Plant Archives Volume 20 No. 2, 2020 pp. 6267-6274 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

COPPER STATUS IN SOILS, RICE (*ORYZA SATIVA* L.) AND WHEAT (*TRITICUM AESTIVUM* L.) PLANTS GROWN IN DAMIETTA GOVERNORATE, EGYPT

Badawy, S.H.[1*], M. A. El-Sayed[1], R.A. El-Motaium[2], H.M. Abdel-Lattif[3] and H.M. Ghorab[4]

[1*]Soil Science Department, Faculty of Agriculture, Cairo University, Egypt.
[2]Plant Researches Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt.
[3]Agronomy Department, Faculty of Agriculture, Cairo University, Egypt.
[4]Health Affairs Directorate, Damietta, Ministry of Health, Egypt.

Abstract

Samples of soils, rice and wheat plants and irrigation water were collected from four districts of Damietta Governorate, Egypt to evaluate their copper status as well as its relationships with some soil properties. The study area is located at the Mediterranean Sea, northeast of the Nile-Delta. It lies between these coordinates 31° 28' 29" to 32° 03'32" E and 31° 09' 28" to 31° 31' 45" N. Agriculture is one of the main activities of the area; rice and wheat plants represent the major cultivated crops. Results showed that the average total soil Cu content are 43.22 ± 14.55 and 33.10 ± 11.49 mg kg^{-1} for the surface and subsurface soil layers, respectively. Average of DTPA extractable-Cu is 1.62 ± 0.71 and 1.30 ± 0.63 mg kg^{-1} for the surface and subsurface soil layers, respectively. The highest total Cu content (51.23 ±7.47 mg kg^{-1}) and available Cu (2.16 ± 0.57 mg kg^{-1}) found in northern district may be attributed to irrigation with sewage effluent or mixed water (Nile water + sewage effluent) and the use of copper pesticides. Significant and positive correlation coefficient was found between soils available Cu and soil OM content (r = 0.86), while, soil pH and soil $CaCO_3$ content recorded significant and negative correlation coefficient (r = -0.83) and (r = -0.79), respectively. The average Cu concentration of the rice (16.97 ± 4.66 mg kg^{-1}) and wheat (15.93 ± 3.93 mg kg^{-1}) straw are higher than that of the rice (3.22 ± 1.09 mg kg^{-1}) and wheat (2.97 ± 0.81 mg kg^{-1}) grains. Copper Concentrations in straw and grains correlated with total and available Cu in the soils. There is evidence that the translocation of Cu from straw to grains is higher in rice than in wheat.

Key words: Copper, soil total copper, soil DTPA extractable-Cu, soil properties, Cu in straw, Cu in grain

Introduction

In soil, the Cu concentration depends on complex interactions between parent materials, physico-chemical properties of the soil and possible exogenous inputs from agriculture or industry. Many researchers indicated that the availability of micronutrients may be controlled by some soil properties such as pH, CEC, texture, organic matter content and $CaCO_3$ (Rieuwert *et al.*, 1998). Copper availability decreases with high soil pH, high organic carbon and high clay content (Baker and Senft, 1995). Agricultural practices can contribute important non-point sources of soil contamination from the overuse of chemical fertilizers, farm animal waste, sewage sludge and industrial waste (Alloway, 1995; Panagos *et al.*, 2013 and Steffan *et al.*, 2018). Over the past decades, Cu has been extensively used as a fungicide which created a dangerous issue by the accumulation of Cu in soils and groundwater (Komárek *et al.*, 2010). Copper threshold value is 100 mg kg^{-1} and the guideline value is 150 mg kg^{-1} proposed by numerous scientific studies to denote unpolluted soils (Adriano, 2013). The threshold is the value beyond that further assessment is needed, while the guideline value is seen as denoting an ecological or health risk (Tóth *et al.*, 2016). Most of the arable soils of Egypt are of the Nile alluvial origin transported by the Nile water with a continuous supply of heavy metals. However, the desert sandy and calcareous soils are usually poor in micronutrients which cause one of the most serious problems (Taha, 1980).

In croplands Cu usually ranged from 5 to 30 mg kg^{-1} in crop tissues as the optimal range since lower

***Author for correspondence :** E-mail: shbadawy60@agr.cu.edu.eg.

concentrations result in Cu deficiency while higher values may lead to toxic effects (Adriano, 2013; Adrees *et al*., 2015). Rice and wheat grown in annual rotation, which is the predominant cropping system in Egypt, leads to alternate flooding and upland conditions, which result in creating different chemical environment in soils during the rice and wheat growing periods. Considering human health, both copper deficiency and excess produce adverse effects (Stern *et al*., 2017). Copper deficiency may lead to serious illnesses such as anaemia and neutropenia (Oliver, 1997), whereas its excess may result in liver diseases, neurological effects and Alzheimer-disease (Uriu-Adams and Keen, 2005).

Although available form of Cu in soils is of great importance from agronomic point of view, the total Cu concentration is of great importance for geochemical studies. Total and available copper content in Egyptian soils tend to increase because of the intensive use of pesticides, which contain pronounced concentrations of Cu. Therefore, the objectives of this work are to determine the concentrations of copper in the agricultural soils and commonly grown plant spices (wheat and rice), in different districts of Damietta governorate.

Materials and Methods

This study was conducted in Damietta governorate, located at the Mediterranean Sea northeast of the Nile-Delta. It lies between 31º 28'29" to 32º 03'32" E and 31º 09'28" to 31º31'45" N coordinates. It covers an area of about 1029 km^2 and it represents about 4.7% of the Delta-region and about 1.22% of Egypt total area (Elnaggar *et al*., 2017). Agriculture is one of the main activities of the area; rice and wheat relatively represent the major cultivated crops. The dominant soil texture in the studied area is clayey, the range of OM content is (0.64 - 2.81%), pH is (7.7 - 8.7), $CaCO_3$ is (0.16 - 4.3%) and EC is (0.74 to 8.34 dS/m^2).

Soil sampling and analysis

One hundred forty two composite soil samples (surface 0-30 cm and subsurface 30-60 cm) were collected from the agricultural area of four districts (A = Al-Zarqa, B = Faraskur, C = KafrSaad, D = Damietta). Soil samples were air-dried, ground using wooden mortar to passed through a 2 mm sieve. The Particle size distribution (sand, silt and clay), soil texture was performed using the pipette method (Claydon, 1989). The soil pH, EC, total $CaCO_3$, organic matter (OM) was measured according to standard methods outlined by Jackson, (1973). Total soil Cu was measured using Aqua regia extraction methods (Cottenie *et al*., 1982) while DTPA-extractable Cu was measured according to (Lindsay and Norvell, 1978) method. Cu concentration in the extractions was measured by Graphite Furnace- Atomic Absorption Spectrophotometer (GF-AAS), (Shimadzu 6800, Japan).

Irrigation water sampling and analysis

Twenty irrigation water samples were collected from different locations to represent the main sources of irrigation water in the study area. Each sample consist of 10 liters were kept in polyethylene bottles, pre-washed with nitric acid (1%) and stored at 4ºC until analyses. Then, Cu concentrations, pH, electrical conductivity (EC) soluble anions and cations were measured according to the standard method of (Keeney and Nelson, 1982). The irrigation water recorded the following values; pH from 7.3 to 8.3, EC from 0.43 to 5.29dS/m^2 and Cu concentration from 0.05 to 0.08 ppm.

Plant samples

At maturity stage, rice and wheat plants were gathered from the same spots where soil samples were collected. Plants were washed with tap water and deionized water three times to remove any adhered soil particles, dried at 80°C for 3 days to reach a constant weight and grounded before analysis. Plant samples were separated to straw and grins. The oven-dried plant materials were ground using stainless steel mill and kept for chemical analysis. Plants were subjected to digestion using a mixture of acids (HNO_3-H_2SO_4-$HCLO_4$) as described by Jackson, (1973). Concentrations of Cu were measured in the digest solution by GF-AAS. All analysis was done in duplicates

Statistical analysis

Factorial experiments with two factors in randomize complete block design was used for analysis all the studied parameters with unequal replications for each treatment according to the procedure described by Snedecor and Cochron, (1981). The Least Significant Differences test (LSD) at 5% level of probability was used to test the significance differences among the means. Simple correlation coefficients were calculated between copper status and each of the other studied traits according to Steel *et al*., (1997). The "MSTAT-C" software package was used to carry out the statistical analysis (Freed *et al*., 1989).

Results and Discussions

Soil Cu content

- **Soil total Cu content:**

Results in table 1 show that the soil total Cu concentrations vary widely from one district to another. The total Cu concentrations ranged from low for the uncontaminated soil to high for soils receiving historically

Table 1: Ranges, Mean levels and standard deviation of soil total copper concentration in the different districts.

Loca-tions*	Soil total Cu content (mg kg^{-1})								
	Surface (0-30 cm)			Subsurface (30-60 cm)			Surface /Subsurface (fold)		
	Range	Mean	±Sd	Range	Mean	±Sd	Range	Mean	±Sd
A	39.9-51.3	45.6	3.28	29.6-42.4	37.9	3.73	1.04-1.42	1.23	0.12
B	42.8-57.8	49.9	4.77	33.2-42.7	37.3	2.75	1.29-1.35	1.34	0.08
C	8.94-57.3	33.4	17.4	6.36-42.9	25.6	13.9	1.15-1.63	1.31	0.12
D	41.2-58.2	51.2	7.47	31.1-51.2	39.9	6.97	1.09-1.51	1.28	0.12
All samples	8.94-58.2	42.9	14.2	6.36-51.2	33.1	11.4	1.04-1.63	1.30	0.12
A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta									

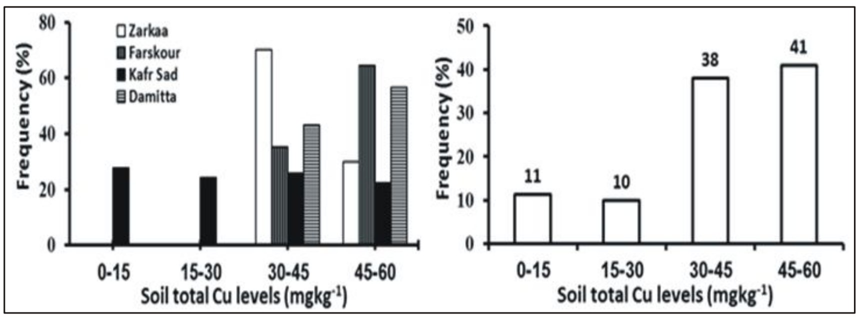

Fig. 1: Frequency distribution of soil total Cuconcentrationof the different districts.

large quantities of Cu through agricultural or industrial activities and fungicides. The total Cu concentrations for all the studied soil ranged from 8.94 to 58.2mg kg^{-1} with an average of 42.9± 14.2 mgkg^{-1} in the surface layer and from 6.36 to 51.2 mg kg^{-1} with an average of 33.1 ± 11.4 mgkg^{-1} in subsurface layers. The average Cu concentration of all the studied soils showed that the surface layers are higher by 1.04 to 1.63 with an average of 1.30 ±0.12 fold than the subsurface layers. The common characteristic of Cu distribution in soils is it accumulates in the surface layers. This is attributed to various factors, the most important ones are: the bioaccumulation of Cu and the recent anthropogenic sources of Cu (Pendias and Pendias, 1992). The districts average concentrations of surface soil Cu are lowest (33.4 ± 17.4 mg kg^{-1}) in Kafr Sad district, but highest in Damietta district (51.2±7.47 mg kg^{-1}). The high values may be attributed to irrigation with sewage effluent or mixed water (Nile water + sewage effluent). The frequency distributions of total Cu in soils (Fig. 1) shows that 21% of the studied soils contain less than 30 mg kg^{-1}, while 38% of the studied soils contain from 30-45 mg kg^{-1}. Soils contain relatively high levels of Cu (from 45 to 60 mg kg^{-1}) represented 41% of the studied soils which mainly located in clay soils.

Comparing the soil's total Cu concentration of Damietta governorate with its levels in the different locations of Egypt we found that; total Cu concentration in El-Fayoum governorate vary from 9.8 to 104 mgkg^{-1} (El-Sayad, 1988 and Ibrahim, 2001); from 20-70 mg kg^{-1} in the Nile alluvial soils, while it ranged from 10-30 mg kg^{-1} in calcareous soils (Mohamed, 1990). Ballabio *et al*., (2018) investigate copper distribution in the soils of 25 European Union States and reported that Cu concentration range is from 16.85 to 90.26 mgkg^{-1}. In china, the paddy site was severely contaminated with heavy metals from the mining activities with 122-797 mgkg^{-1} Cu concentration (Cui *et al*., 2019). The concentrations of Cu were 7-47 times higher than the background level (17 mgkg^{-1}) in Guangdong (Cui *et al*., 2017). Comparing the levels of total Cu in Damietta governorate soils with the permissible critical limits recommended by most of the above mentioned countries. It could be stated that the concentrations of the total Cu in all the

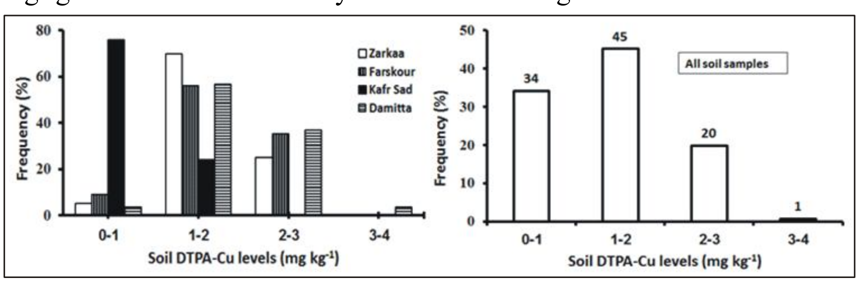

Fig. 2: Frequency distribution of soil DTPA-extractable Cuof the different districts.

Table 2: Mean levels, ranges and standard deviation of soil DTPA extractable-Cu concentration in the different districts.

Loca-tions*	Soil DTPA extractable-Cu content (mg kg^{-1})								
	Surface (0-30 cm)			Subsurface (30-60 cm)			Surface /Subsurface (fold)		
	Range	Mean	±Sd	Range	Mean	±Sd	Range	Mean	±Sd
A	1.12-2.58	1.87	0.39	0.89-2.19	1.43	0.45	1.06-1.94	1.31	0.29
B	1.14-2.88	2.09	0.53	0.75-2.10	1.45	0.42	1.29-1.76	1.44	0.14
C	0.37-2.20	0.99	0.40	0.28-1.33	0.64	0.25	1.33-1.66	1.55	0.26
D	1.13-3.29	2.16	0.57	0.99-2.77	1.62	0.47	1.11-1.77	1.33	0.19
All samples	0.37-3.29	1.62	0.71	0.28-2.77	1.14	0.56	1.06-1.77	1.42	0.24
A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta									

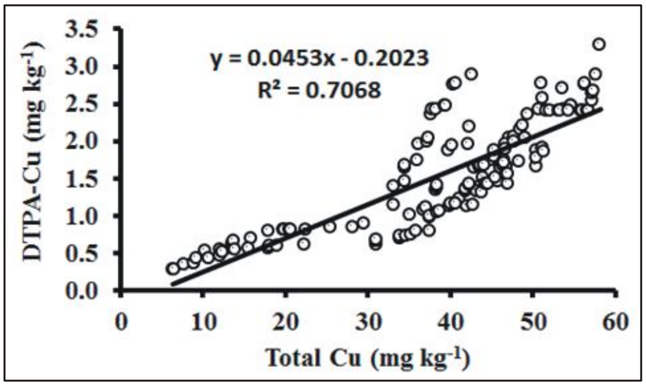

Fig. 3: Relationship between soil DTPA-extractable and total Cu of the different districts.

Table 3: Mean performance of two depths evaluated fewer than four locations for total and DTPA extractable-Cu of the different districts.

Depth (cm)	Loca-tion*	Soil Cu concentration (mg kg^{-1})	
		Total	DTPA
0 - 30		42.933	1.624
30 - 60		33.102	1.140
L.S.D at 0.05 level		2.172	0.149
	A	41.747	1.639
	B	43.605	1.769
	C	29.465	0.814
	D	45.735	1.870
L.S.D at 0.05 level		4.672	0.022
0 - 30	A	45.637	1.874
	B	49.954	2.092
	C	33.352	0.987
	D	51.208	2.158
30 - 60	A	37.857	1.404
	B	37.256	1.447
	C	25.578	0.642
	D	39.872	1.581
L.S.D at 0.05 level		9.894	0.047
A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta			

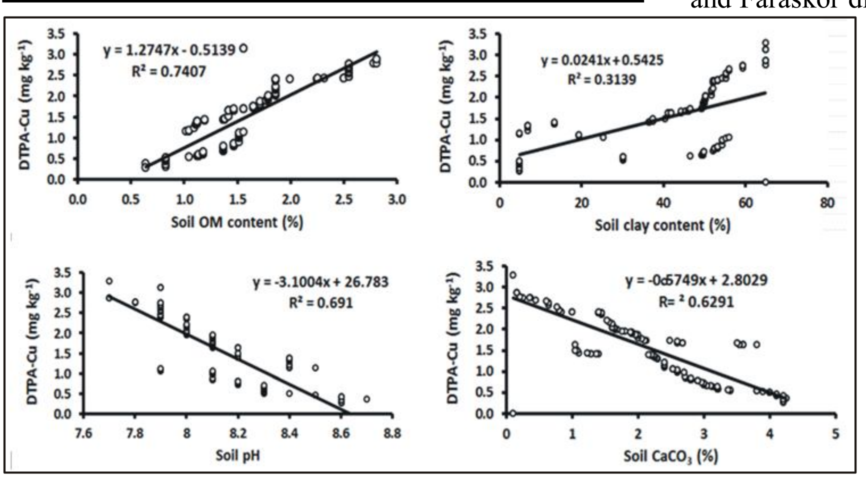

Fig. 4: Relationshipbetween DTPA-extractable Cu and soil's organic matter, clay, pH and calcium carbonate contents.

studied soils are within the permissible limits; however there is evidence of Cu accumulation in some sites particularly in the soil surface.

- **Soil DTPA-extractable-Cu:**

Results in table 2 show that the concentrations of soil DTPA-extractable Cu ranged from 0.37 to 3.29mg kg^{-1} with an average of 1.62±0.71 mg kg^{-1} in the soil surface layers. While the Cu concentrations range is from 0.28 to 2.77mg kg^{-1} with an average of 1.14±0.56 mg kg^{-1} in the soil subsurface layers. The results agree with Aboulroos *et al*., (1996) who reported that the values of DTPA extractable Cu in 82 samples of Egyptian soils varied from 1.05 to 4.86 mg kg^{-1}, with an average of 2.96 ± 0.18 mg kg^{-1}. In addition, Sadik *et al*., (2002) and Ragheb *et al*., (2017) showed that the available Cu, DTPA extractable, ranged from 0.30 to 3.68mg kg^{-1} and from 0.90 to 6.70 mg kg^{-1} in calcareous and the Nile alluvial soils, respectively. The concentrations of DTPA-extractable Cu of the soil surface layers is higher than that of the subsurface layers by 1.06 to 1.77 fold with an average of 1.42± 0.24 fold. This may be due to the higher amount of organic matter and the lower values of the soil pH of the surface layers than those of the subsurface layers. Under such conditions the solubility of Cu in the surface soil layers is higher than that of the subsurface layers. The district average Cu concentration of the soil surface layers is lowest in Kafr Sad district (0.99 ±0.40 mg kg^{-1}) followed by the El-Zarqa district (1.87±0.39mg kg^{-1}). The highest values was found in Damietta district (2.16±0.57 mg kg^{-1}) followed by Faraskor district (2.09±0.53 mg kg^{-1}). The high Cu values in Damietta and Faraskor districts may be attributed to the use of sewage effluent, mixed water (Nile water + sewage effluent) and industrial water in irrigation practice. Another factor which resulted in high Cu concentration in Damietta and Faraskor districts is the use of Cu pesticides.

The frequency distribution of DTPA-extractable Cu in the studied soils (Fig. 2) shows that 34% of the studied soils contain less than 1.0 mg kg^{-1}, while 45% of the studied soils contained from 1.0 to 2.0 mg kg^{-1} of available Cu. Soils contain relatively high levels of DTPA-extractable Cu (from 2.0 to 4mg kg^{-1}) represented 21% of the studied soils. Generally, the DTPA-extractable Cu is lower than the total Cu in all the studied soils. The concentration of DTPA- extractable Cu are positively correlated (r = 0.84) with the total concentration of Cu in the soils

(Fig. 3). The available Cu represents a small fraction of the total Cu accumulated in the soils. It represents a range from 1.98% to 6.86% with an average of 4.42% ± 1.04 for all the studied soils. The highest percentages that exist in Damietta districts may be attributed to the high organic matter contents and the low soil pH.

Results in fig. 4 show that, there are non-significant positive correlation between DTPA-extractable Cu and soil clay content. On the other hand, a significant positive correlation was found between soils available Cu and the organic matter content (R^2 = 0.7407). While a significant negative correlation were found between soils available Cu and soil pH (r = -0.83) and calcium carbonate content (r = -0.79). Our results agree with Ibrahim, (2001) and Badawy, (1992) who reported that $CaCO_3$, organic matter and pH are the most important factors that affect total and available Cu in soils. Also, results (Table 3) cleared that a significant increase ($P \leq 0.05$) in both of total and DTPA extractable-Cu in surface compare with subsurface layers. However, no significant increases between location except Kafr Sad. While, at the same locations a significant increase were found only in Faraskor and Damietta districts.

Copper in plants

• Copper in rice plant:

Results in table 4 show that the concentration of Cu in the rice straw of all samples ranged from 9.06 to 24.87 with an average of 19.97 ± 4.66mg kg^{-1}. While in rice grains the Cu concentration ranged from 1.16 to 5.28 with an average of 3.70 ± 1.09 mg kg^{-1}. Results show that, rice grains contain less Cu than the straw. The reduction in the Cu content of the rice grains relative to that of the straw represent 12.4 to 22.5% with an average of 18.4% ±2.58. The low Cu content of the grains relative to that of the straw is an evidence of the low accumulation of Cu in the grain than in the straw. Along the same line, Cui *et al*., (2019) found low translocation of Cu from roots to straw in rice plant. A significant positive correlation (r = 0.89) between Cu concentration of rice grains and straw.

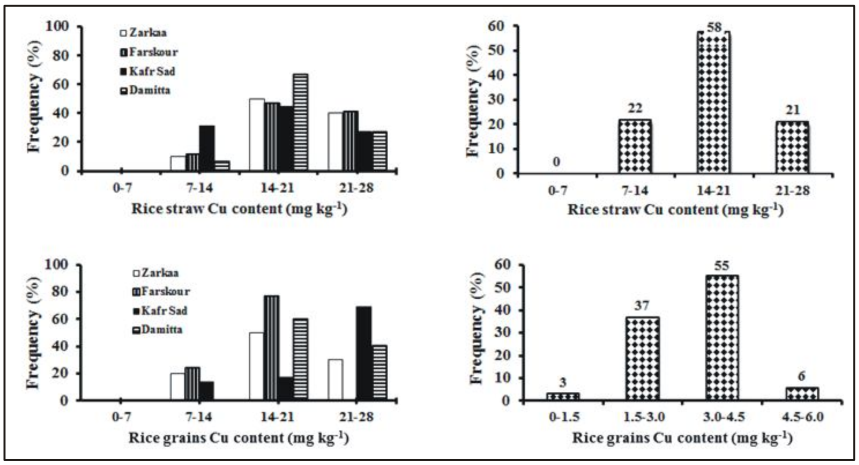

Fig. 5: Frequency distribution of Cu concentration in the straw and grains of rice plants grown at the different districts.

Table 4: Mean levels, ranges and standard deviation of copper concentration in straw and grains of rice plants grown at the different districts.

Loca-tions*	Rice dry weight Cu content (mg kg^{-1}DW)								
	Straw			Grains			Grains/Straw (%)		
	Range	Mean	±Sd	Range	Mean	±Sd	Range	Mean	±Sd
A	13.5-24.3	19.97 a	3.88	2.98-4.86	3.93 a	0.58	17.6-21.9	19.9 a	1.48
B	12.8-24.8	19.75 a	4.18	2.16-4.60	3.41 b	0.70	14.7-19.7	17.4 b	1.69
C	9.06-24.9	19.85 a	5.78	1.16-5.28	3.78 a	1.31	12.8-21.2	19.1 c	2.59
D	14.8-23.8	20.20 a	3.44	2.07-5.01	3.19 b	1.22	14.0-21.1	18.3bc	3.45
All samples	9.06-24.9	19.93	4.66	1.16-5.28	3.70	1.09	12.4-22.6	18.4	2.58

A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta

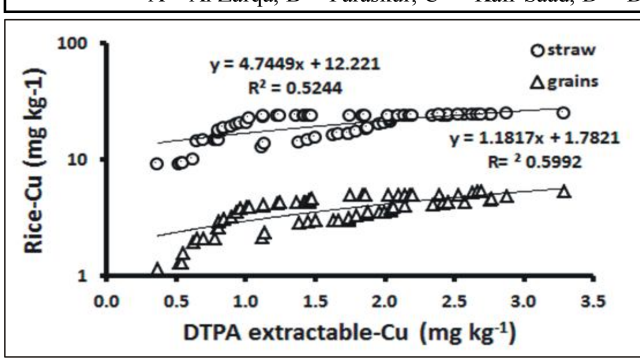

Fig. 6: Relationship between soil DTPA extractable-Cu and Cu concentrations in rice straw and grains.

Fig. 5 shows that 22% of the rice straw contain less than 14 mg kg^{-1} Cu; 58% contain from 14 to 21 mg kg^{-1} Cu and 21% contain from 21 to 28 mg kg^{-1} Cu concentration. While, about 40% of the rice grains contain less than 3.0 mg kg^{-1} Cu; 55% contain between 3 to 4.5 3mg kg^{-1} Cu and 6% contain more than 4.5 mg kg^{-1} Cu concentration.

Results show that the lowest average of Cu concentrations (19.75 ± 4.18 in rice straw and 3.41 ±.0.70 mg kg^{-1} wheat grains) was found in Faraskor district. However, the highest average (20.23 ± 3.44 in rice straw and 3.71 ± 1.31 mg kg^{-1} wheat grains) was found in Damietta district. This relationship is related to the soil DTPA extractable-Cu (Fig. 6), which shows significant positive correlation with rice straw and grains Cu concentration (r = 0.72 and 0.77), respectively. The positive correlation between soil DTPA available Cu and rice straw and grains Cu concentration indicate that Cu is readily taken up by plants.

• Copper in wheat plant:

The concentration range of Cu in wheat straw (Table 5) is from 8.98 to 22.87 with an average of 15.93 ± 3.93mg kg^{-1}. While in wheat grains the concentration ranged from 1.40 to 4.53 with an average 2.97 ± 0.81 mg kg^{-1}. Copper concentration is lower in wheat grains than that of the straw. Copper concentration of wheat grains represents from 15.59 to 19.81% with an average 17.70% ± 2.25 from that of the wheat straw. The low Cu concentration of wheat grains relative to that of the straw is an evidence of the low Cu accumulation in the grain than in the straw. Results show a significant positive correlation (r = 0.88) between wheat grain and straw Cu concentration. In another word, as the straw Cu concentration increases the grains Cu concentration increase.

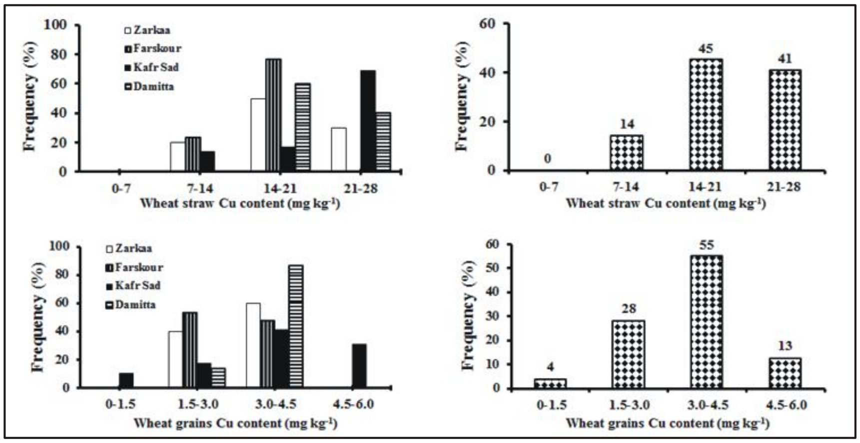

Fig. 7: Frequency distribution of Cu concentration in wheat straw and grainsgrown at the different districts.

Table 5: Mean levels, ranges and standard deviation of copper concentration in straw and grains of wheat plants grown at the different districts.

Loca-tions*	Wheat dry weight Cu content (mg kg^{-1} DW)								
	Straw			Grains			Grains/Straw (%)		
	Range	Mean	±Sd	Range	Mean	±Sd	Range	Mean	±Sd
A	12.9-21.9	17.1 a	3.62	2.19-4.11	3.02 a	0.65	16.9-18.7	18.2 a	1.41
B	10.8-20.9	16.5 a	2.96	1.83-3.98	2.88 a	0.60	16.8-18.9	17.7 a	1.81
C	8.90-22.8	16.4 a	4.63	1.44-4.51	2.94 a	0.86	16.0-19.7	17.8 a	2.27
D	10.9-22.3	18.1 a	3.59	1.40-4.53	3.17 a	1.03	12.7-20.2	17.7 a	3.11
All samples	8.90-22.8	17.03	3.93	1.40-4.53	3.05	0.81	15.5-19.8	17.9	2.25
A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta									

Fig. 7 shows that 14% of the wheat straw contain less than 16 mg kg^{-1} Cu; 45% contain from 14 to 21 mg kg^{-1} Cu and 41% contain from 21 to 28 mg kg^{-1} Cu. However, about 4% of the wheat grains contain less than 1.5 mg kg^{-1} Cu; 28% contain between 1.5 to 3.0 mg kg^{-1} Cu and 55% of the samples contain between 3 to 4.5 mg kg^{-1} Cu and only 13% contain more than 4.5 mg kg^{-1} Cu.

Results demonstrate that, the lowest average of Cu concentration is (16.44 ± 4.63mg kg^{-1} in wheat straw and 2.94± 0.0.86 mg kg^{-1} in wheat grains) was found in Kafr Sad district. However, the highest average is (18.29 ± 3.59 mg kg^{-1} in wheat straw and 3.25± 1.03 mg kg^{-1} wheat grains) was found in Damietta district. These results is attributed to the soil DTPA extractable-Cu (Fig. 8), which showed a significant positive correlation (r = 0.82 and r = 0.87) with wheat straw and grains Cu concentrations.

Also, results (Table 6) cleared that a significant increase (P≤0.05) in both of straw and grains compare with both rice and wheat plants. However, no significant increases between location. While, at the same locations a significant increase were found. A glance at our results in (Fig. 9) shows that the concentration of Cu in the straw

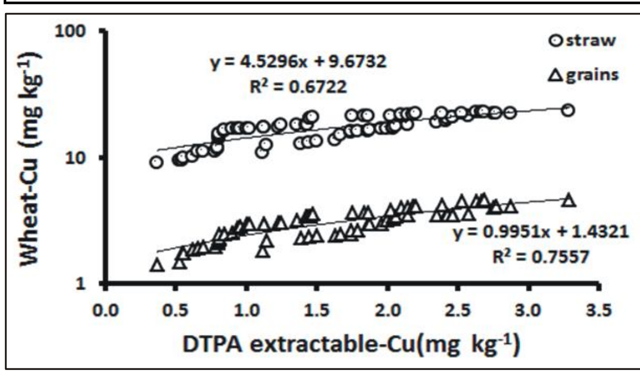

Fig. 8: Relationship between soil DTPA extractable-Cu and rice straw and grains Cu concentrations.

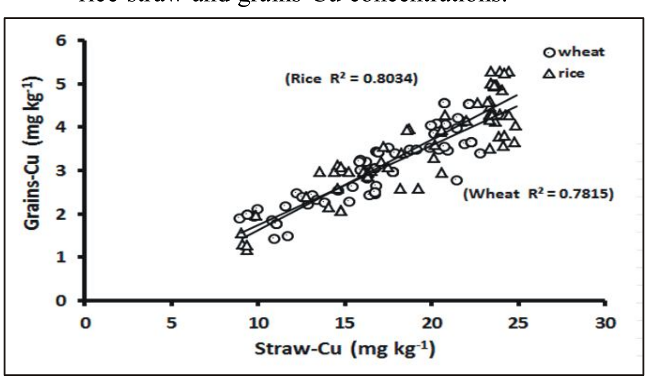

Fig. 9: Relationship between Cu concentration in the grains and straw of rice and wheat plants.

Table 6: Mean performance of two crops evaluated fewer than four locations for straw and grains Cu concentration of the different districts.

Plant	Location*	Plant Cu concentration (mg kg^{-1} DW)		
		Straw	Grains	Straw/grains
Wheat		17.028	3.048	16.610
Rice		19.925	3.701	20.727
L.S.D at 0.05 level		1.152	0.416	1.991
	A	18.770	3.573	19.319
	B	18.177	3.183	19.180
	C	18.145	3.362	18.335
	D	19.261	3.482	18.301
L.S.D at 0.05 level		1.350	0.072	0.176
Wheat	A	17.569	3.212	17.135
	B	16.603	2.954	16.240
	C	16.438	2.940	17.005
	D	18.290	3.254	15.917
Rice	A	19.972	3.934	21.502
	B	19.751	3.412	22.120
	C	19.852	3.785	19.664
	D	20.233	3.711	20.686
L.S.D at 0.05 level		2.779	0.147	0.363

A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta

and grains is different in the two plant species (rice vs. wheat). Copper concentration is higher in rice grains than in wheat grain. This may be due to genetic variation between the two species.

Conclusion

The four districts (A = Al-Zarqa, B = Faraskur, C = Kafr-Saad, D = Damietta) of Damietta governorate show that copper concentration in the soil is within the permissible critical limits, established by the European Union. This indicates the possibility of using such land for growing agriculture crops. In all the studied districts, total and available Cu accumulated more in the soil surface layers than the subsurface layers. The concentration of DTPA-available Cu is much lower than the total copper, however, it correlate with total Cu. Copper concentration is higher in rice and wheat straw than the grain. Rice straw and grain contain higher Cu concentration than wheat straw and grain. This may be due to genetic variability between the two species.

References

Aboulroos, S.A., Sh. Sh. Holah and S.H. Badawy (1996). Background levels of some heavy metals in soils of Egypt and associated corn plant. *Egypt. J. Soil Sci.*, **36:** 1-4.

Adrees, M., S. Ali, M. Rizwan, M. Ibrahim, F. Abbas, M. Farid, M. Zia-ur-Rehman, M.K. Irshad and S.A. Bharwana (2015). The effect of excess copper on growth and physiology of important food crops: a review. *Environ. Sci. Pollut. Res.*, **22 (11):** 8148-8162.

Adriano, D.C. (2013). Trace elements in the terrestrial environment. Springer, New York.

Alloway, B.J. (1995). Heavy metals in soils.Blackie Academic and Professional, Glasgow, Scotland.

Badawy, S.H. (1992). Studies on some heavy metals in soils of Egypt and plant grown there on ARE. Ph.D. Thesis, Fac. of Agric., Cairo Univ., Egypt.

Baker, D.E. and J.P. Senft (1995).Copper. In: Alloway, B.J. (Ed.), Heavy Metals in Soils, 2nd edition Blackie Academic and Professional, Glasgow, 177-205.

Ballabio, C., P. Panagos, E. Lugato, J. Huang, A. Orgiazzi, A. Jones, O. Fernández-Ugalde, P. Borrelli and L. Montanarella. (2018). Copper distribution in European top soils: An assessment based on LUCAS soil survey. *Science of the Total Environment,* **636:** 282-298.

Claydon, J.J. (1989). Determination of particle size distribution in fine grained soil: Pipette method. Lower Hutt, New Zealand: Department of Scientific and Industrial Research.

Cottenie, A., M. Verloo, L. Kiekens, G. Velgh and R. Camerlynch, (1982). Chemical analysis of plants and soils, Lab, Anal Agrochem. State Univ. Ghent Belgium, 63.

Cui, J.L., C.L. Luo, C.W.Y. Tang, T.S. Chan and X.D. Li (2017). Speciation and leaching of trace metal contaminants from e-waste contaminated soils. *J. Hazard. Mater.*, **329:** 150-158.

Cui, J.L., Y.P. Zhao, T.S. Chan, L. Zhang, D.C.W. Tsang and X.D. Li (2019). Spatial Distribution and Molecular Speciation of Copper in Indigenous Plants From Contaminated Mine Sites: Implication for Phytostabilization. *Environment International,* **126:** 717-726.

Elnaggar, A.A., Kh. H. El-Hamdi and T.Y. Daibes (2017). Fertility evaluation of some soils in Damietta governorate, Egypt using GIS. *J. Soil Sci. and Agric. Eng., Mansoura Univ.*, **8(2):** 58-92.

El-Sayad, E.A. (1988). Status of some trace elements in relation to the nature of the main sediments in the Fayoum (Egypt) Depression. Ph.D. Thesis, Dept. of Soil Sci., Aberdeen Univ., Scotland, U.K.

Freed, R.S.P., S. Eisensmith, D. Goetz, V. Reicosky, W. Smail and P. Wolberg (1989). User's Guide to MSTAT-C: A Software Program for the Design, Management and Analysis of Agronomic Research Experiments, Michigan State University, East Lansing, ML, USA.

Ibrahim, M.S., A. Abd El-Galil and M.M. Ktob (2001). Total and available Fe, Mn, Zn and Cu in some soil Sohag Governorate and their associations with some soil properties. *Assiut J. Agric. Sci.,* **32:** 71-85.

Jackson, M.L. (1973). Soil chemical analysis prentice Hell of India Private Limited, New Delhi.

Keeney, D.R. and D.W. Nelson (1982). Nitrogen-inorganic forms. 643-698. In A. L. Page (ed.), Methods of soil analysis. Agron. 9, Part 2: Chemical and microbiological properties, 2nd ed., Am. Soc. Agron., Madison, WI, USA.

Komárek, M., E. Èadková, V. Chrastný, F. Bordas and J.C. Bollinger (2010). Contamination of vineyard soils with fungicides: a review of environmental and toxicological aspects. *Environment international*, **1; 36(1):** 138-51.

Lindsay, W.L. and W.A. Norvell (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, **42:** 421-428.

Mohamed, N.A. (1990). Nutrients status in some soils as related to Mineralogical Composition. M. Sc. Thesis, Fac. of Agric., Ain Shams Univ., Egypt.

Oliver, M.A. (1997). Soil and human health: a review. *Eur. J. Soil Sci.*, **48(4):** 573-592.

Panagos, P., M. Van Liedekerke, Y. Yigini and L. Montanarella (2013). Contaminated sites in Europe: review of the current situation based on data collected through a European network. *J. Environ. Public Health*.

Pendias, A.K. and H. Pendias (1992). Trace elements in soils and plants. CRC Press, Inc., United States.

Ragheb H.M.A., H. Hala, M.A. Youssef and A.M.A. Ali (2017). Fertility Status and Indices of Micronutrients in Nile Valley Soils, East of the Nile River, Assiut Governorate, Egypt. *J. Soil. Sci.,* **57(2):** 189-199.

Rieuwert, J.S., I. Thornton, M.E. Farago and M.R. Ashmore (1998). Factors influencing metal bioavailability in soils: Preliminary investigations for the development of a critical loads approach for metals. *Chemical Speciation and Bioavailability.,* **10:** 61-75.

Sadik, M.K., A.H. Abd El-Hameed and M.A. Abd Alla (2002). Evaluation of some micronutrient chemical extractants. *Egypt. J. Soil Sci.*, **42(2):** 277-297.

Snedecor, G.W. and W.G. Cochron (1981). Statistical Methods 7th ed. Iowa State Univ., Press, Ames, Iowa.

Steffan, J.J., E.C. Brevik, L.C. Burgess and A. Cerdà (2018). The effect of soil on human health: an overview. *Eur. J. Soil Sci.*, **69(1):** 159-171.

Steel, R.G.D., J.H. Torri and D.A. Dickey (1997). Principles and Procedures of Statistics: A Biometrical Approach, 3rd ed., McGraw-Hill, New York.

Stern, B.R., M. Solioz, D. Krewski, P. Aggett, S. Baker, K. Crump, M. Dourson, L. Haber, R. Hertzberg, C. Keen, B. Meek, L. Rudenko, R. Schoeny, W. Slob and T. Starr (2017). Copper and human health: biochemistry, genetics and strategies for modeling dose-response relationships. *J. Toxicol. Environ. Health*, **Part B 10 (3):** 157-222.

Taha, S.A.E. (1980). Studies on manganese in some soils of Egypt. Ph.D. Thesis, Fac. of Agric., Cairo Univ., Egypt.

Tóth, G., T. Hermann, M.R. Da-Silva and L.Montanarella (2016). Heavy metals in agricultural soils of the European Union with implications for food safety. *Environment International*, **88:** 299-309.

Uriu-Adams, J.Y. and C.L. Keen (2005). Copper, oxidative stress and human health (2005). *Mol. Asp. Med.*, **26 (4-5):** 268-298.