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Evaluation of Genotypic Variation in Lead and Cadmium Accumulation of Rice (*Oryza sativa*) in Different Water Conditions in Egypt

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Authors' contributions

All authors designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author HBEH managed the lab analyses of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Lead (Pb) and cadmium (Cd) can be absorbed and transported effectively by rice plants and could easily enter into the food chain. This research aimed at identifying rice germplasm with low Pb and Cd concentrations, and to assess their potential risks to human health. A 2-year pot experiment if 30 rice genotypes were conducted in a greenhouse at Rice Research and Training Center (RRTC) Sakha Kafr El-Sheikh, Egypt during 2012 and 2013 rice growing seasons, under irrigating with fresh water from the River Nile (FW), drainage water from El-Gharbia main drain Kitchener (DK) and drain No. 8 (D8). The pots were arranged in a randomized complete block design with four replications. All genotypes tested in this study gave high grain and straw yield under irrigation by DK than irrigation by D8 and FW. The concentrations of Pb and Cd in all organs of tested rice genotypes (roots, straw and grains) decreased in the sequence of Indica > Japonica >Indica /Japonica types under all sources of irrigation water in this study. Pb and Cd concentrations in grains of some rice genotypes were above the safety limits 2.00 and 0.40 ppm, respectively. In the same time grains of 13 genotypes were below the safety limits. The risk assessment of Pb and Cd through consumption of some rice genotypes indicated that the target hazard quotient of Pb (THQ_{Pb}) and Cd (THQ_{Cd}) in

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some rice genotypes exceeded the permissible limits (1.00) for an adult but not in all tested genotypes. THQ_{Pb} and THQ_{Cd} values for Pb and Cd through the consumption of rice decreased in the order Indicia > Japonica >Indicia /Japonica. Rice germplasm with a strong tendency for accumulating Pb and Cd should be avoided when using poor water quality in irrigation.

Keywords: Rice; varieties; heavy metals; daring water; soil; rice grain.

1. INTRODUCTION

Egypt falls under arid and semi-arid Zone of the world. The river Nile is the main source of water in Egypt. The water sector in Egypt is facing many challenges including water scarcity and deterioration of water quality because of population increase, lack of renewable resource and bad practices followed by human. The River deterioration in quality of water due to over 90 agricultural drains that discharge into Nile also, includes industrial wastewater [1]. Egypt indicated that there was an overall deficit of approximately 8 billion m^3 [2]. The present per capita water share is below 1,000 m^3 /year and it might reach 600 m^3 / year in the year 2025, which would indicate water scarcity (water poverty limit starts at 1,000 m^3/ year)) [3] . Also, in the Delta region, drainage water is reused for irrigation after mixing with Nile water, while in Upper Egypt drainage water disposed into the River Nile [4]. Moreover, the use of chemical fertilizers and pesticides has significantly increased after the construction of high dame, resulting in increased pollution, particularly by heavy metals. Heavy metals are severe contaminants in the environment. Their accumulation in the atmosphere, soil and water can cause serious problems to all organisms, and their bioaccumulation in the food chain can be highly dangerous to human's health. Among the heavy metals cadmium (Cd) and lead (Pb) are common considered as toxic to both plant and humans [5-6]. Lead and Cd are considered potential carcinogens and are associated with etiology of a number of diseases, especially cardiovascular, kidney, nervous system, and blood as well as bone diseases [7]. Water quality management and water pollution control to produce safe crop products is the main issue to ensure food security for us and the next generation. Efforts have been made to remediate contaminated water and soil to allow safe crops with low heavy metal contents particularly, in rice which is one of the most consumed crops in the world including Egypt. However, the traditional methods to treat water and soil are extremely environmentally disruptive and expensive [8]. Great efforts should be done to reduce heavy metals accumulation in agricultural crops following easy and economic methods. One of these methods is screening low accumulation rice varieties of Pb and Cd concentrations in all organs of plant. Previous studies reported that significant genotypic variation was detected in Cd, Cr, As, Ni and Pb concentrations of rice grains, indicating the possibility to reduce the concentrations of these heavy metals in grains through breeding approach [9]. There is a great difference among crop species and genotypes within a species in heavy metal uptake and accumulation [10]. In rice, a wide difference exists among genotypes in their ability to accumulate Cd in grains [11,12]. Japonica brown rice varieties have the lowest average Cd and Pb uptake rates compared to the other two varieties namely, indica and Hybrid [13]. The fundamental requirement for breeding low grain Pb and Cd-accumulation rice cultivars is to know the genotypic variation in Pb and Cd accumulation and the physiological processes and genetic basis governing the Pb and Cd accumulation in rice grain [14]. So, exploiting rice varieties that do not accumulate Pb and Cd can be a viable option for rice cultivation in polluted areas or areas that oblige to irrigate by polluted water. Identification of these varieties can also be a first step towards breeding rice varieties that are highly tolerant to heavy metals [15-16]. Recently a number of advanced studies reported that a novel rice gene Low cadmium (LCD) is involved in Cd ac accumulation and tolerance [17,18]. LCD is not homologous to any other genes, and the authors concluded that LCD is a novel protein related to Cd homeostasis. [19]. reported that a novel cysteine-rich peptides encoded by OsCDT1 is possibly involved in rice Cd tolerance. Over expression of OsCDT1 in A. thaliana increased the growth of plants under Cd exposure. Our efforts were, therefore, directed toward evaluating the effect of different kind of irrigation water (FW, DK and D8) on 1) genotypic variation among different rice genotypes in the accumulation of Pb and Cd and select the best genotypes for cultivation under irrigation by poor water quality, 2) the quantity and safety of grain and straw yield of 30 tested rice genotypes under this study and 3) Assess possible risks of consuming rice grains contaminated with Pb and Cd on human health using the target hazard quotient (THQ Pb) and (THQ Cd) for Pb and Cd respectively

2. MATERIALS AND METHODS

A Pot experiment was conducted in a greenhouse at Rice Research and Training Center (RRTC) Sakha Kafr El-Sheikh, Egypt during rice growing seasons 2012 and 2013.In this study, 30 rice genotypes from different origins are shown in Table 1, (Indica, Japonica and Indica/Japonica types) were evaluated under irrigation by fresh water from the River Nile (FW), wastewater from Kitchener drain (DK) which consists of industrial, sewage and agricultural wastewater(El-Gharbia main drain)and drain No.8 (D8) which consists of sewage and agricultural wastewater. Alluvial soil was taken from the farm of Rice Research and Training Center, Sakha Kafr El-Sheikh (RRTC) from the surface layer (0-20 cm) to fill the pots. After air dried and sieved (2 mm sieve), twenty kg of soil was placed in each plastic pot (37 cm in diameter x 45 cm in height). Chemical analysis of the soil, fresh water (FW) and drainage water (DK and D8) which were used in this experiment during 2012 and 2013 seasons are presented in Table 2. The experiments were carried out under open air conditions. The pots were arranged in a randomized complete block design with four replications. All calculations of fertilizers (N, P, K and Zn) were done based on the weight of the soil for one Fadden at 15 cm, according to recommended fertilizer doses at RRTC, Sakha, and Kafr El-Sheikh in Egypt. All pots were maintained under flooded conditions with 3 cm of water above soil surface during the rice growth period. Seeds of different rice genotypes were soaked for 24 hours and incubated for 48 hours at room temperature. The pre germinated seeds were planted on 20th of May at rate of 10 seeds/ pot for each genotype and thinned at 5 plants after 2 weeks in both seasons 2012 and 2013. At maturity the rice plants were harvest from pots and divided into roots, straw and grains, freshly weighted, dried at 70 Co to constant weight for yield grain and straw. The oven dried samples were ground and kept for analysis according to [20]. Plant samples (roots, straw and polished grains) were digested in glass tubes containing 5 ml of concentrated HNO3 and 1 ml of HCLO4 placed in a heat block at 100°C until the solution became clear. The samples volumes were diluted to 50 ml with distilled water. Available heavy metals (Pb and Cd) in soil were extracted by DTPA. Aqua regia were extracted the total heavy metals in water according to the method describe by [21]. The concentrations of heavy metals in soil and plant organs were determined using Atomic Absorption Spectrophotometer (GBC Avanta ∑). Total soluble cations and anions in soil paste extract were assessed according to [22]. All the collected data were subjected to statistical analysis according to procedure described by [23]. Data means were compared at $p< 0.05$ by the revised least significant differences (LSD), which adapted by [24]. Statistical analyses were made with commercial computer software (Genstat).

Table 1. List of rice genotypes used in this study

No	Variety	Group	N0	Variety	Group
1	IR71131-BF-4-B-30-5	Indica	21	Giza177	Japonica
2	IR73688-82-2-3-2	Indica	22	Sakha101	Japonica
3	IR74506--28-4-3-2	Indica	23	Sakha102	Japonica
4	Giza182	Indica	24	Sakha104	Japonica
5	E.YASMINE	Indica	25	GZ7576-10-3-2	Japonica
6	IR64	Indica	26	Sakha105	Japonica
7	N22	Indica	27	Azucena	Japonica
8	TCCP 266-49-B-B	Indica	28	Gaori	Indica-Japonica
9	CSR-90IR-2	Indica	29	Giza178	Indica-Japonica
10	WAB 880-1-32-1-2-P1-HB	Indica	30	GZ6292-12-1-2-1-1	Indica-Japonica
11	IR29	Indica			
12	Moroberkan	Indica			
13	IR 65598-112-2-1	Indica			
14	IR 65564-44-2-3	Indica			
15	IR 65600-96-1-2-2	Indica			
16	IR 66158-38-3-2	Indica			
17	IR 66738-118-1-2	Indica			
18	IR 67962-40-6-3-3	Indica			
19	IR 66160-5-2-3-2	Indica			
20	IR 66160-121-4-5-3	Indica			

Table 2. Chemical analysis of soil, fresh water (FW), drainage water of Kitchener drain (DK) and drain No. 8 (D8) used in this study during 2012 and 2013 seasons

	Soil Before planting		Soil After planting		Fresh water (FW)		Water of Kitchener drain (DK)		Water of No. 8 drain (D8)	
	2012	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
pH	8.23	8.42	8.15	8.20	7.23	7.12	7.66	7.78	7.67	7.51
Ec(ds/m)	3.10	2.95	3.83	3.63	0.53	0.58	2.70	2.82	2.39	2.54
Anions (meq/l)										
$CO_3^{=}$	-	-	-	-	-	-	0.10	0.40	-	-
$HCO_3^{=}$	5.55	6.23	6.80	7.00	3.66	3.77	5.75	5.90	4.78	4.89
Cl	9.81	11.23	10.20	12.30	1.02	1.23	4.90	5.03	13.2	14.50
$SO_4^{=}$	24.24	22.33	21.39	19.37	0.69	0.83	16.30	17.00	6.00	6.01
Cations (meq.l^{-1})										
Ca	12.30	11.50	11.90	10.30	1.77	1.81	3.65	2.90	5.00	5.59
Mg	5.60	6.80	5.00	7.30	1.52	1.70	3.70	4.00	3.60	3.86
Na	9.80	8.50	11.12	9.77	1.83	1.95	17.00	18.30	14.80	15.21
K	11.90	12.99	10.30	9.00	0.31	0.45	2.70	2.90	0.51	0.61
Heavy metals (ppm)										
Cd	0.98	1.20	1.34	1.50	0.008	0.009	6.30	10.80	0.056	0.087
Pb	5.30	4.80	7.30	6.90	0.895	1.22	35.00	44.00	3.70	4.20
Ni	2.33	1.90	3.50	4.33	0.30	0.41	28.00	35.50	3.87	4.68

Permissible limits of (Pb and Cd) in irrigation water (5.00 and 0.01) [25], [26]
Critical level of (Pb and Cd) in soil (100 and 3.0) [27]

Heath risk assessment: The health risk associated with grain consumption of different rice genotypes contaminated with Pb and Cd was assessed based on the target hazard quotient (THQ) [25]. A THQ of less than 1.00 means the exposed population is assumed to be safe. The THQ values of Pb and Cd were determined following equation 1:

$$THQ = \frac{E_F\, E_D\, F_{IR}\, C}{R_{FD}\, W_{AB}\, T_A} \times 10^{-3}$$

where, E F (365 days/yr) is the exposure frequency; E D (70 years) is the exposure duration; F IR (g /(person. day)) is the food (rice) ingestion rate, assuming the average daily rice ingestion rates for adults of 134.20g /(person. day) (World Top Ten Population Countries in, 2013); C (mg /kg) is the metal concentration (Pb or Cd) in the food; R FD (mg /(kg·day)) is the oral reference dose, which was obtained from the Integrated Risk Information System [25] with the exception of Pb and Cd for which we used the formula RFD= PTWI/7, where PTWI is the provisional tolerable weekly intake ($mg.kg^{-1}.day^{-1}$) as defined by the Joint FAO/WHO Expert Committee on Food Additives [26],W AB (kg) is the average body weight in Egypt (65 Kg for adult), and TA is the averaged exposure time for non-carcinogens (365 days/year, number of exposure years assumed as 70). Oral reference doses for Pb and Cd were based on 1×10^{-3} and 1.5×10^{-3} mg/ (kg·day) respectively [28,29]. If the value of THQ is less than one it is assumed to be safe for risk of non-carcinogenic effects. If it exceeds one it is believed that there is a chance of carcinogenic effects, with an increasing probability as the value of THQ increases [30,31].

3. RESULTS AND DISCUSSION

3.1 Grain and Straw Yield

Significant differences were observed among the types of irrigation water for straw and grain yield (Table 3). Grain and straw yield significantly increased under irrigation by drainage water whether, from DK or D8 compared to irrigation with FW in both 2012 and 2013 seasons for the same genotypes. This may be due to that the drainage water contains organic matter that release nutrients to plant and other substances growth promotion for plant. These results are agreed with the findings of [32] who indicated that using of wastewater in agriculture undoubtedly helps to recycle useful nutrients by plant uptake.

As shown in Table 3, highly significant differences were observed among the 30 tested rice genotypes for grain and straw yield in this study. All rice genotypes gave higher grain and straw yield under irrigation by water of DK than using the water of D8. Variation of grain and straw yield among the tested rice genotypes was mainly due to the differences in their genetic background. Average of grain and straw yield for all rice varieties under irrigation by FW, DK and D8 during the two years in Table 3 show that the highest values of grain yield/plant were 38.78 and 42.41 g for Sakha 102 followed by Azucena 38.55 and 42.18 g and Sakha105 38.35 and 41.99 g rice genotypes during 2012 and 2013 seasons respectively. For straw yield/plant, the rice genotypes IR74506-28-4-3-2 and E.Yasmine recorded highest values (36.52 and 39.60 g) and (36.40 and (39.47 g) in 2012 and 2013 seasons respectively.

Table 3. Grain yield (g. plant^{-1}) and Straw yield (g/plant).of different rice genotypes under irrigation by FW, DK and D8 in 2012 and 2013 seasons

Treatments	Grain yield (g/plant))		Straw yield (g/plant)	
Water Sources (A)	**2012**	**2013**	**2012**	**2013**
DK	41.27	46.55	34.72	38.41
D8	37.00	41.76	27.43	30.81
FW	22.40	23.28	27.27	29.41
LSD 0.05	1.654	2.670	0.111	0.169
F Test	*	*	*	*
Genotypes (B)				
IR71131-BF-4-B-30-5	31.51	35.14	29.21	32.29
IR73688-82-2-3-2	32.44	36.08	30.30	33.38
IR74506--28-4-3-2	30.63	34.27	36.52	39.60
Giza182	31.91	35.55	30.18	33.25
E.YASMINE	31.04	34.68	36.40	39.47
IR64	32.44	36.07	26.82	29.89
N22	33.20	36.84	23.21	26.28
TCCP 266-49-B-B	31.60	35.24	28.31	31.39
CSR-90IR-2	32.06	35.70	31.11	34.19
WAB 880-1-32-1-2-P1-HB	31.04	34.68	34.60	37.67
IR29	33.19	36.82	33.07	36.15
Moroberkan	32.75	36.39	29.21	32.28
IR 65598-112-2-1	33.12	36.76	30.46	33.49
IR 65564-44-2-3	34.24	37.87	28.00	31.07
IR 65600-96-1-2-2	33.77	37.40	26.28	29.89
IR 66158-38-3-2	33.28	36.92	31.06	34.13
IR 66738-118-1-2	31.64	35.28	32.67	33.74
IR 67962-40-6-3-3	32.08	35.72	31.05	34.12
IR 66160-5-2-3-2	32.08	35.72	33.85	36.92
IR 66160-121-4-5-3	34.47	38.10	31.42	34.50
Giza177	33.60	37.23	30.18	33.25
Sakha101	35.82	39.46	23.35	26.42
Sakha102	38.78	42.41	25.22	28.30
Sakha104	33.11	36.75	36.67	35.75
GZ7576-10-3-2	33.44	37.08	27.83	30.90
Sakha105	38.35	41.99	27.76	30.84
Azucena	38.35	42.18	30.49	33.56
Gaori	36.77	40.41	24.59	27.66
Giza178	35.27	38.91	32.77	35.85
GZ6292-12-1-2-1-1	34.52	38.16	24.58	27.66
LSD 0.05	1.783	1.564	1.961	1.653
F Test	*	*	*	*
Interaction: A*B	*	*	*	*

FW= fresh water, DK= El-Gharbia main drain or Kitchener drain, D8= drain No. 8
**= significant*

The interaction between types of irrigation water and 30 tested rice genotypes were highly significant for grain and straw yield during the two seasons. All 30 genotypes tested, gave higher grain yield under irrigation by DK compared with FW and D8 in both seasons (Tables 4 and 5). This may be due to the higher contents of organic nutrients and some growth substances in DK than FW and D8.These results agreed with finding of [33] who found that a significant increase in straw and grains yield for Giza177 and Giza 178 rice cultivars resulted in irrigation by wastewater than irrigation by fresh water. Data in Tables 3, 4 and 5 reveal that generally the grain and straw yield increased in 2013 compared with 2012 season under irrigated by FW, DK and D8. This may be due to the fact that most nutrients contents in water and soil in 2013 was higher than 2012 as shown in Table 1.

Table 4. Grain yield (g. plant^{-1}) of rice genotypes as affected by the interaction between water types and different genotypes in 2012 and 2013 seasons

Genotypes	2012 season			2013 season		
	FW	DK	D8	FW	DK	D8
IR71131-BF-4-B-30-5	22.04	37.58	34.54	23.28	42.86	39.29
IR73688-82-2-3-2	22.09	38.44	36.81	22,95	43.72	41.46
IR74506--28-4-3-2	22.02	36.22	33.66	22.90	41.50	38.41
Giza182	22.19	38.76	34.78	23.07	44.41	39.53
E.YASMINE	22.60	37.32	33.21	23.48	42.60	37.96
IR64	21.00	40.74	35.57	21.38	46.02	40.32
N22	21.39	42.02	36.20	22.27	47.30	40.95
TCCP 266-49-B-B	20.45	39.80	34.56	21.33	45.08	39.31
CSR-90IR-2	19.89	40.20	36.09	20.77	45.48	40.84
WAB 880-1-32-1-2-P1-HB	21.58	40.08	31.46	22.46	45.36	36.22
IR29	23.44	41.00	35.12	24.32	46.28	39.87
Moroberkan	21.01	42.12	35.12	21.89	47.40	39.87
IR 65598-112-2-1	22.09	41.14	6.13	22.97	46.42	40.88
IR 65564-44-2-3	21.75	44.24	36.72	22.63	49.52	41.47
IR 65600-96-1-2-2	24.03	41.46	35.62	24.91	46.92	40.37
IR 66158-38-3-2	23.38	40.06	36.40	24.26	45.34	41.15
IR 66738-118-1-2	20.11	40.22	34.60	20.99	45.50	39.35
IR 67962-40-6-3-3	22.33	38.90	35.01	23.21	44.18	39.76
IR 66160-5-2-3-2	22.50	38.70	35.05	23.38	43.98	39.80
IR 66160-121-4-5-3	24.20	44.12	35.08	25.08	49.40	39.83
Giza177	21.85	39.50	39.44	22.73	44.78	44.19
Sakha101	25.60	43.30	38.46	26.48	48.58	43.13
Sakha102	23.68	46.76	45.66	24.56	52.04	50.63
Sakha104	24.98	39.80	34.56	25.86	43.08	39.31
GZ7576-10-3-2	21.36	38.60	40.37	22.24	43.88	45.13
Sakha105	22.50	48.30	44.26	23.38	53.58	49.01
Azucena	24.83	44.88	45.94	25.71	50.16	50.69
Gaori	20.74	46.90	42.68	21.62	52.18	47.43
Giza178	25.05	42.60	38.17	25.93	47.88	43.91
GZ6292-12-1-2-1-1	20.94	44.06	38.57	21.82	49.34	43.33
LSD 0.05=		3.269			2.839	
F test		*			*	

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain, D8 = drain No. 8
**= significant*

Table 5. Straw yield (g. plant^{-1}) of rice genotypes as affected by the interaction between water types and different genotypes in 2012 and 2013 seasons

Genotypes	2012 Season			2013 Season		
	FW	DK	D8	FW	DK	D8
IR71131-BF-4-B-30-5	26.95	33.96	26.37	29.09	37.06	30.12
IR73688-82-2-3-2	27.53	35.36	28.01	29.67	39.06	31.40
IR74506--28-4-3-2	30.87	43.36	35.35	23.01	47.06	38.73
Giza182	27.47	35.20	27.87	29.61	38.90	31.35
E.YASMINE	30.80	43.20	35.42	32.94	46.90	38.59
IR64	25.67	30.38	23.91	27.81	34.58	27.29
N22	23.73	26.24	19.65	25.87	29.44	23.04
TCCP 266-49-B-B	26.47	32.80	25.67	28.61	36.50	29.05
CSR-90IR-2	27.97	36.40	28.97	30.11	40.10	32.35
WAB 880-1-32-1-2-P1-HB	29.83	40.88	33.07	31.97	44.58	36.46
IR29	29.02	38.92	31.28	31.16	42.62	34.66
Moroberkan	26.95	33.95	26.72	29.09	37.65	30.11
IR 65598-112-2-1	27.83	36.08	28.67	29.97	39.78	32.06
IR 65564-44-2-3	26.30	32.40	25.30	28.44	36.10	28.69
IR 65600-96-1-2-2	25.67	30.88	23.91	27.81	34.58	27.69
IR 66158-38-3-2	27.94	36.33	28.90	30.08	40.02	32.29
IR 66738-118-1-2	28.80	38.40	30.80	30.94	42.10	34.19
IR 67962-40-6-3-3	27.93	36.32	28.89	30.07	40.02	32.58
IR 66160-5-2-3-2	29.43	39.92	32.91	31.57	43.62	35.58
IR 66160-121-4-5-3	28.13	36.80	29.33	30.27	40.50	32.72
Giza177	27.47	35.20	27.87	29.61	38.90	31.25
Sakha101	23.81	26.42	19.81	25.95	30.11	23.20
Sakha102	24.81	28.83	22.03	26.95	32.53	25.42
Sakha104	28.81	38.81	30.81	30.94	42.10	34.20
GZ7576-10-3-2	26.21	32.18	25.09	28.35	35.87	28.48
Sakha105	26.17	32.10	25.02	28.31	35.79	28.41
Azucena	27.63	35.60	28.23	29.77	39.30	31.62
Gaori	24.47	28.02	21.28	26.61	31.71	24.67
Giza178	28.86	38.54	30.92	31.00	42.23	34.31
GZ6292-12-1-2-1-1	24.47	28.01	21.27	26.61	31.70	24.66
LSD 0.05		3.340			2.630	
F test		*			*	

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain, D8 = drain No. 8
**= significant*

3.2 Lead (Pb^{2+}) Concentrations (ppm) in the Different Organs of Rice Genotypes

Data in Table 6 demonstrate that the high concentration of Pb in roots, straw and grains under irrigation by DK followed by the irrigation from D8 as compared with irrigation by FW. Data also, showed that the highest of Pb concentration was found in the roots followed by straw, while the grains had the lowest value of Pb concentration for all tested rice genotypes in both seasons 2012 and 2013. This may confirm the retention of Pb in plant roots and its low translocation to straw and grains with all genotypes. These results agreed with the findings of [34], [35], [36], [37], who found that the variation among different parts of rice genotypes in Pb concentrations were generally in order roots > shoots > grains at maturity.

Table 6. Lead (Pb) concentrations (ppm) in roots, straw and grains of different rice genotypes under irrigation by FW, DK and D8 in 2012 and 2013 seasons

Treatments	Roots		Straw		Grains	
Water source (A)	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
DK	51.82	52.61	19.16	17.99	2.69	2.72
D8	42.34	40.66	18.35	17.89	2.37	2.51
FW	23.66	23.52	10.70	11.13	1.35	1.39
LSD 0.05	0.038	0.34	0.48	0.20	0.14	0.18
Ftest	*	*	*	*	*	*
Genotypes (B)						
IR71131-BF-4-B-30-5	44.33	42.54	11.04	10.36	2.50	2.56
IR73688-82-2-3-2	44.46	47.96	15.27	14.40	3.05	2.86
IR74506--28-4-3-2	35.43	36.94	10.91	10.41	1.36	1.60
Giza182	60.80	54.64	16.11	15.31	2.81	3.06
E.YASMINE	41.02	47.64	18.07	16.73	3.02	3.08
IR64	38.70	41.17	13.02	11.50	1.79	1.57
N22	36.37	35.12	13.23	13.63	2.01	1.98
TCCP 266-49-B-B	56.90	55.33	20.46	20.11	3.40	3.64
CSR-90IR-2	41.53	42.39	16.18	17.57	1.96	1.68
WAB 880-1-32-1-2-P1-HB	62.88	55.50	18.47	20.49	3.45	3.17
IR29	52.70	49.84	19.55	17.31	3.00	3.10
Moroberkan	43.36	43.76	27.92	26.63	3.40	3.48
IR 65598-112-2-1	27.46	27.30	13.78	15.27	0.86	0.86
IR 65564-44-2-3	40.89	35.38	25.93	25.05	2.28	2.53
IR 65600-96-1-2-2	25.24	24.38	10.19	9.48	0.48	0.62
IR 66158-38-3-2	38.16	38.00	16.77	15.73	1.62	1.70
IR 66738-118-1-2	37.00	38.93	22.68	19.28	3.08	3.17
IR 67962-40-6-3-3	41.11	46.33	19.19	19.12	1.93	1.93
IR 66160-5-2-3-2	17.14	23.06	8.34	8.63	0.50	0.62
IR 66160-121-4-5-3	32.57	34.08	19.87	17.29	2.56	3.04
Giza177	42.46	36.68	19.00	19.06	2.65	2.76
Sakha101	40.52	38.49	13.43	11.76	2.01	2.01
Sakha102	33.93	31.79	8.96	9.76	1.27	1.34
Sakha104	44.46	41.50	16.27	15.86	2.47	2.40
GZ7576-10-3-2	36.93	33.60	17.00	17.83	2.12	2.15
Sakha105	33.26	34.45	17.05	17.10	1.98	2.22
Azucena	37.76	38.30	17.41	18.40	2.22	2.33
Gaori	29.10	32.20	11.38	10.33	1.33	1.68
Giza178	26.96	28.94	12.74	13.95	1.70	1.47
GZ6292-12-1-2-1-1	30.67	31.70	11.53	11.97	1.53	1.64
LSD 0.05	1.79	4.08	1.22	0.67	0.29	0.37
F test	*	*	*	*	*	*
*Interaction: A*B*	*	*	*	*	*	*

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8
**= significant*

Highly significant differences in Pb concentrations were observed among 30 rice genotypes for both seasons. The data also, clarified that IR65598-112-2-1, IR65600-96-1-2-2 and IR66160-5-2-3-2 as Indica type had the lowest Pb concentrations in their roots, straw and grains followed by both Sakha102 as Japonica type and Giza78 as Indica/Japonica type compared with the other tested genotypes. It is important to notice that the great diversity in Pb concentration in organs of tested genotypes may be due to genetic behavior of these genotypes for its controlling the uptake and translocation of Pb. Also, recent reports have indicated the existence in plants of a Pb-resistance mechanism that results in the exclusion of Pb from the root apex through the release of Pb-binding ligands such as organic acids. When these ligands are released from roots to the rhizosphere, they effectively chelate Pb and reduce its entry into the root.

Data indicated that there are highly significant differences in the interaction between 30 rice genotypes and types of irrigations water in Pb concentrations in roots average of both seasons presented in Fig. 1. Data revealed that the rice irrigated by water DK gave highest value of Pb concentrations in roots for all the tested genotypes followed by irrigation from D8, while the irrigation by FW gave the lowest concentration of Pb in the roots. The highest Pb concentration in roots was obtained in rice genotypes, WAB880-1-3-2-1-2-PI-HB and Giza182 with irrigated by water from DK or TCCP266-49-B-B. On the other hand, the lowest Pb concentration in roots was found in rice, genotypes IR66160-5-2-3-2 or IR65600-98-1-2-2 under irrigated by FW.

Significant differences were observed in Pb concentrations of straw studied genotypes due to the interaction between types of water irrigation and the tested rice genotypes. Average of both seasons was presented in Fig 2. The results revealed that using water of DK and D8 for irrigation significantly increase the Pb concentrations in most tested genotypes as compared with FW which gave the lowest value in both seasons. It is clear from the data that IR64 and IR6560096-1-2-2 as Indica type and Sakha102 as Japonica type as well as Giza178 as Indica/Japonica type had the lowest Pb concentration in rice straw not only under irrigation by FW but also, with DK and D8. It can be easily noticed that Pb concentration in rice straw was higher in IR65564-44-2-3 and Moroberkan. Also generally Pb concentration was higher in Indica type followed by Japonica and /Japonica types. These results are accordance with those obtained by [37] who found that the Pb concentration in straw of different rice types were in the order Indica > Japonica.

There are significant differences in Pb concentration in rice grain due to the interaction between types of irrigation water and tested rice genotypes (Table 7) in both seasons. The highest concentration of Pb in rice grains was obtained in rice genotypes TCCP226-49-B-B-WAB 880-1-32-1-2-P1-HB and IR66738-118-1-2 as Indica type irrigated by drainage water whether, from DK or D8. In contrast, rice genotypes, IR66160-5-2-3-2, IR65600-96-1-2-2 and IR65598-112-2-1as Indica type and Sakha102 as Japonica type had the lowest concentration of Pb and did not exceed safety limits of Pb in grains (2.00 ppm) according to [38] under irrigation by FW and drainage water either DK or D8. For Indica/Japonica type in this study, the Pb concentration did not exceed safety limit independently of the irrigation water used.

A large genotypic difference among Indica, Japonica and Indica/Japonica types in grains Pb concentrations when irrigated with different sources of irrigation water. Also, the Pb concentration could vary greatly between rice cultivars within the same group. This could be attributed to, the distribution of Pb concentration in rice plant that differs with the genotype and the growing stages, differences in Pb transfer from stem and leaves to grains and the differences among rice cultivars and types in Pb uptake may result from their characteristic in roots absorption and exudates [12].

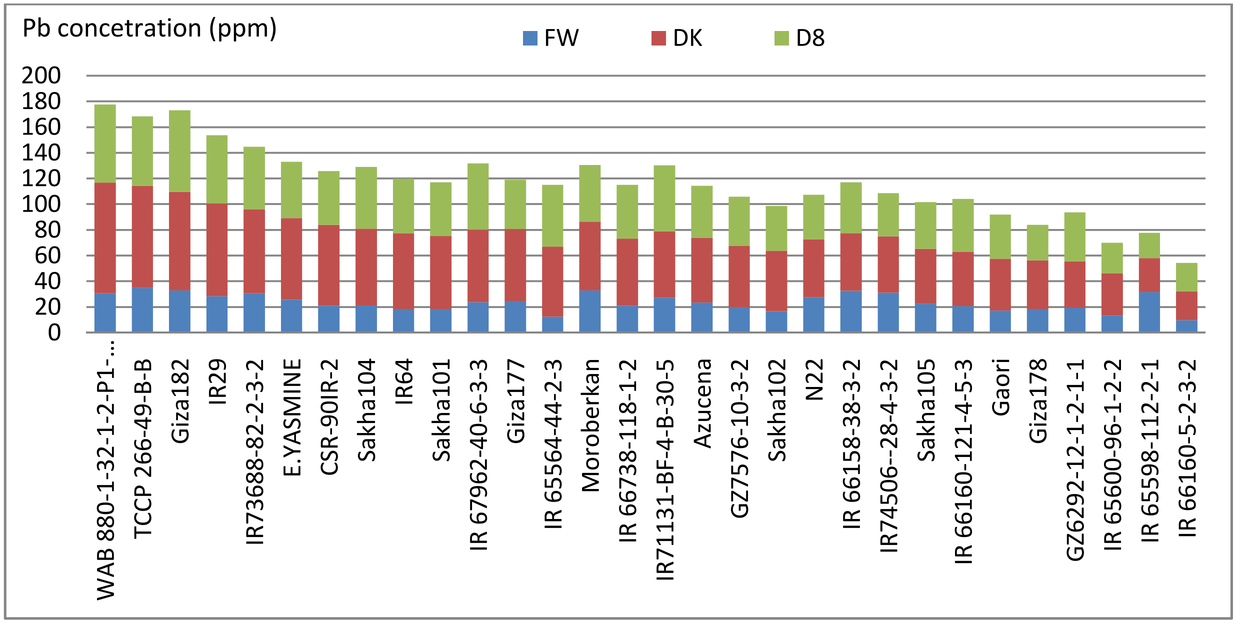

Fig. 1. Average of Lead (Pb) concentrations (ppm) in roots of different rice genotypes as affected by the interaction between Water types and different genotypes

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

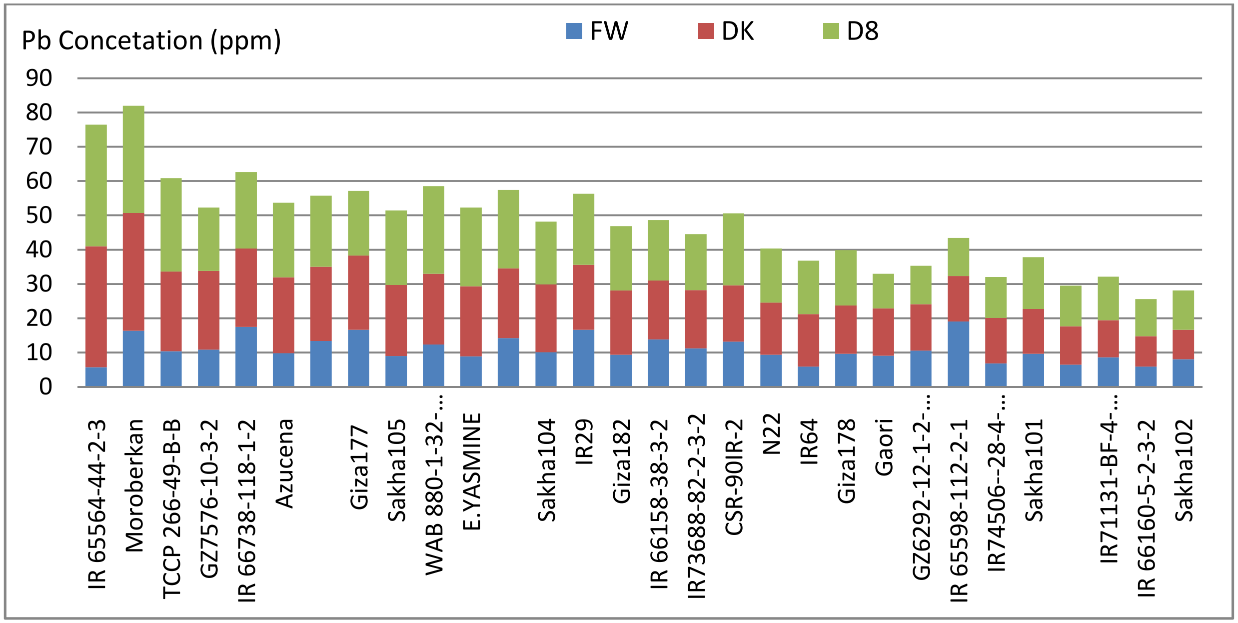

Fig. 2. Average Lead (Pb) concentrations (ppm) in straw of rice entries as affected by the interaction between Water types and different genotypes

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

Table 7. Lead (Pb) concentrations (ppm) in grains of rice genotypes as affected by the Interaction between Water types and different genotypes in 2012 and 2013 seasons

Genotypes	2012 Season			2013 Season		
	FW	DK	D8	FW	DK	D8
IR71131-BF-4-B-30-5	0.99	3.33	3.20	1.00	3.60	3.10
IR73688-82-2-3-2	1.53	4.18	3.44	1.39	3.90	3.09
IR74506--28-4-3-2	0.75	1.87	1.50	0.93	1.98	1.90
Giza182	1.75	3.79	2.90	1.32	4.20	3.34
E.YASMINE	1.82	4.05	3.20	1.45	4.00	3.80
IR64	0.87	2.71	1.79	1.42	2.00	1.30
N22	1.25	2.66	2.12	1.40	1.98	2.57
TCCP 266-49-B-B	1.89	4.62	3.70	2.66	4.22	4.05
CSR-90IR-2	1.16	2.76	1.98	0.93	2.45	1.67
WAB 880-1-32-1-2-P1-HB	2.70	4.25	2.50	2.39	4.90	2.22
IR29	2.16	3.83	3.35	1.89	3.43	4.00
Moroberkan	1.99	4.33	3.90	2.02	4.70	3.77
IR 65598-112-2-1	0.30	0.80	0.50	0.22	0.70	0.67
IR 65564-44-2-3	0.40	3.25	3.20	0.60	3.88	3.12
IR 65600-96-1-2-2	0.70	0.25	0.50	0.75	0.35	0.76
IR 66158-38-3-2	1.93	1.98	1.30	2.05	1.56	1.50
IR 66738-118-1-2	1.30	4.20	3.75	1.44	3.88	3.88
IR 67962-40-6-3-3	1.25	3.04	1.50	0.99	2.90	1.90
IR 66160-5-2-3-2	0.48	0.80	0.22	0.43	0.90	0.55
IR 66160-121-4-5-3	1.31	3.18	3.20	1.60	3.60	3.09
Giza177	2.00	3.12	2.83	2.10	3.20	3.00
Sakha101	1.50	2.30	2.50	1.32	2.33	2.07
Sakha102	1.13	1.35	1.35	1.20	1.48	1.33
Sakha104	1.22	2.57	3.64	1.30	2.20	3.70
GZ7576-10-3-2	1.19	2.67	2.50	1.29	2.61	2.55
Sakha105	1.15	1.93	3.20	1.21	1.89	3.25
Azucena	1.26	2.34	3.07	1.35	2.88	2.76
Gaori	0.88	1.92	1.55	1.20	1.79	2.01
Giza178	1.35	2.01	1.76	0.99	1.25	1.86
GZ6292-12-1-2-1-1	1.43	1.77	1.40	1.05	2.09	1.78
LSD 0.05		0.50			0.64	

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

Finally, as shown in Table 3 the grain yield of IR66160-5-2-3-2, IR65600-96-1-2-2 and IR65598-112-2-1, Sakha102 and Giza178 rice genotypes ranged about 8 to 10 t/ha after modification from g/plant to t/ha with the lower Pb concentrations according to safety limit of [38]. So, it is recommended cultivation of these genotypes in polluted area or under irrigation by drainage water but Sakha104 not recommended in these conditions to minimize the hazard effect of heavy metals on human health.

3.3 Cadmium (Cd^{2+}) Concentrations (ppm) in the Different Organs of Rice Genotypes

There are large differences in Cd concentrations for all organs of rice tested; roots, straw and grains among the 30 rice genotypes depending on types of irrigation water used (Table 8). Data showed that using irrigation of DK gave the highest concentration of Cd in, roots, straw and grain yield, while FW gave the lowest concentration of Cd in, roots, straw and grain yield. Accumulation of Cd in the root was higher than the straw and grains. Data also, indicated that there were significant differences among three types of irrigation water or three tested organs of rice in 2012 and 2013 seasons. Data in the same table revealed that there were significant differences among all tested rice genotypes in Cd concentrations.

Table 8. Cadmium (Cd) concentrations (ppm) in roots, straw and grains of different rice genotypes under irrigation by FW, DK and D8 in 2012 and 2013 seasons

Treatments	Roots		Straw		Grains	
Water sources (A)	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
DK	7.01	7.33	2.99	3.15	1.113	1.098
D8	5.43	4.94	2.81	2.90	0.871	0.807
FW	3.53	3.42	2.21	2.26	0.366	0.384
LSD 0.05	0.074	0.09	0.075	0.14	0.013	0.024
Ftest	*	*	*	*	*	*
Genotypes (B)						
IR71131-BF-4-B-30-5	6.80	7.38	3.71	3.30	1.655	1.534
IR73688-82-2-3-2	4.83	5.46	2.54	3.07	0.987	1.026
IR74506--28-4-3-2	5.98	4.67	2.86	2.85	1.033	0.902
Giza182	5.67	3.95	2.67	2.88	1.153	0.980
E.YASMINE	7.29	6.28	2.40	2.55	0.935	0.968
IR64	6.85	5.36	3.04	3.21	0.981	1.100
N22	6.07	6.45	2.93	2.74	1.060	1.202
TCCP 266-49-B-B	4.93	5.45	3.89	3.08	1.298	1.504
CSR-90IR-2	3.91	3.60	2.21	2.24	0.388	0.339
WAB 880-1-32-1-2-P1-HB	5.93	5.49	3.37	3.40	1.152	1.148
IR29	4.71	4.49	2.29	2.74	0.429	0.336
Moroberkan	7.96	8.54	3.48	4.52	1.364	1.528
IR 65598-112-2-1	3.70	3.71	2.07	2.22	0.308	0.344
IR 65564-44-2-3	5.65	6.18	2.42	2.21	0.352	0.368
IR 65600-96-1-2-2	5.10	5.25	3.92	4.24	0.961	0.973
IR 66158-38-3-2	4.08	4.57	2.02	2.28	0.346	0.356
IR 66738-118-1-2	6.17	6.66	2.81	3.51	1.860	1.241
IR 67962-40-6-3-3	4.48	4.77	2.42	2.08	0.325	0.416
IR 66160-5-2-3-2	4.79	4.23	1.60	1.84	0.310	0.302
IR 66160-121-4-5-3	5.94	4.32	1.91	2.06	0.336	0.341
Giza177	5.32	4.70	3.56	3.59	1.701	1.465
Sakha101	6.22	6.60	2.87	2.91	1.073	1.123
Sakha102	4.50	4.61	2.41	2.23	0.341	0.355
Sakha104	5.94	5.48	2.54	3.07	0.590	0.583
GZ7576-10-3-2	5.90	6.08	2.38	2.63	0.605	0.580
Sakha105	5.13	4.64	2.39	2.03	0.583	0.473
Azucena	3.84	4.40	2.01	2.00	0.298	0.283
Gaori	4.37	4.33	2.84	2.55	0.309	0.374
Giza178	4.17	5.25	2.35	2.66	0.387	0.367
GZ6292-12-1-2-1-1	3.50	3.95	2.28	2.21	0.383	0.377
LSD 0.05	0.14	0.300	0.131	0.136	0.047	0.056
F test	*	*	*	*	*	*
*Interaction: A*B*	*	*	*	*	*	*

*FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8 *= significant*

It is clear from the results that, Indica type had higher Cd concentration than both Japonica and Indica/Japonica types in their different organs under this study. Moroberkan and E.YASMINE as indica type gave the highest value of Cd concentration, while the lowest Cd concentration in grains were obtained with IR65598-112-2-1 and IR6610-5-2-3-2 as Indica type, Sakha102 and Azucena as Japonica and Giza178 as Indica/Japonica types when irrigated with drainage water whether DK or D8. The differences between rice genotypes in heavy metals concentrations such as Pb and Cd may be due to the difference in mechanisms of metals tolerance can be classified into 1) internal tolerance mechanisms in the symplasm and 2) exclusion mechanisms in the apoplasm and at the plasma membrane [39,40]. The internal tolerance mechanisms immobilize, compartmentalize, or detoxify metals in the symplasm by using metal binding compounds [41,42,43,44]. In contrast, the exclusion mechanisms prevent metals from entering or staying in the symplasm and coming in contact with sensitive intracellular sites. For example, there are differential physiological mechanisms of cadmium tolerance among plant species and varieties [45]. Once taken up by plants, heavy metals are bound to the cell walls (polysaccharides), and / or complexed by the low- molecular- weight compounds (phytochelatins and organic acids) [46]. Hence, the distribution of heavy metals in the plant cells is uneven, which has been reported to be a cellular mechanism for heavy metal detoxification in plants [47,48].

Data in Fig. 3 shows that there were significant differences between the studied rice genotypes and three types of irrigation water in Cd concentrations in roots. Using irrigation water from DK caused significant increase in Cd concentrations with all tested genotypes than either D8 or FW in both seasons. The greatest value of Cd concentration was obtained with Moroberkan irrigated with DK in both seasons, while the lowest Cd concentrations in roots were observed with IR65598-112-2-1, CSR90IR-2 and GZ6292-12-1-2-1-1.

Fig. 4, presents the effect of interaction between the tested rice genotypes and different sources of irrigation water in Cd concentrations in straw of studied genotypes. It is clear from the results that using the water DK or D8 for irrigation the tested rice genotypes significantly increase Cd concentration in their straw as compared with FW. The response of 30 tested rice genotypes to drainage water significantly differ from variety to another. Moreover, Moroberkan gave the highest Cd concentration in straw when irrigated from DK or D8, while IR66160-5-2-3-2 type gave the lowest value in this aspect. It can be noted that the Cd concentrations in straw for all tested genotypes was higher under irrigated with DK than either D8 or FW. Also, the results pointed out that the Cd concentration in straw of most varieties within the same subspecies for Indica type was higher than both Japonica/ Indica types. It can be observed from the results in Figs. 3 and 4, that the concentration of Cd in roots was higher than straw especially with the varieties which had the lowest of Cd concentration due to the control of these varieties in translocation of Cd from roots to straw according to the genetic behavior.

Cadmium concentrations in grains of different rice genotypes as affected by the interaction between three sources of irrigation water and tested genotypes in 2012 and 2013 seasons are presented in Table 9. There were significant differences in Cd concentrations in grains due to the interaction between water irrigation sources and studied genotypes. The concentration of Cd in grains of most tested genotypes was the maximum value when irrigated with DK and D8. The data clarified that TCCP266-49-B-B and Moroberkan as Indica type and Giza177 as Japonica type gave the highest Cd concentration in their grains, while IR66160-5-2-3-2, Sakha102, Sakha105 and Giza178 varieties produced the lowest Cd concentration in their grains and reached to less than safety limit (0.40 ppm) according to [38]. These results agreed with the findings of [49] who found that the diversity in Cd concentrations in different genotypes of rice was dependent on absorption and transport from leaf and stem to grains among different genotypes. We propose the concept of pollution safe cultivars, which edible parts accumulate Pb and Cd at level low enough for safe consumption of rice grains even when grown under irrigation by poor water quality or in contaminated soil by heavy metals.

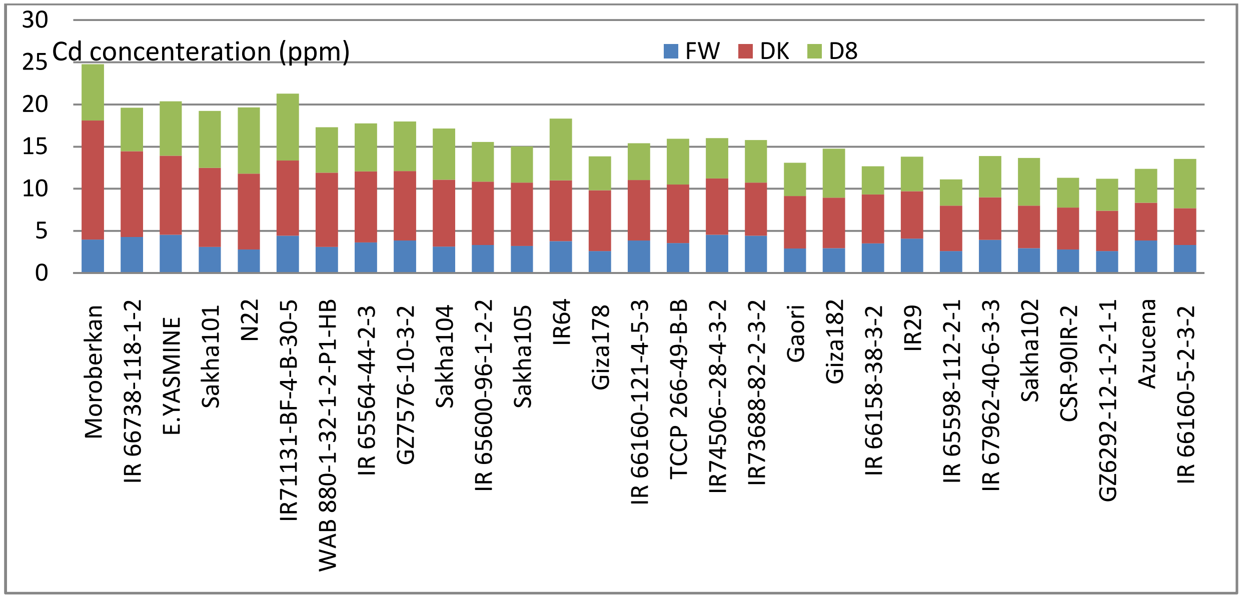

Fig. 3. Average of Cadmium (Cd) concentrations (ppm) in roots of rice entries as affected by the Interaction between water types and different genotypes in 2012 and 2013 seasons

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

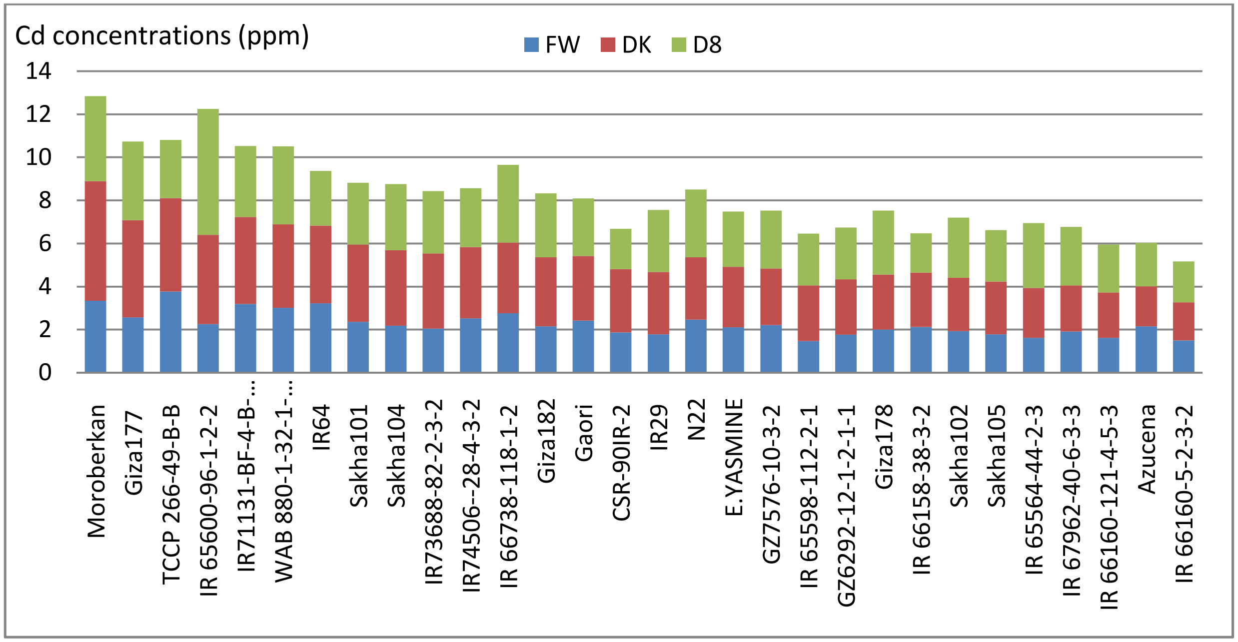

Fig. 4. Average Cadmium (Cd) concentrations (ppm) in straw of rice entries as affected by the interaction between water types and different genotypes

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

Table 9. Cadmium (Cd) concentrations (ppm) in grains of different rice genotypes as affected by the Interaction between Water sources and different genotypes in 2012 and 2013 seasons

Genotypes	2012 season			2013 season		
	FW	DK	D8	FW	DK	D8
IR71131-BF-4-B-30-5	0.345	2.601	2.020	0.378	2.343	1.886
IR73688-82-2-3-2	0.334	1.501	1.126	0.335	1.650	1.095
IR74506--28-4-3-2	0.352	1.676	1.071	0.400	1.678	0.951
Giza182	0.378	1.955	1.126	0.302	1.768	0.872
E.YASMINE	0.343	1.293	1.171	0.353	1.289	1.264
IR64	0.339	1.504	1.102	0.395	1.601	1.305
N22	0.345	1.633	1.203	0.400	1.701	1.507
TCCP 266-49-B-B	0.709	1.982	1.205	0.865	2.042	1.606
CSR-90IR-2	0.335	0.403	0.426	0.285	0.379	0.353
WAB 880-1-32-1-2-P1-HB	0.390	1.952	1.124	0.380	1.703	1.361
IR29	0.380	0.405	0.503	0.250	0.376	0.382
Moroberkan	0.649	2.012	1.432	0.801	2.234	1.551
IR 65598-112-2-1	0.212	0.334	0.399	0.266	0.387	0.381
IR 65564-44-2-3	0.271	0.401	0.385	0.280	0.408	0.417
IR 65600-96-1-2-2	0.381	1.293	1.210	0.325	1.503	1.091
IR 66158-38-3-2	0.315	0.421	0.302	0.380	0.287	0.401
IR 66738-118-1-2	0.400	2.975	2.205	0.590	2.790	2.345
IR 67962-40-6-3-3	0.273	0.303	0.401	0.401	0.467	0.381
IR 66160-5-2-3-2	0.294	0.366	0.331	0.217	0.355	0.334
IR 66160-121-4-5-3	0.225	0.369	0.393	0.271	0.394	0.339
Giza177	1.100	2.504	1.501	1.032	1.744	1.623
Sakha101	0.312	1.450	1.457	0.335	1.639	1.395
Sakha102	0.321	0.351	0.353	0.330	0.401	0.334
Sakha104	0.210	0.842	0.719	0.205	0.895	0.651
GZ7576-10-3-2	0.302	0.811	0.702	0.343	0.734	0.665
Sakha105	0.251	0.637	0.863	0.239	0.673	0.509
Azucena	0.223	0.368	0.303	0.203	0.303	0.344
Gaori	0.201	0.395	0.333	0.327	0.396	0.401
Giza178	0.355	0.403	0.404	0.327	0.415	0.359
GZ6292-12-1-2-1-1	0.423	0.332	0.396	0.320	0.389	0.423
LSD 0.05		0.082			0.098	

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

3.4 Health Risk Assessment

The target hazard quotient (THQ) has been recognized as a useful parameter for evaluation of risk associated with the consumption of rice grains contaminated by heavy metals [50], [51]. Genotypes whose THQ_{Pb} (Table 10) and THQ_{Cd} (Table 11) were below 1.00 had grains assumed to be safe for eating. IR74506--28-4-3-2, IR65598-112-2-1, IR65600-96-1-2-2, IR66158-38-3-2 and IR66160-121-4-5-3 (indica) and Sakha 102 (japonica) were below the permissible THQ_{Pb} threshold, while CSR-90IR-2, IR29, IR65598-112-2-1, IR65564-44-2-3, IR66158-38-3-2, IR 67962-40-6-3-3, IR66160-5-2-3-2 and IR66160-121-4-5-3 (indica), Sakha102, Sakha104, Sakha105, GZ7676-10-3-2 and Azucena (japonica), and Gaori, Giza178 and GZ6292-12-1-2-1 (indica-japonica) had permissible THQ_{Cd} after using wastewater sources for irrigation. These genotypes could be used for breeding germplasm in areas with poor water quality. Rice cultivars with low Pb and Cd could provide an option for farmers to reduce the influx of heavy metals in the human food chain when growing rice in locations with poor water quality. It is important to notice that there are wide variations in the THQ_{Pb} and THQ_{Cd} values among rice genotypes under irrigation by DK and D8. Also, the THQ_{Pb} and THQ_{Cd} values were higher under irrigated by DK than FW and D8.

Table 10. The target hazard quotient (THQ_{Pb}) values of Pb for different rice genotypes under irrigation by FW, DK and D8 in 2012 and 2013 seasons

Genotypes	2012 season			2013 season		
	FW	DK	D8	FW	DK	D8
IR71131-BF-4-B-30-5	0.50	1.67	1.61	0.50	1.81	1.56
IR73688-82-2-3-2	0.77	2.10	1.73	0.70	1.96	1.55
IR74506--28-4-3-2	0.38	0.94	0.75	0.47	0.99	0.95
Giza182	0.88	1.90	1.45	0.66	2.11	1.68
E.YASMINE	0.91	2.03	1.61	0.73	2.01	1.91
IR64	0.44	1.36	0.90	0.71	1.00	0.65
N22	0.63	1.33	1.06	0.70	0.99	1.29
TCCP 266-49-B-B	0.95	2.32	1.86	1.33	2.12	2.03
CSR-90IR-2	0.58	1.38	0.99	0.47	1.23	0.84
WAB 880-1-32-1-2-P1-HB	1.35	2.13	1.25	1.20	2.46	1.11
IR29	1.08	1.92	1.68	0.95	1.72	2.01
Moroberkan	1.00	2.17	1.96	1.01	2.36	1.89
IR 65598-112-2-1	0.65	0.40	0.25	0.62	0.35	0.34
IR 65564-44-2-3	0.20	1.63	1.61	0.30	1.95	1.57
IR 65600-96-1-2-2	0.35	0.13	0.25	0.38	0.18	0.38
IR 66158-38-3-2	0.97	0.99	0.65	1.03	0.78	0.75
IR 66738-118-1-2	0.65	2.11	1.88	0.72	1.95	1.95
IR 67962-40-6-3-3	0.63	1.52	0.75	0.50	1.45	0.95
IR 66160-5-2-3-2	0.24	0.40	0.11	0.22	0.45	0.28
IR 66160-121-4-5-3	0.66	1.60	1.61	0.75	1.81	1.55
Giza177	1.00	1.57	1.42	1.05	1.61	1.50
Sakha101	0.75	1.15	1.25	0.66	1.17	1.04
Sakha102	0.57	0.68	0.68	0.60	0.74	0.67
Sakha104	0.61	1.29	1.83	0.65	1.10	1.86
GZ7576-10-3-2	0.60	1.34	1.25	0.65	1.31	1.28
Sakha105	0.58	0.97	1.61	0.61	0.95	1.63
Azucena	0.63	1.17	1.54	0.68	1.44	1.38
Gaori	0.44	0.96	0.78	0.60	0.90	1.00
Giza178	0.68	1.01	0.88	0.50	0.63	0.93
GZ6292-12-1-2-1-1	0.72	0.89	0.70	0.53	1.01	0.89

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

Table 11. The target hazard quotient (THQ_{Cd}) values of Cd for different rice genotypes under irrigation by FW, DK and D8 in 2012 and 2013 seasons

Genotypes	2012 season			2013 season		
	FW	DK	D8	FW	DK	D8
IR71131-BF-4-B-30-5	0.23	1.73	1.34	0.25	1.56	1.25
IR73688-82-2-3-2	0.22	1.00	0.75	0.22	1.10	0.73
IR74506--28-4-3-2	0.23	1.11	0.71	0.27	1.11	0.63
Giza182	0.25	1.30	0.75	0.20	1.17	0.58
E.YASMINE	0.23	0.86	0.78	0.23	0.86	0.84
IR64	0.23	1.00	0.73	0.26	1.06	0.87
N22	0.23	1.08	0.80	0.27	1.13	1.00
TCCP 266-49-B-B	0.47	1.32	0.80	0.57	1.36	1.07
CSR-90IR-2	0.22	0.27	0.28	0.19	0.25	0.23
WAB 880-1-32-1-2-P1-HB	0.26	1.30	0.75	0.25	1.13	0.90
IR29	0.25	0.27	0.33	0.17	0.25	0.25
Moroberkan	0.43	1.34	0.95	0.53	1.48	1.03
IR 65598-112-2-1	0.14	0.22	0.26	0.18	0.26	0.25
IR 65564-44-2-3	0.18	0.27	0.26	0.19	0.27	0.28
IR 65600-96-1-2-2	0.25	0.86	0.80	0.22	1.00	0.72
IR 66158-38-3-2	0.21	0.28	0.20	0.25	0.19	0.27
IR 66738-118-1-2	0.27	1.98	1.46	0.39	1.85	1.56
IR 67962-40-6-3-3	0.18	0.20	0.27	0.27	0.31	0.25
IR 66160-5-2-3-2	0.20	0.24	0.22	0.14	0.24	0.22
IR 66160-121-4-5-3	0.15	0.25	0.26	0.18	0.26	0.23
Giza177	0.73	1.66	1.00	0.69	1.16	1.08
Sakha101	0.21	0.96	0.97	0.22	1.09	0.93
Sakha102	0.21	0.23	0.23	0.22	0.27	0.22
Sakha104	0.14	0.56	0.48	0.14	0.59	0.43
GZ7576-10-3-2	0.20	0.54	0.47	0.23	0.49	0.44
Sakha105	0.17	0.42	0.57	0.16	0.45	0.34
Azucena	0.15	0.24	0.20	0.13	0.20	0.23
Gaori	0.13	0.26	0.22	0.22	0.26	0.27
Giza178	0.24	0.27	0.27	0.22	0.28	0.24
GZ6292-12-1-2-1-1	0.28	0.22	0.26	0.21	0.26	0.28

FW = Fresh water, DK = El-Gharbia main drain or Kitchener drain D8 = drain No. 8

4. CONCLUSION

From the obtained data of this study, it can be concluded that the great diversity among rice genotypes in Pb and Cd concentrations under irrigation with poor water quality allows the cultivation of IR66160-5-2-3-2, IR65600-96-1-2-2 and IR65598-112-2-1 as Indica type, Sakha102 as Japonica type and Giza178 as Indica/Japonica type in some areas, it is may be necessary to use drainage water for irrigation. It is not recommended to cultivate Sakha104 rice cultivar under these conditions. As well as, the great diversity among genotypes helps us to selection and breeding of rice cultivars that have ability for low Pb and Cd accumulation also, the use of drainage water for rice production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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