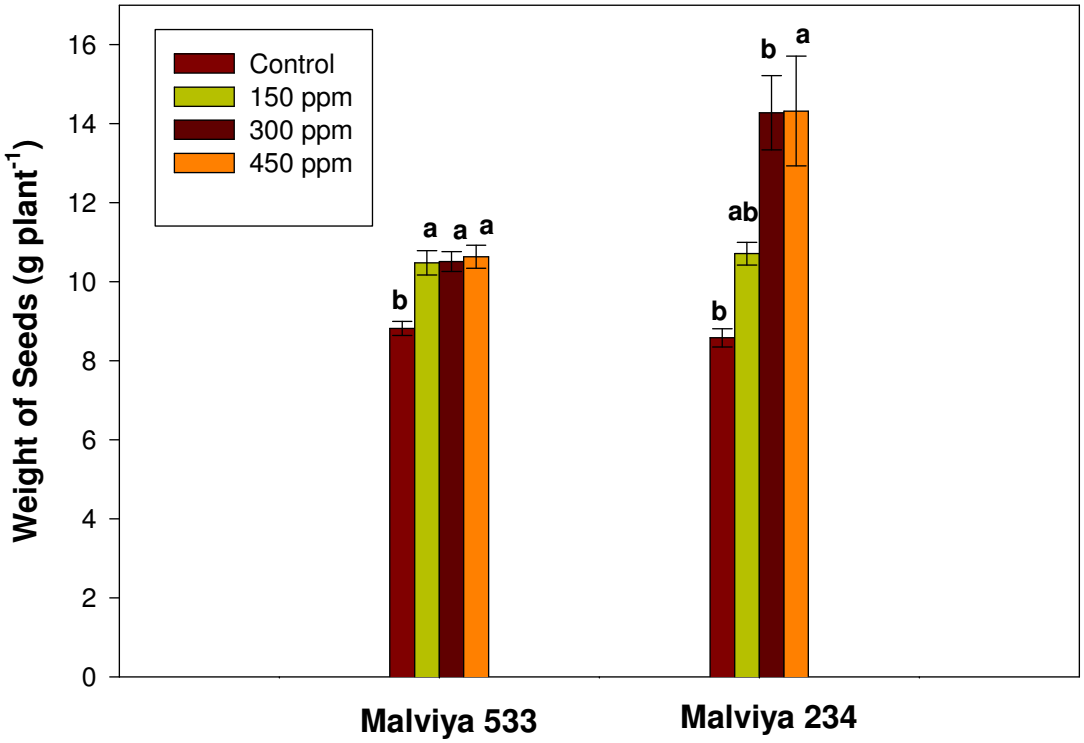
Agewise changes in ear weight of two wheat cultivars at different levels of EDU concentrations



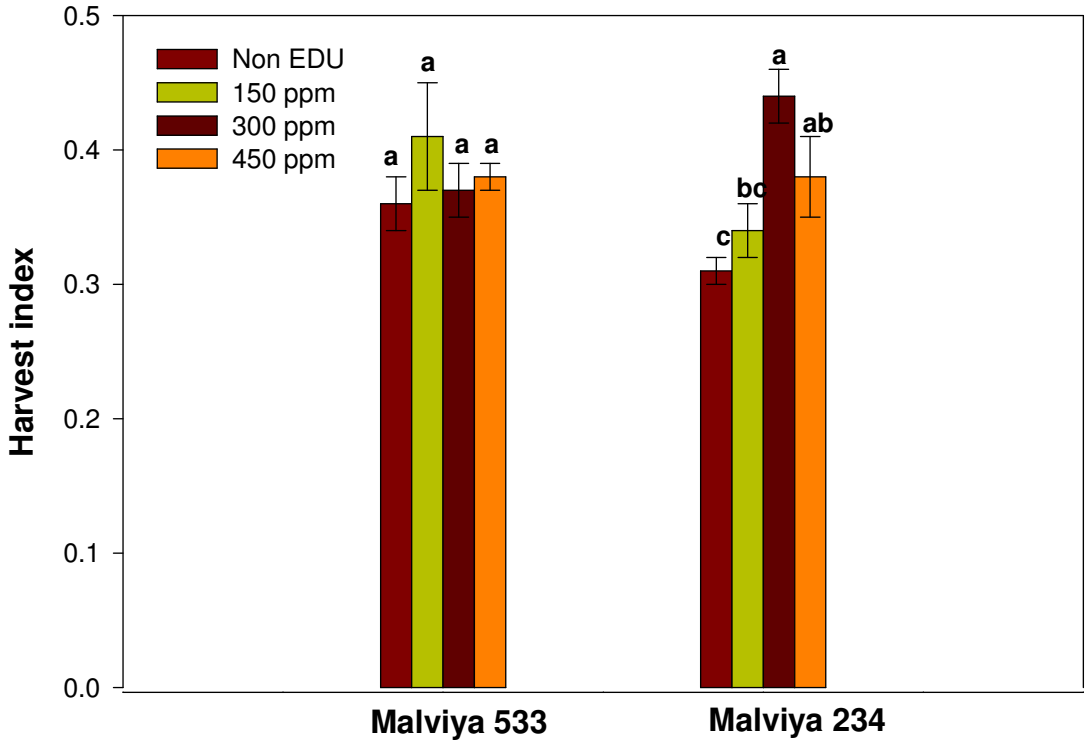
Variations in seed number of two wheat varieties at different EDU concentrations



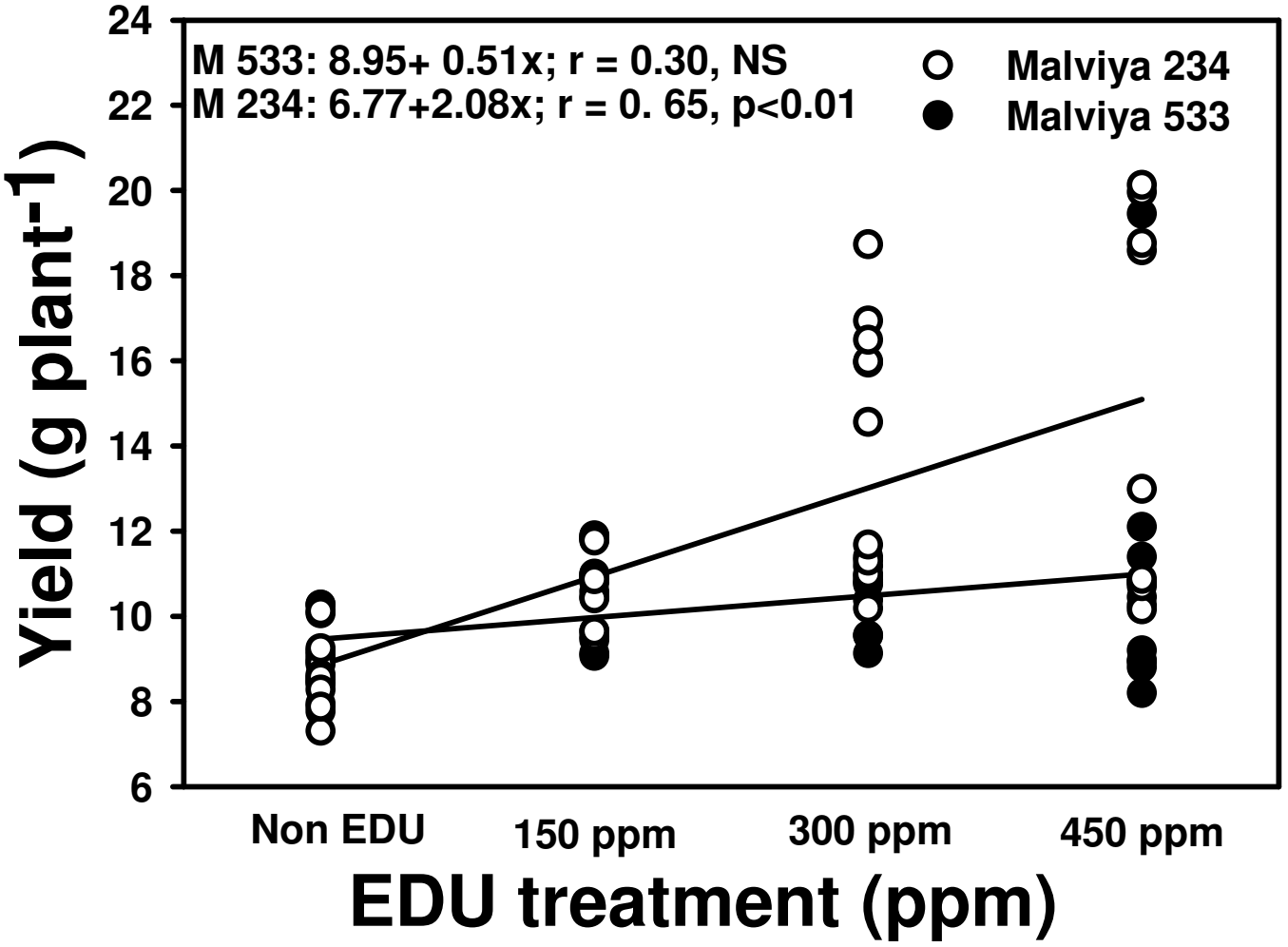
Variations in the seed weight of two wheat varieties at different EDU concentrations



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



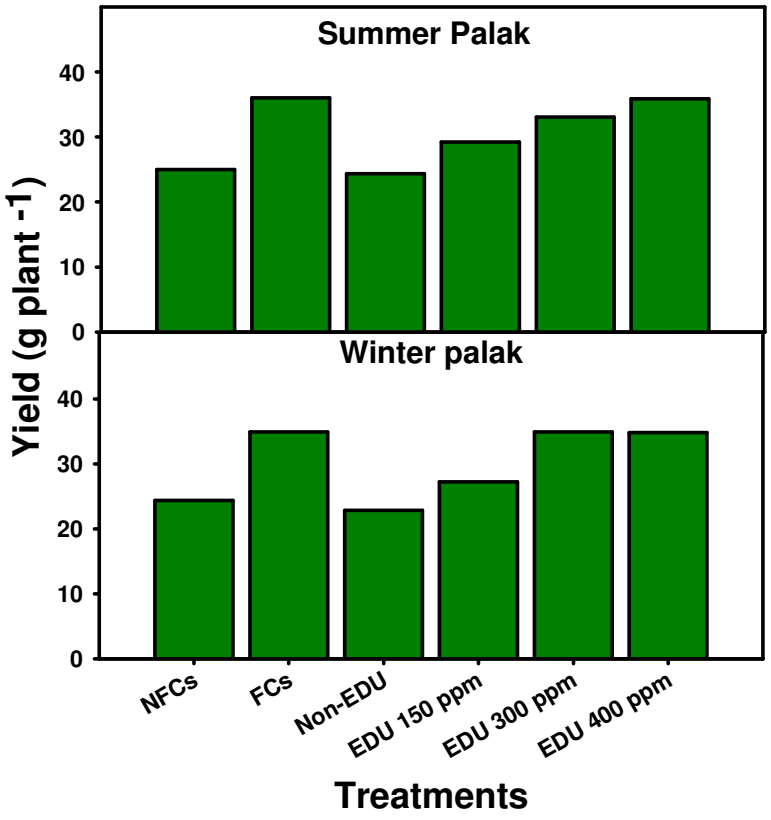
Relationship between concentrations of EDU and yields of wheat cultivars



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

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



Mechanism of action

- **Biochemical or biophysical or both**
- **Detoxification of O_3 in apoplastic region of cells, not working directly as antioxidant**
- **Maintenance of higher levels of cellular antioxidants associated with protection during O_3 stress**

Conclusions

In EDU –treated mung bean plants:

- **Maintained higher levels of pigments, protein and ascorbic acid contents**
- **Reduction in free radical generation and associated enzyme activities**
- **Enhancement in plant height, leaf area, biomass accumulation and yield**

In EDU-treated wheat plants:

- **Effect on plant growth varied with cultivars, growth stage and concentrations of EDU**
- **Increase in root and shoot lengths, number of tillers plant^{-1} and total biomass**
- **Increase in weight of ears plant^{-1} and weight and number of seeds plant^{-1}**
- **No significant variation in harvest index for cv M533 but significant variation in cv M234 more sensitive to ozone**
- **Higher magnitude of protection to yield as compared to growth parameters (high concentration of O_3 during anthesis period)**
- **Higher magnitude of protection to sensitive as against resistant cultivar**

In field studies:

- **Greater protection in the rural areas having higher ozone levels compared to urban areas having relatively lower averages of ozone**
- **Greater protection during summer as compared to winter season**

General Conclusions

- **EDU can be successfully used for assessing O_3 induced changes in plants under ambient field conditions**

- **EDU can be used as a tool in biomonitoring programme to map O_3 injury in plants especially in developing countries (major constraints: continuous electricity and non-availability of monitoring equipments)**


THANKYOU