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EVALUATING THE EFFECTS OF OXIDANTS ON CANOLA GROWTH AND YIELD AT URBAN, RURAL ROADSIDE AND RURAL REMOTE SITES USING ETHYLENEDIUREA IN LAHORE-PAKISTAN

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ABSTRACT

Canola (*Brassica napus*L.) plants were grown using and without using the ozone protectant ethylenediurea at rural, remote rural and urban roadside in and nearby the city of Lahore, Pakistan. The yield and growth of canola was assessed in 2 successive canola growth seasons. NO_2 and photochemical oxidants concentrations were measured at rural, remote rural and urbansites along roadside. Greater increases in yield and its components in both canola cultivars were recorded in EDU-SD treatment plants when compared to their NEDU counterparts. However, the differences between EDU-SD and EDU-FS treatments were much small compared with those between EDU-SD and NEDU. The effect on yield of EDU-SD at the urban site (BG) (64% & 48% increase in per plant seed weight for cv. Dunkeld and Cyclon respectively for the second growth season relative to the untreated plants (NEDU).

Keywords: Canola; Growth; Ozone; Yield; Lahore; Pakistan.

INTRODUCTION

Significant increase in atmospheric air pollutant concentrationsin the developing countries during last few decades is basically due to increase in amount of industries and urban population. (UNEP, 2012). In Pakistan,immense increase in urban air pollution problems is due to excess use of fuels with bad show towards environment, poor road maintenance, increased number of motors and unproductive rules and regulations for environment.Urban originated air pollutants gradually cause problems to agricultural lands in line to urban areas.Crop production is badly affected due to phytotoxic gases which cause high effect on periurban and urban farmers and consumer's livings and well beings (TeLintelo *et al.,* 2002). Raised concentrations of tropospheric urban O_3 and peri-urban locations of main cites in developing countries, like India (Agrawal *et al.,* 2005), Pakistan (Wahid *et al.,*2001 and Ahmed, 2005) and Indonesia (Pardede, 1991) has been reported.

Ozone (O_3) is a major component of the photochemical oxidants and is known to be a phytotoxic air pollutant in the troposphere, which covers high concentrations in climatic ambient air pollution in peri-urban, urban and industrialized areas around the world. Its behaviour as a major air pollutant in urban peripheral and rural areas of many parts of the world proposes that concentrations of ambient ozone could be increased in rural areas outside the major cities like Lahore (Pakistan). Ozone concentration is setup high in rural areas around the Lahore, and their effects found on major agricultural crops like; rice, wheat, barley, maize, mungbean, soybean and some vegetable in the OTCs, were mainly due to ozone concentration, then this would point out the significant yield loss possible overwidespread agricultural related areas in Pakistan. On the further side, in the open-top chamber experiments effects found due to the specific mixture of different pollutants at that site, and yield losses not indicated over wider pastoral areas, subsequently the effects might be observed as a more inadequatereason for concern. Hypothesis was to test for reduction in yield at different rural sites in Lahore metropolitan city area.Two locally grown canola cultivars were selected to test the sensitivity against ozone in canola(*Brassica napus*L.).

MATERIALS AND METHODS

Laboratory experiment: To evaluate the effect of Ethylenediurea (EDU) concentration, simple method was carried out to give shield for two cultivars of canola against ozone, Cyclon and Dunkeld; both of these cultivars are used currently in different areas of Pakistan. Pots containing 500g of wet type of compost (John Innes No.2) were selected for sowing of seeds.Three different concentrations of EDU solution (l00, 200 and 400 ppm) were selected to apply on canola plants in the form of soil drench (75 ml per pot), eleven days after germination. The important chemical EDU was supplied by the courtesy of Prof. Dr. William J. Manning, Department of Plant, Soil and Insect, University of Massachusetts, USA. To check different EDU treatments, 32 plants were sown in separate pots used; 16 for two different cultivars.

According to Maggs (1996), plants were transferred to per-spex fumigation system consisting of eight chambers, four chambers in two parallel rows. Four different rates of EDU application on two cultivars at each of the eight chambers. Each chamber was fully randomised with 16 plants.Throughout the experiment, all plants of canola were required to be givenwater every 2-3 days. After acclimation period of three days, 100 ppb O_3 fumigation was done in half of the chambers, the air filtered by charcoal was received in other chambers. Plants were fumigated for five days at eight hours per day, after that EDU was reapplied withsecond EDU application after two days; the fumigation recommenced for a further three days. After each fumigation session end, visible injury was assessed on canola plants. Two main symptoms were shown as visible ozone injury;bronzing and mottling.

Field experiments

Two successive canola growth seasons: According to the laboratory experiment, effect of ambient ozone pollution inthe field were designed on two cultivars of canola (Cyclon and Dunkeld) at locations of three different sites. The first (urban) site was the Botanic Garden (BG) located at GC University Lahore, which is in the city centre. The second site, Rakh Dera Chahl (RDC), east of Lahore at 35 km, is a rural location. The third site, Kala Shah Kaku (KSK), 35 km north of Lahore is rural area but close to an industrial zone. Seeds of Cyclon and Dunkeld cultivars of canola were sown on 2nd October, for first canola growth season, in earthen pots (approx. diameter 30 cm) each containing 10 kg substrate which included a mixture of 1 part cow dung, 1 part humus, 2 parts canal silt and 3 parts local soil to act in accordance with local agricultural practices. Botanic Garden site was selected for all seeds sowing. Seedlings emerged on 8th October and were thinned to 2 per pot on 12th October. On 16th October, plants were distributed to the three experimental sites; 90 pots per cultivar with three treatments viz., NEDU (non EDU or control), EDU-SD (EDU applied as soil drench), EDU-FS (EDU applied as foliar spray). Each treatment was replicated 30 times with 2 plants per replicate pot. Hence in each experiment, there were 180 plants per cultivar. So in each experiment, during the course of investigation with two cultivars of canola, there were 180 pots (90+90) having 360 plants. All the pots were arranged following randomized complete block design (RCBD) in order to provide similar environmental conditions. During whole experiment no fertilizers were applied.

Application of EDU on canola plants began on 25th October, and was repeated at interval of 10-days, so that a total of 10 applications were made with EDU, which stopped at the time of wet silique. At a concentration of 400 ppm EDU eachcanola plant, 1500 ml of EDU solution were received. Similarly to laboratory experiment, the different application rate of 150 ml of 400 ppm EDU solution/kg of soil substrate. Warm tap water was used to prepare the solutions due to the lack of availability of distilled water. Canola plants with N-EDU received tap water(1500 ml) each time ethylenediurea was applied. Application of EDU on canola plants was as a foliar as well as a soil drench on leaves.

Ambient climate measurements were taken at all the three experimental sites in order to interpret their effect on the data obtained for growth and yield of canola crop. Air temperature, relative humidity and light intensity were continuously monitored on daily basis at 08:00, 12:00 and 16:00 hours throughout the experiments at all the three sites using a portable light meter (Horticultural Lux Meter, Ogawa Seiki Co., Tokyo, Japan, Model OSK-2711) and temperature humidity probe (Thermohygrometer, Hanna Instruments, USA, Model HI-8564) respectively. At three different experimental sites nitrogen dioxide and total oxidant concentrations were measured by Salzman and Gilbert (1959) and Atkins *et al.*(1979) respectively.

During the experimental period, plant leaf numbers, stem height, number of branches and stem diameter were measured on weekly basis, with the first measurement taken on 25th October. Experimentended on 12th March and plants were harvested for analysis. Different measurements were taken at harvest; number of silique per plant, total seeds number per plant, seeds weight per plant and thousand seed weight. The second field experiment was carried out at next successive canola growth season using the same cultivation methods as for the first canola growth season experiment.

RESULTS

Laboratory experiment: Ozone injuries were mainly measured in term of symptoms like bronzing and mottling. These symptomsdid notappear in the filtered air chamberscanola plants. In two cultivars there was no significant difference in injury levels, so from average treatments results were combined (Table 1). By applying 400 ppm EDU treatment to canola plants showed no visible injury from 100 ppb fumigation with ozone(Table 1). No symptoms of visible injury (data not shown) after application of 400 ppm concentration of EDU to plants grown in filtered air. It was therefore obvious that EDU 400 ppm concentration used as a soil drench as well as foliar spray at 10-day intervals would besuitableapplication for the field experiments.

Field experiments: Two successive canola growth seasons:

Ambient Climate and Pollutant concentrations: Once-a-month means of ambient temperature, relative humidity and light intensityfrom October to March for both the canola seasons are summarized in Fig 1. It is worth noting that December, January and February are the coldest and most humid months with low light intensity during both the canola growing seasons, followed by bright sunny and warmish weather in March. It is clear that the prevailing climatic conditions from season to season within the canola experiments were found to be very similar over the months of October to March. Seasonal mean temperatures were 20.5°C and 20.3°C for the first and second season respectively. Light levels were found to be higher in the second season, with a seasonal mean of 34.1 Kilolux as compared to a seasonal mean of 30.4 Kilolux in the first season. Overall seasonal means for relative humidity over the two seasons were more or less similar.

Thepollutants data after monitoringtwo field experiments were shown in Table 2. The mean oxidant concentration (09:00- 17:00) in the first canola growth season, was 61 ppb at the urban site (BG), but the values were higher at the two different rural sites: 74 ppb at remote rural site (RDC) & 69 ppb at rural roadside site (KSK). The mean concentrations of oxidant in the second growth season (65 ppb at BG, 81 ppb at RDC, and 74 ppb at KSK) were all much higher. As in the first growth season experiment, at the urban site (BG), concentrations of oxidant were clearly lowest, but, a difference between the two rural sites was also observed.

A different pattern mean nitrogen dioxide concentrations was found which was consistently higher at the urban site (BG) as compared to the rural site, where low values were found. While, at the rural roadside site (KSK), nitrogen dioxide concentration was the highest in both season experiments as compared to remote rural site (RDC) but much lesser than urban site. During first growth experiment, monthly mean NO_2 concentrations of 49 ppb, 40 ppb, and 3 ppb in October gradually rose to 63 ppb, 55 ppb, and 6 ppb in February while in second growth experiment it increased from 49 ppb, 42 ppb, and 3 ppb in October to 64 ppb, 56 ppb and 7 ppb in February followed by slight reductions in the month of March at BG, KSK and RDC sites respectively. It may be pointed out that monthly mean NO_2 concentrations for different months of second experiment were slightly higher than for the corresponding months of first experiment.

Effects on canola plant growth and development: In the second canola growth season experiment atall three sites, the leaf production rate was faster in the EDU (EDU-SD & EDU-FS) treated plants as compared to NEDU plants, clearly demonstrating an effect caused by oxidants. Significantly different leaf numbers between the three treatments at all the dates of measurementfrom 25th and 28th October in both seasons respectively, onwards in two canola cultivars, at all experimental sites. During the first week of January at the second growth season, when silique was set, the EDU-SD treated plants had shown 50% more leaf production over NEDU plants (16% & 18% at BG; 24% & 25% at RDC; and 33% & 36% at KSK for cv. Cyclon and Dunkeld respectively) in both the canola cultivars at all three experimental sites than first growth experiment. However, this parameter was also showed similar pattern in EDU-SD vs. EDU-FS treated plants in both seasons at all sites but the increased % age magnitude was very low ranged from 2-5% in both the cultivars (Table 3).

These differences in treatment of development in leaf were also reflected in the maximum final plant height and leaf number achieved at each site. The data were summarised in Table 3, shown on number of branches per plant formed at each site. The data may also be expressed as increase in plant height in EDU-SD as % relative of NEDU. It may be pointed out that plant height for different months of first growth season were slightly higher than for the corresponding months of second growth season. However, generally plant height was greatlylesser in NEDU, & effects of EDU treated plants (EDU-SD & EDU-FS) were somewhat more or less similar during both the canola growth seasons (EDU-SD as compared to NEDU approximately 37%, 47% and 57% for cv. Cyclon, and 33%, 47% and 60% for cv. Dunkeld at BG, RDC and KSK, respectively). The magnitude of increase in the final number of branches per plant in EDU-SD compared to NEDU during both the seasons was similar at all sites (48% & 48% at BG, 51% & 52% at RDC, 57% & 58% at KSK for cv. Cyclon and 51% & 52.1% at BG, 55.4% & 56.1% at RDC, 60.5% & 62.5% at KSK for cv. Dunkeld), while it was comparatively higher in Dunkeld cultivar.

Rate of senescence of leaves per plant in both canola cultivars over the two seasons followed an almost similar pattern. In both the cultivars, rate of senescence in EDU-SD treatment plants remained significantly lower than NEDU during the active phase of vegetative growth (i.e., November – January) over both the seasons (Fig. 2). Thus more leaves on plants remained lush green for a relatively longer period of time in EDU-SD plants as compared to NEDU. Hence in EDU-SD treatment, overall photosynthetic ability of plants did not decline as rapidly during the active vegetative growth phase as in the NEDU, resulting in their healthier and more luxurious growth. However, the difference is clear between the different sites in the effects of EDU which were not obvious in the leaf senescencecase but found obvious for leaf numbers. The senescent leaves number reduction in theplants treated with EDU in the first growth trial was less noticeable as compared to the second experiment.In all the vegetative parameters; like plant height, leaf and branch number, stem diameter and senescent leaf per plant in EDU-SD treated plant was slightly higher than EDU-FS in both cultivars throughout the course of growth during both seasons at all three experimental sites and these differences ranged from 2-8% as shown in Table 3.

Effects on yield: Seed weights per plant at the three different sites during two field experiments are shown in Table 4. In the EDU treatment there were increased seed weights per plant largely, as compared to NEDU treatment, at all three different sites. The difference is significant between the three different sites by the effects of EDU, and of oxidants. The seed weight per plant magnitude increase in EDU-SD in cv. Dunkeld during both the seasons (67.4% & 63.9% at BG, 76.9% & 71.1% at RDC, 85.6% & 85.0% at KSK respectively for first and second growth seasons) was markedly higher than the corresponding increases in cv. Cyclon (56.2% & 48.4% at BG, 68.7% & 63.8% at RDC, 82.5% & 79.3% at KSK respectively for first and second growth seasons) at three experimental sites.

Itis clear from Table 4 that the effects of less numbers were primarily of silique produced, somewhatlesser in numbers of seeds per silique or 1000 seed weight. As compared to the NEDU plants, the highersilique number was observed onEDU-SD treated plants, maybe due to the fact that smaller amount of flowers were produced in NEDU, while in the onset or duration of silique set between different EDU applicationsas there was no deceptive difference. The effects of EDU-SD on silique number per plant were35 & 38%; 44 & 46% and 52 & 55% for BG, RDC & KSK for cv. Cyclon and Dunkeld, respectively (Table 4). Total seed weight per plant of EDU-SD were increased at all sites during both seasons in Dunkeld cultivar (67.4% & 63.9% at BG, 76.9% & 71.1% at RDC, 85.6% & 85.0% at KSK respectively) and was also markedly higher than the corresponding increase in Cyclon (56.2% & 48.4% at BG, 68.7% & 63.8% at RDC, 82.5% & 79.3% at KSK respectively) at three experimental sites.The effects of EDU-SD on the components of yield on two canola cultivars during both growth seasons at three sites were primarily due to the silique number reduced, somewhat to reductions in numbers of seeds per silique or 1000 seed weight (Table 4). The application of EDU was found to increase the yield in both cultivars of canola in the two successive growth seasons studied at three experimental sites. However, the differences between EDU-SD and EDU-FS treatments were much small compared with those between EDU-SD and NEDU.

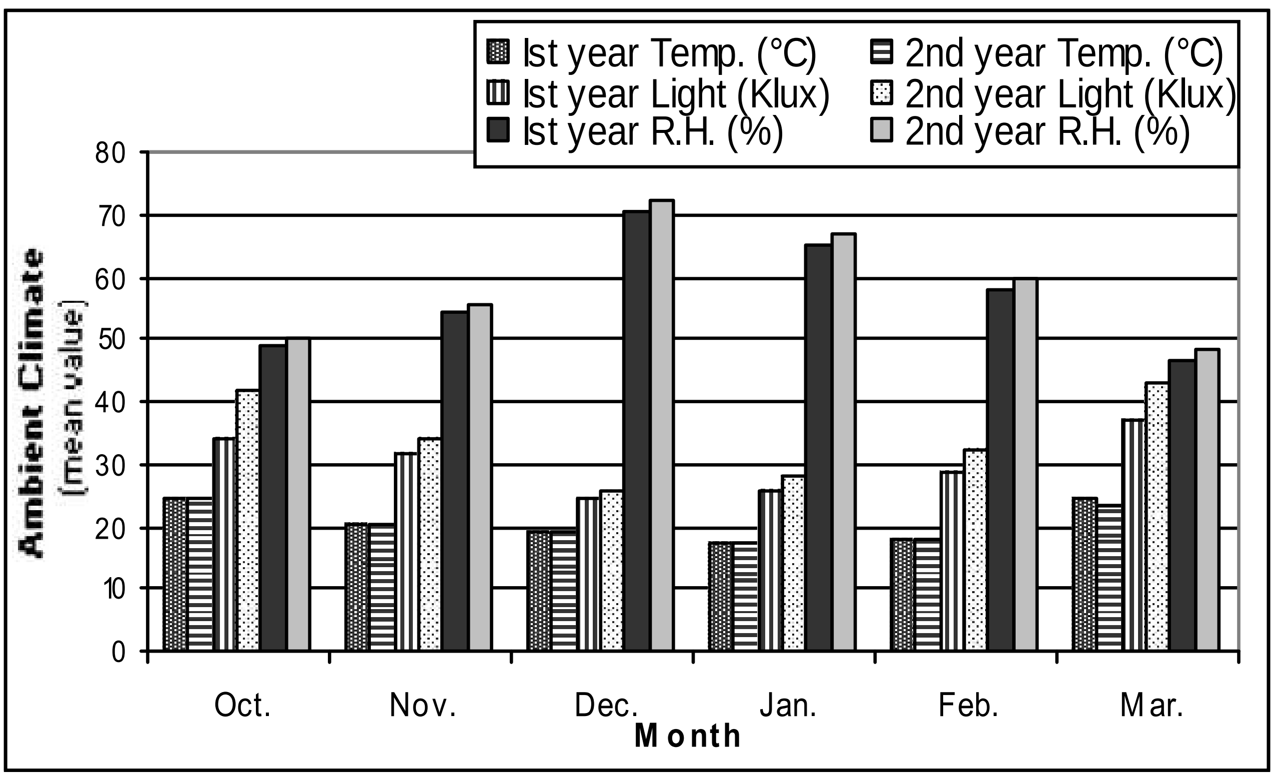
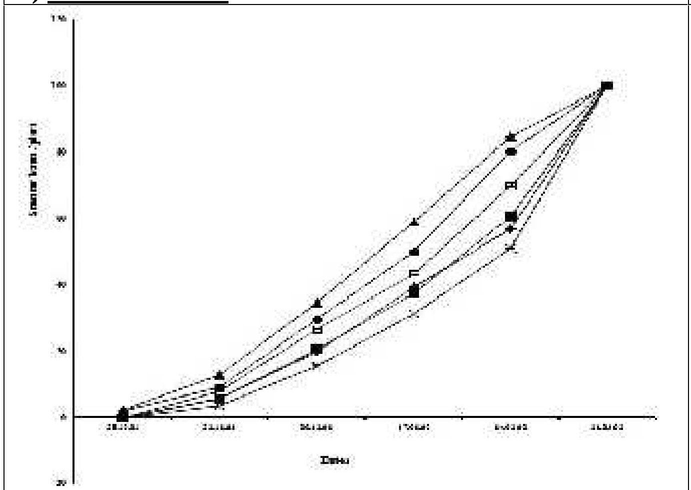
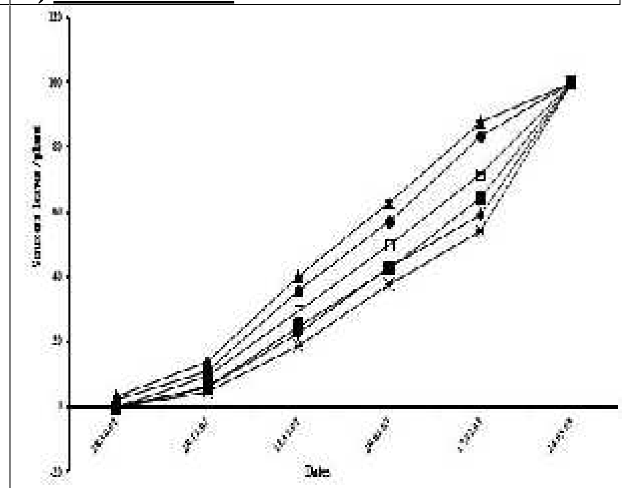


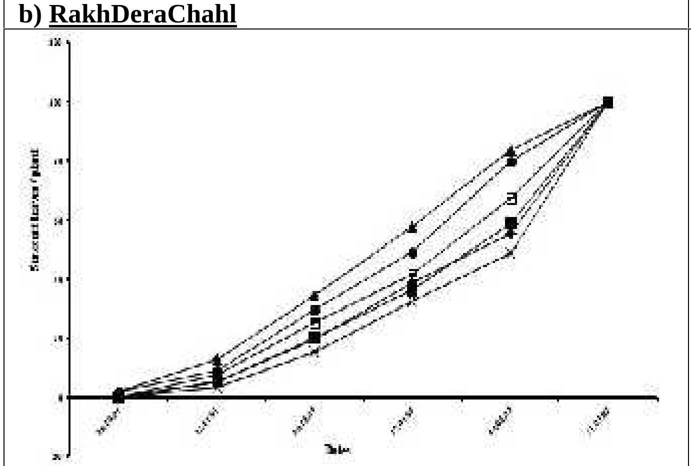
Fig: 1. Ambient Climate: monthly mean for temperature, light intensity and relative humidity during two successive canola growth seasons.

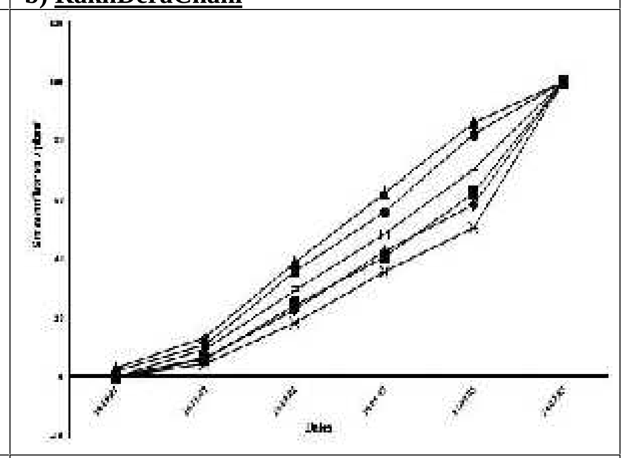
Growth Season 2001-02	**Growth Season 2002-03**
a) **Botanic Garden**	a) **Botanic Garden**



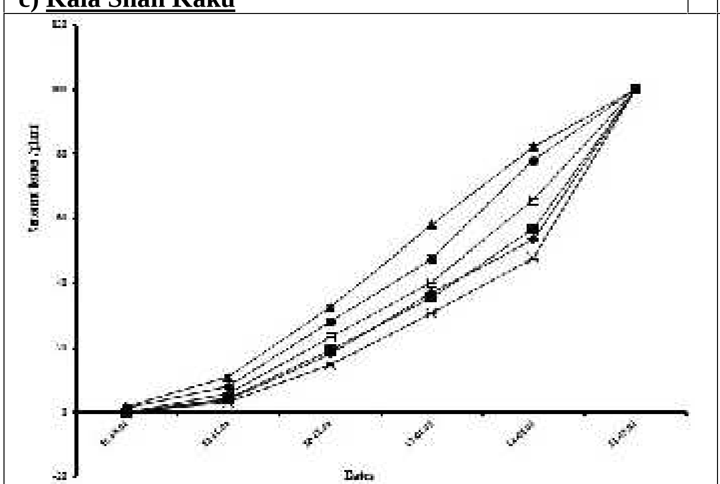


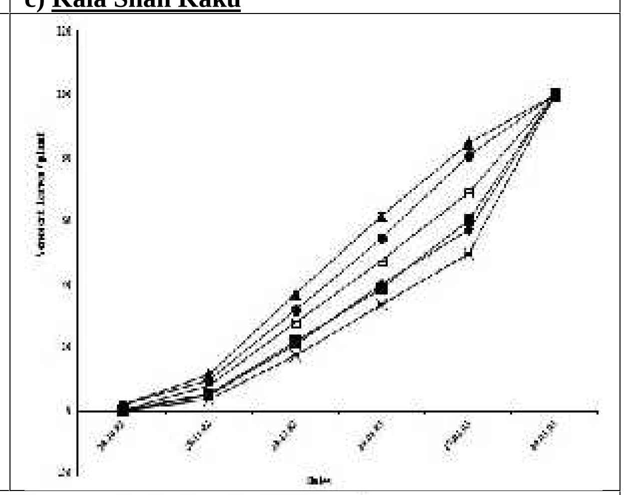
b) **RakhDeraChahl**	b) **RakhDeraChahl**





c) **Kala Shah Kaku**	c) **Kala Shah Kaku**





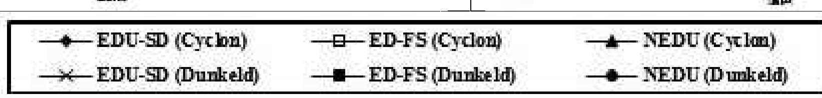


Fig. 2. Impact of ambient air pollution on number of senescent leaves per plant of two canola cultivars (Cyclon&Dunkeld during two successive growth seasons at three experimental sites with the passage of time

Table 1. Five days fumigation studies of two canola cultivars with 100ppb ozone for mottling and bronzing.

EDUConcentration(ppm)	Avg. score for mottling (F= 16.9, P< 0.001)	Avg. score for bronzing(F= 25.8, P<0.001)
0	4.2	3.1
100	2.5	1.5*
200	1.3*	0.6**
400	0**	0**

* Difference from the non-EDU (0 ppm) is significant a t< 0.05 level

** Difference from the non-EDU (0 ppm) is significant a t< 0.001 level

Table 2. Mean values of oxidant and nitrogen dioxide concentrations (ppb) during the two successive canola experiments [a]

Site	Growth season 2001-02		Growth season 2002-03	
	Oxidant	Nitrogen dioxide	Oxidant	Nitrogen dioxide
Urban [Botanic Garden (BG)]	61.2	26.1	65.3	27.8
Rural remote [RakhDeraChahl (RDC)]	74.1	4.1	86.6	4.3
Rural roadside [Kala Shah Kaku (KSK)]	66.8	46.8	73.5	47.8

[a] Measurements took place from 16 October, 2001–12 March, 2002 and 20 October, 2002–18 March 2003 for the two successive experiments, respectively.

Table 3. Effect of EDU on vegetative growth of canola cultivars during two successive growth seasons

Parameters	Treatments	Canola season 2001-02			Canola season 2002-03		
		Sites			Sites		
		Urban (BG)	Rural remote (RDC)	Rural roadside (KSK)	Urban (BG)	Rural remote (RDC)	Rural roadside (KSK)
cv. Cyclon							
Total leaf number	EDU-SD	17.85a ±0.09	18.19a ±0.14	18.82a ±0.12	16.05a ±0.11	16.91a ±0.15	17.25a ±0.17
	EDU-FS	17.21b ±0.10	17.73b ±0.09	18.13b ±0.21	15.39b ±0.07	16.02b ±0.29	16.47b ±0.20
	NEDU	16.69c ±0.07	16.48c ±0.51	16.01c ±0.83	15.03c ±0.20	14.87c ±0.41	14.68c ±0.16
Total plant height (cm)	EDU-SD	107.12a ±1.05	112.29a ±1.08	116.11a ±1.10	104.29a ±1.2	108.75a ±2.7	112.64a ±2.4
	EDU-FS	101.81b ±1.95	106.75b ±1.89	110.62b ±1.07	98.81b ±1.1	102.21b ±1.51	106.16b ±1.56
	NEDU	78.37c ±1.06	76.47c ±1.57	73.95c ±1.59	77.25c ±1.99	75.98c ±2.05	73.51c ±2.14
Stem diameter	EDU-SD	1.10a ±0.04	1.15a ±0.01	1.19a ±0.03	1.07a ±0.02	1.12a ±0.02	1.16a ±0.01
	EDU-FS	1.04b ±0.01	1.09b ±0.03	1.13b ±0.02	1.02b ±0.01	1.06b ±0.03	1.10b ±0.04
	NEDU	0.95c ±0.04	0.84c ±0.11	0.81c ±0.05	0.91c ±0.07	0.82c ±0.08	0.79c ±0.07
Total branches	EDU-SD	6.65a ±0.03	6.73a ±0.05	6.87a ±0.04	6.56a ±0.02	6.68a ±0.04	6.79a ±0.03
	EDU-FS	6.51b ±0.07	6.64b ±0.02	6.79b ±0.02	6.47b ±0.04	6.54b ±0.03	6.70b ±0.01
	NEDU	4.51c ±0.85	4.46c ±0.91	4.37c ±0.55	4.43c ±0.51	4.38c ±0.76	4.28c ±0.51
cv. Dunkeld							
Total leaf number	EDU-SD	19.76a ±0.17	20.27a ±0.13	20.72a ±0.17	18.91a ±0.15	19.12a ±0.07	19.93a ±0.11
	EDU-FS	19.01b ±0.12	19.32b ±0.21	19.68b ±0.13	18.12b ±0.09	18.49b ±0.20	18.97b ±0.25
	NEDU	18.62c ±0.11	18.29c ±0.59	17.93c ±0.81	17.86c ±0.11	17.78c ±0.17	17.49c ±0.19
Total plant height (cm)	EDU-SD	91.92a ±1.99	98.34a ±2.9	105.10a ±1.20	89.71a ±1.31	95.89a ±2.83	100.81a ±2.6
	EDU-FS	83.01b ±1.30	90.62b ±1.21	102.25b ±0.99	80.89b ±2.10	89.15b ±1.69	96.96b ±1.0
	NEDU	69.24c ±1.63	67.11c ±1.9	65.74c ±1.76	68.79c ±1.31	66.81c ±1.71	63.68c ±1.69
Stem diameter	EDU-SD	1.28a ±0.01	1.34a ±0.03	1.41a ±0.03	1.27a ±0.01	1.32a ±0.01	1.38a ±0.02
	EDU-FS	1.21b ±0.03	1.29b ±0.01	1.34b ±0.02	1.15b ±0.04	1.27b ±0.02	1.30b ±0.03
	NEDU	1.05c ±0.05	1.02c ±0.10	1.00c ±0.09	1.04c ±0.03	1.01c ±0.06	0.99c ±0.07
Total branches	EDU-SD	7.51a ±0.05	7.60a ±0.02	7.67a ±0.06	7.44a ±0.07	7.51a ±0.01	7.59a ±0.05
	EDU-FS	7.34b ±0.12	7.46b ±0.07	7.56b ±0.03	7.25b ±0.05	7.38b ±0.08	7.46b ±0.03
	NEDU	4.97c ±0.49	4.89c ±0.89	4.78c ±0.71	4.89c ±0.75	4.81c ±0.86	4.67c ±0.67

Treatment means of a cultivar followed by different letters in the same column differ significantly at P= 0.05 according to Duncan's multiple range test; ± Standard error of mean; EDU-SD: EDU applied as soil drench; EDU-FS: EDU applied as foliar spray; NEDU: Non EDU

Table: 4. Effect of oxidants on yield and yield components of canola cultivars at final destructive harvest (23-weeks-old) during two successive canola growth seasons at three experimental sites

Parameters	sites	Growth season 2001-02								Growth season 2002-03							
		Cyclon				Dunkeld				Cyclon				Dunkeld			
		EDU-SD	EDU-FS	NEDU	L.S.D	EDU-SD	EDU-FS	NEDU	LS.D	EDU-SD	EDU-FS	NEDU	L.S.D	EDU-SD	EDU-FS	NEDU	L.S.D
Average number of silique per plant	BG	381^{a}	366^{b}	282^{c}	5.0	486^{a}	474^{b}	351^{c}	4.0	369^{a}	354^{b}	276^{c}	6.0	465^{a}	453^{b}	339^{c}	5.0
	RDC	393^{a}	375^{b}	273^{c}	7.0	501^{a}	489^{b}	342^{c}	5.0	381^{a}	363^{b}	267^{c}	8.0	477^{a}	462^{b}	327^{c}	6.0
	KSK	399^{a}	381^{b}	367^{c}	6.0	510^{a}	498^{b}	336^{c}	3.0	390^{a}	372^{b}	261^{c}	7.0	486^{a}	477^{b}	321^{c}	4.0
Average number of seeds per silique	BG	25.08^{a}	22.79^{b}	14.80^{c}	1.03	28.13^{a}	25.69^{b}	15.92^{c}	1.10	24.98^{a}	22.61^{b}	14.72^{c}	1.04	27.91^{a}	25.47^{b}	15.71^{c}	1.12
	RDC	26.19^{a}	23.85^{b}	14.20^{c}	1.12	28.89^{a}	26.10^{b}	15.21^{c}	0.84	26.37^{a}	22.99^{b}	14.11^{c}	0.99	28.72^{a}	25.95^{b}	15.09^{c}	1.09
	KSK	26.39^{a}	24.01^{b}	13.99^{c}	1.01	29.01^{a}	26.47^{b}	14.96^{c}	1.00	26.17^{a}	23.92^{b}	13.91^{c}	1.01	28.95^{a}	26.39^{b}	14.93^{c}	0.97
Seed wt. per plant (g)	BG	18.76^{a}	16.24^{b}	12.01^{c}	1.04	33.26^{a}	30.97^{b}	19.87^{c}	0.34	17.52^{a}	15.01^{b}	11.81^{c}	0.13	32.19^{a}	30.24^{b}	19.63^{c}	0.21
	RDC	20.01^{a}	17.95^{b}	11.86^{c}	1.02	34.84^{a}	32.15^{b}	19.69^{c}	0.27	18.89^{a}	16.32^{b}	11.53^{c}	1.00	33.10^{a}	31.14^{b}	19.35^{c}	0.29
	KSK	21.32^{a}	19.38^{b}	11.68^{c}	0.67	36.10^{a}	34.56^{b}	19.45^{c}	0.19	20.10^{a}	17.94^{b}	11.21^{c}	0.14	35.19^{a}	33.74^{b}	19.02^{c}	0.37
1000 seed wt. (g)	BG	3.05^{a}	2.97^{b}	2.91^{c}	0.03	3.17^{a}	3.07^{b}	2.97^{c}	0.04	3.02^{a}	2.97^{b}	2.89^{c}	0.01	3.14^{a}	3.07^{b}	2.94^{c}	0.02
	RDC	3.11^{a}	3.04^{b}	2.88^{c}	0.01	3.20^{a}	3.14^{b}	2.95^{c}	0.02	3.10^{a}	3.01^{b}	2.87^{c}	0.03	3.19^{a}	3.12^{b}	2.92^{c}	0.03
	KSK	3.14^{a}	3.08^{b}	2.86^{c}	0.02	3.22^{a}	3.17^{b}	2.94^{c}	0.01	3.15^{a}	3.09^{b}	2.85^{c}	0.02	3.21^{a}	3.18b	2.91^{c}	0.01

Treatment mean followed by different letters in each row within cultivars are significantly different from one another at P= 0.05 according to Duncan's multiple range test; BG: Botanic Garden; RDC: RakhDeraChahl; KSK: Kala Shah Kaku; L.S.D.: Least Significant Difference at P= 0.05; EDU-SD: EDU applied as soil drench; EDU-FS: EDU applied as foliar spray; NEDU: Non EDU

DISCUSSION

Extensive quantitative information on growth and yield losses of economically important crops due to ambient air pollution has been obtained both in US and Europe under NCLAN programme and EOTCs protocol, respectively. Both studies used open-top chambers to assess the impact of ambient levels of gaseous pollutants and to establish exposure-response relationships (Bonte and Mathy, 1988; Jager, 1993). Among the atmospheric pollutants, ozone is the most phytotoxic air oxidant found in air pollution climate of heavily populated and industrialized areas of the world (Bell and Treshow, 2002), and is known to have a substantial impact on agricultural production around the globe (Krupa *et al*., 1994; Emberson *et al*., 2003), that is partly attributable to its high concentrations in rural areas, as well as urban and industrial locations (Hassan *et al*., 1995; Wahid *et al*., 1997; Ahmed, 2005).

In a sequence of experiments in the USA, the effects of ozone have been extensively studied on a range of agricultural crops, to establish exposure-response relationships using open-top chambers. But there is no well establish exposure response relationship reported in case of canola with respect to ozone and EDU. Canola is among the sensitive crop as comparisons of the canola responses with those of other species (Heagle *et al.*, 1988).

It has been felt since long that the problems of air pollution are becoming severe in major cities of Pakistan because the infrastructure development in the big cities has not kept pace with population influx, thereby giving rise to poor planning, faulty traffic systems and blatant disregard for vehicle maintenance. As a consequence thereof, atmospheric conditions of major cities have been deteriorating for the last two decades. In Karachi and Lahore, major contributors to environmental degradation are industry and transport. This issue has also been highlighted by a report on air pollution in twenty “mega cities” of the world, which are mainly in developing countries, including Pakistan (UNEP, 2012); this provide clear indications of rapidly deteriorating air quality.

REFERENCES

Agrawal, S.B., A. Singh and D. Rathore (2005). Role of ethylenediurea (EDU) in assessing impact of ozone on *Vigna radiate* L. plants in a suburban area of Allahabad-India. Chemosphere. 61: 218-228

Ahmed, S. (2005). Studies on the impact of ambient air pollution on the productivity and nutritional quality of some oil seed crops. Ph.D. thesis, Department of Botany, GC University, Lahore – Pakistan

Atkins, D.H.F., C. Healy and J.B. Tarrant (1979). The Use of Simple Diffusion Tubes for the Measurements of Nitrogen Dioxide Levels in Homes Using Gas and Electricity for Cooking. Report R9184, AERE. Harwell, Didcot, Oxon, UK.

Bell, J.N.B. and M. Treshow (2002). Air Pollution and Plant Life *(*2nd ed). John Wiley & Sons, Ltd., England.

Bonte, J. and P. Mathy, eds. (1988). The European Communities Research Project on Open-Top Chambers. Results on Agricultural Crops, 1987-1988. Air Pollution Research Report No. 19,CEC. Brussels.

Emberson, L.D., M.R. Ashmore and F. Murray (2003). Air Pollution Impacts on Crops and Forests – A Global Assessment. Imperial College Press, London.

Hassan, I. A., M.R. Ashmore and J.N.B. Bell (1995). Effect of ozone on radish and turnip under Egyptian field conditions. Environmental Pollution.89: 107-114.

Heagle, A.S., L.W. Kress, P.J. Temple, R.J. Kohut, J.E. Miller and H.E. Heggestad (1988). Factors influencing ozone dose-yield response relationships in open-top field experiments. In: Heck, W.W., Taylor, O.S., Tingey, D.T. (eds.), Assessment of Crop Loss from Air Pollution. Elsevier, London, pp. 141-179.

Jäger, H.J. (1993). Looking forward in environmental issues: Future research needs. In: Effects of Air Pollution on Agricultural Crops in Europe. (Jäger, H.J., Unsworth, M., De Temmerman, L.O. and Mathy, P. eds.). Air Pollution Research Report, NO.46. CEC, Brussels. pp. 23-42.

Krupa, S. V., M. Nosal and A.H. Legger (1994). Ambient ozone and crop loss: Establishing a cause -effect relationship. Environ. Pollut.83: 269-276.

Maggs, R. (1996). The effects of ozone and nitrogen dioxide on Pakistan wheat *(Triticumaestivum*L.) and rice *(Oryzasativa*L.*)* cultivars. PhD thesis, University of London.

Pardede, L.S. (1991). Surface ozone measurements at Bandung. In: IIyas, M. (Ed.), Ozone Depletion: Implication for the Tropics. Univ. Sci. Malaysia and the United Nations Environment Programme (UNEP), pp. 189-195

Salzman, B.E. and K. Gilbert (1959). Iodometric micro-determination of organic oxidants and ozone. Analytical Chemist. 31: 1914-1920.

TeLintelo, D.T.H., F. M. Marshall and D.S. Bhupal, (2002). Urban food: the role of urban and peri-urban agriculture in India: A case study from Delhi. Food Nutr. Agric. 29: 4-13.

UNEP. (2012). Global Environment Outlook. Earthscan, London.

Wahid, A., S.R.A Shamsi, E. Milne, F.M. Marshall, and M.R. Ashmore, (2001). Effects of oxidants on soybean growth and yield in the Pakistan Punjab. Environmental Pollution.113: 271-280.

Wahid, A., S.R.A. Shamsi, J.N.B. Bell and M.R. Ashmore (1997). Effects of ambient air pollution on the yield of some wheat and rice varieties grown in OTC in Lahore, Pakistan. Acta Scientia. 7(2): 141-152.