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An open-top chamber study to evaluate the impact of airborne pollutants on the growth of pea (*Pisum sativum* L.) cultivars at three sites of Sharkia Province, Egypt

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ABSTRACT
The effects of atmospheric pollution on Egyptian agroecosystems have recently become a topic of increasing concern. The present study can be considered a pioneering investigation conducted in the Nile Delta of Egypt. The effects of ambient air pollutants at rural, suburban and urban sites of Sharkia Province, Egypt on three cultivars of pea (*Pisum sativum* L.) were determined. O_3, SO_2 and NO_x had their highest levels at the urban site, and lowest at the rural site. Loss in pea growth reached 40% at the urban site, less in others. Concentrations of SO_2 and NO_x at the rural and suburban sites were below the known thresholds for yield loss in plants. There was extra carbon fixed in charcoal-filtered treatments which stimulated shoot and root growth, while there was a decline in grain yield, plant height and number of pods/plant in the non-filtered and ambient-air treatments, suggesting that less dry matter was invested in leaf-area expansion. All plants exposed to polluted air developed visible symptoms typical of gaseous injury, and the effect on carbon assimilation was reflected in reduced pea growth, and shoot growth maintained at the expense of the root. The short cultivar 'Little Marvel' had more resistance to air pollutants than others. Important adjustments are required in our interpretation of these kinds of experiments, and in understanding potential plant growth under a changed climate.

Keywords: Air pollution, Filtration, Growth, OTCs, Pea cultivars, Sharkia sites, Egypt.

INTRODUCTION

Current interest in the field of investigating the impact of air pollutants on agricultural crops is now centred on the short-term low-level effects of the main phytotoxic gases O_3, SO_2 and NO_x on crop production (Ollerenshaw & Lyons 1999, Manning & Godzik 2004). Chronic exposure to air pollutants can cause yield losses (Muzika *et al*. 2004). Apart from crop-yield losses, changes in plant development and reduced net growth occur (Gould & Mansfield 1988) as well as changes in crop quality (Vandermeiren *et al*. 1992).

In contrast, research into the impact of air pollution on crops in developing countries like Egypt is extremely limited; in many cases only limited reliable monitoring data are available (Nasralla & Ali 1985, Elkiey & Ormrod 1987, WHO/UNEP 1992, Ali 1993, 2003, Ali & Salama 2004). Ambient air in Egypt is characterised by very high levels of O_3, SO_2 and NO_x that exceed WHO guidelines (WHO/UNEP 1992).

Open-top chambers with filtered and non-filtered air have been used extensively to give qualitative and quantitative assessments of economic losses arising from air pollution ((USEPA 1996, Bytnerowicz *et al.* 2003). The pattern of pollutants is the same as in ambient air, making it possible to study their impact over long or short periods of time under a variety of climatic conditions. Since the complete life cycle is studied, it is possible to monitor plant growth and development, and to determine several parameters such as biomass and yield (Maggs *et al*. 1995, Fuhrer 2003).

Given the broad range of responses both within and among plant taxa (genera, species, cultivar or variety, genotype), differences in sampling methodology, exposure regimes and length of studies, it is clear that more research is needed to clarify the nature and mechanism of the effects of air pollution on plant- and soil-associated microbiota (Islam *et al*. 1999, 2000; Ali *et al*. 2002). Several plant species develop characteristic symptoms of injury to air pollutants, and are used as biological indicators to assess relative exposures in various geographic locations (Krupa *et al*. 2001; Manning and Godzik 2004). More recently, a white-clover indicator system consisting of two specific clones differing in their biomass responses to ambient levels of air pollutants is being used in the United States and Europe to indicate geographic areas where plants suffer adverse growth and yield effects (by 25% on Long Island, NY, and by at least 50% in California) due to ambient air-pollutant stress, with or without foliar injury symptoms (Heagle *et al*. 1995; McGrath 2000; Manning *et al.* 2004). Thus there must be a serious question as to whether agriculture is being hampered by losses of crop yield due to ambient air pollution.

The aim of the present investigation was to quantify the effects of air filtration on the productivity and growth parameters of pea cultivars at three sites in Sharkia province, Egypt.

MATERIALS AND METHODS

In Sharkia province we chose rural, suburban and urban sites at Nazlet Elarin village (about 115 km from Cairo), Abokabeer city (107 km from Cairo) and Zagazig (82 km from Cairo), respectively. Each site was divided into two areas, one with loamy clay (pH = 8.3) and another with loamy sand (pH = 6.2) soil textures. The rural site is about 2 km from the nearest road, where major pollutants are absent; it is surrounded by high trees on one side and a wall on another side, protecting the chambers from the wind. The suburban and urban site receive many kinds of pollutants.

The experiment was carried out in portable open-top chambers of the design of Heagle *et al.* (1973) in open-field 2-m square plots. Briefly, each chamber consists of a framework 2 m in diameter and 2 m in height, covered by transparent, low-density polyethylene, and placed over the plot in the field. Air was distributed into the chambers by a perforated internal double membrane. Air filtration within the chamber was carried out continuously during the experiment.

The treatments were designated in split-plot design consisted of charcoal-filtered air (CF) and non-filtered air (NF) chambers, and ambient-air (AA) open field plot. The experiment was carried out in September - December. Air temperature, soil temperature, relative humidity and light intensity were monitored regularly inside and outside the chambers. The monitoring of air quality (O_3, SO_2 and NO_x) was performed over the four successive growth months as described by Nasralla & Shakour (1981).

Prior to sowing, dried cow manure was added to the soil. Seeds of pea (*Pisum sativum* L.) cultivars were hand-sown directly into the soil in the first week of September (3rd, 4th, and 5th). The harvest dates depended on the cultivar. Three long, medium and short cultivars were used (Little Marvel, Perfection and Alderman). There were 6 rows in each replicate, sown 30 cm apart. Two weeks after sowing when the first true leaf expanded, seedlings were thinned. No pesticides or fertilisers were applied. Visible injury symptoms were visually assessed as a percentage of the total leaf area damaged for each leaf. The number of injured leaves and the appearance of foliar injury were recorded as soon as they developed, and then weekly thereafter until the end of the experiment. Growth and yield of the cultivars were assessed destructively throughout. Plants were divided into organs and the number, length and weight of fresh pods determined immediately after every harvest; material was then dried in an oven at 105 ^oC for a week and weighed. The total carbon content (%) for plant organs and soil were estimated by the method described by Piper (1947). The total nitrogen content (%) of plants and soil was determined using the micro-Kjeldahl technique.

Data of the split-plot design were subjected to one-way analysis of variance (ANOVA) using SPSS based on the assumption that two plants grown in different chambers receiving the same treatments were as likely to be different (or as similar) as plants in the same chambers. This assumption was supported by the fact that microclimatic conditions and gas concentrations were almost identical among chambers. Significant differences between pairs of treatments was determined using Duncan's multiple range test, using 0.05 and 0.01 levels of significance.

RESULTS

The mean light intensity, and air and soil temperatures were on average reduced, and relative humidity increased inside the chambers (Fig 1). The mean relative humidity increase, and all other meteorological data decreased during pea life cycle decreased from month to month except relative humidity (Fig. 1).

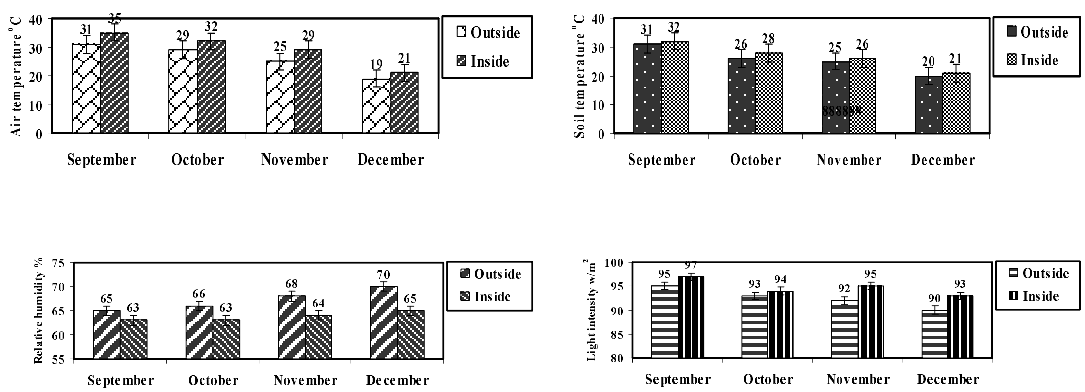
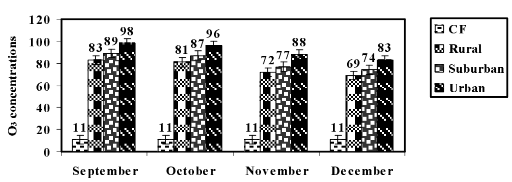
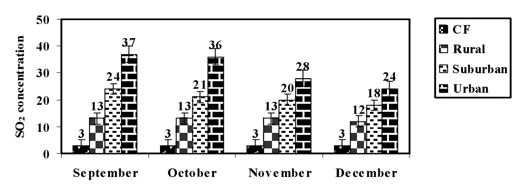


Fig. 1. Mean values of meteorological parameters of air temperature (°C), soil temperature (°C), relative humidity (%), and light intensity (Wm^{-2}), recorded outside and inside chambers during the pea life cycle.





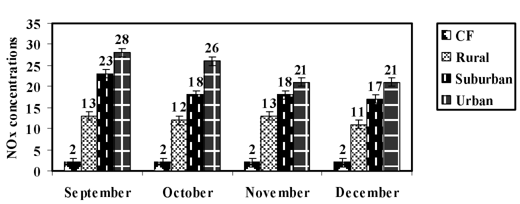


Fig. 2. Mean concentrations (nl l-1) of studied pollutants during the pea life cycle at three sites in north-eastern Egypt. CF = charcoal-filtered air; other data come from ambient air.

The mean concentrations of the major air pollutants (O_3, SO_2 and NO_x) through the growth season of pea showed that air quality at the experimental sites was characterised by very low concentrations of SO_2 and NO_x at the rural site, while the suburban and urban sites recorded high concentrations for both gases, especially during hot months (Fig. 2). The same pattern, but with smaller differences, was evident for mean 8-hour concentrations of O_3. Increased O_3 concentrations coincided with a slight seasonal increase in the mean temperature. Filtration efficiencies were 86% for O_3 and 74% for SO_2 and NO_x (Fig. 2).

Pea plants showed extensive paper-white necrotic spots on older leaves. The percentage of area damaged per leaf and the number of injured leaves of different cultivars through the growing seasons are shown in Table 1. The percentage damage and the number of injured leaves were higher in the tallest cultivar (Alderman) than in the other two. The urban site recorded high levels of visible injury, whilst the other two sites had roughly similar levels. There was no significant difference in the extent of symptoms between the plants of the ambient-air and non-filtered treatments for all three cultivars through the four growth months. Damaging symptoms of air pollutants significantly increased when plants grew in loamy sand rather than loamy clay soil. The extent of injury was significantly reduced by charcoal-filtered air treatments, by about 89% (Table 1).

Table 1. Effect of air filtration on mean values of growth parameters and damaging symptoms of three cultivars of pea (*Pisum sativum* L.) grown in OTCs exposed to air pollution. OTCs = Open-Top Chambers, CF = Filtered Air, NF = Non-filtered air, AA = Ambient Air, F.wt = Fresh weight, D.wt = Dry weight; Values followed by the same letter are not significantly different at $P \geq 0.05$, NS = non-significant; * means $P \leq 0.05$; ** means $P \leq 0.01$

Parameters/ Factor effects	Shoot biomass (gm)	Root biomass (gm)	Root/ Shoot ratio	% damaged area/leaf	No. injured leaves/ plant	Total plant biomass (gm)	Plant height (cm)
Effect of soil types							
Loamy clay (LC)	999.112^a	0.7657^a	0.000766^a	1.6665^a	5.6490^a	1027.09^a	99.565^a
Loamy sand (LS)	912.872^b	0.4541^b	0.000493^b	1.8555^b	8.1880^b	939.76^b	91.244^b
F-test	**	*	**	NS	**	**	**
Effect of sites							
Nazlet Elareen- LC	951.111^d	0.5144^c	0.000536^a	1.3785^a	5.1230^a	971.71^a	90.229^a
Nazlet Elareen- LS	911.084^b	0.4666^a	0.000504^a	1.3777^a	5.1229^a	939.46^b	87.233^b
Abokabeer- LC	933.544^c	0.4911^b	0.000525^a	1.4830^b	6.3859^b	957.92^c	85.285^b
Abokabeer- LS	911.084^b	0.4898^b	0.000526^a	1.4833^b	6.3855^b	934.41^b	81.555^c
Zagazig- LC	938.554^c	0.5138^c	0.000543^a	1.8174^c	10.4489^c	959.26^c	73.218^d
Zagazig- LS	901.077^a	0.4659^a	0.000499^a	1.8114^c	10.4489^c	921.67^d	72.218^d
F-test	**	**	NS	**	**	**	**
Effect of air quality							
CF	921.713^a	1.0500^a	0.001140^a	0.6856^a	1.1133^a	959.42^a	107.667^a
NF	858.794^b	0.2107^b	0.000228^b	2.0756^b	11.7926^b	884.44^b	70.759^b
AA	840.803^b	0.2107^b	0.000228^b	2.0178^b	11.0519^b	863.48^b	70.307^b
F-test	**	**	NS	**	**	**	**
Cultivars x air filtration							
Filtered air (CF)							
Little marvel	921.168^c	0.5170^a	0.000553^a	0.0944^a	0.11781^a	954.96^a	50.604^a
Perfection	918.047^a	0.4974^b	0.000533^a	0.0296^a	0.1635^a	952.21^a	112.600^b
Alderman	901.094^b	0.4570^c	0.000499^b	0.0548^a	0.1212^a	935.18^b	185.529^c
F-test	**	**	NS	**	**	**	**
Non-filtered air (NF / AA)							

Little marvel	821.666[c]	0.5000[a]	0.000609[a]	1.7945[a]	9.1193[a]	851.38[a]	33.444[a]
Perfection	811.777[a]	0.4900[b]	0.000604[a]	1.9294[b]	16.0637[b]	840.81[b]	92.644[b]
Alderman	800.334[b]	0.4511[c]	0.000562[b]	1.9543[c]	17.7748[c]	827.38[c]	125.129[c]
F-test	**	**	NS	**	**	**	**

Data summarizing the effects of air pollutants (O_3, SO_2, NO_x) on growth parameters of pea are presented in Table 1. The charcoal-filtered treatment markedly stimulated plant growth, but there was a disproportionate effect on the growth of roots; there was no difference between non-filtered and ambient-air treatments on shoot or root growth. The root: shoot ratio was markedly (40%) affected in plants exposed to air pollutants. In contrast, pollutants significantly reduced total plant growth, with shoot growth (32 % reduction) maintained at the expense of the root (42 % reduction). Differential effects on root and shoot growth were reflected in a lower root: shoot ratio in plants exposed to pollutants, an effect on the borderline of statistical significance. Despite shifts in the pattern of carbon allocation, exposure to ambient air resulted in a marked reduction in total plant biomass. In addition, pea height decreased significantly in loamy sand soil (by 8%), while air filtration significantly increased this by 34.5% (Table 1).

Table 2. Effect of air filtration on mean values of yield components of three cultivars of pea (*Pisum sativum* L.) grown in OTCs exposed to air pollution at three sites in north east of Egypt. OTCs = Open-Top Chambers, CF = Filtered Air, NF = Non-filtered air, AA = Ambient Air, F.wt = Fresh weight, D.wt = Dry weight; Values followed by the same letter are not significantly different at $P \geq 0.05$, NS = non-significant; * means $P \leq 0.05$; ** means $P \leq 0.01$

Yield components/ Factor effects	No. of seeds/ pod	Length of pod (cm)	No. of Pods/ plant	Fresh wt. of pods (gm/plant)	Wt. 100 seeds (gm)	Grain yield (gm)
Effect of soil types						
Loamy clay (LC)	9.112[a]	8.675[a]	12.9781[a]	27.2123[a]	17.2431[a]	845.77[a]
Loamy sand (LS)	8.124[b]	7.650[b]	11.6501[b]	26.4444[b]	15.3321[b]	654.34[b]
F-test	*	**	*	*	**	**
Effect of sites						
Nazlet Elareen- LC	9.772[a]	8.563[a]	13.4793[a]	28.7741[a]	14.2741[a]	720.64[a]
Nazlet Elareen- LS	9.332[a]	8.112[a]	12.1123[b]	27.9970[a]	14.3222[a]	718.22[a]
Abokabeer- LC	7.974[b]	6.980[b]	12.4815[b]	23.9370[b]	12.3253[b]	714.56[b]
Abokabeer- LS	7.111[b]	6.232[b]	12.3345[b]	22.9322[b]	12.1370[b]	701.00[c]
Zagazig- LC	6.854[c]	5.999[c]	7.0578[c]	20.2111[c]	10.1170[c]	698.33[d]
Zagazig- LS	6.224[c]	5.473[c]	6.1112[d]	20.2111[c]	10.1214[c]	696.1[d]
F-test	**	**	**	**	**	**
Effect of air quality						
CF	9.654[a]	9.777[a]	14.1989[a]	36.6667[a]	15.7815[a]	874.33[a]
NF	7.904[b]	5.941[b]	11.9204[b]	25.4444[b]	12.0926[b]	678.78[b]
AA	7.493[b]	6.990[c]	11.8993[b]	22.4741[c]	12.8593[b]	670.19[b]
F-test	**	**	**	**	**	**
Cultivars x air filtration						
Filtered air (CF)						
Little marvel	7.365[a]	7.786[a]	15.1259[a]	33.2926[a]	14.6852[a]	791.70[a]
Perfection	8.655[b]	7.888[a]	13.1530[b]	32.6704[b]	15.5370[b]	725.93[b]
Alderman	9.222[c]	12.758[b]	11.7396[c]	33.6222[a]	14.5111[a]	705.67[c]
F-test	**	**	**	**	**	**
Non-filtered air (NF / AA)						
Little marvel	5.759[a]	5.734[a]	10.1233[a]	29.2226[a]	11.6356[a]	681.30[a]
Perfection	6.507[b]	6.555[b]	9.1220[b]	28.5434[b]	10.5660[b]	625.77[b]

Alderman	7.332[c]	9.222[c]	8.4546[c]	26.6002[c]	10.4411[b]	545.77[c]
F-test	**	**	**	**	**	**

The non-filtered treatment induced a significant decline in pea-plant grain yields, suggesting effects of all gases on the density or relative thickness of individual leaves. The ambient-air treatment also reduced the number of pods per plant (Table 2). The charcoal-filtered treatment reduced the detrimental effects of all gases on pod length. The number of seeds per pod of pea plants exposed to non-filtered air was not significantly different from that of plants treated with ambient air. In case of interaction between pea cultivars and air filtration, the charcoal-filtered treatment had a greater in pod growth. Consequently, results of NF or AA showed significant decrease in pea yield components compared with plants exposed to CF treatments (Table 2). Maximum loss in pea yield and pod characters were obtained in the urban sites (Zagazig city with loamy clay and loamy sand soils), while the rural site (Nazlet Elarin village with loamy clay and loamy sand soils) has less reduction for these characters.

Table 3. Effect of air filtration on mean values of total C and N (% air dry weight) of shoot and soil of three cultivars of pea (*Pisum sativum* L.) grown in OTCs exposed to air pollution at three sites in north east of Egypt. OTCs = Open-Top Chambers, CF = Filtered Air, NF = Non-filtered air, AA = Ambient Air, F.wt = Fresh weight, D.wt = Dry weight; Values followed by the same letter are not significantly different at $P \geq 0.05$, NS = non-significant; * means $P \leq 0.05$; ** means $P \leq 0.01$

Parameters/ Factor effects	Shoot total carbon (%)	Shoot total nitrogen (%)	Shoot carbon/ nitrogen ratio	Soil total carbon (%)	Soil total nitrogen (%)	Soil carbon/ nitrogen ratio
Effect of soil types						
Loamy clay (LC)	28.4445[a]	4.1081[a]	6.9365[a]	33.8259[a]	1.4830[a]	22.8581[a]
Loamy sand (LS)	26.4563[b]	4.1111[a]	6.4536[b]	33.8159[a]	1.4730[a]	23.0068[b]
F-test	**	NS	*	NS	NS	**
Effect of sites						
Nazlet Elareen- LC	28.3037[a]	4.1081[a]	6.9245[a]	33.8259[a]	1.4696[a]	23.0136[a]
Nazlet Elareen- LS	28.1127[a]	4.1081[a]	6.8560[b]	33.8259[a]	1.4696[a]	23.0136[a]
Abokabeer- LC	27.4111[b]	4.1196[b]	6.6856[c]	32.6963[a]	1.4600[a]	22.3972[b]
Abokabeer- LS	27.6333[b]	4.1196[b]	6.7390[d]	32.6963[a]	1.4600[a]	22.3972[b]
Zagazig- LC	24.4443[c]	4.1274[b]	5.9609[e]	32.1185[b]	1.4830[a]	21.7027[c]
Zagazig- LS	24.4533[c]	4.1274[b]	5.9634[e]	32.1185[b]	1.4830[a]	22.3972[b]
F-test	*	*	**	**	NS	*
Effect of air quality						
CF	29.4593[a]	4.6222[a]	7.3650[a]	34.7556[a]	1.9167[a]	18.1041[a]
NF	28.0293[b]	4.1667[b]	6.8714[b]	32.0630[b]	1.6067[b]	19.9130[b]
AA	27.9896[b]	4.1663[b]	6. 4357[c]	32.0222[b]	1.5893[b]	20.1383[c]
F-test	**	**	**	**	**	**
Cultivars x air filtration						
Filtered air (CF)						
Little marvel	28.3222[a]	4.5144[a]	6.9073[a]	33.0296[bc]	1.9885[a]	16.5979[a]
Perfection	28.3037[a]	4.5185[a]	6.7380[b]	33.1000[b]	1.9578[a]	16.8877[a]
Alderman	28.7222[b]	4.5222[a]	7.000[c]	32.7111[ac]	1.9655[a]	16.5989[a]
F-test	**	NS	**	*	NS	*
Non-filtered air (NF / AA)						
Little marvel	24.4442[a]	4.0144[a]	5.9609[a]	30.1116[bc]	1.4615[a]	20.6164[a]
Perfection	24.3437[a]	4.0185[a]	5.9365[a]	30.1220[b]	1.4878[a]	20.2147[a]
Alderman	22.1112[b]	4.0222[a]	5.3795[b]	32.6222[ac]	1.4633[a]	22.3287[b]
F-test	**	NS	**	*	NS	*

The effects of air filtration on mean values of carbon and nitrogen composition of shoots and soils of three cultivars of pea are shown in Table 3. The common observation with important implications for these two nutrients in plant and soil where there is short-term stimulation, is that there was a reduction of both carbon and nitrogen in polluted air (AA, NF) treatments compared with non-polluted air. Progressive degradation at the end of study draws attention to the dangers in extrapolating from effects of pollutants on plant productivity. Charcoal-filtered air is effective in the removal of pollutants, resulting in more carbon and nitrogen in all pea cultivars. Exposure to pollutants resulted in comparatively greater changes in these two nutrients in the soil than in the shoot. The AA did not affect the C: N ratio compared with NF in most cases. The nitrogen content was not significantly different between plants raised in non-polluted vs. polluted air treatments. In combination between air quality treatments and pea cultivars, the Little Marvel cultivar was more resistant than others; we recorded less reduction in total carbon and nitrogen of shoots, and for the total soil carbon, and no difference in the total soil nitrogen (Table 3).

DISCUSSION

Quantitative assessments and alleviation of the effects of air pollutants on communities of crops are difficult because of the complex nature of pollution stress, the influence of many interacting external factors on the impact of pollutants, and variations in stability and growth of crops (Kozlowski 1980, Fuhrer 2003). In our experiments, pea growth and grain yield significantly altered with changes in the climate of the chambers, increasing atmospheric gas concentrations, increasing temperature and varying availability of soil type. These results agree with previous studies (Miller 1988, Martin *et al.* 1991, Andersen & Rygiewicz 1998, Chernikova 1998, Piikki *et al.* 2004).

Pea plants showed extensive paper-white necrotic spots on older leaves. This is due to the SO_2, NOx and O_3, which can cause more injury to plants than all other air pollutants combined (Muzika *et al.* 2004). Gaseous air pollutants injure leaves after being absorbed through stomata over a long time in sublethal amounts. The damage is characterized by slowly developing chlorosis, associated with early leaf senescence. Sometimes chronic injury is accompanied by necrotic markings (Manning & Godzik 2004). When only a single pollutant induces injury, the symptoms generally are distinct. For example, SO_2 injury on broad-leaved trees is characterized by areas of injured leaf tissue located between the healthy tissues around the veins. The O_3 symptoms appear as necks or stipples of dead tissues. When O_3 injury is severe, the flecks usually coalesce into larger lesions. Several pollutants (including SO_2, O_3, and NO_X) cause tip burn, depending on the dosage and plant species (Roberts 1984, Muzika *et al.* 2004).

The damaging effect of air pollutants causing a reduction in photosynthesis would be also expected when leaves are injured or shed, but the rate is reduced by many air pollutants including SO_2, O_3, and NOx long before visible injury or growth reduction occur (Kozlowski 1976, Muzika *et al.* 2004). The degree of inhibition of photosynthesis and of recovery following a pollution episode, as well as the mechanism of inhibition, vary appreciably with specific air pollutants. Photosynthetic suppression by pollutants may variously reflect changes in stomatal aperture as well as biochemical fixation of CO_2 (Bennett & Hill 1974, Manning *et al.* 2004).

The rate of absorption of air pollutants depends on the concentration gradient from the leaf exterior to the leaf interior as well as the resistance of gaseous flow along the diffusion pathway (Muzika *et al.* 2004). Hence, the effects of air pollutants often vary appreciably with differences in stomatal diffusion resistance, which is a function of stomatal size, stomatal frequency, and control of stomatal aperture. Stomatal diffusion resistance varies widely among species of plants as well as clones and cultivars (Pallardy & Kozlowski 1979). For a given plant it also varies diurnally and seasonally (Manning *et al.* 2004).

The air pollutants have numerous sites of action and influence many metabolic processes. Our data showed that air pollutant NO_x, SO_2 and O_3 reduced the carbon and nitrogen for pea shoot and soil samples. Individual enzyme systems are stimulated by certain pollutants and inhibited by others. There is considerable evidence that growth of crops is reduced by air pollutants because of lowered availability of metabolites at growth sites. Usually decrease in growth does not occur until some time after metabolite pools are reduced. Both SO_2 and O_3 affect plant metabolism rapidly. Both carbohydrates and proteins (C and N sources) were reduced most by SO_2 and O_3, an intermediate amount by SO_2 and least by O_3. Decreases in carbohydrates and proteins were detected within a day after exposure to pollutants, inhibition of leaf expansion a week later, and decrease in dry weight increment of stems and roots (Constantinidou & Kozlowski 1979, Manning & Godzik 2004).

Certain pollutants themselves induce stomatal opening or closing and amounts of pollutants absorbed. Low dosages of SO_2 and O_3 induced stomatal opening of *Ulmus americana* seedlings; higher dosages caused stomatal closure (Noland & Kozlowski 1979). The initial opening effect of SO_2 and O_3 probably is related to reduce turgor of subsidiary cells. Stomatal closure at high SO_2 and O_3 dosages may be associated with accumulation of CO_2 in substomatal cavities following SO_2 and O_3 inhibition of photosynthesis or with changes in permeability of guard cell membranes (Manning *et al.* 2004).

Pollutants in the air influence crops at the cellular, plant, species, and ecosystem levels. Biochemical changes induced in cells sequentially lead to changes in metabolic pathways of whole organisms, loss of integrity of cytoplasmic membranes resulting in loss of control of diffusion of water and solutes, and breakdown of cellular components that eventually are expressed in chlorosis, necrosis, senescence of leaves and other organs, and often death of trees. Air pollutants also induce changes that do not produce visible injury symptoms but adversely affect growth, yield, and quality of plants and plant products (Heck 1973, Manning *et al.* 2004).

The present study suggests into two critical points: firstly, that there are important differences in the air-pollution flux between the open-top chambers and the ambient plots; and second, that the pollution climate of Egypt needs to be described to a much greater extent. It is possible to provide much better description of the co-occurrence of SO_2, O_3, and NO_X for dose-effect studies, and this may be an important contribution to the differences in filtration experiments between charcoal-filtered treatments and non-filtered exposure treatments.

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الملخص العربى

دراسة استخدام الصوبات المفتوحة في تقييم تأثيرملوثات الهواء علي نمو أصناف من نبات البسلة فـي ثـلاث مواقع بمحافظة الشرقية– مصر

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تهدف هذه الدراسة إلى تقييم مدي التأثير المشترك لغازات الأوزون وثاني أكسيد الكبريت و أكاسيد النيتروجين علي بعض الخصائص لنبات البسلة الذي تم زراعتة في صوبات نباتية مفتوحة في مناطق ريفيـة و شـبه حـضرية وأخري حضرية بمحافظة الشرقية. تعتبر هذه الدراسة الأولي من نوعها بدلتا مصر. لوحظ ارتفاع تركيـز غـاز الأوزون في المناطق الحضرية عنها في المناطق الأخري في حين تم تسجيل تباين طفيف في تركيـزات غـازات ثاني أكسيد الكبريت و أكاسيد النيتروجين في المناطق المختلفة في مستوى غير مؤثر علي نمـو النبـات. وصـل الدمار في نبات البسلة الناتج عن التركيزات العالية لغاز الأوزون الي ٤٠%. أظهرت الدراسة استجابة عالية مـن النباتات النامية في صوبات مفتوحة والمعرضة لهواء نقي في تحسين معدلات النمو. بينمـا النباتـات المعرضـة للهواء الجوي مباشرة أو النامية في صوبات مفتوحة والمعرضة لهواء غير نقي وجد نقص في انتاج البذورو طول النبات .كذلك أوضحت النتائج ظهور أعراض مرضية واضحة بتأثير الغازات محل الدراسة ولكن أعراض أكثـر وضوحا لغاز الأوزون. وقد اثبت الدراسة ضرورة علاج الأثر الناتج عن إتلاف المحاصيل في المناطق المختلفـة بمصربفعل الملوثات خاصة غاز الأوزون.