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The impact of different soils and wastewater on castor bean (*Ricinus communis* L.) growth

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Abstract

The oilseed plant castor bean (*Ricinuscommunis* L.) has many applications in medicine, industry and agriculture. This study aims to evaluate the growth of castor bean on different soils as affected by wastewater (sewage effluent) irrigation. Thus, castor bean seeds were sown in six different soils (sandy soil - sandy soil + compost - polluted soil - clay soil - calcareous soil - saline soil) and irrigated using equal amounts of sewage effluent. The physical and chemical properties of the soils used and the chemical constituents of sewage effluent were investigated. The results showed that the highest percentage of germination of castor bean seeds (96.6%) were achieved in the clay as well as sandy soil with added compost, followed by sandy soil (92.2%). On the other hand the lowest germination percentages were shown with the seeds sown in calcareous soil (50.3%) and saline soil (30.3%). The time duration required for the radical protrusion was also shortest (quick germination) and longest in the polluted, calcareous, and saline soils. There has been also a marked impact on the plant growth, fresh weight and dry weight gain of, where highest values were shown with the plants cultivated in clay soils followed by sandy soil with added compost. These plants exhibited in addition best criteria (weight, length, width). Thus, the results obtained confirmed the ability of castor beanto grow in different types of soils under irrigation by sewage effluent.

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Introduction

Castor bean plant is an important oilseed crop raised under limited resource condition available per unit area productivity. Dhimmar (2009) reported that N and P are generally deficientin calcareous soils; K availability is usuallyconsidered adequate for plant growth. Salty soils extensively exist in arid and semi-arid climate regions of the world and cause salt stress in plants (Khan *et al.,* 2001). Salinity is an important environmental abiotic stress factor seriously affecting plant productivity and survival (Eker*et al.,* 2006). It causes high ion concentration in the rhizosphere, ion toxicity and water limitation.Decreasing of photosynthetic pigments and total soluble protein contents were evident under short time salt exposure in three different tomato cultivars (Doganlar*et al.,* 2010), which disturb the establishment and growth of seedlings by retarding plumule and radicle growth. Two effects of salt stress on plant growth and development are osmotic (water stress) and ionic effect. Osmotic influence of salinity results as a consequence of salt-induced decrease in soil water potential. However, salinity-induced water stress have been reported not to be the limiting factor at cellular (Mansour, 1997) or whole plant level (Munns and Termaat, 1986). In several plant species, salinity resulted in an increase in sodium (Na^+) and chloride (Cl^-) levels and a decrease in potassium (K^+) and calcium (Ca^{2+}) concentration (Munns, 1993).

Scarcity of conventional sources of water in arid and semi-arid regions of the world has been behind the movement to find alternative or additional sources. Consequently, wastewater reuse for agricultural irrigation is becoming a common and rapidly increasing practice in arid and semi-arid regions around the world, where treated wastewater serves as an extra source of water available for the rural sector (Scott *et al.,* 2004). Plants irrigated with sewage water produced more oil yield than the control by 206.6, 319.4, 28.8, 90.5 and 371.5 kg acre^{-1}for castor bean, sunflower, soybean, sesame and peanut crops, respectively. With similar treatment, oil yield of cotton crop was decreased by 16.2 kg acre^{-1}(Hussein *et al.,* 2004).

Thus, the objective of the present work was to evaluate the germination potential as well as the growth of castor bean in different soil, under irrigation with wastewater.

Materials and methods

Plant material

Castor bean (*Ricinuscommunis* L.) seeds were collected from a homogenous wild community in clay soil at Kalubia governorate, North Cairo, Egypt.

Experimental layout

A greenhouse experiment was carried out at the Agricultural Department for Soils and Water Research, Nuclear Research Centre, Atomic Energy Authority, Egypt. Germination and seedling growth affected by sewage effluent were followed up in different soils. Plastic pots (30 cm diameter and 20 cm depth) were filled with 10 kg air dry soil of six different soils representative sandy soil, sand soil + compost, clay, polluted soil, calcareous, and saline soil. Irrigation was carried out routinely using equal amounts of wastewater (sewage effluent) from Elgabal El Asfar farm, Kalubia governorate, Egypt. The experiment was designed as completely randomized with three replicates. Samples of soil and water were analyzed according to Page *et al.* (1982).

Extraction and determination of photosynthetic pigments

One gram of leaf tissue (the third leaf from the top) was taken and grinded in 85% acetone. The extract was then filtrated and the total volume completed with acetone (85%) up to 50 ml. The pigment contents were determined spectrophotometrically according to Lichtenthaler (1987). The optical density of the extract was measured against a blank of pure 85% aqueous acetone using spectrophotometer at wavelengths 663, 644 and 452.5 nm. The contents of chlorophylls a and b and carotenoids were obtained in µg/ml using the following equations:

Chlorophyll a = 10.3 E663 – 0.918 E644

Chlorophyll b =19.7 E644 – 3.870 E663

Carotenoids = 4.2 E452.5 – (0.0264 chlorophyll a + 0.426 chlorophyll b).

Finally, the pigment contents were calculated as mg/ g fresh weight of leaves.

Properties of the experimented soil and irrigation water

Sewage water has been used to support agricultural production in many countries over a considerable period of time. Effluent reuse can provide considerable benefit when used under controlled conditions to establish protection of health of both farm workers and consumers of the product. The main components of sewage effluent that warrant consideration for irrigation include major and minor nutrients like nitrogen, potassium, phosphorous, calcium, iron, zinc, copper and manganese as well as heavy metals (Table 1). The use of sewage effluents for the irrigation of government farms in Egypt has been in implementation since 1915 (Yudhistra and Vikram, 2010).The main presence of certain cations and anions which might cause adverse effect on soil properties and plant growth was noticed (Brown *et al.,* 1991, Amin and Migahid, 2000). The physical and chemical properties of the different soils used in the present study are shown in Table 2. This table indicates that the soils used are: sandy, clay, sandy loam, silt loam and loamy types. The analysis of variance for the final data was statistically assayed using the system ANOVA and the values of least significant differences (L.S.D) from the controls were calculated at 5% level to compare between means of treatments (Duncan's test) according to SAS software program (2002).

Results and discussion

Germination percentages

Germination percentage of castor bean, grown on different soils as affected by irrigation with sewage effluent, are shown in Table 3.

Table 1. Some chemical characteristics of the experimental wastewater (sewage effluent) collected from Elgabal El Asfar farm, Kalubia governorate, Egypt.

EC dSm^{-1}	pH	C/N ratio	Solibulecations and anions (Meq L^{-1})							
6.1	7.6	18	Cations				Anions			
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	$HCO3^{2-}$	$CO3^{2-}$	$SO4^{2-}$
			11.3	0.58	16	23	46	6.7	-	8.4
Macronutrient (Meq L^{-1})			Micronutrient (Meq L^{-1})							
N	P		Fe		Mn		Cu		Zn	Pb
3.71	1.46		0.21		0.093		0.039		0.012	0.073

Table 2. Some physical and chemical properties of the experimental soils.

Type of soil	Particle sizeDistribution (%)				Texture	pH 1 : 2.5	EC (dSm^{-1}) paste	$CaCO_3$	Soluble cations ($MeqL^{-1}$)				Soluble anaions (Meq L^{-1})		
	Coarse Sand	Fine sand	Clay	Silt					Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO^{3-}	SO_4^{2-}
Sandy	64.1	26.4	6.8	2.7	Sandy	7.97	0.27	1.3	0.32	0.45	1.25	1	1.25	0.88	0.53
Clay	6.1	14.7	57.5	21.6	Clay	7.9	1.2	7.2	0.6	0.94	8.1	2.3	1.27	2.2	6.5
Polluted	49	17.7	13.8	19.5	Sandy loam	7.5	1.8	15	1.1	9.3	8.2	12.9	3.4	17	9.4
Calcareous	30.3	-	16.2	54.5	Silt loam	8.68	2.18	54	0.95	0.8	23	0.7	1.8	3.8	1.74
Saline	91	-	7	2	Loamy sand	7.86	4.38	45.8	1.2	0.55	23	20	54	6	9

The seeds were sown in the greenhouse in pots containing the types of soil shown. Irrigation was carried out using equal amounts of sewage effluent. Each value is the mean of three replicates; each of 10 seeds. The highest germination percentage was occurred with sandy soil + compost as well as clay soil (96.6% in each case). Meanwhile, the fastest germination was occurred in sandy soil with or without compost followed by clay soil. On the other hand, the lowest germination percentage and longest duration for the radical protrusion of castor bean seeds, was on saline soil. In this respect, germination rate and durability are highly affected by soil types, where highest germination performance is generally carried out in the light soils and it progressively decreases in heavier soils (Idu*et al.,* 2011). In the present work, the reduced germination ability of castor bean seeds in saline soil is in alliance with the general trend that salinity stresses restrict crop establishment with a greater sensitivity to germination at early stages of seedling growth (Patanè*et al.,* 2012). Certain traits of castor bean have been detected starting from 30 days from sowing and up till plant yield (60, 90, and 120 days). The early growth stage (30-day-old plants) is physiologically critical for establishment of growth vigor (Srivastava, 2002). On the bases of the European guidelines for reclaimed wastewater in the Mediterranean region, Marecos*et al.* (1996) stated that reusing wastewater for agriculture has several advantages, such as reducing the amount of effluent discharged into receiving water bodies, nutrient recovery as fertilizers, and increase crop production. So wastewater reuse for agriculture could be a key alternative water source (Kim *et al.*, 2008; Qadir*et al.*, 2010).

Table 3. Effect of irrigation with wastewater on the percentage and duration of germination of castor bean seeds in different soils.

Age of plants	Sandy soil	Sandy soil + compost	Claysoil	Polluted soil	Calcareous soil	Salinesoil
10 days	92.2%	96.6 %	-	-	-	-
20 days	-	-	96.6 %	-	-	-
30 days	-	-	-	80.3 %	50.3 %	-
60 days	-	-	-	-	-	30.3 %

Table 4. Effect of irrigation with wastewater on the stem length (cm) of castor bean plants in different soils.

Age of plants	Sandy soil	Sandy soil + compost	Clay soil	Polluted soil	Calcareous soil	Saline soil
30 days	12±0.44	14±0.89	15±0.51	13±0.51	-	-
60 days	18±0.44	25±0.93	28±0.51	21±0.51	6±0.51	3±0.41
90 days	25±0.51	35±1.36	41±0.51	30±0.89	9±0.44	4±0.44
120 days	40±0.51	50±0.51	63±0.89	46±0.51	15±0.89	6±0.25

Each value is the mean three replicates (± SD).

Table 5. The effect of irrigation with wastewater on the fresh weight (g plant-1) of castor bean plant.

Age of plants	Sandy Soil	Sandy soil + compost	Clay soil	Polluted soil	Calcareous soil	Saline soil
30 days	4.31±0.118	6.73±0.322	12.94±0.659	6.88±0.287	-	-
60 days	4.48±0.273	8.33±0.273	16.21±0.831	8.54±0.314	4.12±0.186	2.09±0.26
90 days	6.12±0.322	9.57±0.314	19.44±0.338	9.7±0.322	4.82±0.089	2.49±0.051
120 days	6.31±0.273	10.84±0.508	27.22±0.981	12.25±0.698	5.21±0.051	2.73±0.051

Each value is the mean three replicates (± SD).

Seedling establishment

The seeds were sown in the greenhouse in pots of different soils. Irrigation was carried out using equal amounts of sewage effluent. Measurements were taken at different ages during plant growth and development. Each value is the mean of 3 replicates; each of 10 plants ± standard deviations. Seeds germinating on either the calcareous or saline soil failed to establish seedlings at 30 days of germination(Table 4). On the other hand, maximum extension growth of the stems was shown in the plants grown on clay soil followed by those of sandy soil plus compost. A similar trend was also observed at all stages of the plant growth and development. In addition, the plants grown on the clay soil exhibited maximum fresh weights (Table 5) and dry matter gains (Table 6), as compared with those cultivated in other types of soil and similarly irrigated with wastewater.

Table 6. The effect of irrigation with wastewater on the dry weight (g plant-1)of castor bean plant.

Age of plants	Sandy Soil	Sandy soil + compost	Clay Soil	Polluted soil	Calcareous soil	Saline soil
30 days	0.89±0.22	1.52±0.025	1.85±0.054	1.51±0.044	-	-
60 days	1.16±0.013	1.85±0.037	2.6±0.044	1.94±0.047	1.04±0.045	0.66±0.013
90 days	1.37±0.032	2.13±0.023	3.89±0.051	2.16±0.047	1.17±0.023	0.68±0.032
120 days	1.49±0.023	2.46±0.027	5.62±0.186	2.76±0.057	1.25±0.047	0.72±0.008

Each value is the mean three replicates (± SD).

Table 7. The effect of irrigation with wastewater on the photosynthetic pigments (mg g fresh weight-1) of castor bean plant after 90 days from planting.

Pigment	Sandy soil	Sandy soil + compost	Clay soil	Polluted soil	Calcareous soil	Saline soil
Ch a	1.215±0.009	1.571±0.022	1.454±0.015	1.66±0.081	-	-
Ch b	0.266±0.004	0.782±0.005	1.081±0.049	0.352±0.002	-	-
Carotenoids	0.342±0.002	0.844±0.005	0.739±0.002	0.817±0.005	-	-

*plants in calcareous soil and saline soil not survived.

The mean weight, length and width of the yielded seeds of the plants, cultivated in different soils and irrigated with sewage effluent, are shown in Table (8). The results obtained indicated that maximum measurements were obtained with the plants cultivated on clay soil, followed by those of sandy soil plus compost. Enhanced seed criteria of castor bean is of economic significance since the seeds contains up to 60% fatty acids, compared to approximately 20% and 40% in soybean (*Glycine max*) and rapeseed (*Brassica napus*), respectively (Weiss, 2000). Castor oil is a major component of many industrial lubricants and is currently of special interest as being considered for biofuel use (Baldwin and Cossar, 2008; Scholz and da Silva, 2008).

Table 8. The effect of irrigation with wastewater on the seeds, dry weight (g 10 seeds-1), length (cm), wideness (cm) and thickness (cm) of castor bean plant.

Seeds properties						
	Sandy soil	Sandy soil + compost	Claysoil	Polluted soil	Calcareous soil	Saline soil
Weight of (10)seeds	1.5±0.089	2.1±0.089	4.38±0.225	1.85±0.022	-	-
Length of seed	0.72±0.013	0.91±0.008	1.26±0.047	0.85±0.013	-	-
Wideness of seed	0.39±0.008	0.45±0.005	0.75±0.008	0.47±0.015	-	-
Thickness of seed	0.2±3.04	0.35±0.013	0.4±0.010	0.25±0.005	-	-
Yield of seeds	6.5±1.1	10.5±1.5	24.7±2.3	9.1±1.7	-	-

Seed maturation or seed filling is a phase of development that plays a major role in the storage reserve composition of a seed. In many plant seeds photosynthesis plays a major role in this process, although oilseeds, such as castor (Ricinuscommunis), are capable of accumulating oil without the benefit of photophosphorylation to augment energy demands. To characterize seed filling in castor, a systematic quantitative proteomics study was performed.(Norma *et al.*, 2009). In Table (7) chlorophyll [a], chlorophyll [b] and cartenoid were recorded. Chlorophyll b was the highest in clay soil followed by sandy soil +

compost then polluted soil. While chlorophyll a was higher in polluted soil than sandy soil+ compost and the clay soil. Oilseeds, such as castor bean are capable of accumulating oil without the benefit of photophosphorylation to augment energy. In a systematic quantitative proteomics study by Houston *et al.* (2009), the carbon assimilatory pathways in castor bean were compared with previous studies of the photosynthetic oil seeds syobean (*Glycine max*) and rapeseed (*Brassica napus*). The authors revealed metabolic differences in the carbon flow, carbon recapture, as well as ATP and NADPH production in castor bean from photosynthetic oilseeds. However, there were no appreciable changes in the contents of different photosynthetic pigments of leaves of the plants under investigation. This might indicate that the pigment content is not a main limiting factor for the growth and development of in castor bean plants. Castorbean (*Ricinuscommunis*) is a model heterotrophic oilseed thatcontains up to 60% fatty acids compared to approximately 20%and 40% in autotrophic oilseeds soybean (*Glycine max*) and rapeseed(*Brassica napus*), respectively (Weiss, 2000). Castorbean oil isa major component of many industrial lubricants and is currentlyof special interest, as it is being considered for biofuel use(Baldwin and Cossar, 2008 ; Scholz and daSilva, 2008). In oilseeds, fatty acid reserves are synthesized mainly duringthe seed-filling phase of seed development. Seed filling is a phase definedby morphological, cellular, and metabolic changes in the endospermand embryo that coincide with rapidly increasing storage reserves,such as fatty acids and protein (Ruuska*et al.,* 2002). Metabolic hallmarks of the seed-filling phaseof **castor** seed development have been reported (Greenwood and Bewley, 1981 ; Weiss, 2000). During development,seed length increases from 6 to 14 mm. Dried seeds of castor oil plant, Ricinuscommunis L., were obtained from different types of experimental soil recorded in Table (8). Generally, using of the clay soil as a source of castor bean seeds for cultivation of castor bean plant on most different types of soil gave the heights percentage of germination and best growth. There is a need for further studies on propagation ability of castor bean plant on different types of soils. It may be necessary to evaluate the performance of castor bean inrevegetation of cleaned up polluted soils. More importantly, we need to look at the improving of the productivity and growth of castor bean plants. There is need for further studies on metal accumulating ability of R. communis. It may be necessary to evaluate the performance of R.communis in revegetation of cleaned up polluted soils.Consequently, the results of the present work might help in evaluating castor bean for fitting future cultivation in different soils in Egypt, using wastewater sources. Thus, it might be concluded that clay soil is the most suitable for cultivation of castor bean plant. This soil was most fitting for seed germination, growth and characteristics of the yielded seeds under the influence of sewage effluent. It is also suggested to carry out long-term studies for assessing the feasibility of wastewater reuse.

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