J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 6 (3): 375 - 386 , 2015

Growth and some macronutrients uptake by castor bean irradiated with gamma ray and irrigated with wastewater under sandy soil condition

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ABSTRACT

A field experiment was carried out at Experimental Farm of Soil and Water Research Department, Nuclear Research Centre, Atomic Energy Authority, Inshas Egypt, to follow up the effects of different doses of gamma ray on castor bean (*Ricinus communis L.*) grown on a sandy soil and irrigated with either fresh water or wastewater from El-Gabal El Asfar. Irradiation resulted in higher values of both fresh and dry weight of castor bean. This effect seemed more obvious by increasing the dose of gamma ray up to 50 Gy beyond which a gradual decrease occurred. Nitrogen, phosphorus and potassium contents in castor bean under the effect of gamma irradiation were arranged in the following descending order; 50Gy > 100Gy > 150Gy > 200Gy > 0 > 250Gy> 300 Gy. Nitrogen, phosphorus, potassium and oil contents in castor bean plants irrigated with wastewater were higher than the corresponding ones in plants irrigated with fresh water.

Keywords: Castor bean, Gamma ray, Nitrogen, Phosphorus, Potassium and Wastewater.

INTRODUCTION

Castor bean (*Ricinus communis* L.) is an important drought-resistant shrub belonging to the family Euphorbiaceae a diverse and economically-important family of flowering plants. Castor bean probably originated from Africa and was used in ancient Egypt and by the Romans and Greeks (Scarpa and Guerci, 1982, Weiss, 2000). Castor bean is a plant of enormous significance and diversified uses of its products ranging from farm yard manure and fuel to its multiple uses like leaves for feeding silkworms. Castor bean oil is non- edible traditionally used as purgative and in the preparation of various cosmetic products, plastic industry, lubricants and manufacturing of biofuel. The oil extracted from castor bean already has a growing international market, assured by more than 700 uses (Weiss, 2000, Azevedo and Lima, 2001).

Wastewater is a preferred marginal water source, since its supply is reliable and uniform. Costs of this water source are low compared with those of other nonconventional irrigation water sources (e.g. desalinization) since agricultural reuse of urban wastewater serves also to dispose of treated urban sewage water (Haruvy and Sadan, 1994). The use of wastewater for irrigation is a viable option to reduce the use of water resources and to increase the supply of quality water for more restrictive uses, such as drinking water (Toze, 2006). In Egypt, sewage effluent has been used in irrigation long time ago in a desert sandy area northeast of Cairo. At present, small scattered plots are also irrigated with sewage effluent. Sewage effluent generated from sewer stations in both Lower and Upper Egypt, raw or treated, falls in a good permissible range for most crops according to their salinity and heavy metal contents. In addition, their high nitrogen and other nutrient element contents significantly reduce or even exterminate the exigency for chemical fertilizers (Hussein *et al.,* 2004, Hussein *et al.,* 2012). Crops with improved characteristics have successfully been developed by mutagenic inductions (Majeed and Zahir, 2010). Gamma rays generally influence plant growth and development by inducing cytological, genetically, biochemical, physiological and morphogenetic changes in cells and tissues (Rahimi and Bahrani, 2011). These effects can occur both spontaneously in nature and artificial by mutagens.

This work, therefore, aimed at following the effect of both gamma ray and irrigation with wastewater on macronutrients uptake by castor bean crop as well as its oil content.

MATERIALS AND METHODS

A field experiment was carried out in the experimental farm of Soil and Water Research Department, Nuclear Research Center, Inshas Egypt. Seeds of castor bean were exposed to six doses of gamma rays (Co-60 source) {50, 100, 150, 200, 250 and 300 Gray (Gy)} in addition to non-irradiated control. Castor bean seeds were divided into two parts, the first one was irrigated with wastewater which was gained from El-Gabal El-Asfar irrigation canals, while the second one was irrigated with fresh water. Castor bean seeds were cultivated on a sandy soil at distance of 3m x 3m between plants (1111 plant/ hectare). Some physical and chemical properties of the investigated soil are presented in Table1. Only plants which were irrigated with fresh water received chemical fertilization, where N, P and K were added at the rates of 150,110 and 110kg/ha in the forms of ammonium sulphate, supper phosphate and potassium sulphate, respectively. Plants were irrigated every 10 days in summer and 15 days in winter. After one year from cultivation, both the soil and plants were sampled, the sampled soil was prepared for physical and chemical analysis according to Carter and Gregreich (2008) (Table 2). Samples of irrigation water was transferred to laboratory in closed bottles and then filtered to remove any suspended materials. Irrigation water swere analyzed for EC, pH, cations and anions and heavy metals (Table 3) .The plants sampled were oven dried at $70^{o}{}_{C,}$ digested using a mixture of H_2SO_4 and H_2O_2 and analyzed according to Hamdy (2005),

Table (1): Physical and chemical properties of the experimental soil.

pH (1:2.5)	EC (dS m^{-1})	$CaCO_3$ (g kg^{-1})	OM (g kg^{-1})	SP (%)			
7.91	1.11	0.00	0.30	31.96			
Soluble Ions ($mmol_c$ L^{-1})							
Cations			Anions				
Na^+	3.16		CO_3^{-2}	0.00			
K^+	3.21		HCO^{-3}	3.34			
Ca^{+2}	2.12		CL^-	4.55			
Mg^{+2}	2.61		SO_4^{-2}	3.21			
Available nutrients* (mg kg^{-1})							
N	P	K	Fe	Mn	Zn	Pb	Cu
2.11	1. 42	1.54	2.10	1.29	0.40	0.01	0.40
Particle size distribution(%)							
Sand		Silt		Clay		Texture	
90.5		2.7		6.8		Sand	

***Extracted by: KCl (N), Na_2CO_3 (P), NH_4-AOc (K) and DTPA (Fe, Mn, Zn and Cu).**
SP: Saturation percent.

Table 2. Physical and chemical properties of the soil used in the study after planting

pH (1:2.5)	EC (dS m^{-1})	$CaCO_3$ (g kg^{-1})	OM (g kg^{-1})	SP (%)			
7.1	1.67	0.00	0.65	38.91			
Soluble Ions (mmolc L^{-1})							
Cations				Anions			
Na+		5.16		CO_3^{-2}		0.30	
K+		4.21		HCO^{-3}		4.40	
Ca^{+2}		3.23		CL^-		5.80	
Mg^{+2}		4.10		SO_4^{-2}		6.20	
Available nutrients (mg kg^{-1})							
N	P	K	Fe	Mn	Zn	pb	Cu
4.14	3.51	2. 18	9.10	0.99	0.60	0.11	0.64
Particle size distribution(%)							
Sand	Silt			Clay		Texture	
86.5	4.7			8.8		Sand	

See footnotes of Table 1.

The treatments were statistically arranged in a complete randomized block design with three replicates. The final data were statistically analyzed using ANOVA system and the values of LSD at 0.05 level. by SPSS (ver. 22) according to Snedecor and Cochran (1982).

Table (3): Experimental wastewater and fresh water properties

Analysis	Fresh water	Waste water
EC (dS/m^{-1})	0.89	1.49
pH	7.58	7.33
BOD 5 mg/L	43.00	95.00
COD mg/L	30.00	78.00
Soluble anions ($mmol_cL^{-1}$)		
SO_4^{2-}	2.19	3.34
CO_3^{2-}	0.00	0.05
HCO_{3-}	3.05	4.05
Cl^-	2.86	7.46
Soluble cations ($mmol_cL^{-1}$)		
K^+	2.82	4.06
Na^+	1.39	3.28
Ca^{2+}	2.70	4.17
Mg^{2+}	1.19	3.39
Soluble elements (mgL^{-1})		
Fe	0.12	1.21
Cu	0.02	0.03
Mn	0.09	0.24
Zn	0.06	0.15
Pb	0.00	0.16
Cd	0.01	0.03
P	0.02	3.02
NH_4^{-N}	0.00	10.89
NO_3^{-N}	0.01	2.10

Oil extraction

The seed kernels were ground using a mechanical grinder and defatted in a soxhlet apparatus according to the method described by Akbar et al. (2009). The extraction was carried out by using hexane (boiling point of 40–60◦C) as a solvent. The process continued for 6 h. The extracted lipid was obtained by filtrating the solvent lipid contained to get rid of the solid from solvent before the hexane was removed. The solvent was removed by vacuum evaporation and exposure to heat in a drying oven at 50°C. Extracted seed oil was stored in freezer at −2 ◦C for subsequent analysis. The amount of oil recovered was calculated as percentage of total oil present in seed kernels. Each extraction was run in triplicate and the final value is the average of all.

RESULTS AND DISCUSSION

Fresh weight

Data in Table 4 show that irrigation with wastewater resulted in higher fresh weights of roots, shoots, leaves, seeds and the whole plants than the corresponding ones irrigated with fresh water. This may be due to the wastewater contents of nutritive elements such as N, P and K beside of its higher content of organic material, which was reflected positively on the characteristics of the plant (Hussein *et al.*, 2012). Also, the results show that fresh weights of castor bean plants increased gradually with increasing dose of gamma ray and reached maximum values at the dose of 50 Gy, thereafter gradually declined until reached the minimum values at the dose of 300 Gy. The high doses of gamma irradiation were reported to be harmful in several studies. Nassar *et al.* (2004) reported that higher doses of gamma ray (120 k-rad) reduced plant height, number of leaves and branching capacity of safflower.(1k- rad=10 Gy).

Table (4): Effect of gamma rays irradiation (Gy) and irrigation with wastewater on fresh weight of castor bean (g plant^{-1}).

Plant part	Water type (B)	Gamma ray dose (A)							Mean
		0	50	100	150	200	250	300	
Seeds	FW	2500	5000	4500	4000	3000	1500	1000	3071
	WW	3000	6500	5500	4500	4000	2500	1500	3929
	Mean	2750	5750	5000	4250	3500	2000	1250	
L.S.D. at 005		A =350			B=654			A*B=92	
Leaves	FW	3800	6100	60	60	4020	3250	2500	4524
	WW	4100	6900	6850	6520	4450	3800	2200	4974
	Mean	3950	6500	6425	6260	4235	3525	2350	
L.S.D. at 005		A =355			B=664			A*B=939	
Shoots	FW	7240	9473	9460	9120	7500	60	5100	7699
	WW	7580	9587	9530	9380	7900	6800	5500	8040
	Mean	7410	9530	9495	9250	7700	6400	5300	
L.S.D. at 005		A =355			B=664			A*B=939	
Roots	FW	1645	2520	2510	2440	1870	1280	1012	1897
	WW	1840	2700	2580	2500	1980	1520	1200	2046
	Mean	1743	2610	2545	2470	1925	1400	1106	
L.S.D. at 005		A =64			B=119			A*B=169	
Whole	FW	15525	23093	22470	21560	16390	12030	9612	17240
	WW	16180	25687	24460	23900	18330	14620	10400	19082
	Mean	15853	24390	23465	22730	17360	13325	10006	
L.S.D. at 005		A =748			B=1399			A*B=1979	

FW: Fresh water **WW: Wastewater**

Dry weight

Dry weight values of the different plant organs as well as the corresponding whole plant dry weight have almost taken the same trend as in the fresh weight, where the wastewater resulted in higher dry weights of the roots, shoots, leaves, seeds and whole plants than the corresponding ones resulted due to the fresh water (Table 5). Also, the gamma irradiation at a dose of 50 Gray recorded the highest dry weight values whereas; at a dose of 300 Gray recorded the lowest dry weight ones. This may be due to the simulative effect of gamma ray irradiation on growth, especially at low doses. These results are in agreement with those of Khan (1970) who exposed seeds of *Cicer arietinum* to gamma rays at doses ranging from 5 to 15 k-rad, and found stimulating effect of irradiation on branching capacity, fresh weight and dry weight of plant.

Table (5): Effect of gamma rays irradiation (Gy) and irrigation with wastewater on dry weight of castor bean (g plant^{-1}).

Part of plant	Water type (B)	Gamma ray dose (A)							Mean
		0	50	100	150	200	250	300	
Seeds	FW	2225	4500	4250	3600	2700	1350	900	2789
	WW	2700	5900	4950	4050	3600	2250	1350	3543
	Mean	2463	5200	4600	3825	3150	1800	1125	
L.S.D. at 005	A =322			B=602				A*B=851	
Leaves	FW	1377	2576	2300	2119	1540	1150	540	1657
	WW	1480	2914	2440	2260	1763	1290	637	1826
	Mean	1429	2745	2370	2190	1652	1220	589	
L.S.D. at 005	A =79			B=147				A*B=208	
Shoots	FW	3240	3515	3500	3480	3010	2065	1925	2962
	WW	3500	3654	3620	3600	3020	2180	1985	3080
	Mean	3370	3585	3560	3540	3015	2123	1955	
L.S.D. at 005	A =71			B=133				A*B=18	
Roots	FW	524	1050	1045	1005	515	435	400	711
	WW	635	1230	1225	1215	720	550	420	856
	Mean	580	1140	1135	1110	618	493	410	
L.S.D. at 005	A =63			B=118				A*B =167	
Whole	FW	7366	11641	11095	10204	7765	50	3765	8119
	WW	8415	13698	12235	12575	9103	5270	4392	9384
	Mean	7891	12670	11665	11390	8434	5135	4079	
L.S.D. at 005	A =687			B=1286				A*B=1819	

FW: Fresh water **WW: Wastewater**

Similar results were observed by Kaul and Bradu (1972) on *Atropa belladonna*, Suhas *et al.* (1976) on *Cassia angustifalia*, Selenina and Stepanenko (1979) on *Matricaria recutita* and Youssef *et al.* (2000) on Geranium. In this respect, Pitirmovae, (1979) explained that the stimulating effect of low doses of gamma ray irradiation on plant growth may be due to stimulation of cell division or cell elongation, alteration of metabolic processes that affect synthesis of phytohormones or nucleic acids.

Nutrient uptake

Irrigation of castor bean plants with wastewater, recorded higher nitrogen uptake values than those irrigated with fresh water (Table 6). This result is on line with those of Mohammad and Ayadi (2004) who found that N uptake values by maize grains and stover were significantly increased by wastewater irrigation. Moreover, there was a gradual increase in nitrogen uptake by castor bean plants due to increasing irradiation dose until it reached a maximum value at the dose of 50 Gray where a gradual decline occurred in N uptake by increasing irradiation dose until it reached the minimum value at the dose of 300 Gray. Gamma irradiation was reported to affect the mineral content of several plants. An increase in nitrogen content was found by Maltseva and Kuzin (1975) when *Vicia faba* seeds were irradiated with 0.1 and 10 k-rad of gamma rays. Habba (1989) exposed seeds of Hyoscyamus and Atropa spp. to 1-2.5 k-rad G.I. and found an increase in nitrogen percentage. Also Deaf (2000) reported an increase in nitrogen contents of lemongrass when seeds were exposed to 1-4 k-rad of gamma irradiation.

Table (6): Effect of gamma rays irradiation (Gy) and irrigation with wastewater on nitrogen uptake (mg plant-1) by castor bean plants.

Part of plant	Water type (B)	Gamma ray dose (A)							Mean
		0	50	100	150	200	250	300	
Seeds	FW	20530	40910	32810	27280	19950	9153	5796	22347
	WW	27320	77990	63450	49730	39560	24590	14530	42453
	Mean	23925	59450	48130	38505	29755	16872	10163	
L.S.D. at 005		A =10224			B=19128			A*B=27051	
Leaves	FW	578	2808	2024	1779	1170	644	362	1338
	WW	1968	4255	3440	3141	2380	1702	777	2523
	Mean	1273	3532	2732	2460	1775	1173	570	
L.S.D. at 005		A =339			B=634			A*B=896	
Shoots	FW	3143	4323	3850	3375	2799	1425	1078	2856
	WW	3325	9683	9122	8964	6946	3400	2501	6277
	Mean	3234	7003	6486	6170	4873	2413	1790	
L.S.D. at 005		A =2033			B=3803			A*B=5379	
Roots	FW	759	3076	2916	2774	1380	1148	1020	1868
	WW	3258	10980	9616	9526	5508	4015	3198	6586
	Mean	2009	7028	6266	6150	3444	2582	2109	
L.S.D. at 005		A =2181			B=4080			A*B=5770	
Whole	FW	25010	51110	41600	35210	25290	12370	8256	28407
	WW	35870	102900	85620	71360	54390	33710	21010	57837
	Mean	30440	77005	63610	53285	39840	23040	14633	
L.S.D. at 005		A =14360			B=26866				A*B=37994

FW: Fresh water **WW: Wastewater**

Phosphorus uptake

Phosphorus of castor bean plants generally had similar trend as N uptake, where plants irrigated with wastewater, accumulated higher values of P uptake than fresh were irrigated ones (Table 7). Furthermore, there was a gradual increase in P uptake values of castor bean plants until reached a maximum at the dose of 50 Gy and then a gradual decline occurred with increasing irradiation dose until reached the minimum P uptake at the dose of 300 Gray. Similar results were reported by Rennie and Nelson (1975) who found that phosphorus contents of cabbage, onion and carrot were increased due to irradiation with 0.1 to 1.25 k-rad. Deaf (2000) also reported increases in phosphorus contents of lemongrass when seeds were exposed to 1-4 k-rad , while Mahmoud (2002) indicated that gamma irradiation increased phosphorus content of delphinium plants.

Table (7): Effect of gamma rays irradiation (Gy) and irrigation with wastewater on phosphorus uptake (mg plant^{-1}) by castor bean plants.

Mean	Gamma ray dose (A)							Water type (B)	Part of plant
	300	250	200	150	100	50	0		
3152	936	1458	2997	4392	5227	5895	1157	FW	Seeds
6995	2065	4252	6912	7816	10440	13510	3969	WW	
	1501	2855	4955	6104	7834	9703	2563	Mean	
L.S.D. at 005	A=1918				B=3589			A*B=5076	
254	064	161	215	317	368	569	82	FW	Leaves
4693	1127	3147	4989	6486	7466	9471	163	WW	
	596	1654	2602	3402	3917	5020	123	Mean	
L.S.D. at 005	A=2987				B=5589			A*B=7904	
437	212	248	391	487	630	703	388	FW	Shoots
7286	4406	5450	7583	9504	10425	11290	2345	WW	
	2309	2849	3987	4996	5528	5997	1367	Mean	
L.S.D. at 005	A=2953				B=5524			A*B=7813	
524	248	283	371	734	815	1019	199	FW	Roots
2400	642	1419	1973	3815	3956	4145	851	WW	
	445	851	1172	2275	2386	2582	525	Mean	
L.S.D. at 005	A=1128				B=2111			A*B==2986	
4367	1460	2150	3974	5930	7040	8186	1826	FW	Whole
21370	8240	14260	21450	27620	32280	38410	7328	WW	
	4850	8205	12712	16775	19660	23298	4577	Mean	
L.S.D. at 005	A=8656				B=16194			A*B=22902	

FW: Fresh water **WW: Wastewater**

Potassium uptake

Data in Table (8) revealed that K uptake values by roots, shoots, leaves, seeds and the whole castor bean were significantly higher due to irrigation with the wastewater than the corresponding K uptake values achieved by irrigation with the fresh water. It is worthy to mention that potassium is important and the most abundant macronutrient cation in plant tissues (Zhao *et al.*, 2003, Jordan- Meille and Pellerin, 2008). In addition, Galavi *et al.* (2010) found that potassium uptake values increased due to irrigation with wastewater as compared with the well water. Total soil potassium increased in the soil as a result of wastewater application (Monnett *et al.*, 1996., Fuentes *et al.*, 2002). The gamma irradiation at a dose of 50 Gray recorded the highest K uptake values in all plant parts. Similar effects were reported by Deaf (2000) who found an increase in potassium contents of gamma irradiated lemongrass.

Table (8): Effect of gamma rays irradiation (Gy) and irrigation with wastewater on potassium uptake (mg plant^{-1}) by castor bean plants.

Mean	Gamma ray dose (A)							Water type (B)	Part of plant
	300	250	200	150	100	50	0		
3902	891	1363	2916	5400	6502	8865	1379	FW	Seeds
8966	3253	5467	8784	10080	12770	16630	5778	WW	
	2072	3415	5850	7740	9636	12748	3579	Mean	
L.S.D. at 005	A=161			B=301				A*B=426	
502	065	230	369	529	644	1597	82	FW	Leaves
1267	420	928	1286	1649	1610	2476	503	WW	
	243	579	828	1089	1127	2037	293	Mean	
L.S.D. at 005	A=265			B=496				A*B=702	
500	154	268	482	554	776	879	388	FW	Shoots
6576	3871	4665	6553	8460	9427	10816	2240	WW	
	2013	2467	3518	4507	5102	5848	1314	Mean	
L.S.D. at 005	A=2699			B=5050				A*B=7142	
476	252	274	339	683	721	777	288	FW	Roots
2406	1025	1436	2045	3584	3675	4354	724	WW	
	639	855	1192	2134	2198	2566	506	Mean	
L.S.D. at 005	A=1127			B=2109				A*B=2983	
5380	1362	2135	4106	7166	8643	12110	2137	FW	Whole
19212	8569	12490	18660	23770	27480	34270	9245	WW	
	4966	7313	11383	15468	18062	23190	5691	Mean	
L.S.D. at 005	A=539			B=1008				A*B=1426	

FW: Fresh water **WW: Wastewater**

Oil content

Table (9) shows that the increments in the amount of oil produced by castor bean irradiated with gamma rays could be arranged in the following descending order; 50 Gy > 100 Gy > 150 Gy > 200 Gy > 0 > 250 Gy> 300 Gy. These occurred regardless of the type of irrigation water used. Our results are in agreement with those of Sarwar *et al.* (2010).

Table (9): Effect of gamma rays irradiation (Gy) and irrigation with wastewater on oil content (kg plant^{-1}) produced by castor bean plants .

Mean	Gamma ray doses (A)							Water type (B)
	300	250	200	150	100	50	0	
951.6	225	405	864	1260	1530	1665	712	FW
1293	337.5	675	1368	1539	1881	2360	891	WW
	1800	540	1116	1399.5	1705.5	2012.5	801.5	Mean
L.S.D. at 005	A =184.7				B=354.57			A*B=691.14

FW: Fresh water **WW: Wastewater**

CONCLUSION

Use of wastewater as a source of water for irrigation either individually or in a combination with gamma irradiation achieved significant positive effects on castor bean growth and N, P and K uptake. There were considerable increases in nitrogen, phosphorous and potassium uptake by roots, shoots, leaves, seeds and whole plant as affected by wastewater irrigation (treated sewage water), especially when plants were exposed to low dose (50 Gy) of gamma rays. The increases of nitrogen, phosphorous and potassium uptake by castor bean under the effect of gamma radiation could be arranged in the following descending order; 50Gy > 100Gy > 150Gy > 200Gy > 0 > 250Gy> 300 Gy. Generally, use of wastewaters in irrigation can improve castor bean plant growth because they are considered as natural conditioners through their contents of nutrients and organic matter which affect the productivity of plants.

From the above mentioned results, we can conclude that castor bean growth and nutrients uptake as well as oil production were enhanced due to synergetic effect of wastewater irrigation. Irradiated seeds with gamma rays at dose of 50 Gy resulted in the highest values of the estimated parameters.

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نمو وامتصاص بعض المغذيات الكبرى بواسطة الخروع المشعع بأشعة جاما والمروى بالمياه العادمة تحت ظروف الأرض الرملية

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**** قسم بحوث الأراضى والمياه - مركز البحوث النوويه – هيئة الطاقه الذريه المصريه**

أجريت تجربة حقلية في مزرعه قسم بحوث الأراضى و المياه، مركز البحوث النووية، هيئة الطاقة الذرية، مصر. لتقييم تأثير جرعات مختلفة من أشعة جاما على نبات الخروع المنزرع فى التربه الرمليه مع الرى بالمياه العادمه (الصرف الصحي) وذلك كمحاوله لأدخال وتأسيس زراعه هذا المحصول الغير غذائى في التربة الرملية والأراضى الصحراويه مع الأستفاده من المياه العادمه. وتم تقدير الوزن الطازج والجاف للنباتات تحت الفحص كما تم تقييم محتوى نبات الخروع من عناصر النيتروجين والفوسفور والبوتاسيوم وانتاجيه الزيت تحت تأثير أشعة جاما وقد اوضحت النتائج الترتيب التنازلى تبعا لتأثير التشعيع كما يلي . 50Gy> 100Gy> 150Gy> 200Gy> 0> 250Gy> 300 جراي . ايضا زاد محتوى نبات الخروع من عناصر النيتروجين والفوسفور والبوتاسيوم وانتاجيه الزيت المروي بمياه الصرف الصحي مقارنه بتلك المرويه بالماء العذب.