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Harmful Effect of Ambient Ozone on Growth and Productivity of Two Legume Crops *Visia Faba*, and *Pisum sativum* in Riyadh City, K.S.A.

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***Abstract*—**Ozone (O_3) is considered as one of the most phytotoxic pollutants with deleterious effects on living and non living components of Ecosystems. It reduces growth and yield of many crops as well as alters the physiology and crop quality. The present study described series of experiments to investigate the effects of ambient O_3 at different locations with different ambient levels of O_3 depending on proximity to pollutant source and ranged between 17 ppb/h in control experiment to 112 ppb/h in industrial area respectively. The ambient levels in other three locations (King Saud University botanical garden, King Fahd Rd, and Almanakh Garden) were 61,61,77 ppb/h respectively. Tow legume crops species (vicia vaba L ; and Pisum sativum) differ in their phenology and sensitivity were used. The results showed a significant negative effect to ozone on morphology, number of injured leaves, growth and productivity with a difference in the degree of response depending on the plant type. Visia Faba showed sensitivity to ozone to number and leaf area and the degree of injury leaves 3, pisum sativum show higher sensitivity for the gas for degree of injury 1,The relative growth rate and seed weight, it turns out there is no significant difference between the two plants in plant height and number of seeds.

***Keywords*—**Ozone, Legume crops, growth and production, Resistance, Riyadh city.

I. Introduction

OZONE gas (O_3) pollution is consider one of hazards that affects the components of the ecosystem. The gas is produced in large quantities in the lower atmosphere due to the interactions that occur between the ultraviolet radiation and lightning as well as those resulting from fuel burning by cars, factories and power plants [1], [2]. Ozone plays a secondary role in Earth warming, where it contributes about 7% [3] because its natural concentration ranges between 20-30% nano- liter / liter [4]. A recent rise of up to four times the normal level has been recorded in urban areas [5].

Plants are frequently exposed to acute or chronic doses of O3 that greatly affect plant growth for a few consecutive hours for days (acute doses) while chronic exposure represents exposure to relatively low levels (40 nano liters / liter) for the entire plant life. A number of studies [3], [6], [7], [8] have shown that the effects of exposure to O_3 appear as burns on the upper surface of the leaf and changes in its color and the appearance of premature aging. Reference [9] pointed to a change in leaf color and leaves spotted on the lower surface as symptoms caused by the exposure to high level of O_3 as well as a decline in plant growth, development and productivity. Among the most important damages caused by O_3 is the damage to the cell membranes and ion imbalance that leads to a decline or loss of the ability of plant photosynthesis and imbalance in the distribution of metabolic products and reduces growth, production and accelerated aging.

The Riyadh city is not an exception, experiences at the present time high degrees of O_3 pollution due to human activities. The highest level of O_3 pollution recorded was 40-148 ppm [10], [11], [12] A. Therefore, the objectives of the present paper were to identify the different effects of O_3 in different parts of the Riyadh City limits on Faba bean and pea plants growth and productivity.

II. Materials and Methods

A. Study Site

Please The city of Riyadh, Saudi Arabia lies between latitudes 19º 30' and 27º 30' N and between longitudes º42 and º48 east, and at an altitude of about 600 m above sea level. The total area of Riyadh is 4.900 km^2. The city of Riyadh had dry desert climate which is extremely hot in summer (45º C) and moderately cold winter cold (7ºC). Also characterized by low rainfall and relative humidity as the highest average rainfall reached 20.1 mm during the winter [13].

B. Methods

The research was conducted in four sites within the city of Riyadh, representing different levels of pollution and another for comparison (Fig. 1), where the gas concentrations set at 17 ppb using a field growth chamber [14]. The levels of gas area determined in the different sites in the city as follows: King Saud University(61), King Fahad Road (71), Climate Garden (77), the second industrial city (112) using an ozone analyzer Model UV-100, Serial # 111 EcoSensors Inc.

Two plant species that belong to the Leguminosae family

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differing in the nature of their growth, namely Faba bean (Visia Faba) (C.V. Giza 40) and pea plant (Pisum sativum) (C.V. Rondo).

The seeds were Germinated in plastic pots (40 cm) packed with sand, clay soil mixed at a 1:1 ratio in 14/11/2007, near the field growth chamber, and after the completion of the growth of initial leaves, the posts moved to various sites on 28/11/2007, 24 pots were distributed in each site, each pot contained five plants. Harvest of plants were divided into three stages according to the stage of growth, first harvest was conducted after a month, the second after two months, and the third after three months, transfer to the sites. Samples were brought to the Department of Botany Laboratory from their where, were plants separated to different parts and dried in an oven at a temperature of 80ºC for 48 hours.

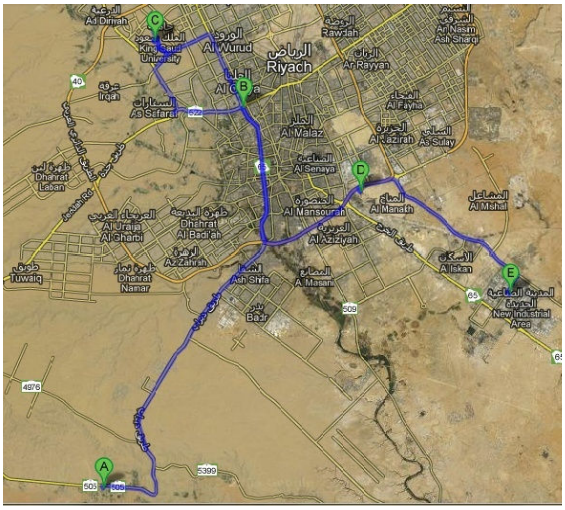

Fig. 1 Sites in Riyadh city organized depending on ozone level: A- Derab area B- King Saud University C- King Fahad Road D- Climate Garden E- Second Industrial area
Source: http://maps.google.com.sa/maps?hl=ar&tab=wl

Leaf area was also measured using a Portable leaf area meter model L1-3000, and the degrees of injury were estimated in accordance to [15] and also the relative growth rate for the two plants were measured using the following equation [16]:

$$\frac{\log W_2 - \log W_1}{t2} - \times 100$$

III. Results

A. Morphological Characteristics and Symptoms of Injury

Table I (A) shows the results of the effects of O_3 on the morphological characteristics of Faba bean and pea. The mean stem length of the two plants was 52.8 and 52.7 cm, respectively, and the results showed significant differences between the mean values of Levels I, II and III with those of Level IV and V and with respect to the effects of O3levels on pea plants, those under the effects of Level V gave the lowest values.

The mean leaf area of the two plants were 1776.6 and 1623.22 cm 2. In Faba bean, plants of the V plants gave the least values which differed significantly from the others , while there were no significant differences between the values of levels I to IV. As for the pea plants, there were no significant differences in the effects of Levels I, II and III , however they all differed significantly from those of Levels IV and V. the V level gave the lowest leaf area of 46.9 cm 2which is significantly different from that of the IV level.

The mean number of leaves was 78.3, 58.4/plant for both Faba bean and peas, respectively. In case of Faba bean plants, the results indicated that the I level plants had the highest number of leaves/plant which differed significantly the others. The II and III levels had lesser number but were significantly higher than those for the IV and V plants while the latter had the least number of leaves/ plant. With respect to the pea plants, the plants of levels I and II gave the highest values that had significant differences with those of the rest. The III plants had a significantly higher number of leaves than both IV and V plants.

TABLE I
THE EFFECTS OF O_3 ON THE MORPHOLOGICAL CHARACTERISTICS OF THE FABA BEAN AND PEA PLANTS AS WELL AS THE MEAN RATES OF DECLINE DUE TO THE EFFECTS OF THE O3 LEVELS II-V AS COMPARED TO THE CONTROL (%), MEAN ± STANDARD DEVIATION FOR EACH TRAIT FOR EACH TREATMENT, MEANS WITH THE SAME LETTERS WERE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL USING THE LEAST SIGNIFICANT DIFFERENCE TEST (LSD0.05)

Plant Ozone levels	**(A)**					
	Plant height (cm)		**Leaf area(cm^2)**		**No. of leaves**	
	Faba bean	**Pea**	**Faba bean**	**Pea**	**Faba bean**	**Pea**
1	55.5±9.9a	55.9±7.9a	2092.6±692a	1792.2±385a	94.1±30.9a	65.9±14.9a
2	54.2±9.8a	54.8±6.4a	1948.9±609a	1740.0±+224a	84.1±31.0b	69.3±17.7a
3	55.3±9.8±	54.0±6.3	2010.1±630a	1768.6±327a	84.0±27.5b	59.0±10.6b
4	50.1±5.4b	51.0±4.2b	1505.0±436b	1463.9±271b	67.3±22.2c	54.3±8.4c
5	48.7±8.1b	46.9±9.0c	1290.0±426c	1351.1±347c	61.8±25.3d	48.7±13.8c
LSD0.05	3.1	3.5	171.2	71.2	4.6	4.1
Mean	52.8±8.9±	52.7±7.4a	1776.6±631a	1623.2±+352b	78.3±28.9a	58.4±14.2b

(B)

	Plant height (cm)			Leaf area(cm^2)			No. of leaves		
Rate of decline	Faba bean	Pea	LSD 0.05	Faba bean	Pea	LSD 0.05	Faba bean	Pea	LSD 0.05
	6.6a	6.9 a	3.4	18.0a	11.2 b	2.8	21.6b	14.3 a	2.1

TABLE II
THE EFFECTS OF O_3 ON THE MEAN (A) INJURY SYMPTOMS IN FABA BEAN (B) PEA LEAVES AND THE MEAN RATES OF DECLINE DUE TO THE EFFECTS OF O_3 LEVELS OF II-V AS COMPARED WITH THE CONTROL, (%), MEAN ± STANDARD DEVIATION FOR EACH TRAIT FOR EACH TREATMENT, MEANS WITH THE SAME LETTERS WERE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL USING THE LEAST SIGNIFICANT DIFFERENCE TEST (LSD0.05)

Plant	(A)									
Ozone	0		1		2		3		4	
levels	Faba bean	Pea	Faba bean	Pea	Faba bean	Pea	Faba bean	Pea	Faba bean	Pea
1	98.7±0.02a	97.0±0.1a	0.5±0.1d	0.6±0.1c	0.5±0.1c	0.6±0.1d	0.5±0.1d	0.6±0.1d	0.50±0.01a	0.60±0.10a
2	70.1±8.1b	69.5±8.9b	16.5±7.5±	16.2±6.9b	2.0±1.8b	1.8±0.9c	1.7±0.9c	1.7±1.1c	0.50±0.01a	0.60±0.10a
3	63.2±11.8c	68.2±9.1b	13.6±6.2b	17.2±7.2ab	17.2±1.8ab	6.8±2.1b	2.8±2.1b	2.5±1.9b	0.50±0.01a	0.70±0.05a
4	63.2±11.8c	59.3±13.9c	14.0±6.2b	18.0±7.8a	7.5±2.5a	6.8±2.1b	2.8±2.1b	2.5±1.9b	0.50±0.01a	0.70±0.0a
5	60.7±12.2d	55.8±15.2d	11.9±4.8c	18.2±19.7a	7.6±2.3a	8.4±2.9a	7.4±2.7a	3.1±2.5a	0.50±0.01a	0.60±0.10a
LSD0.05	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Mean	74.5±10.8a	72.1±12.4b	9.8±6.2b	12.17.7a	3.0±2.2a	3.1±2.1a	2.1±1.7a	1.8±1.4b	0.70±0.10a	0.60a±0.10

(B)

Rate of decline	Faba bean	Pea	LSD 0.05	Faba bean	Pea	LSD 0.05	Faba bean	Pea	LSD 0.05	Faba bean	Pea	LSD 0.05	Faba bean	Pea	LSD 0.05
	66.3a	63.3b	1.1	14.0b	17.4a	1.04	4.8a	4.7B	3.4	3.5A	2.3B	0.6	0.50	0.60A	0.11

Table II also shows the results of the adverse effects of O_3 on Fababean and pea plants, 74.5% and 82.1%of the total number of leaves per plant were not affected by the gas in Faba bean and peas, respectively. The mean incidence of the effects were 9.8, 3, 2.1, 0.7% in Faba bean and 12.1, 3.1, 1.8, 0.6% in peas for O3 levels I, II, III, IV and V, respectively. Significant differences were recorded treatments with increases in the intensity as the concentration of O_3 increased.

The results also indicated that the mean decline rates for Faba bean plants in the O_3 levels of I- V as compared to the control were significantly different which were higher than those experienced by peas which were also significantly different from the control.

B. Growth and Yield

Table III shows the results of the effects of O_3 on plants growth with a mean dry weight of Faba bean and pea leaves 25 and 20.4 g, respectively. The dry weights were significantly affected by all concentration levels of the gas. No significant differences were observed in the mean rates of decline due to the effects ofO3 conc. II- V for the two plant species (Table III).

TABLE III
THE EFFECTS OF O_3 CONCENTRATION ON (A) LEAF DRY WEIGHT OF FABA BEAN AND PEA PLANTS (G) AND (B) THE MEAN RATES OF DECLINE DUE TO THE EFFECTS OF THE DIFFERENT O3 LEVELS II-V AS COMPARED TO THE CONTROL, (%), MEAN ± STANDARD DEVIATION FOR EACH TRAIT FOR EACH TREATMENT, MEANS WITH THE SAME LETTERS WERE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL USING THE LEAST SIGNIFICANT DIFFERENCE TEST (LSD0.05)

Plant	(A)		
Ozone levels	Faba bean		Pea
1	36.5±16.1a		30.5±14.83a
2	29.3±15.42b		22.8±8.02b
3	26.6±15.93c		18.7±6.57c
4	17.8±9.99d		15.6±2.28d
5	14.9±7.83e		14.3±5.15e
LSD0.05	2.01		1.7
Mean	25.0±15.13a		20.4±10.58b
	(B)		
	Dry Weight (g)		
Rate of decline	Faba bean	Pea	LSD 0.05
	42.1a	39.3b	2.9

The results in Table IV show that the mean relative growth rate to the Faba bean and peas plants were 1.2% and 1.12%, respectively. Significant differences were recorded for Faba bean due to the effects of I, II and III conc. as compared to the effects of IV and V conc. The results for pea plants also showed significant differences between the effects of I level and the effects of the rest as well as significant differences between II and V. The results are presented in Table IV indicated that the mean decline rates for pea due to the effects of II-V conc. as compared to the control were significantly different.

Table V shows the results of the effects of O3 on plant yield and its components. The mean number of seeds per plants was 175.6 and 169.3 seeds for Faba bean and pea plants, respectively.

Faba bean plants under I and II conc. gave the highest numbers of seeds per plants which were significantly different from those of the rest, followed by plants under the III conc. and then IV and V plants, as for the pea plants, those under the I conc. gave significantly higher numbers than those of other concentrations.

TABLE IV
THE EFFECTS OF FIVE LEVELS OF O_3 ON (A) THE MEAN RELATIVE GROWTH RATES FABA BEAN AND PEA PLANTS AND THE (B) MEAN RATES OF DECLINE DUE TO THE EFFECTS OF O3 CONC. II-V AS COMPARED TO THE CONTROL, (%), MEAN ± STANDARD DEVIATION FOR EACH TRAIT FOR EACH TREATMENT, MEANS WITH THE SAME LETTERS WERE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL USING THE LEAST SIGNIFICANT DIFFERENCE TEST (LSD0.05)

Plant / Ozone levels	(A) Faba bean	(A) Pea
1	1.31±1.16a	1.30±1.14a
2	1.27±0.87a	1.17±1.20b
3	1.28±0.83a	1.08±0.99bc
4	1.13±0.59b	1.05±0.63bc
5	1.06±0.60b	0.99±0.84c
LSD0.05	0.1	0.01
Mean	1.21a±0.80a	1.12±0.92b

	(B) Dry Weight (g)		
	Faba bean	Pea	LSD 0.05
Rate of decline	16.9a	9.9b	0.4

The results in Table V also showed that the mean seed weight of Faba bean and pea plants which reached 60.6 and 45.2 g, respectively. Faba bean plants gave higher values under I, II and III O_3 conc. as compared with those of plants under IV and V conc. Similarly, pea plants gave higher seed weights under I O_3 conc. Which were significantly different from those of the second and third conc. that were also significantly different from those of the IV and V plants. The results in Table V also showed significant differences in the reduction of seed weight due to O_3 conc. With higher values for pea plants due to the effects of O_3 II-V conc. as compared to the control treatment for dry seed weight.

TABLE V
THE EFFECTS OF O3 CONCENTRATIONS ON (A) THE NUMBER AND WEIGHT OF FABA BEAN AND PEA SEEDS AND (B) THE MEAN RATES OF DECLINE DUE TO THE EFFECTS OF O3 AS COMPARED TO THE CONTROL, (%), MEAN ± STANDARD DEVIATION FOR EACH TRAIT FOR EACH TREATMENT, MEANS WITH THE SAME LETTERS WERE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL USING THE LEAST SIGNIFICANT DIFFERENCE TEST (LSD0.05)

Plant / Ozone levels	(A) No. of Seeds: Faba bean	No. of Seeds: Pea	Weight of Seeds (g): Faba bean	Weight of Seeds (g): Pea
1	217.3±2.5a	200.0±10.0a	72.3±3.2a	66.0±4.0a
2	209.0±19.9a	186.0±11.6ab	69.3±6.7a	48.7±2.3b
3	181.7±7.6b	183.3±5.8ab	66.0±6.0b	45.7±2.1b
4	146.7±3.5c	173.0±6.1b	54.0±2.0b	40.0±3.0c
5	123.3±2.9d	103.3±15.3c	41.3±2.3c	25.4±2.2d
LSD0.05	14.3	18.9	8.1	5.1
Mean	175.6±37.8a	169.3±36.3±	60.6±12.5a	45.2±13.8b

(B)	No. of Seeds			Weight of Seeds (g)		
	Faba bean	Pea	LSD0.05	Faba Bean	Pea	LSD0.05
Rate of decline	24.0 a	19.2 a	5.88	20.3 b	39.5 a	4.77

IV. DISCUSSION

A number of studies reported that the exposure of plants to O_3, whether acute and chronic, leads to reductions in photosynthesis, respiration and changes in the distribution of photosynthates and thus causes changes in the morphology and biomass of the plants [17], [18]. They also stressed the difference in the response of plants to different O_3 concentrations depending on the type of plant and the phases of growth, and [19] pointed out that the growth rate is greater in crop plants than in trees, where the percentage of growth in crop plants reaches 30%, while in trees, it is only 13%.The growth rate was reduced much more in crop plants due to O_3 and this is consistent with the results of this study, where the exposure to O_3 caused a reduction in the vegetative traits of the studied plants (number of leaves and leaf area and plant height). In the current study the exposure of the plants to high and continuous conc. of O_3 caused significant decreases in the number and area of leaves that increase with the increase in the concentration of the gas depending on the site, and Faba bean plants showed higher sensitivity to the gas as compared to pea plants. As for the number of leaves, significant effects of O_3 appeared at the level of 61 ppp (University site), and these findings are consistent with those reported by [20], [21] on clover, beans and strawberries. As for the response of the leaf area to O_3, there were significant effects on the two plants at the level 77 ppm conc. (Al-manakh).

The visible injury depends on the concentration and duration of exposure of the plants to O3 in addition to the type of plant and the prevailing environmental conditions [22]-[25] attributed the visible injury to the loss of the affected cells to their water content as a result of the damage to the cell membrane and show the visible injury in the form of patches yellowish chlorosis due to the crushing of the chlorophyll followed by injury or death of cells and then followed by ulceration [6]. The study showed that these symptoms start at the beginning of the vegetative stage of growth and increases with the progress at the age of the plant where it begin with leaf yellowing then mottling with patches of red or white and a decrease in the edges of the leaves. In the current study, the effects of high ozone levels were reflected on the incidence of visual injuries to the plant. In low conc. of the gas, the number of sound leaves was high and the ratio of the affected area in the leaf was low and vice versa for the high conc. of the gas where the number of sound leaves was low and the infected area ratio is high, Faba bean plant gave significantly different higher performance than pea plants. The significant effects of the gas on the two plants appeared at the level of 61 ppp (University site).

Reference [26] reported that the concentration of ozone in the air lies between 40 - 60 ppp is sufficient to cause a reduction in biomass and grain yield. Also a number of studies [27], [28] confirmed that the biggest effects occurs late in the growth period. Reference [29] attributed the effects to the cumulative impacts of the gas on the exposed leaves, leading to the emergence of the signs of premature aging, which leads to reduced leaf area, number of leaves and thus lead to lower biomass of the plant. In the current study, the exposure of the plants to continuous high levels of O_3 led to significant decreases in the biomass of the leaves and plants, and the significant influence of the gas on the two plants appeared at the conc of 61 ppp (University site), and these findings are consistent with those of [30], [31].

The results also indicated that the exposure to high levels of ozone caused significant lowering in the seed yield in terms of the number and weight of seeds, and the decline increases with the increase in the level of gas. Pea plants were more sensitive to the gas than Faba bean plants. The significant influence of gas on number of seeds of Faba bean plants appeared at 71 ppp (King Fahd Road site) and for the pea plants at the level of 61 ppp (University site), and for the seed weight the significant influence on Faba bean appeared at the level of 77 ppp (Al- manakh site) and the pea at the level of 61 ppp (University site), the low response to gas of the two plants was consistent with the findings of [32] for resistant beans R123 as well as what was found by [33] on wheat plants where the significant influence of the gas on the relative growth rate of Faba bean appeared at 77 ppp (Al- manakh site)and of pea plants appeared at 61 ppp (University site) which agreed with those recorded by [34] on spring wheat plants.

It appeared from this study that the exposure of Faba bean and pea plants to different levels of ozone gas in the air leads harmful and negative effects on the morphology, growth and production of both plants although these effects vary according to the degree of exposure to the gas. Comparing the rates of decline of the traits studied due to the II-V effects with that of the control it was noted that Faba bean plants has shown higher sensitivity to the gas for leaf area , number of leaves per plant and the zero and third degree injury, while the pea plants showed higher sensitivity to the gas at the one degree injury, the relative growth rate and weight of the seeds.

V. Recommendations

Based on the findings of the study, the most important recommendations include:

First: It is possible to use the plants under study as vital indicators to denote the O_3 pollution.

Second: There is an urgent need for the formulation of laws and legislations to reduce the emission of polluting gases in the city of Riyadh, and ask the institutions producing air pollutants, fixed and mobile, to reduce them when they exceed the allowable limit, and the establishment of a body concerned with the environ-mental matters to reduce pollution and develop an integrated program to achieve this goal.

Third: Increasing the green areas within cities limits and around the sources of pollution and establishment of green belts to reduce pollutants and their effects.

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