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Effect of Polluted Irrigation Water on Some Crops and Their Contents of Heavy Metals.* 2. Sugar Beet

F.I. Zein, M.S. El-Yammani, A.A. El-Leithy, and A.T.A. Moustafa

Soil, Water and Environment Research Institute, ARC, Egypt.

THE MAIN objective of the current study is to investigate the resistance of four sugar beet cultivars, Maribo, Cawemera, Raspoly and Dobreah local (Syrian variety) to long-term effect of three water qualities; Nile water (W1) polluted water (W3) and mixed water: 50% W1 + 50% W3 used for irrigation since 1987. Treatments were incorporated in split-plot design in four replications. The study was carried out in above ground concrete lyzemeters at Sakha Agric. Res. Station, Kafr El-Sheikh, Egypt during two successive seasons; 1995/96 and 1996/97.

The obtained data showed that Maribo cultivar was the superior in sugar yield (t/ha) at the two seasons, for W1 and W2 water quality treatments.

The obtained data showed that Dobreah local cultivar was the superior in its root yield for 3 water quality treatments in 1995/96 , while Maribo cultivar was the superior under W1 and Ras Poly was superior under W2 and W3 in 1996/97.

The data also revealed that the sugar beet roots content of studied heavy metals; Pb, Mn, Zn, Cd, Ni and Cu (mg/kg) were generally increased in the second season than those in the first season, specially when irrigated with drainage water and followed by that of mixed water treatment. Data also showed that sugar beet roots content of Ni was higher than permissible limits when irrigated with mixed water or drainage water in both seasons. Meanwhile, the content of Pb and Cd achieved the maximum permissible limits (10 mg/kg for Pb and 0.8 mg/kg for Cd) in sugar beet root in the second season, when irrigated with drainage water.

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It was found that Maribo cultivar roots were generally the lowest in their content of studied heavy metals, while Cawemera was generally the highest one.

These results clear that Maribo cultivar can be recommended for planting in areas obliged to reuse mixed or drainage water for irrigation.

Keywords Pollution, heavy metals, sugar beet

Fresh water for agriculture in arid and semi-arid region, is considered the most limiting factor for food production. So, Egypt started to look to drainage water reuse for irrigation in order to cover the shortage of fresh water and meet their demands for more food production. In some areas, this water is polluted by the sewage effluents which are damped into the agricultural drainage system. In north Delta region, soils irrigated by drainage water polluted by waste water effluent of some factories were higher in heavy metals content than the normal soils (Zein *et al.*, 1998). The content of heavy metals in soils, water and plant has become of increasing interest due to their impact on polluting natural resources and public health. Mengel and Kirkby (1987) and Zein *et al.* (1996) concluded that crop cultivars vary markedly in metal uptake depending on crop species and genotypes. Increasing levels of heavy metals in soil irrigated with sewage sludge are considered to cause potentially serious hazards in the soil-plant-animal system (Aboulroos *et al.*, 1991). Sugar beet was chosen for this study. Mass (1986) stated that sugar beet is a tolerant crop to salt concentration.

The objective of the present investigation was to evaluate the ability of four sugar beet cultivars to the uptake of some heavy metals.

Material and Methods

Lyzimeter experiments were conducted at Sakha Agric. Res. Station during two successive seasons 1995/96 and 1996/97. The investigation aimed at studying the effect of three irrigation water qualities: (W_1) Nile water (good quality water), (W_2) mixed water (50% Nile water + 50% waste water) and (W_3) waste water (poor quality water) on the content of some heavy metals for four sugar beet cultivars; (V_1) Kawemera, (V_2) Maribo, (V_3) Ras Poly and (V_4)

Dobreah local (Syrian variety). The trials were carried in above ground cement lyzimeters established since 1987 (100 x 70 x 90 cm). The soil is a clay soil (typic ustorthent); 58% clay, 16% silt and 26% sand since 1987. The experimental design was a split-plot design with four replicates. The main plots were randomly assigned to three irrigation water qualities. Sugar beet cultivars occupied the sub-plots. It is important to note that the experiment was repeated in the second season with the same design.

The seeds were sown on 16th and 18th of Nov., 1995 and 1996, respectively for the two seasons of the experiment were treated with 36 kg P_2O_5/ha (super phosphate 15.5% P_2O_5) added before sowing. Nitrogen fertilizer at the rate of 167 kg N/ha (Ammonium sulphate 20% N) was splitted in two equal doses. The first dose was added at thinning and the second dose was added after 30 days afier thinning. The K fertilizer at the rate of 114.0 kg K_2O/ha (K_2SO_4; 48% K_2O) was applied after 50 days from sowing. Plants were thinned to one plant per hill after 50 days from sowing. Sugar beet was harvested on 15 of June of the two seasons.

Representative samples of sugar beet roots were taken at the same time of harvesting from each lyzemeter for analysis, dry ashing technique was used for samples digestion (Chapman and Pratt, 1961) and analyzed for Pb, Mn, Zn, Cd, Ni and Cu using Atomic Absorption Method (Perkin Elmer 3300). Soil samples were taken before planting from each lyzemeter for chemical analysis; total soluble salts (TSS), soluble cations and soluble anions in soil paste extract, (Richards, 1969).

Chemical characteristics of Nile and drainage water used for irrigation during the two seasons are shown in Table 1.

TABLE 1. Chemical characteristics of Nile and waste water during 1995/96 and 1996/97 seasons.

Irrigation water	EC dS/m at 25°C	pH	Anions (me/L)				Cations (me/L)				SAR	Water class
			$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+		
Nile	0.30	7.25	-	3..09	0.75	0.63	1.70	0.97	1.30	0.23	1.13	C_2S_1
Waste 1st season	2.68	8.30	-	4.05	21.00	3.40	4.30	3.98	19.70	0.47	9.68	C_3S_2
Waste 2nd season	2.30	8.40	-	4.05	18.00	3.47	4.30	4.35	16.40	0.47	7.89	C_3S_2

* According to Richards (1969)

Soil samples representing each lyzimeter were taken before planting for chemical analysis. Chemical soil properties are presented in Table 2. Soil samples were analysed for Pb, Mn, Zn, Cd, Ni and Cd by the Atomic Absorption spectrophotometer Perkin Elmer 3300 (Lindsay and Norvel, 1978).

TABLE 2. Effect of irrigation water on chemical analysis of soil saturation paste extract before sowing during 1995/96 and 1996/97 season.

Water treatment	Anions (me/L)				Cations (me/L)				Soil pH	ECe dS/m	SAR
	$CO^{=}_3$	HCO^-_3	Cl^-	$SO^{=}_4$	Ca^{++}	Mg^{++}	Na^+	K^+			
November 1995											
Nile waters	-	3.25	12.90	43.11	24.24	11.92	22.74	0.36	7.8	5.67	5.35
Mixed water	-	3.31	19.99	45.32	26.61	12.97	28.59	0.45	8.1	6.75	6.42
Waste water	-	2.77	30.43	45.41	28.72	14.32	35.13	0.44	8.2	7.58	7.57
November 1996											
Nile waters	-	3.19	6.91	45.87	26.00	11.91	24.19	0.39	8.0	4.24	5.52
Mixed water	-	2.91	27.36	52.37	31.25	12.58	38.35	0.46	8.1	5.68	8.19
Waste water	-	2.81	41.21	59.14	35.21	17.42	49.98	0.55	8.2	7.32	9.74

Results and Discussion

Heavy metals content of Nile and drainage water (ppm)

Data in Table 3 showed that the mean values of studied heavy metals; Pb, Mn, Zn, Cd, Ni and Cu concentration in Nile water were 0.03, 0.011, 0.10, 0.004, 0.021 and 0.022 for Pb, Mn, Zn, Cd, Ni and Cu, respectively. According to the Guidelines of water quality criterion Nat. Acad. of Sci., (1972) the good quality water is considered safe for irrigation. However, the concentration of heavy metals in drainage water were 0.5, 0.19, 0.19, 0.02, 4.95 and 0.08 ppm for the first season and 0.73, 0.27, 0.18, 0.030, 3.47 and 0.06 ppm for Pb, Mn, Zn, Cd, Ni and Cu in the second season, respectively. These variation in heavy metals concentration in drainage water may be due to the differences in pollutant sources. These results are in agreement with those obtained by Zein *et al.* (1996). The mean value of heavy metal concentration in poor quality water indicate that the values of available Mn, Zn and Cd surpassed the critical levels to cause phytotoxicity. Results reported by El-Wakeel and El-Mowelhi (1993) indicated that the values of available Ni, Cd and Co surpassed the permissible limits to cause phytotoxicity.

TABLE 3. Heavy metals content of irrigation water qualities (ppm) during 1995/96 and 1996/97 season.

Water sources	Heavy metals content (ppm) **					
	Pb	Mn	Zn	Cd	Ni	Cu
Nile	0.03	0.011	0.10	0.004	0.021	0.022
Drainage 1st season	0.50	0.19	0.19	0.020	4.95	0.080
Drainage 2nd season	0.73	0.27	0.18	0.030	3.470	0.060
RMC (mg/L)*	5.00	0.011	0.01	0.01	0.200	0.200

* Recommended Maximum Concentration of trace elements in irrigation water mg/L according to Nat. Acad. of Sci. 1972.
* Means of 5 samples.

Heavy metals content of DTPA soil extract during the growing seasons

Data in Table 4 showed that the application of poor quality water since 1987 resulted in a substantial increase of some heavy metals content yet their levels are still below the tolerable limits recommended by Nat. Acad. of Sci. and Nat. Acad. of Eng. (1972). Similar results were reported by Aboulroos *et al.* (1996) who reported that the levels of total and DTPA-extractable heavy metals in the soil and associated crops increased with increasing years of using sewage effluent in irrigation.

TABLE 4. Heavy metals content of DTPA-soil extract during 1995/96 and 1996/97 seasons.

Water treatments	Heavy metals of DTPA-soil extract mg kg^{-1} **					
	Pb	Mn	Zn	Cd	Ni	Cu
November 1995 (before planting 1st season)						
W_1	2.75	8.73	2.03	0.11	0.63	3.92
W_2	3.21	12.32	2.85	0.15	0.86	4.80
W_3	4.06	14.84	4.08	0.32	1.03	5.46
July 1996 (After harvesting 1st season)						
W_1	2.83	8.94	2.12	0.13	0.69	4.03
W_2	3.43	13.70	3.52	0.39	1.69	4.92
W_3	4.34	14.96	5.63	0.71	2.59	5.78
November 1996 (Before planting 2nd season)						
W_1	2.91	9.05	2.25	0.150	0.75	4.11
W_2	3.55	14.01	4.01	0.560	2.42	5.23
W_3	4.63	15.02	7.40	0.930	4.03	6.16
July 1997 (After harvesting 2d season)						
W_1	2.99	9.25	2.41	0.170	0.78	4.20
W_2	3.76	14.39	4.78	0.790	3.34	5.56
W_3	4.87	15.40	8.60	1.250	5.80	6.95
Normal conc.*	100-400	150-300	70-400	3-8	100	60-125

* Normal concentration mg kg^{-1} according to Kabata-Pendias and Pendias (1992).
** Means of 4 samples.

Data in Table 4 also show that the levels of DTPA-extractable heavy metals in soils were generally high in the soils irrigated with waste and mixed water and decreased with the soils irrigated with good quality water. DTPA extractable heavy metals of soils can be arranged according to water qualities as follows: $W_1 < W_2 < W_3$ before sowing. The mean values of DTPA extractable studied heavy metals were increased by 6.9 & 19.9, 0.8 & 3.8, 38.0 & 110.80 and 121.8 & 291% and by 151.5 & 463.4 and 5.9 & 27.3% of that before planting for Pb, Mn, Zn, Cd, Ni and Cu at the ends of first & second seasons, respectively, as a result irrigation by drainage water. This is due to the higher content of polluted water with the oil and soap factory. These results coincide with that of Zein *et al.* (1998) who concluded that the waste of oil and soap factory and drainage water, which contains the leachable fertilizers and pesticides were the main sources of studied soil pollution in Kafr El- Sheikh Governorate.

Effect of polluted irrigation water on root and sugar yields of sugar beet cultivars

Data in Table 5 showed that root yield of sugar beet cultivars were significantly affected with sugar beet cultivars. The higher mean root yields (58.55 and 62.94 (ton/ha) in 1995/96 and 1996/97, respectively) were obtained with Dobreah local in 1995/96 and with Maribo cultivar in 1996/97.

The obtained data showed that Dobreah local cultivar was the superior in its root yield for all water quality treatments in 1995/96 while Maribo cultivar was the superior under W_1 and Ras Poly was superior under W_2 and W_3 in 1996/67.

TABLE 5. Effect of irrigation water qualities on root and sugar yields of four sugar beet cultivars in 1995/96 and 1996/97 seasons.

Sugar beet cultivars	Irrigation water qualities							
	1995/96 season				1996/97 season			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
	Root yield (ton/ha)							
Kawemira	57.51 a	49.54 b	50.43 a	52.49 b	55.72 b	56.18 a	62.51 a	58.13 b
Maribo	44.37 b	51.57 ab	53.11 a	49.68 ab	63.79 a	61.54 a	63.50 a	62.94 a
Dobreah local	62.28 a	58.8 a6	54.50 a	58.55 a	55.71 b	59.89 a	61.39 a	59.00 ab
Ras Poly	47.67 b	52.07 ab	52.90 a	50.88 ab	51.79 b	63.71 a	66.57 a	60.69 ab
	Sugar yield (ton/ha)							
Kawemira	7.46 ab	6.55 b	7.44 a	7.15 b	7.80 ab	8.45 a	8.50 a	8.25 a
Maribo	8.62 a	8.06 a	7.56 a	8.08 a	8.76 a	8.49 a	8.76 a	8.66 a
Dobreah local	7.71 a	7.36 ab	6.90 a	7.32 b	7.35 b	8.26 a	8.41 a	8.01 a
Ras Poly	6.35 b	7.78 ab	7.72 a	7.28 b	8.23 a	8.25 a	8.65 a	8.38 a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

The results in Table 5 also show that sugar yield of sugar beet cultivars were significantly affected with sugar beet cultivars. The highest mean sugar yields (8.08 and 8.66 ton/ha in 1995/96 and 1996/97) were obtained with Maribo cultivar in the two seasons. Maribo cultivar was the superior in its sugar yield under W_1 and W_2 in the two seasons. While Ras Poly cultivar was the superior under W_3 in the two seasons. The gross sugar of sugar beet cultivars, as affected by polluted irrigation water, were in the order: Maribo > Dobreah local > Ras Poly > Kawemira in the first season and Maribo >Ras Poly > Kawemira > Dobrea local in the second season.

Effect of polluted irrigation water on some heavy metals content of four sugar beet cultivars

Data in Fig 1 showed that heavy metals content in sugar beet cultivars generally increased by the application of poor quality water. This increase was more pronounced with Kawemira cultivar for the two seasons. Data also revealed that sugar beet content of studied heavy metals generally increased in the second seasons than that corresponding in the first season specially soils irrigated with waste water possibly due to the accumulation effect. Data also show that in general the concentration of heavy metals content of Kawemira cultivar was the largest while Maribo cultivar was the lowest one under the same irrigation treatment.

First season

Data in Fig.1 show that the highest mean values of heavy metals content of Kawemira cultivar irrigated with waste water which were in order: Zn > Mn >Cu>Ni>Pb>Cd. Zein *et al.* (1996) found that the application of waste water increased the concentration of heavy metals in four soybean cultivars used in their study. However, the magnitude of such increase differed according to the nature of the elements, its level in the irrigation water, as well as the sugar beet variety. While the lowest values of heavy metals content of Pb, Mn, Zn, Cd, Ni and Cu were obtained with Maribo cultivar by using fresh Nile water which thier mean values were in the following descending order: Mn > Zn > Cu > Ni> Pb > Cd. It could be noticed that the application of waste water resulted in a substantial increase of heavy metals content in sugar beet cultivars, yet the levels of Pb, Mn, Zn, Cd and Cu lies within the normal concentration range. While the Ni concentration in sugar beet cultivars is much higher than the normal concentration range under the application of waste and mixed water, according to Helal *et al.*(1984).

Second season

Data in Fig. 1 showed that heavy metals content in sugar beet cultivars increased generally in the second season than that in the first season, specially when irrigated by waste water followed by mixed water. It can be due to the high content of heavy metals in soils irrigated by waste or mixed water. These results are in agreement with those obtained by Aboulroos *et al.* (1996) who found that heavy metal content of the leaves of corn increased with increasing levels of extractable metals in the soils.

The highest values of heavy metals content 6.8, 14.30, 25.3, 0.703, 9.90 and 12.6 mg kg^{-1} for Pb, Mn, Zn, Cd, Ni and Cu, respectively were obtained with Kawemira cultivar by using poor quality water. The mean values of heavy metals content were in the order: Zn> Mn > Cu > Ni> Pb> Cd. The concentration of pb, Mn, Zn, Cd and Cu lies within the normal concentration range, while the concentration of Ni in sugar beet cultivars is much higher than the normal concentration range. The high Ni content in sugar beet cultivars under soils irrigated by poor quality water reflects the high level of Ni concentration in

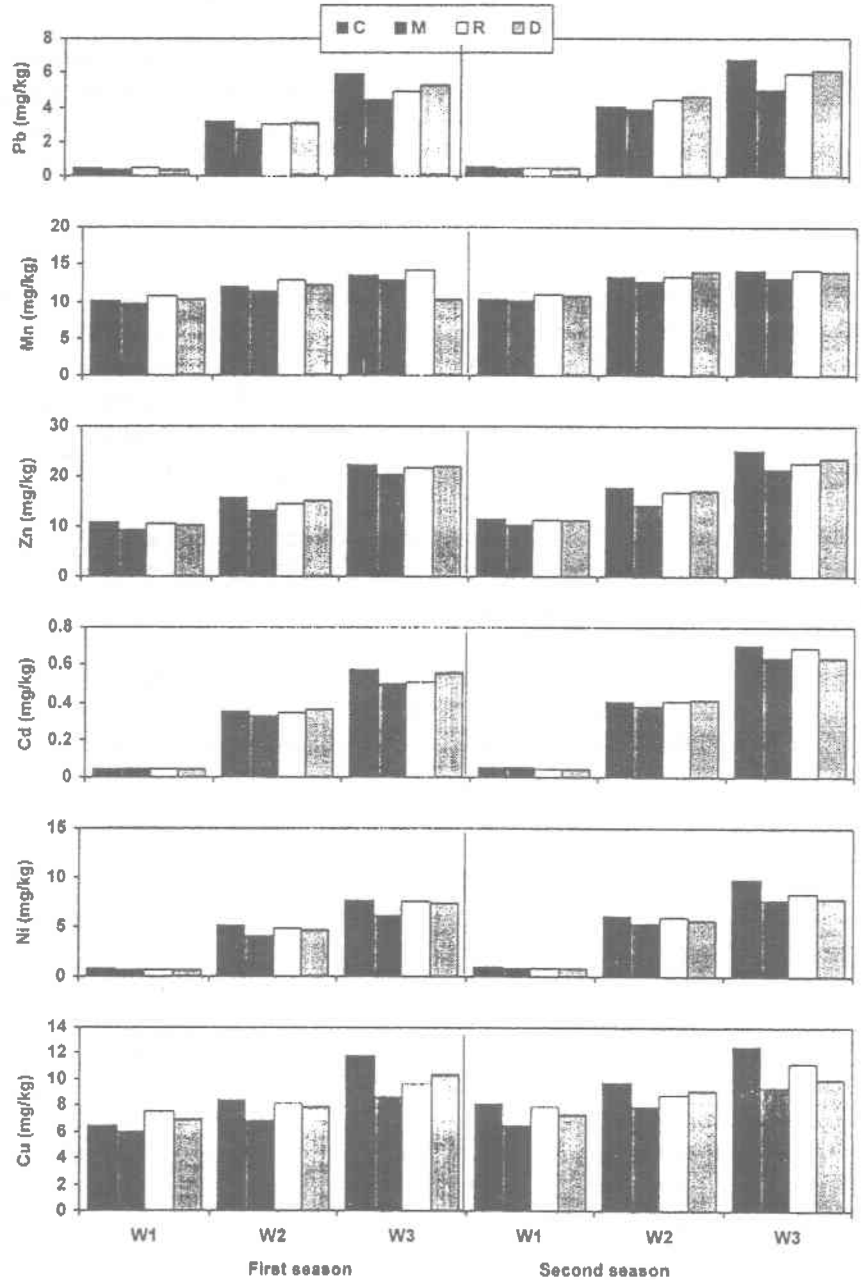

Fig. 1. Heavy metals content in sugar beet cultivars as affected by water treatments 1995/96 and 1996/97.

waste and mixed water. While the lowest values of heavy metals content 5.01,13.20,21.4,0.639, 7.80 and 9.40 mg kg^{-1} were obtained with Maribo cultivar by using fresh Nile water. The mean values of heavy metals content being in the following order: Zn > Mn > Cu > Ni > Pb> Cd. This content of heavy metals lies within the normal concentration range (15-200, 15-100, 4-15, 1.0,0.1-1.0, and 0.2-6.8 mg kg^{-1}) dry plant, respectively according to Helal *et al.,* (1984).

It may be concluded that fresh Nile water is considered safe for irrigation. However, the waste one increased the DTPA extractable heavy metals in soils and the concentration of heavy metals in sugar beet cultivars, Ni content was higher than permissible limits. Maribo cultivar was the lowest one in their heavy metals content. Therefore, it can be recommended for planting in areas obliged to reuse waste water for irrigation.

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تاثير نوعية المياه على بعض المحاصيل ومحتواها من العناصر الثقيلة ٢- بنجر السكر

فاروق إبراهيم زين، محمد صابر اليمانى ، عابدين عبد الحميد الليثى و أحمد طاهر مصطفى

معهد بحوث الأراضى والمياه والبيئة - مركز البحوث الزراعية - الجيزة - مصر.

الهدف الرئيسى لهذا البحث هو دراسة مقاومة أربعة أصناف من بنجر السكر هم ماريبو ، كاواميرا ، راسي بولي، ودبرية محلي (صنف سوري) لتاثير ثلاثة نوعيات لمياه الري لفترات طويلة : (W_1) مياه النيل ، (W_2) مياه مخلوطة (٥٠٪ مياه النيل + ٥٠٪ مياه الصرف) ، (W_3)مياه الصرف الملوثة.

* أقيمت التجربة في تصميم قطع شقية مع أربعة مكررات .

*أقيمت التجربة فى ليزميترات أسمنتية فى محطة البحوث الزراعية بسخا - كفر الشيخ - مصر خلال موسمين متعاقبين ١٩٩٦/٩٥ ، ١٩٩٧/٩٦.

تشير النتائج الي ان الصنف دبرية محلي (صنف سوري) تفوق في محصول الجذور تحت ظروف معاملات الري المختلفة في الموسم ١٩٩٦/٩٥ بينما تفوق الصنف ماريبو تحت معاملة الري بمياه النيل وتفوق الصنف راسي بولي تحت معاملتي الري بماء الصرف والمياه المخلوطة فى موسم ١٩٩٧/٩٦.

النتائج المعطاة توضح أن محتوي جذور بنجر السكر من العناصر الثقيلة تحت الدراسة : الرصاص ، المنجنيز ، الزنك ، الكادميوم ، النيكل ، والنحاس (مجم/كجم) عموما يزيد المحتوى في الموسم الثانى مقارنة بالموسم الأول خصوصا تحت ظروف الري بمياه الصرف يليها الري بالمياه المخلوطة .

توضح النتائج أيضا أن محتوى جذور بنجر السكر من النيكل كان أعلى من الحدود المسموح بها تحت ظروف الري بمياه الصرف أو المياه المخلوطة في كلا الموسمين .

بينما محتوى الرصاص والكادميوم اقترب من الحد الأقصى المسموح به (١٠ مجم/كجم للرصاص، ٨ ر. مجم/كجم للكادميوم) فى جذور بنجر السكر فى الموسم الثانى تحت ظروف الري بمياه الصرف.

وقد لوحظ أن جذور بنجر السكر للصنف ماريبو تحتوى أقل كميه للعناصر الثقيلة تحت الدراسة بينما الصنف كاواميرا عموما يحتوى على أعلى كميه من العناصر الثقيلة .

هذه النتائج توضح أن الصنف ماريبو يمكن أن يوصى بزراعته فى المساحات التى تجبر على إعادة إستخدام مياه الصرف أو المياه المخلوطة فى الري .

هذ الدراسة تم تمويلها من المجالس الإقليمية للبحوث والإرشاد - مصر .