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GROWTH, PHYSIOLOGICAL AND ANATOMICAL TRAITS OF LUPINE PLANTS AS AFFECTED BY SEWAGE SLUDGE AND SEWAGE WATER APPLICATION

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ABSTRACT: Two pot experiments were carried out during the two winter successive seasons of 2003/2004 and 2004/2005 in the wire-house of Agric. Bot. and Plant Pathology Dept., Fac. Agric., Zagazig University, to investigate the effect of sewage sludge application, sewage water irrigation and their interactions on growth characters, chlorophyll content, enzymes activities, yield and its components, seed chemical composition and organs structure of lupine plants cv. Giza 1.

The obtained results indicated that, application of sewage sludge at the rate of 2 % and/or the recommended rate of NPK significantly increased plant height, leaf area, dry weight of different plant parts, chlorophyll a, b and carotenoids in leaf tissues as well as total carbohydrates, total sugars and total protein in seeds of lupine plants. Also, both seeds weight and number of seeds per plant, 100-seeds weight, and P content in seeds were increased, while application of recommended NPK increased K content in seeds. On the other hand, catalase and peroxidase activities were significantly increased up to 1 % sewage sludge, while sewage sludge application at 2 % significantly decreased it.

Irrigation lupine plants with sewage water significantly affected leaf area, stem and leaves dry weight/plant, chlorophyll a and b in leaf tissues, protein and nitrogen content in seeds. While, it did not significantly affect plant height, root dry weight, carotenoids content in leaf tissues, catalase and peroxidase activity in leaves, total carbohydrate, yield and its components and K content in seeds.

The most effective interaction treatment for increasing plant height, leaf area, dry weight of different plant parts, total

carbohydrates, total sugars, total protein in seeds, yield and its components was application of 2 % sewage sludge + irrigation with 100 % sewage water. Catalase and peroxidase activities were at maximum values with the interaction between 1 % sewage sludge + 100 % sewage water.

Application of 2 % sewage sludge or irrigation with 100 % sewage water increased Cr, Cd, Ni and Pb in lupine seeds, While application of sewage sludge increased the thickness of blade, midveinal bundle, palisade tissue and spongy tissue of leaves. On the other hand, application of sewage sludge increased number of both cortical layer and cortex thickness of stem.

Key words: *Lupinus termis* F, sewage sludge, NPK, sewage water, heavy metals, morphology, physiology, anatomy.

INTRODUCTION

Lupinus termis Forsk (Egyptian lupine) has been known and practiced in Egypt as early as 2000 years before Christ. The name of the species (termis) is an arabic name. The lupine is important winter pulse crop, used mainly as a green manure in the light soil. Lupine crop is a good source of high quality protein, oil, and forage as well as ornamentals and other uses.

The sources of toxic amounts of trace elements in soil are mainly due to using of sewage sludge in agriculture and intensive fertilization. Whereas, commercial fertilizers may contain small amounts of trace elements as impurities. Heavy metals are likely to cause toxicity to plants in soils treated with large amounts of domestic sludge for a number of years (Nadia, 1997).

Sewage sludge contains more than 50 % of its weight organic matter, humic acid and fulvic acid represent the most important constituents in this organic matter since they form organo-metal complexes. Sewage sludge contains macro-nutrients; *i.e.*, N, P, K, micronutrients and heavy metals; *i.e.*, Fe, Zn, Mn, Cu, Pb, Ni, and Cd (El-Said, 1987).

Application of sewage sludge to agriculture soils increased plant height, number of leaves/plant and leaf area (Eleiwa *et al.*, 1996 on faba bean), dry weight (Shata *et al.*, 1990 on Egyptian clover).

photosynthetic pigments (Abdel-Sabour and Abo EL-Seoud, 1996 on sesame), Activity of catalase and peroxidase (Chakrabarti and Chakrabarti 1988 on wheat and Jiang, 1996 on maize and Abdorhim *et al.*, 2004 on wheat), yield (El-Sokkary and El-Keiy, 1989 on alfalfa and wheat; Park *et al.*, 1991 on barley and soybean and Derar and Eid, 1996 on wheat), and increased levels of N, P and K in grain (Mashaly *et al.*, 1993 on bean and Derar and Eid 1996 on wheat), also application of sewage water to agriculture soil increased the activity of catalase and peroxidase (Chakrabarti and Chakrabarti 1989 on cotton crop), and increased yield of maize (Kutera and Czyzyk, 1992).

Addition of mineral N + P stimulated plant height of lupine plants (Mohamed, 1985); increased plant height, leaf surface area, number of pods, 1000-seeds weight and yields of green manure green gram (Sardana and Verma 1987). The highest values of total number of branches and pods per plant, 100-seed weight and seed yield/feddan as well as N content in seeds of lupine plants were obtained from using NPK in combination compared to other treatments (El-Far *et al.*, 2001).

Water is considered as the most important agent for all types of life. Water quality is generally described through a set of variables relating to physicochemical and biological properties.

In Egypt, the valuable limited water resources necessitate, the refuse of agricultural drainage water and sludge water in irrigation to meet the future agricultural expansion and development needs specially in sandy soils.

Therefore, the aim of this work was to study the effect of sewage sludge application and sewage water irrigation on growth, physiological and anatomical traits of lupine plants under Egyptian conditions.

MATERIALS AND METHODS

This work was carried out during the two winter successive seasons of 2003/2004 and 2004/2005 under wire-house conditions at the Experimental Farm, Faculty of Agriculture, Zagazig University.

Sandy soil used in this experiment was collected from Abou-Hammad city, Sharkia

Governorate, the mechanical and chemical analyses of the used soil carried out according to Black (1965) are illustrated in Table 1. The soil distributed in plastic pots of 40 cm inner diameter (upper and lower diameter) and 45 cm height filled with 20 kg soil.

Seeds of lupine cv. Giza 1 were obtained from the Legume Res. Dept., Field Crops Res. Inst., Agric. Res. Center, Ministry of Agric., Giza, Egypt. Fifteen seeds were sown in each pot on 1st November in both seasons after inoculation with root nodules bacteria (*Rhizobium leguminosarum*), at 25 days from sowing they were thinned to leave ten uniformity plants per pot.

Sewage sludge was taken from the waste water treatment plant at Serabium city, Ismaillia Governorate, Egypt. Characteristics of sewage sludge are presented in Table 1.

Sewage water samples were collected from waste water treatment station at Zagazig city in special plastic containers (25 L capacity) and taken immediately to site of pots to be used for irrigation of lupine plants at the three water regimes; *i.e.*, 100 % tap water as control, 50 % tap water + 50 %

Table 1. Physiological and chemical properties of soil, sewage sludge, sewage water and tap water used in experiment

Parameters	Soil	Sewage sludge	Sewage water	Tap water
Mechanical analysis:				
Sand %	83	-	-	-
Silt %	11	-	-	-
Clay %	6	-	-	-
Texture:	Sandy	-	-	-
Chemical analysis:				
E.C (dS/m)	0.87	0.760	2.80	0.93
pH	7.36	7.480	8.01	7.14
Organic matter %	0.09	31.18	1.07	0.15
N (ppm)	11.20	25.180	19.56	2.54
$NaHCO_3$ extractable P mg/kg	3.10	13.250	7.15	1.68
NH_4OAC- extractable K mg/kg	20.10	45.200	31.34	0.27
DTPA-extractable C mg/kg:				
Cr (ppm)	0.007	0.029	0.018	0.012
Pb (ppm)	0.017	0.000	0.027	0.159
Cd (ppm)	0.025	0.004	0.025	0.067
Ni (ppm)	0.378	0.047	0.388	0.428

sewage water and 100 % sewage water. Characteristics of sewage water and tap water are presented in Table 1.

The experiment included 15 treatments which were the combination between three rates of sewage sludge and NPK recommended plus control (control, NPK recommended, 0.5 %, 1 % and 2 % sewage sludge rates) and three sewage water irrigation (100 % T.W., 50 % T.W. + 50 % S.W. and 100 % S.W.). These treatments were arranged in randomized complete block design with three replications. Each treatment involved six pots which divided to three pots for measuring plant growth and physiological characters and three pots for yield and yield components of lupine plants.

The recommended NPK rate was added in the form of urea (46.5 % N) at rate of 40 kg/feddan (0.8 g/pot), calcium superphosphate (15.5 % P_2O_2) at rate of 200 kg/feddan (4 g/pot) and potassium sulphate (48 % K_2O) at rate of 50 kg/feddan (1 g/pot).

All amount of P, half amount of K and third amount of N fertilizers were added to the soil before sowing, whereas, the rest amount of K fertilizer was added at 45 days from sowing and two thirds of N were divided into two portions and added at 30 and 60 days after sowing. The other normal agricultural treatments irrigation, best control, weed control, etc. of growing lupine plants were practiced.

DataRecorded

Plant Growth

Arandom sample of three pots was taken from each plot at 90 days after sowing and the following data were recorded: plant height (cm), leaf area (cm^2) and dry weight/plant (g) of different plant organs which dried at 70° C till constant weight.

Physiological Characters

Photosynthetic pigments

The photosynthetic pigments were extracted from the second fresh leaf from the plant tip of each treatment using pure acetone according to the method described by Fadeels (1962). The pigment concentration (chlorophyll a, b and carotenoids) were determined according to method described by Wettestein (1957).

Catalase and peroxidase activity

The methods described by Feinstein (1949) and by Purr

(1950) were used to determine catalse and peroxidase activity, respectively.

Seeds Constituents

Mineral nutrients (NPK)

Chemical determination of nitrogen, phosphorus and potassium content were carried out using the acid digest of the dry lupine seeds according to Piper (1947). Total nitrogen was estimated colourimetrically using Nisslar solution (Naguib, 1963), total phosphorus was determined colourimetrically as described by Murphy and Riley (1962). In addition, total potassium estimation was carried out using Flamephotometer as mentioned by Brown and Lilleland (1946).

Carbohydrate fractions and sugars and total protein

Carbohydrate fraction was determined in the dried samples of seeds of all treatments photometrically according to the method described by Bernfeld (1955) and Miller (1959). Total protein (%) was determined by multiplying total nitrogen × 6.25.

Heavy metals in seeds

Heavy metals; *i.e.*, Ni, Pb, Cd and Cr were determined with an atomic absorption apparatus (Unicam Sp 1900) atomic absorption spectrophotometer.

Yield and its Components

Dry pods of each pot were harvested at proper maturity stage then counted and weighed in each pot and the following parameters were calculated: number of seeds/plant, weight of seeds/plant and 100-seeds weight.

Anatomical Traits

The anatomical studies were carried out only in the second season to follow the changes occurring in Egyptian lupine plant as affected by sewage sludge and sewage water application. Samples were taken from the first basal node of stem, the second leaf tip and the main root after 55 days from sowing according to the methods of Johanson (1940) and the following data were recorded.

Root structure

Root diameter, pith diameter, phloem thickness, secondary tissue thickness, xylem and pith thickness and periderm thickness.

Stem structure

Stem diameter, pith diameter, epidermis thickness, tissue outside pith cavity, number of cortical layers and cortex thickness.

Leaf structure

Upper epidermis thickness, lower epidermis thickness, midveinal bundle thickness, palisade tissue thickness, spongy tissue thickness and blade thickness.

Statistical analysis

All the data were subjected to statistical analysis of variance according to Snedecor and Cochran (1982). Means separation was done by L.S.D. at 0.05 and 0.01 levels of probability.

RESULTS AND DISCUSSION

Plant Growth

Morphological Characters

Results in Table 2 show that application of sewage sludge or NPK at recommended rate significantly increased plant height and leaf area compared to control. The highest plant height and maximum leaf area were recorded with 1 %, 2 % sewage sludge or NPK recommended. Adding sewage water irrigation to lupine plants did not show any significant effect on plant height, but it significantly affected leaf area. Sewage sludge at 2 % gave the greatest leaf area compared to the other sewage water treatments. The interaction between different treatments did not reflect any significant effect on plant height and leaf area.

Since sand soil had low organic matter and low mineral nutrients as shown in Table 1, sewage sludge can improve its content of organic matter, and this in turn led to improve soil properties such as soil water holding capacity, soil fertility and increase mineral availability and this in turn increase plant growth parameters.

These results are in agreement with those reported by Eleiwa *et al.*, 1996 on faba bean, regarding plant height, and leaf area/plant. They found that application of sewage sludge to faba bean plants increase plant height and number of leaves/plant. Also, Mohamad (1985) on lupine, Sardana and Verma (1987) on green gram and El-Far *et al.* (2001) on lupine who found that NPK increased plant height, leaf area and total number of branches.

Dry weight

Data in Table 3 reveal that adding sewage sludge significantly increased the dry weight of different plant parts; *i.e.*, roots, stems and leaves in comparison with control. Also, application of

Table 2. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on plant height and leaf area of lupine plants at 90 days after sowing during seasons of 2003/2004 and 2004/2005

Characters	Plant height (cm)								Leaf area (cm^2)							
	1st season (2003/2004)				2nd season (2004/2005)				1st season (2003/2004)				2nd season (2004/2005)			
Treatments (I) / (A)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
Control	48.60	44.30	45.30	46.11	55.60	51.66	52.33	53.22	13.92	13.98	14.01	13.97	13.15	13.70	14.12	13.66
Mineral nutrients (NPK)	52.30	50.00	52.30	51.55	62.33	61.00	60.60	61.33	18.40	18.54	19.12	18.69	19.50	19.79	19.36	19.55
0.5 % sewage sludge	47.00	48.60	48.30	48.00	59.30	58.00	58.30	58.55	15.01	16.21	16.13	15.78	15.47	15.54	16.77	15.92
1 % sewage sludge	49.00	49.60	50.60	49.77	60.30	62.30	60 30	61.00	18.97	19.89	19.89	19.58	20.03	19.76	21.54	20.44
2 % sewage sludge	59.60	61.30	60.60	60.66	69.60	71.60	74.00	71.77	20.04	19.97	20.26	20.09	21.45	21.94	22.78	22.05
Mean	51.33	50.80	51.53	-	61.46	60.93	61.13	-	17.27	17.72	17.88	-	17.92	18.14	18.91	-
L.S.D. for	(A)	(I)	(A×I)		(A)	(I)	(A×I)		(A)	(I)	(A×I)		(A)	(I)	(A×I)	
	4.81**	N.S.	N.S.		5.39**	N.S.	N.S.		0.65**	0.50**	N.S.		1.36**	0.77*	N.S.	

T.W: Tap water ; S.W: Sewage water ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

Table 3. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on roots, stems and leaves dry weight of lupine plants at 90 days after sowing during seasons of 2003/2004 and 2004/2005

Characters	Root dry weight (g)				Stems dry weight (g)				Leave dry weight (g)			
	1st season (2003/2004)											
Treatments (I) / (A)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean
Control	1.78	1.52	1.58	1.62	5.09	5.87	6.11	5.69	3.86	4.53	4.32	4.23
Mineral nutrients (NPK)	1.67	1.97	1.98	1.87	7.16	7.39	6.21	6.92	6.37	5.51	4.68	5.52
0.5 % sewage sludge	2.32	2.06	2.21	2.20	4.52	5.97	4.05	4.85	5.33	5.59	4.49	5.12
1 % sewage sludge	2.37	2.28	2.00	2.21	6.22	7.28	6.06	6.52	5.67	7.63	7.95	7.08
2 % sewage sludge	2.45	2.33	2.66	2.42	9.19	10.56	6.91	8.88	10.26	14.00	8.24	10.84
Mean	2.08	2.03	2.08	-	6.43	7.41	5.87	-	6.30	7.44	5.94	-
L.S.D. for	(A) 0.49*	(I) N.S.		(A×I) N.S.	(A) 0.75**	(I) 0.58**		(A×I) 1.31**	(A) 1.16**	(I) 0.90**		(A×I) 2.01**
	2nd season (2004/2005)											
Control	1.81	1.55	1.59	1.65	4.16	5.98	5.25	5.13	5.52	5.97	5.18	5.55
Mineral nutrients (NPK)	1.65	1.95	1.95	1.85	7.18	7.34	6.13	6.88	8.03	6.91	6.78	7.24
0.5 % sewage sludge	2.36	2.37	2.73	2.49	4.37	5.12	4.00	4.50	6.15	5.97	5.63	5.91
1 % sewage sludge	2.40	2.27	1.91	2.19	6.12	7.39	6.18	6.56	6.82	6.39	8.25	7.15
2 % sewage sludge	2.19	2.42	2.60	2.40	9.28	10.44	5.93	8.88	11.04	10.80	9.06	10.30
Mean	2.08	2.11	2.16	-	6.22	7.25	5.70	-	7.51	7.21	6.98	-
L.S.D. for	(A) 0.53**	(I) N.S.		(A×I) N.S.	(A) 0.34**	(I) 0.26**		(A×I) 0.59**	(A) 0.59**	(I) 0.46**		(A×I) 1.03**

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

NPK gave the same effect of sewage sludge. Regarding sewage water irrigation, it is clear that irrigation of lupine plants with sewage water significantly increased stem and leaves dry weight, but did not significantly affect root dry weight in both seasons. The interaction between the two factors significantly affected both stem and leaves dry weight, but did not reflect significant effect on root dry weight. The best interaction treatment was application of 2 % sewage sludge + irrigation with 100 % sewage water. The increment in dry weight of different plant organs of lupine plants may be due to the increase in plant growth parameters resulted from adding sewage sludge (Table, 3).

Nitrogen is an important constituent of protoplasm and other biological agents (Mengel and Kirkly, 1978). In addition, Gardener *et al* (1985) declared that P is an essential component of the energy transfer compounds, genetic information system, cell membranes and phosphoproteins. Obtained results are in accordance with those reported by Shata *et al.* (1990) on Egyptian clover and Eleiwa *et al.* (1996) on faba bean. They reported that adding sewage sludge to the abovementioned plants increased dry weight/plant.

Plant Chemical Composition

Photosynthetic pigments

Obtained data in Table 4 reflect that, increasing sewage sludge application significantly increased chlorophyll a, b and carotenoids concentration in leaf tissues. Application of NPK recommended rate increased the abovementioned photosynthetic pigments compared to control. Irrigation of lupine plants with sewage water significantly increased chlorophyll a and b concentration, but did not show significant effect on carotenoids in both seasons of study. There were significant interaction effect between the two studied factors regarding chlorophyll a, b and carotenoid in the two seasons, except chlorophyll a in the first season and carotenoid in the second one.

The favorable effect of manure application on enhancing leaves tissues pigments was reported by Hseih and Hsu (1993) who reported that use of manure increased soil acidity, organic matter, available P, extractable Mg, Mn and Zn and this in turn may affect leaves pigments. These

Table 4. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on chlorophyll a, b and carotenoids of lupine leaves at 90 days after sowing during seasons of 2003/2004 and 2004/2005

Characters	Chlorophyll (a) (mg/g F.W.)				Chlorophyll (b) (mg/g F.W.)				Carotenoids (mg/g F.W.)			
Treatments (I) / (A)	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
					1[st] season (2003/2004)							
Control	1.76	1.76	1.64	1.71	0.50	0.46	0.41	0.46	0.98	0.95	0.99	0.97
Mineral nutrients (NPK)	2.97	3.02	2.94	2.97	0.69	0.73	0.68	0.70	1.06	1.10	1.02	1.06
0.5 % sewage sludge	2.96	2.97	2.91	2.94	0.60	0.63	0.70	0.64	0.83	0.88	0.90	0.87
1 % sewage sludge	2.94	3.05	2.96	2.98	0.77	0.75	0.70	0.74	1.30	1.33	1.25	1.29
2 % sewage sludge	3.01	3.05	2.99	3.02	0.87	0.87	0.79	0.84	1.21	1.24	1.28	1.24
Mean	2.72	2.77	2.68	-	0.69	0.69	0.66	-	1.08	1.10	1.09	-
L.S.D. for	(A) 0.07**	(I) 0.05**		(A×I) N.S	(A) 0.04**	(I) 0.02*		(A×I) 0.07**	(A) 0.04**	(I) N.S.		(A×I) 0.05*
					2[nd] season (2004/2005)							
Control	1.22	0.78	0.81	0.94	0.23	0.19	0.27	0.23	1.22	0.83	0.57	0.87
Mineral nutrients (NPK)	0.89	1.19	1.07	1.05	0.28	0.28	0.16	0.24	0.94	1.22	1.01	1.05
0.5 % sewage sludge	0.88	0.67	0.65	0.73	0.13	0.10	0.17	0.13	0.83	0.63	0.70	0.72
1 % sewage sludge	1.14	1.06	1.12	1.10	0.27	0.34	0.34	0.31	1.20	1.11	1.65	1.32
2 % sewage sludge	1.66	0.61	1.30	1.19	0.44	0.21	0.35	0.33	1.65	0.59	1.66	1.30
Mean	1.16	0.86	0.99	-	0.27	0.22	0.26	-	1.16	0.87	1.11	-
L.S.D. for	(A) 0.32**	(I) 0.25*		(A×I) 0.56**	(A) 0.06**	(I) 0.03*		(A×I) 0.10**	(A) 0.40*	(I) N.S.		(A×I) N.S.

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability. ; F.W: Fresh weight.

results agree with those reported by Abdel-Sabour and Abo El-Seoud (1996) who found that organic-waste compost enhanced photosynthetic pigments of sesame.

Catalase and peroxidase activity

Data in Table 5 show that, sewage sludge at 1 % was the best treatment for increasing the activity of catalase and peroxidase in the two seasons, except catalase in the second one. Generally application of sewage sludge at different used rates or the recommended dose of NPK significantly increased the activity of the two mentioned previously enzymes. On the other hand, irrigation of lupine plants with sewage water did not show significant effect on enzymes activity on the two seasons. There were no significant interaction effect on catalase and peroxidase activities in leaves of lupine plants in both studied seasons. The most effective interaction treatment was adding 1 % sewage sludge + irrigation with 100 % sewage water.

These results are in agreement with those reported by Chakrabarti and Chakrabarti (1988) on wheat, Jiang and Jiang (1996) on maize and Abdorhim *et al.*, (2004) on wheat. They found that sewage sludge increased the activity of catalase and peroxidase. Irrigation of cotton crop with 100 and 66 % sewage water increased the activity of catalase and peroxidase (Chakrabarti and Chakrabarti, 1989).

Seed Chemical Constituents

Total carbohydrate, sugars and protein

Data in Table 6 show that, the content of total carbohydrate, total sugars and total protein in lupine seeds were significantly affected by both sewage sludge and NPK application. The most favorable treatment for increasing the previously mentioned traits was application of 2 % sewage sludge. Application of sewage water irrigation significantly increased protein and sugar contents in seeds of lupine in both seasons, except sugar content in the first season. On the other hand, carbohydrate content was not affected by sewage water irrigation in the two seasons. The interaction between the two studied factors did not reflect any significant effect on carbohydrate and sugars. But it had significant effect on protein content in lupine seeds in the two

Table 5. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on catalase and peroxidase activity of lupine leaves at 90 days after sowing during seasons of 2003/2004 and 2004/2005

Characters	Catalase (µm/g/min)							
	1st season (2003/2004)				2nd season (2004/2005)			
Treatments (A) \ (I)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
Control	140.00	139.33	140.33	139.89	132.33	132.33	133.67	132.78
Mineral nutrients (NPK)	176.33	176.33	179.67	177.44	185.67	187.00	185.67	186.11
0.5 % sewage sludge	166.67	166.00	166.33	166.33	165.33	166.33	166.67	166.11
1 % sewage sludge	181.67	182.00	182.33	182.00	184.67	184.33	184.67	184.55
2 % sewage sludge	174.67	175.67	176.33	175.55	195.67	193.33	194.00	194.33
Mean	167.87	167.87	169.00	-	172.73	172.67	172.93	-
L.S.D. for	(A) 5.11**	(I) N.S.		(A×I) N.S.	(A) 4.50**	(I) N.S.		(A×I) N.S.
	Peroxidase (µm/g/min)							
Control	40.00	45.00	43.33	42.78	51.00	50.33	50.67	50.67
Mineral nutrients (NPK)	65.33	64.00	65.33	64.89	67.00	66.00	66.00	66.33
0.5 % sewage sludge	58.00	56.00	56.33	56.78	49.00	51.00	50.33	50.11
1 % sewage sludge	67.33	68.00	68.00	67.78	75.00	75.67	76.33	75.67
2 % sewage sludge	55.00	54.67	55.00	54.89	64.33	66.33	66.33	65.67
Mean	57.13	57.53	57.60	-	61.27	61.87	61.93	-
L.S.D. for	(A) 3.89**	(I) N.S.		(A×I) N.S.	(A) 3.22**	(I) N.S.		(A×I) N.S.

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability. ; µm: Micromole

Table 6. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on total carbohydrate, sugars and protein content of lupine seeds during seasons of 2003/2004 and 2004/2005

Characters	Total carbohydrate content (%)				Total sugar content (%)				Protein content (%)			
					1st season (2003/2004)							
Treatments (I) / (A)	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean
Control	24.00	24.33	24.33	24.22	9.87	10.70	10.35	10.31	25.20	23.54	23.81	24.18
Mineral nutrients (NPK)	26.33	26.00	24.33	25.55	14.25	14.49	14.51	14.42	24.83	25.81	25.48	25.37
0.5 % sewage sludge	23.67	23.67	23.67	23.67	10.80	12.25	12.08	11.71	23.89	24.39	25.35	24.54
1 % sewage sludge	24.67	27.33	26.33	26.11	12.71	13.16	13.92	13.26	26.33	29.99	29.47	28.60
2 % sewage sludge	25.33	29.00	28.67	27.67	15.88	15.36	16.74	15.99	29.29	31.29	32.54	31.04
Mean	24.80	26.07	25.47	-	12.70	13.19	13.52	-	25.91	27.00	27.32	-
L.S.D. for	(A) 2.08**	(I) N.S.		(A×I) N.S.	(A) 1.10**	(I) 0.62*		(A×I) N.S.	(A) 0.47**	(I) 0.36**		(A×I) 0.81**
					2nd season (2004/2005)							
Control	25.00	23.67	24.00	24.22	10.82	12.15	11.90	11.62	25.17	25.79	26.92	25.95
Mineral nutrients (NPK)	27.67	28.00	29.00	28.22	15.17	15.68	16.23	15.69	28.79	33.37	38.37	33.51
0.5 % sewage sludge	24.67	23.67	24.33	24.22	12.28	13.24	12.30	12.61	31.08	31.02	32.33	31.47
1 % sewage sludge	26.67	29.67	29.33	28.55	15.63	15.16	16.29	15.69	32.87	34.16	35.06	34.03
2 % sewage sludge	28.67	28.00	29.00	28.55	16.39	16.36	16.73	16.49	35.71	40.21	41.17	38.36
Mean	26.53	26.60	27.13	-	14.06	14.52	14.69	-	30.32	32.91	34.77	-
L.S.D. for	(A) 2.17**	(I) N.S.		(A×I) N.S.	(A) 1.10**	(I) N.S.		(A×I) N.S.	(A) 0.45**	(I) 0.35**		(A×I) 0.78**

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

seasons. The best interaction treatment was adding 2 % sewage sludge + 100 % sewage water irrigation.

Content of N, P and K

Adding sewage sludge to lupine plants significantly increased N and P contents in seeds, while application of NPK significantly increased K content in seeds in both seasons. The best results were obtained with 2 % sewage sludge followed by NPK mineral. Irrigation lupine plants with sewage water significantly increased N content in seeds, but did not affect P and K content in seeds. The interaction between the two studied factors did not reflect significant effect in this respect (Table. 7). Sewage sludge application increased levels of N, P and K in grain (Mashaly *et al.*, 1993 on beans; Derar and Eid, 1996 on wheat).

Heavy metals in seeds

Data in Table 8 illustrate that increasing sewage sludge application rate increased Cr, Cd, Ni and Pb content in lupine seeds, while application of mineral NPK did not increase it, except Ni content which increased by NPK recommended dose application compared to control. The same data in Table 8 show that irrigation of lupine plants with sewage water increased the four determined heavy metals; *i.e.*, Cr, Cd, Ni and Pb in seeds of lupine plants compared to irrigation with tap water. The highest seed contents of heavy metals were recorded with 2 % sewage sludge or irrigation with 100 % sewage water. Also it is clear that, the interaction between the two tested factors increased the heavy metals accumulation in lupine seeds up to the highest used levels from the two factors. The highest Cr, Cd, Ni and Pb contents in seeds of lupine plants were recorded when plants were fertilized with 2 % sewage sludge + irrigation with 100 % sewage water.

These results are similar to those obtained by Chaney *et al.*, (1978) on lettuce plants. It could be concluded that there is no risk factor on human health from bioaccumulation of heavy metals in lupine seeds produced from lupine plants fertilized with 2 % sewage sludge in sandy soil. Content of Cd and Pb in lupine seeds are still far below the background level and did not reach the admissible residual contents as shown in Table 8. Since, recommended limits for heavy

Table 7. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on nitrogen, phosphorus, and potassium content of lupine seeds during seasons of 2003/2004 and 2004/2005

Characters	Nitrogen content (%)				Phosphorus content (%)				Potassium content (%)			
	1st season (2003/2004)											
Treatments (I) / (A)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
Control	4.03	3.76	3.80	3.86	0.46	0.47	0.48	0.47	1.94	2.16	1.92	2.00
Mineral nutrients (NPK)	3.97	4.12	4.07	4.07	0.79	0.90	0.89	0.86	4.16	4.11	4.16	4.14
0.5 % sewage sludge	3.83	3.90	4.05	3.42	0.82	0.82	0.80	0.81	2.26	2.15	2.13	2.18
1 % sewage sludge	4.21	4.79	4.71	4.57	0.88	0.89	0.86	0.88	3.86	3.62	3.38	3.62
2 % sewage sludge	4.68	5.00	5.20	4.96	0.97	1.02	1.06	1.02	3.18	3.62	3.18	3.33
Mean	4.14	4.32	4.37	-	0.79	0.82	0.82	-	3.08	3.13	2.95	-
L.S.D. for	(A) 0.07**	(I) 0.05**		(A×I) 0.12**	(A) 0.06**	(I) N.S.		(A×I) N.S.	(A) 0.47**	(I) N.S.		(A×I) N.S.
	2nd season (2004/2005)											
Control	4.02	4.12	4.31	4.15	0.54	0.54	0.58	0.55	2.11	2.05	2.41	2.19
Mineral nutrients (NPK)	4.61	5.34	6.14	5.36	0.89	0.91	0.98	0.93	3.43	3.38	3.72	3.51
0.5 % sewage sludge	4.97	4.96	5.17	5.04	0.85	0.86	0.88	0.86	1.87	2.02	2.14	2.01
1 % sewage sludge	5.26	5.47	5.61	5.45	0.98	1.05	1.08	1.04	2.05	2.31	1.69	2.01
2 % sewage sludge	5.71	6.43	6.58	6.24	1.00	1.07	1.09	1.05	3.57	3.48	3.52	3.52
Mean	4.91	5.27	5.56	-	0.85	0.89	0.92	-	2.61	2.65	2.63	-
L.S.D. for	(A) 0.07**	(I) 0.05**		(A×I) 0.12**	(A) 0.06**	(I) 0.04**		(A×I) N.S.	(A) 0.47**	(I) N.S.		(A×I) N.S.

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

Table 8. **Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on heavy metals accumulation of lupine seeds during the growing season of 2004/2005**

Characters	Chromium (Cr) (mg/kg)				Cadmium (Cd) (mg/kg)			
Treatments (I) / (A)	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W + 50 % S.W	100 % S.W	Mean
Control	0.000	0.000	0.095	0.032	0.024	0.030	0.035	0.030
Mineral nutrients (NPK)	0.016	0.048	0.065	0.043	0.026	0.033	0.077	0.045
0.5 % sewage sludge	0.029	0.101	0.122	0.084	0.038	0.042	0.060	0.047
1 % sewage sludge	0.041	0.073	0.090	0.068	0.054	0.081	0.088	0.074
2 % sewage sludge	0.122	0.162	0.403	0.229	0.071	0.090	0.090	0.084
Mean	0.042	0.077	0.155	-	0.043	0.055	0.070	-
	Nickel (Ni) (mg/kg)				Lead (Pb) (mg/kg)			
Control	0.040	0.041	0.030	0.037	0.000	0.043	0.075	0.039
Mineral nutrients (NPK)	0. 133	0.246	0.217	0.199	0.029	0.055	0.074	0.053
0.5 % sewage sludge	0.269	0.223	0.143	0.212	0.038	0.080	0.069	0.062
1 % sewage sludge	0.208	0.295	0.346	0.283	0.040	0.093	0.110	0.081
2 % sewage sludge	0.262	0.147	0.487	0.299	0.026	0.072	0.112	0.070
Mean	0.182	0.190	0.245	-	0.027	0.069	0.088	-

T.W: Tap water S.W: Sewage water.

Recommended limits for heavy metals content in foods mg kg-1 of grain according to ZEBS-BERICHT, (1/1979) as follow: 0.5 for Pb and 0.1 for Cd.

metals content in foods mg kg-1 of grain according to ZEBS-BERICHT (1/1979) as follows: 0.5 for Pb and 0.1 for Cd.

Yield and its Components

Data in Table 9 show that, fertilization of lupine plants with 2 % sewage sludge or NPK recommended dose significantly increased all studied yield parameters; *i.e.*, number and weight of seeds/plant as will as 100-seed weight in the two seasons. While, neither sewage water irrigation nor the interaction between the two factors show significant effect on yield and its components in both seasons.

The increments of yield resulted from application of sewage sludge may be due to their high contents of organic matter, high availability of nutrients, increased both nitrogen fixation, and rhizosphere microorganisms which release phytohormones substances lead to increase plant growth (Table, 2), and dry weight of different plant organs (Table, 3) and that in turn increase the yield and its components.

These results agree with those reported by El-Sokkary and El-Keiy (1989) on alfalfa, wheat, faba bean and soybean; Park *et al.* (1991) on barley and soybean and Derar and Eid (1996) on wheat who found that adding sewage sludge increased the yield and Kutera and Czyzyk (1992) on maize who found that irrigation with sewage water increased the yield. Also, Sardana and Verma (1987) on green gram and El-Far *et al.* (2001) on lupine who found that NPK increased 100-seed weight and seed yield.

Anatomical Traits

Root structure

Data presented in Table 10 and Fig. 1 indicate that all studied root structure parameters were significantly affected by sewage sludge application. except root diameter and secondary tissue thickness. It is clear from the same data that application of 2 % sewage sludge to lupine plants recorded the highest value of pith diameter and xylem and pith thickness. Irrigation lupine plants with tap water gave the maximum values of both root and pith diameter and the thickness of phloem, periderm, secondary tissues, xylem and pith of lupine plant root. The interaction between the two factors significantly affected all studied root structure parameters. except the thickness of

Table 9. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on yield components of lupine plants during seasons of 2003/2004 and 2004/2005

Characters	Seeds weight/plant (g)				Number of seeds/plant				100-seeds weight (g)			
Treatments (I) / (A)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
					1st season (2003/2004)							
Control	9.77	9.92	9.39	9.69	12.33	11.00	11.00	11.44	27.08	27.48	27.40	27.32
Mineral nutrients (NPK)	14.27	13.90	12.21	13.46	27.00	23.33	26.33	25.55	37.13	41.39	41.89	40.14
0.5 % sewage sludge	12.46	12.24	12.40	12.37	18.33	15.00	17.33	16.88	34.75	33.64	33.25	33.88
1 % sewage sludge	13.43	12.78	12.61	12.94	26.67	23.33	24.67	24.88	40.61	39.72	39.16	39.83
2 % sewage sludge	13.46	14.40	14.99	14.28	26.67	24.33	20.33	23.77	40.15	41.55	41.00	40.90
Mean	12.67	12.65	12.32	-	22.20	19.40	19.93	-	35.94	36.75	36.54	-
L.S.D. for	(A) 1.82**	(I) N.S.		(A×I) N.S.	(A) 7.21**	(I) N.S.		(A×I) N.S.	(A) 3.22**	(I) N.S.		(A×I) N.S.
					2nd season (2004/2005)							
Control	9.24	9.67	9.26	9.39	11.00	13.67	14.00	12.89	25.42	27.12	25.73	26.09
Mineral nutrients (NPK)	14.40	13.58	14.22	14.07	31.67	28.00	34.00	31.22	41.26	43.62	43.22	42.70
0.5 % sewage sludge	11.86	12.24	12.14	12.08	14.67	18.67	14.67	16.00	32.42	30.97	31.59	31.66
1 % sewage sludge	13.76	11.45	12.61	12.61	31.33	33.00	29.67	31.33	42.95	41.72	41.49	42.05
2 % sewage sludge	13.46	13.73	13.99	13.73	30.67	34.67	25.67	30.33	43.15	42.89	41.67	42.57
Mean	12.54	12.13	12.44	-	23.87	25.60	23.60	-	37.04	37.26	36.74	-
L.S.D. for	(A) 1.29**	(I) N.S.		(A×I) N.S.	(A) 9.28**	(I) N.S.		(A×I) N.S.	(A) 3.01**	(I) N.S.		(A×I) N.S.

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

Table 10. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on root structure of lupine plants at 55 days after sowing during season of 2004/2005

Treatments	Root structure											
	Root diameter (mm)				Pith diameter (mm)				Phloem thickness (mm)			
(A) \ (I)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
Control	1.58	1.58	1.57	1.57	0.52	0.37	0.18	0.35	0.28	0.29	0.31	0.29
Mineral nutrients (NPK)	1.71	1.26	1.50	1.49	0.34	0.36	0.39	0.36	0.31	0.24	0.27	0.27
0.5 % sewage sludge	1.66	1.35	1.39	1.46	0.48	0.38	0.29	0.38	0.22	0.29	0.24	0.25
1 % sewage sludge	1.42	1.50	1.31	1.41	0.29	0.32	0.43	0.34	0.30	0.34	0.26	0.30
2 % sewage sludge	1.52	1.51	1.66	1.56	0.43	0.36	0.66	0.48	0.29	0.24	0.26	0.26
Mean	1.58	1.44	1.48	-	0.41	0.36	0.39	-	0.28	0.28	0.27	-
L.S.D. for	(A) N.S.	(I) 0.10^{*}		(A×I) 0.23^{*}	(A) 0.04^{**}	(I) 0.03^{**}		(A×I) 0.07^{**}	(A) 0.04^{**}	(I) N.S.		(A×I) 0.07^{**}
	Secondary tissue thickness (mm)				Xylem and Pith thickness (mm)				Periderm thickness (mm)			
Control	1.38	1.33	1.25	1.32	1.00	0.99	0.94	0.98	0.27	0.27	0.32	0.29
Mineral nutrients (NPK)	1.42	1.00	1.08	1.16	1.11	0.76	0.81	0.89	0.38	0.26	0.42	0.35
0.5 % sewage sludge	1.27	1.04	1.14	1.15	1.06	0.75	0.90	0.90	0.46	0.31	0.25	0.34
1 % sewage sludge	1.39	1.22	1.00	1.20	0.80	0.87	0.75	0.80	0.28	0.29	0.31	0.29
2 % sewage sludge	1.27	1.26	1.30	1.28	0.98	1.02	1.04	1.01	0.25	0.23	0.37	0.28
Mean	1.35	1.17	1.15	-	0.99	0.88	0.88	-	0.33	0.27	0.33	-
L.S.D. for	(A) N.S.	(I) 0.14^{**}		(A×I) N.S.	(A) 0.14^{*}	(I) N.S.		(A×I) N.S.	(A) 0.06^{**}	(I) 0.04^{**}		(A×I) 0.10^{**}

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

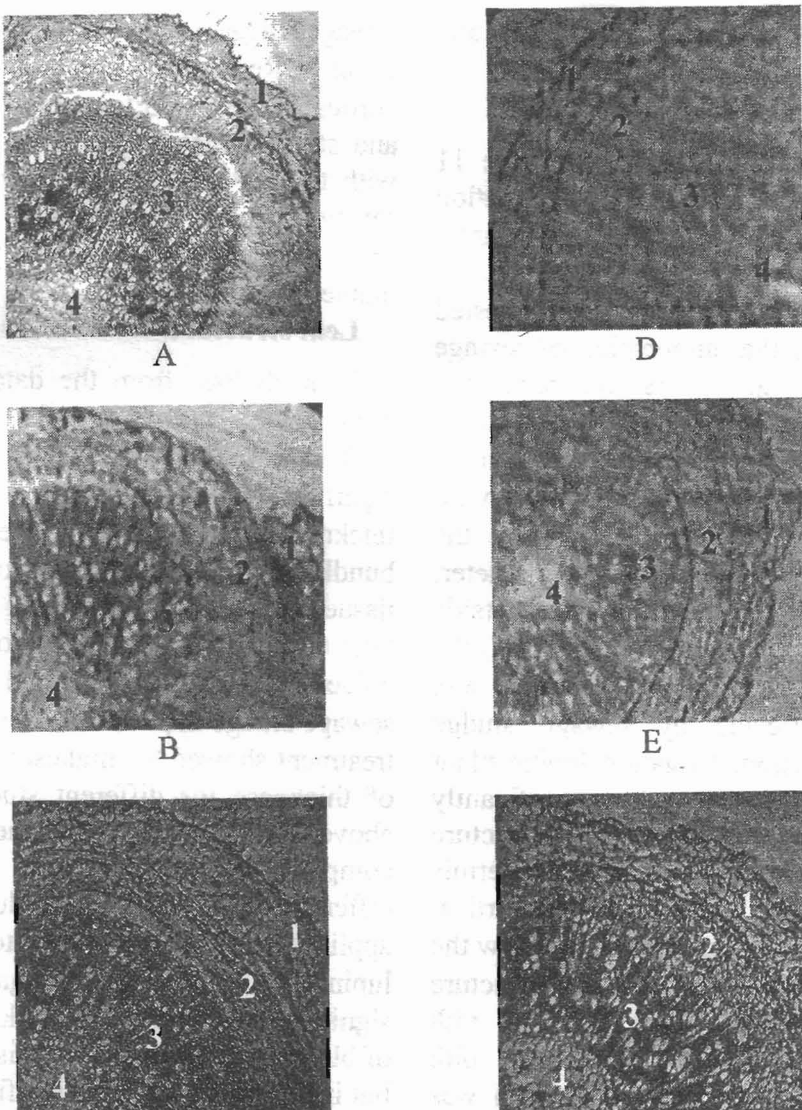

Fig. 1. Effect of sewage sludge, sewage water and their interactions on anatomical traits of root

A: Control- 100 % tap water; B: Control- 50 % tap water + 50 % sewage water; C: Control- 100 % sewage water; D: 2 % sewage sludge - 100 % tap water; E: 2 % sewage sludge - 50 % tap water + 50 % sewage water; F: 2 % sewage sludge - 100 % sewage water.

1: Periderm; 2: phloem; 3: Xylem; 4: Pith.

secondary tissue and xylem and pith of lupine plant root.

Stem structure

The obtained data in Table 11 and Fig. 2 indicate that application of sewage sludge significantly affected stem structure, except epidermis thickness. It is interested to note that application of sewage sludge at 2 % recorded the maximum value of both number of cortical layer and cortex thickness. Whereas, the untreated plants with sewage sludge (control) have the maximum values of stem diameter, pith diameter and tissue outside pith cavity. On the other hand, the epidermis thickness of stem was not affected by sewage sludge application. Irrigation lupine plant with sewage water significantly affected all studied stem structure parameters, except epidermis thickness and number of cortical layers. The best treatment show the highest values of stem structure parameters (tissue outside pith cavity, cortex thickness, pith diameter and stem diameter) was irrigation of lupine plants with tap water compared to the other irrigation treatments. Data in Table 11 show also that the most favorable interaction treatment for increasing stem structure studied parameters was application of 2 % sewage sludge + irrigation with tap water. Regarding number of cortical layers, cortex thickness and stem diameters was irrigation with tap water + control (without sewage sludge application) for tissue outside pith cavity and pith diameter.

Leaf structure

It is obvious from the data in Table 12 and Fig. 3 that application of sewage sludge significantly decreases the thickness of blade, midveinal bundle, palisade tissue and spongy tissue of leaves. While, the thickness of upper and lower epidermis was not affected by sewage sludge application. Control treatment showed the highest value of thickness for different studied abovementioned parameters compared to mineral NPK and different rates of sewage sludge application. Using sewage water in lupine plants irrigation significantly affected the thickness of blade, bundle and spongy tissue, but it did not reflect any significant effect on the thickness of both upper and lower epidermis and palisade tissue of leaves. The highest thickness in this respect was recorded with application lupine plants with 50 % tap water + 50 % sewage water. Data in

Table 11. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on stem structure of lupine plants at 55 days after sowing during season of 2004/2005

Treatments	Stem structure											
	Stem diameter (mm)				Pith diameter (mm)				Epidermis thickness (mm)			
(A) \ (I)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
Control	3.65	3.86	3.63	3.71	2.07	2.08	1.70	2.05	0.01	0.02	0.02	0.02
Mineral nutrients (NPK)	3.74	3.50	3.16	3.46	1.68	1.78	1.20	1.55	0.02	0.02	0.02	0.02
0.5 % sewage sludge	3.66	3.10	3.88	3.54	1.34	1.42	1.47	1.41	0.02	0.02	0.02	0.02
1 % sewage sludge	3.23	3.76	3.74	3.57	1.68	1.88	1.75	1.77	0.02	0.02	0.02	0.02
2 % sewage sludge	3.89	3.11	3.61	3.53	1.85	1.34	1.47	1.55	0.02	0.02	0.02	0.02
Mean	3.63	3.46	3.56	-	1.72	1.66	1.52	-	0.02	0.02	0.02	-
L.S.D. for	(A) 0.03**	(I) 0.02**	(A×I) 0.06**		(A) 0.04**	(I) 0.03**	(A×I) 0.07**		(A) N.S.	(I) N.S.	(A×I) N.S.	
	Tissue outside pith cavity (mm)				Number of cortical layers				Cortex thickness (mm)			
Control	1.32	1.15	0.94	1.14	7.60	9.80	9.60	9.00	0.28	0.31	0.29	0.29
Mineral nutrients (NPK)	1.03	0.92	1.01	0.98	11.00	9.80	8.40	9.73	0.34	0.26	0.24	0.28
0.5 % sewage sludge	1.19	0.84	1.19	1.07	9.60	9.20	9.50	9.43	0.33	0.26	0.26	0.28
1 % sewage sludge	0.71	0.32	0.31	0.88	9.00	9.00	9.60	9.20	0.29	0.29	0.29	0.29
2 % sewage sludge	1.05	0.90	0.93	0.96	12.2	8.60	11.80	10.87	0.42	0.28	0.42	0.37
Mean	1.06	0.96	1.00	-	9.88	9.28	9.78	-	0.33	0.28	0.30	-
L.S.D. for	(A) 0.03**	(I) 0.03**	(A×I) 0.06**		(A) 1.29**	(I) N.S.	(A×I) 2.24**		(A) 0.02**	(I) 0.02**	(A×I) 0.04**	

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

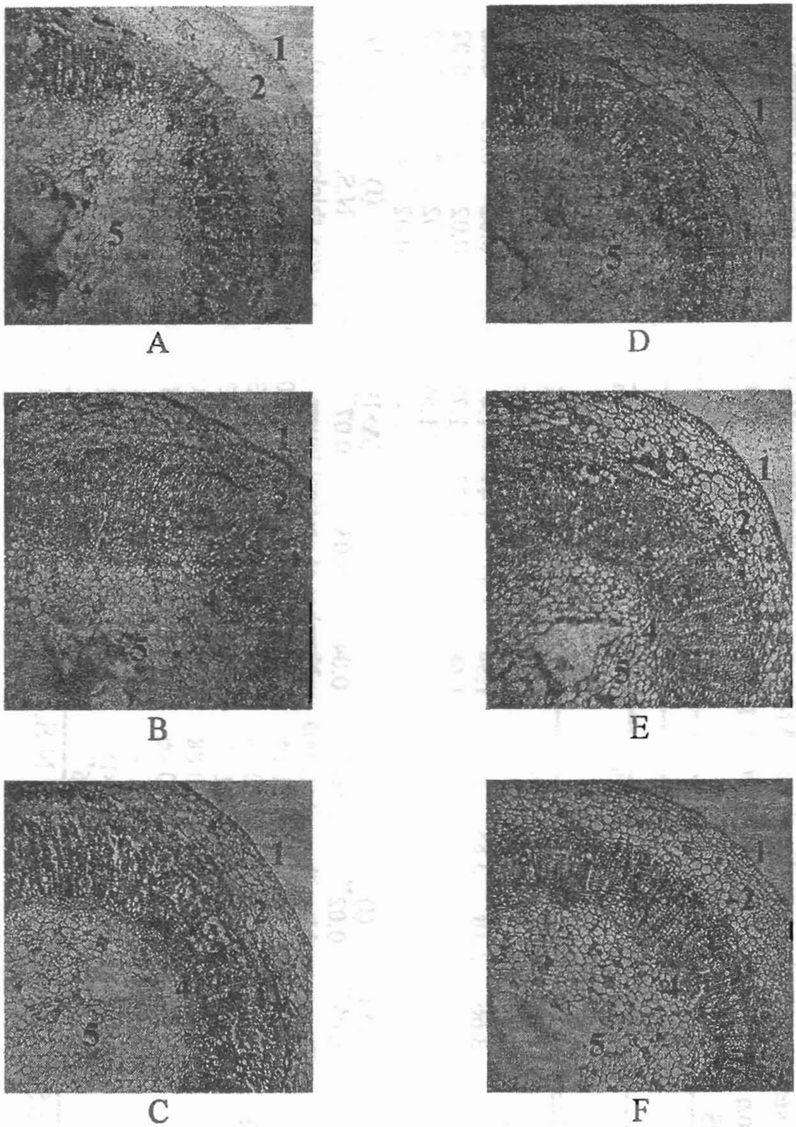

Fig. 2. Effect of sewage sludge, sewage water and their interactions on anatomical traits of stem

A: Control- 100 % tap water; B: Control- 50 % tap water + 50 % sewage water; C: Control- 100 % sewage water; D: 2 % sewage sludge - 100 % tap water; E: 2 % sewage sludge - 50 % tap water + 50 % sewage water; F: 2 % sewage sludge - 100 % sewage water.

1: Epidermis; 2: Cortex; 3: Phloem; 4: Xylem; 5: Pith.

Table 12. Effect of sewage sludge application (A), sewage water irrigation (I) and their interactions (A × I) on leaf structure of lupine plants at 55 days after sowing during season of 2004/2005

Treatments	Leaf structure											
	Upper epidermis thickness (mm)				Lower epidermis thickness (mm)				Midveinal bundle thickness (mm)			
(A) \ (I)	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean	100 % T.W	50 % T.W +50 % S.W	100 % S.W	Mean
Control	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.18	0.21	0.11	0.17
Mineral nutrients (NPK)	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.11	0.18	0.17	0.15
0.5 % sewage sludge	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.17	0.14	0.16	0.16
1 % sewage sludge	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.18	0.12	0.12	0.14
2 % sewage sludge	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.13	0.15	0.13	0.14
Mean	0.02	0.02	0.02	-	0.02	0.02	0.02	-	0.15	0.16	0.14	-
L.S.D. for	(A) N.S.	(I) N.S.		(A×I) 0.007^{**}	(A) N.S.	(I) N.S.		(A×I) N.S.	(A) 0.01^{**}	(I) 0.01^{**}		(A×I) 0.02^{**}
	Palisade tissue thickness (mm)				Spongy tissue thickness (mm)				Blade thickness (mm)			
Control	0.11	0.06	0.16	0.11	0.11	0.07	0.13	0.10	0.25	0.24	0.32	0.27
Mineral nutrients (NPK)	0.13	0.14	0.11	0.13	0.09	0.09	0.09	0.09	0.25	0.28	0.24	0.25
0.5 % sewage sludge	0.09	0.11	0.12	0.10	0.07	0.08	0.12	0.09	0.19	0.28	0.31	0.26
1 % sewage sludge	0.12	0.09	0.07	0.09	0.12	0.07	0.07	0.09	0.30	0.20	0.13	0.21
2 % sewage sludge	0.08	0.09	0.10	0.09	0.07	0.08	0.08	0.08	0.14	0.15	0.15	0.14
Mean	0.11	0.10	0.11	-	0.09	0.08	0.10	-	0.22	0.24	0.23	-
L.S.D. for	(A) 0.02^{**}	(I) N.S.		(A×I) 0.03^{**}	(A) 0.01^{**}	(I) 0.01^{**}		(A×I) 0.02^{**}	(A) 0.02^{**}	(I) 0.01^{*}		(A×I) 0.04^{**}

T.W: Tap water ; S.W: Sewage water. ; N.S.: Not significant at 0.05 or 0.01 levels of probability.

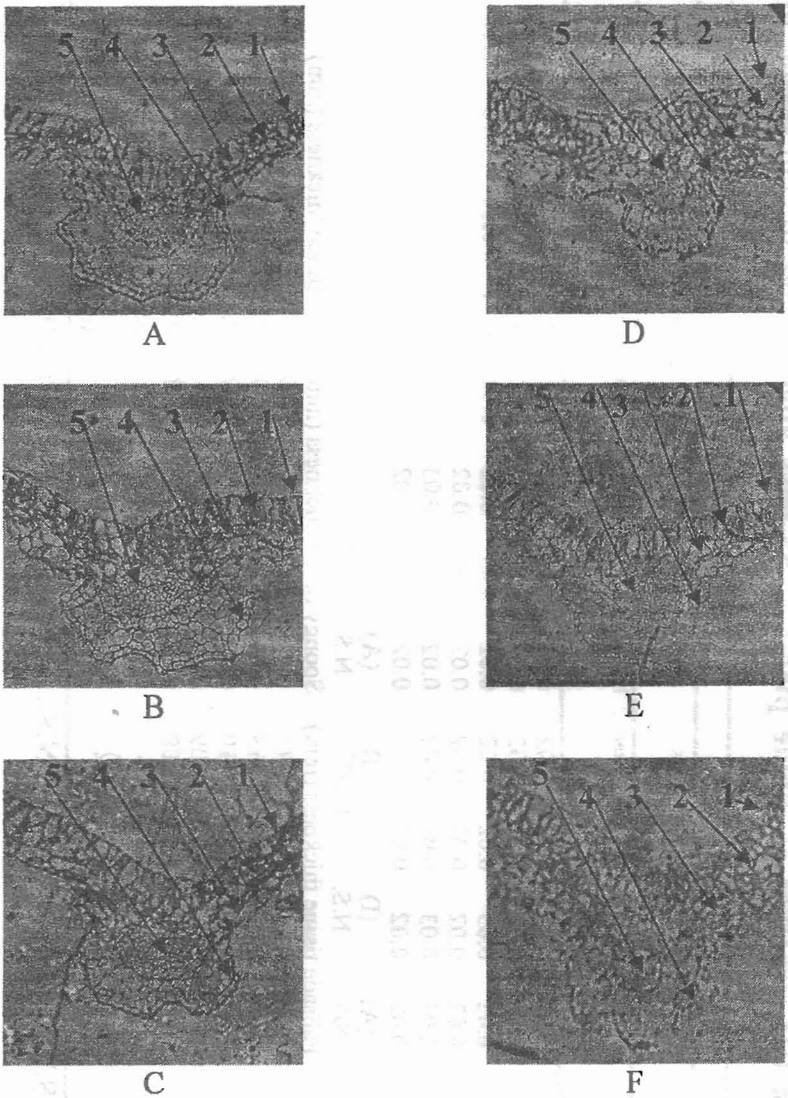

Fig. 3. Effect of sewage sludge, sewage water and their interactions on anatomical traits of leaf

A: Control- 100 % tap water; B: Control- 50 % tap water + 50 % sewage water; C: Control- 100 % sewage water; D: 2 % sewage sludge - 100 % tap water; E: 2 % sewage sludge - 50 % tap water + 50 % sewage water; F: 2 % sewage sludge - 100 % sewage water.

1: Upper epidermis; 2: Palisade tissue; 3: Spongy tissue; 4: Lower epidermis; 5: Midveinal bundle.

Table 12 show also that the interaction between the two factors, significantly affected all studied leaf structure parameters, except lower epidermis thickness. The best interaction treatment for increasing leaf structure thickness was control treatment (without sludge or NPK application) + irrigation with 100 % sewage water.

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النمو و الصفات الفسيولوجية و التشريحية لنباتات الترمس و تأثرها بإضافة حمأة المجارى و مياه المجارى

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أجريت تجربتى أصص خلال شتاء موسمين متعاقبين فى الفترة ٢٠٠٣/٢٠٠٤، ٢٠٠٤/٢٠٠٥ فى الصوبة السلكية بقسم النبات الزراعى و أمراض النبات، كلية الزراعة، جامعة الزقازيق، لدراسة تأثير حمأة المجارى، و الرى بمياه المجارى و التفاعل بينهما على صفات النمو، و محتوى الأوراق من الكلوروفيلات، و النشاط الإنزيمى و المحصول و مكوناته و التحليل الكيميائى للبذور و التركيب التشريحى لأجزاء نباتات الترمس صنف جيزه ١.

توضح النتائج أن إضافة حمأة المجارى بمعدل ٢ % أو إضافة السماد المعدنى (ن ، فو٢ أه ، بو٢ أ) بالمعدل الموصى به أدت إلى زيادة معنوية فى طول النبات و مساحة الورقة و الوزن الجاف لمختلف أجزاء النبات و كلوروفيل أ ، و ب و الكاروتينويدات بأنسجة الأوراق و محتوى بذور الترمس من البروتين و الكربوهيدرات و السكريات، كذلك أدت إلى زيادة كل من وزن و عدد البذور للنبات و وزن الـ ١٠٠ بذرة و محتوى البذور من الفوسفور بينما أدت إضافة السماد المعدنى بالمعدل الموصى به إلى زيادة محتوى البذور من البوتاسيوم. و من ناحية أخرى فقد ازداد النشاط الإنزيمى معنوياً حتى ١ % فقط من حمأة المجارى، بينما أدت زيادة معدل حمأة المجارى إلى ٢ % إلى إنخفاض نشاط إنزيمى الكتاليز و البيروكسيديز.

أثر رى نباتات الترمس بمياه المجارى معنوياً على مساحة الورقة و الوزن الجاف للساق و الأوراق للنبات و كذلك محتوى أنسجة الأوراق من الكلوروفيل أ ، و ب و محتوى البذور من كل من النيتروجين و البروتين. بينما لم يؤثر الرى بمياه المجارى معنوياً على إرتفاع النبات ، الوزن الجاف لجذور النبات و محتوى أنسجة الأوراق من الكاروتينويدات

و نشاط إنزيمى الكاتاليز و البيروكسيديز فى الأوراق و الكربوهيدرات الكلية و البوتاسيوم فى البذور و المحصول و مكوناته.

كانت أفضل معاملات التفاعل لزيادة إرتفاع النبات و مساحة الورقة و الوزن الجاف لأجزاء النبات المختلفة و الكربوهيدرات الكلية و السكريات الكلية و البروتين فى البذور و كذلك المحصول و مكوناته هى إضافة حمأة المجارى بمعدل ٢ % + الرى بمياه المجارى بنسبة ١٠٠ % بينما كان نشاط إنزيمى الكتاليز و البيروكسيديز فى أنسجة الأوراق عند أقصى معدل له مع إضافة حمأة المجارى بمعدل ١ % + الرى بمياه المجارى بنسبة ١٠٠ %.

أدت إضافة حمأة المجارى بنسبة ٢ % أو الرى بمياه المجارى بتركيز ١٠٠ % إلى زيادة محتوى بذور الترمس من كل من الكروم و الكادميوم و النيكل و الرصاص، بينما أدت إضافتها إلى نقص سمك كل من نصل الورقة، الحزمة الوعائية و النسيج العمادى و الإسفنجى لأوراق نباتات الترمس. و من ناحية أخرى فقد أدت إضافة حمأة المجارى إلى زيادة كل من عدد طبقات القشرة و سمكها فى الساق.