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Effect of N-Fertilizer Types and Rates Interacted with Water Regime on Micronutrients Uptake by Potato Grown on Sandy Soil

Soliman, M. A. E.
Soil Department, Faculty of Agriculture, Damietta University, Egypt.

ABSTRACT

A field experiment was conducted on sand soil to evaluate the impact of interaction between nitrogen sources, rates water regime on micronutrients uptake by potato crop. Potato plants were fertilized with urea and ammonium phosphate applied at rates of 150, and 90 kg ha^{-1} of both two different N forms in addition to unfertilized treatment. These two rates were splitted into two equal doses; first one was applied at 20 days after seedling initiation and the second at 25 days from the first dose. Plants were grown under two water regimes, i.e. 100% and 60% Etc. Fe, Mn, Cu and Zn were frequently affected by water regimes. Except Cu, other elements were significantly accumulated in tubers under 60% evapotranspiration (Etc) regimes higher than 100% Etc regime. Fe, Mn in tubers was higher in case of urea than ammonium phosphate at rate of 150 kg N ha^{-1} as compared to 90 kg N ha^{-1}. Cu values in tubers did not significantly affected by water regimes and N rates but urea form still superior over ammonium phosphate. On the other hand, Zn was more accumulated in tubers of plants fertilized ammonium phosphate applied at 90 kg N ha^{-1} under 60% Etc water regime comparing to other treatments. Transfer of Fe from soil to potato tubers seems to be very low. Mn was moderately transferred from soil to potato tubers. Copper was moderately to high transferred from soil to plant tubers as affected by tested factors. Potato tubers act as accumulator for Zn since TF was high and nearly to 1. Ammonium phosphate enhanced the transfer of Zn comparing to urea fertilizer. It increases with application of 90 kg N ha^{-1} as compared to 150 kg N ha^{-1}. There was no significant difference between 100% and 60% Etc water regimes.

Keywords: Micronutrients, Nitrogen rate, N forms, Potato, Transfer factor, Water regimes.

INTRODUCTION

In order to overcome the gap between crop production and human demand for vegetables and essential crops, good and proper nutrient management should be considered. One of the most important crops is potato which came to the fourth rank after rice, wheat and maize (Faostat, 2013). It needs nutritional management strategy for getting remarkable production (Janmohammadi *et al*., 2016). Balanced nutrients management can improve potato production and maintain the soil fertility. Adequate and suitable fertilizers (bio-organic or minerals) could achieve good production components of potato crop grown in irrigated soils under semi-arid conditions (Janmohammadi *et al*., 2016). To obtain high yields of potato, proper N management as the most important factor should be concerned. Nitrogen use efficiency may be enhanced when closed to actual plant growth requirements (Pobereżny *et al*. 2015).

Irrigated potatoes are usually grown on coarse-textured soils low in organic matter. Typically, these soils are sandy loams or loamy sands, low in native fertility, and quite acid. High nutrient demand coupled with low native fertility often results in high fertilizer requirements for irrigated potato production. Over the years, however, continued fertilizer applications can build up the soil test levels of certain nutrients. Environmental concerns, especially for nitrogen leaching, are also an important factor in fertilizer use on irrigated sandy soils.

Application of N fertilizer is usually necessary to ensure profitable potato production, because soil N is largely tied up in organic matter and a relatively small amount of this organic N becomes available for uptake over the growing season. Ensuring adequate N is necessary to achieve high yields, but too much N can also cause problems. Excessive N can reduce both yield and tuber quality and has the potential to leach to groundwater on well-drained sandy soils.

Transmission of metals from soil to plant tissues is studied using an index called Transfer Factor (TF). It is calculated as a ratio of concentration of a specific metal in plant tissue to the concentration of the same metal in soil, both represented in same units (Rangnekar *et al*., 2013a). Higher TF values (≥1) indicate higher absorption of metal from soil by the plant and higher suitability of the plant for phyto-extraction and phytoremediation. On the contrary, lower values indicate poor response of plants towards metal absorption and the plant can be used for human consumption (Rangnekar *et al*., 2013b). The availability of metals for plants is controlled by plant's requests for micronutrients and their capacity to absorb and eliminate toxic elements.

This availability is different, depending on plant species and their adaptation to the environmental conditions. Based on this, plants can be divided into three categories: excluderators, indicators and accumulators. Herbs absorb less metal than fast growing plants such as lettuce, spinach, carrot and tobacco (Smical *et al*., 2008).

This work aimed at tracing the effect of nitrogen fertilization and water regime on accumulation of iron, zinc, manganese and copper in tubers of potato crop and in the soil where plants were grown. Also, transfer of heavy metals from soil to the plants in the unpolluted area may give an impression about the quality of potato tubers.

MATERIALS AND METHODS

A field experiment using Potato tuber crop (*Solanum tuberosum* L., var. Spunta) was conducted in sand soil located at Inshas area which belongs to Sharqeia Governorate. Some physical and chemical characteristics of the experimental soil are presented in Table (1). Soil chemical and physical analyses were carried out according to Carter and Gregorich (2008).

Before cultivation, soil received the recommended rates of phosphorus and potassium fertilizers. Phosphorus was applied as super-phosphate at rate of 180 kg P ha^{-1}, while potassium was applied at rate of 230 kg K ha^{-1} in the form of potassium sulfate. Nitrogen fertilizers were applied as urea and ammonium phosphate forms at rates of 150 kg ha^{-1}(100%), and 90 kg ha^{-1} (60%) from the recommended rate. Nitrogen rates were splitted into two equal doses, first was applied at 25 days after seedling initiation and the second one at 30 days from the first one. Plants grown under drip irrigation system were irrigated at two regimes, i.e. 100% ETc (W1) and 60% ETc (W2), from the crop evapotranspiration (ETc, mm/day). Combination of ETo and the crop coefficient value (Kc) of Potato which obtained from the publication data of Doorenbos and Kassam (1979) gave the chance to estimate the crop water requirement. Reference crop evapotranspiration (ETo) was calculated by Penman-Monteith equation (Allen *et al*., 1998). The meteorological data recorded by the local meteorological weather Station Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Giza, Egypt. Data of water application for potato were shown in Table (2). Data revealed that Potato required 5079.73m^3 ha^{-1} (100% ETc) and 3047.83m^3 ha^{-1} (75% ETc) during the growing season.

Table 1. Some physical and chemical properties of experimental soil

Particle size distribution %			Texture class	B. density gm cm^3	F. C %	PWP %
Sand	Silt	Clay				
98.13	1.40	0.47	Sandy soil	1.64	10.31	1.43

pH 1:2.5	$CaCO_3$ %	O.M %	EC (dS/m) at 25^{o}c	Soluble cations (meq / 100g soil)				Soluble anions (meq / 100g soil)			
				Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^-	HCO_3^-	Cl^-	SO_4^{--}
8.17	0.75	0.004	0.56	2.80	1.13	1.41	0.22	-	2.56	2.20	0.80
OC% 0.10	N% 0.0028	P% 0.006									

Table 2. Amount of irrigation water added throughout potato growth season according to, Doorenbos and Kassam (1979).

Stage	Length of stage	Kc	ETo, mm stage^{-1}	ETc, mm stage^{-1}	Water apply m^3 ha^{-1}
Initial	21	0.50	77.8	38.90	518.67
Development	30	0.80	107.7	86.16	1148.8
Midseason	30	1.15	144.8	166.52	2220.26
Late	23	0.75	119.2	89.40	1192
Total	105 days		449.5	380.98	5079.73

Experimental treatments were distributed in the field in a split-split design where water regime located in the main plots and fertilizer forms and doses were located in sup-plots. Microelements Cu, Fe, Mn, and Zn uptake by plant were determined according to Estefan *et al*., (2013).

Determination of Transfer Factor (TF)

The transfer coefficient was calculated by dividing the concentration of heavy metals in plant by the total heavy metals concentration in the soil.

$$TF = C_{plant} / C_{soil}$$

Where, C_{plant} = metal concentration in plant tissue, mg kg^{-1} fresh weight and C_{soil} = metal concentration in soil, mg kg^{-1} dry weight.

The metal concentrations in the extracts of the soils and plants were calculated on the basis of dry weight. If the ratios >1, the plants have accumulated elements, the ratios around 1 indicate that the plants are not influenced by the elements, and ratios <1 show that plants exclude the elements from the uptake (Olowoyo, *et al*., 2010). If the plants have higher TF values, they can be used for phytoremediation.

The data were subjected to ANOVA statistical analysis using SAS Statistical Software (SAS, software program, 2002), and means were compared with the Least Significant Deference (L.S.D) at the 0.05 level.

RESULTS AND DISCUSSION

Micronutrients uptake by tuber

Iron Fe

More iron was uptake by tubers of plants treated with urea fertilizer either applied at 150 or 90 kg ha^{-1} under 100% Etc water regime (Table 3). Iron content was increased by increasing N rate. It seems that reduction in N rate decreased Fe content as compared to the unfertilized control. Similar trend, but to somewhat higher extent, was noticed under 60% Etc water regime. Mean values of N rates indicated that application of 150 kg N, despite of forms, had doubled the Fe content in potato tubers. Interaction between water regimes and N forms as well as interaction of N forms x rates indicated the superiority of urea over ammonium phosphate in stimulation of iron uptake by tubers. Statistically, water regimes, N rates were significantly affected the Fe content in tubers. In this regard, Ma and Zheng (2018) found that maize stover Fe concentration was negatively related to N rates. Nevertheless, this difference tended to fade out at high N rates.

Table 3. Iron uptake (mg kg^{-1}) by potato tubers as affected by N types and rates and water regimes under sand soil conditions.

Water regime (W) ETc	N type (N)	Tuber N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime	
100%	Urea	757.3	957.9	352.2	689.2		
	A. phosphate	355.8	756.1	292.8	468.2		
	Mean W.R	556.6	857.0	322.5		578.7	
60%	Urea	932.1	998.2	537.9	822.8		
	A. phosphate	792.1	733.1	434.4	653.2		
	Mean W.R	862.1	865.7	486.2		738.0	
Mean of rates			861.4	404.3	632.9		
Mean of N.R	Urea	844.7	1028.1	395.1	N1	756.0	
	A. phosphate	773.9	744.6	663.6	N2	727.4	
LSD 0.05	W	N	R	WN	WR	NR	WNR
	127.1	ns	155.6	179.6	220.0	220.0	ns

Metals	Cd	Cu	Zn
Permissible Limits (µg/g)	0.2	73.3	9.4

Iron remained in soil after harvest showed higher content of Fe as affected by ammonium phosphate than urea at rate of 90 kg ha^{-1} comparing to 150 kg ha^{-1} (Table 4). Water scarce (60% Etc) reflected more Fe was remained in soil after harvest. Despite of N forms, Fe in soil was highly accumulated in case of 150 kg N ha^{-1} as compared to 90 kg N ha^{-1}. It seems that water regimes, N rates and forms either individually or in interactions statistically significantly affected the content of Fe in soil after harvest.

In harmony, Ma and Zheng (2018) indicated that maize grain Cu and Fe concentrations at maturity stage were positively responsive to N rates in all cropping systems. They added that the concurrent augmentation of Cu concentrations in stover and grain, along with increasing N, affirmed the synergism of plant N and Cu nutrition. Grain Fe concentration responded to N application in a manner in contrast to its stover concentration.

Table 4. Iron content (mg kg^{-1}) in soil after harvest under different N types and rates and water regimes.

Water regime (W) ETc	N type (N)	N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime	
100%	Urea	851.4	1395.0	1094.8	1113.7		
	A. phosphate	1617.2	1227.8	1907.0	1584.0		
	Mean W.R	1234.3	1311.4	1500.9		1348.9	
60%	Urea	2239.7	1884.8	1557.3	1893.9		
	A. phosphate	2433.2	1490.5	2073.3	1999.0		
	Mean W.R	2336.4	1687.7	1815.3		1946.5	
Mean of rates			1785.3	1499.5	1658.125		
Mean of N.R	Urea	1545.5	1639.9	1326.1	N1	1503.8	
	A. phosphate	2025.2	1359.2	1990.2	N2	1791.5	
LSD 0.05	W	N	R	WN	WR	NR	WNR
	93.2	93.2	114.2	131.8	161.5	161.5	228.4

Estimated TF of iron to potato tubers not exceeds the limits that negatively affected the quality of potato tubers (Table 5). Transfer of Fe from soil to potato tubers seems to be very low.

Table 5. Transfer factor of Fe to potato tubers as affected by fertilization treatments and irrigation water regimes

Water regime (W) ETc	N type (N)	N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	0.47	0.41	0.24	0.37	
	A. phosphate	0.18	0.38	0.13	0.23	
	Mean W.R	0.33	0.40	0.19		0.31
60%	Urea	0.29	0.35	0.26	0.30	
	A. phosphate	0.25	0.33	0.17	0.25	
	Mean W.R	0.27	0.34	0.22		0.28
Mean of rates						
Mean of N.R	Urea	0.35	0.39	0.23	N1	0.32
	A. phosphate	0.28	0.35	0.25	N2	0.29

Manganese Mn

Manganese uptake by potato tubers under 100% Etc water regime was significantly affected by increasing N fertilizer rate up to 150 kg ha^{-1}, but both rates reflected lower Mn content than those recorded with the unfertilized control (Table 6). Similar trend, but to somewhat higher extent was noticed under 60% Etc water regime. Mean value of interaction between water regime and nitrogen form revealed the superiority of urea over ammonium phosphate under 100% Etc while there was no significant difference between forms when 60% Etc was considered. Mean values of Mn in tubers were higher in case of 60% Etc than those of 100% Etc water regime. Overall means of Mn as affected by interaction between N forms and N rates indicated the superiority of urea over ammonium phosphate.

Table 6. Manganese uptake (mg kg^{-1}) by potato tubers as affected by N types and rates and water regimes under sand soil conditions.

Water regime (W) ETc	N type (N)	Tuber N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime	
100%	Urea	153.4	131.6	153.2	146.0		
	A. phosphate	133.6	102.2	101.8	112.5		
	Mean W.R	143.5	116.9	127.5		129.3	
60%	Urea	182.7	145.7	123.1	150.5		
	A. phosphate	148.0	149.9	155.0	151.0		
	Mean W.R	165.3	147.8	139.0		150.7	
Mean of rates			154.4	132.3	133.3		
Mean of N.R	Urea	168.0	138.6	138.1	N1	148.3	
	A. phosphate	140.8	126.0	128.4	N2	131.8	
LSD 0.05	W	N	R	WN	WR	NR	WNR
	7.6	7.6	9.3	10.8	ns	ns	18.7

These results confirmed those earlier obtained by Saif El-Deen *et al*., (2015) who found that Mn concentration in sweet potato tubers was increased with increasing N fertilizer rates up to 60 kg N fed^{-1}. They added that improvement of micronutrients content in tubers as well as yield may be attributed to stimulating biological activities, i.e., enzyme activity, chlorophyll synthesis, rate of translocation of photosynthetic products and increased nutrient uptake through roots after foliar fertilization.

Manganese remained in soil after harvest reflected that fertilization treatments and water regime has an effective role (Table 7). Slight differences between N forms and rates were observed. This holds true under both water regimes. Also, interactions between tested factors did not reflect significant difference as Mn concentration in soil considered. It seems that Mn was moderately transferred from soil to potato tubers (Table 8). There were no significant differences between tested factors in terms of Mn concentrations in soil after harvest.

Table 7. Manganese content (mg kg^{-1}) in soil after harvest under different N types and rates and water regimes.

Water regime (W) ETc	N type (N)	Tuber N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	82.0	77.0	82.6	80.6	
	A. phosphate	83.5	71.3	75.4	76.7	
	Mean W.R	82.8	74.2	79.0		78.6
60%	Urea	105.4	67.6	76.4	83.2	
	A. phosphate	98.3	89.3	66.8	84.8	
	Mean W.R	101.9	78.5	71.6		84.0
Mean of rates			76.4	76.3	76.3	
Mean of N.R	Urea	93.7	72.3	79.5	N1	81.9
	A. phosphate	90.9	80.3	71.1	N2	80.8
LSD	W	N	R	WN	WR	NR WNR
0.05	3.4	ns	4.1	ns	5.8	5.8 8.2

Table 8. Transfer factor of Mn to potato tubers as affected by fertilization treatments and irrigation water regimes

Water regime (W) ETc	N type (N)	N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	0.7	0.6	0.6	0.63	
	A. phosphate	0.6	0.6	0.6	0.60	
	Mean W.R	0.65	0.60	0.60		0.62
60%	Urea	0.6	0.7	0.6	0.63	
	A. phosphate	0.6	0.6	0.7	0.63	
	Mean W.R	0.60	0.65	0.65		0.63
Mean of rates						
Mean of N.R	Urea	0.6	0.7	0.6	N1	0.63
	A. phosphate	0.6	0.6	0.6	N2	0.60

Copper Cu

As shown in Table (9), copper uptake by tubers was significantly affected by N form and rate where its contents increased with increasing N rates up to 150 kg ha^{-1}and higher in case of urea than ammonium phosphate when plants irrigated at 100% Etc regime. Reversible trend was noticed under 60% Etc regime whereas Cu was higher in case 90 kg N ha^{-1} than those of 150 kg N ha^{-1} but there was no significant difference between N forms. Mean values of Cu as affected by water regimes did not reflect significant difference between them. Mean Cu values as affected by N forms reflected the superiority of urea over ammonium phosphate. These values of Cu concentration in potato tubers are in accordance with those of Lokeshappa *et al*., (2012) who reported that copper was in low concentrations in potato.

Although, the mean value of Cu as affected by N rate did not reflected significant difference, some findings showed increase of Cu uptake by tubers with increasing N rate especially under 100% Etc water regime. This finding was, to some extent, in consistent with those of Ma and Zheng, (2018) who found that Cu concentration in maize stover increased linearly with increasing N rates. It seems that potato tubers were excluder for Cu since the content was under permissible limits reported by Chary *et al*., (2000) and Codex (1995).

Copper content in soil after harvest (Table 10), was not greatly affected by N rates either with 100% Etc or 60% Etc regimes. In case of 100% Etc, Cu remained in soil doesn't varied between N forms. Ammonium phosphate was superior over urea when Cu content under 60% Etc was concerned. Mean Cu values affected by water regime were slightly tended towards 60% Etc regime. Also, mean Cu values as affected by N form and rate reflected the superiority of ammonium phosphate over urea.

Table 9. Copper uptake (mg kg^{-1}) by potato tubers as affected by N types and rates and water regimes under sand soil conditions.

Water regime (W) ETc	N type (N)	Tuber N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	46.2	33.9	33.1	37.7	
	A. phosphate	15.2	31.7	15.0	20.6	
	Mean W.R	30.7	32.8	24.0		29.2
60%	Urea	2.5	19.6	51.8	24.6	
	A. phosphate	35.8	32.2	16.1	28.0	
	Mean W.R	19.2	25.9	34.0		26.3
Mean of rates			29.4	29.3	29.3	
Mean of N.R	Urea	24.4	26.7	42.5	N1	31.2
	A. phosphate	25.5	32.0	15.5	N2	24.3
LSD	W	N	R	WN	WR	NR WNR
0.05	1.5	1.5	1.8	2.1	2.6	2.6 3.6

In this respect, Mirecki *et al*., (2015) reported that permissible limit for Cu (mg kg^{-1}) in soil in UK was 135 at pH 6-7. It means that our soil has lower limits than those mentioned above. This is not our case since our soils tended to be alkaline and Cu as other microelements becomes unavailable for plants. Therefore, Cu remained in soil after harvest were very low as compared to those of Mirecki *et al*., (2015).

Copper was moderately to high transferred from soil to plant tubers as affected by tested factors (Table 11). Data of TF did not reflect any significant difference between water regimes, N forms and N rates and their interactions.

Table 10. Copper content (mg kg^{-1}) in soil after harvest under different N types and rates and water regimes.

Water regime (W) ETc	N type (N)	N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	4.0	8.3	8.5	6.9	
	A. phosphate	2.5	8.7	9.8	7.0	
	Mean W.R	3.3	8.5	9.2		7.0
60%	Urea	3.6	7.8	9.3	6.9	
	A. phosphate	9.0	14.3	11.1	11.5	
	Mean W.R	6.3	11.1	10.2		9.2
Mean of rates			9.8	9.7	9.7	
Mean of N.R	Urea	1.8	4.1	8.9	N1	4.9
	A. phosphate	5.8	8.0	10.5	N2	8.1
LSD 0.05	W	N	R	WN	WR	NR WNR
	1.0	1.0	1.3	1.5	1.9	ns ns

Table 11. Transfer factor of Cu to potato tubers as affected by fertilization treatments and irrigation water regimes.

Water regime (W) ETc	N type (N)	N Rates (R) kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	0.9	0.8	0.8	0.83	
	A. phosphate	0.9	0.8	0.6	0.80	
	Mean W.R	0.9	0.8	0.7		0.80
60%	Urea	0.4	0.8	0.8	0.70	
	A. phosphate	0.8	0.7	0.6	0.70	
	Mean W.R	0.6	0.75	0.7		0.70
Mean of rates						
Mean of N.R	Urea	0.9	0.9	0.8	N1	0.86
	A. phosphate	0.8	0.8	0.6	N2	0.73

Mirecki *et al*., (2015) found that Cu has medium transfer factor for all types of vegetables including potato crop and ranges from 0.01-0.2 in polluted to 0.05-0.5 in unpolluted area. Similar results are reported by Jolly *et al.* (2013) where TF for Cu is medium (0.069-0.127) in comparison with TF for Zn.

Zinc Zn

Zinc accumulated in potato tubers were significantly affected by N forms (Table 12). This phenomenon was more obvious under 60% Etc rather than 100% Etc regime. In the same time, Zn tended to increase with 90 kg N ha^{-1} as compared to 150 kg N ha^{-1}. This was obvious with 100% Etc than 60% Etc regime. Interaction between N form and water regimes reflected the superiority of ammonium phosphate over urea especially with 60% Etc regime. More Zn was accumulated in tubers of plants irrigated with 60% Etc comparing to 100% Etc regime as indicated by overall means of water regime factor. Similar trend was observed by Lokeshappa *et al*., (2012) who reported that zinc was present in moderate concentrations in potato samples.

The synergistic effect of high N rate on Zn uptake by tubers are in consistent with results of Ma and Zheng (2018) who indicated that maize grain Zn concentrations were negatively related to N rates. Similar dilution effect of grain Zn concentration was noted by Feil *et al*. (2005), but the nil-effect of N rates was reported in other studies (Riedell *et al*. 2009; Ciampitti and Vyn 2013).

Table 12. Zinc uptake (mg kg^{-1}) by potato tubers as affected by N types and rates and water regimes under sand soil conditions.

Water regime (W) ETc	N type (N)	Tuber N Rates ® kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	30.8	27.0	69.0	42.2	
	A. phosphate	33.4	30.4	68.4	44.1	
	Mean W.R	32.1	28.7	68.7		43.2
60%	Urea	69.4	48.4	62.2	60.0	
	A. phosphate	143.2	55.7	45.6	81.5	
	Mean W.R	106.3	52.0	53.9		70.7
Mean of rates			40.4	61.3	50.8	
Mean of N.R	Urea	50.1	37.7	65.6	N1	51.1
	A. phosphate	88.3	43.0	57.0	N2	62.8
LSD	W	N	R	WN	WR	NR WNR
0.05	2.6	2.6	3.2	3.7	4.5	4.5 6.4

According to Kloke *et al*., (1984), zinc is not considered to be highly phytotoxic and the toxicity limit for Zn (300-400 mg kg^{-1}) depends on the plant species and its growth stage. High concentrations of zinc in plants may cause loss of leaf production, where low concentrations may cause deformation of leaves.

According to Chary *et al*., (2000) and Codex (1995), zinc content in potato tubers were above permissible limits and the agricultural products like potato (accumulator). Accordingly, among the metals studied (Zn, Cu, Cd and Fe) in the tubers, Zn had the highest mean in potato (Apau *et al*., 2014). They added that the mean concentration of metals in tubers from the selected markets gave a general sequence as follows Fe>Zn>Cu>Cd with the exception of potato which recorded Zn as the highest mean concentration of the metals.

Zinc remained in soil was higher in case of soil fertilized with urea than ammonium phosphate (Table 13) under 100% Etc regime. Reversible trend was noticed with 60% Etc where ammonium phosphate was the best. Mean value of N form interacted with N rate reflected the superiority of urea over ammonium phosphate. Zn in soil was higher with addition of 150 kg N ha^{-1} than 90 kg N ha^{-1} as indicated by mean values of N rate. Mean values of Zn as affected by water regime indicated the superiority of 60% Etc over 100% Etc regime.

Table 13. Zinc content (mg kg^{-1}) in soil after harvest under different N types and rates and water regimes.

Water regime (W) Etc	N type (N)	N Rates ® kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
100%	Urea	25.1	50.0	20.3	31.8	
	A. phosphate	12.6	8.1	11.0	10.6	
	Mean W.R	18.8	29.1	15.7		21.2
60%	Urea	30.9	28.3	24.4	27.9	
	A. phosphate	27.7	38.1	40.0	35.3	
	Mean W.R	29.4	33.2	32.2		31.6
Mean of rates			31.2	24.0	27.6	
Mean of N.R	Urea	28.0	39.2	22.3	N1	29.8
	A. phosphate	20.1	23.1	25.5	N2	22.9
LSD	W	N	R	WN	WR	NR WNR
0.05	0.6	0.6	0.8	0.9	1.1	1.1 1.5

These values of Zn in soil after harvest were very low when compared to permissible limits reported earlier (300 mg kg^{-1} dry weight) at pH 6-7 of UK soils (Mirecki *et al*., 2015).

It seems that potato tubers act as accumulator for Zn since TF was high and nearly to 1. Ammonium phosphate enhanced the transfer of Zn comparing to urea fertilizer (Table 14). It increases with application of 90 kg N ha^{-1} as compared to 150 kg N ha^{-1}. There was no significant difference between 100% and 60% Etc water regimes.

TF values obtained for Zn by Mirecki *et al*., (2015), indicated that all investigated species including potato had Zn accumulation capacity in their organs. Even corn with the lowest TF in this study (0.1-0.2), had a high Zn concentration. According to Sajjad *et al.* (2009) if the transfer coefficient of a metal is greater than 0.5, the plant will have a greater chance of the metal contamination by anthropogenic activities. In the time, it was apparent that TF of Zn, and Cu decreased when the plants were grown in the soil with a higher contamination. Zinc has higher transfer factor for all tested crops including potatoes and ranges from 2-3 in unpolluted locations (Mirecki *et al*., 2015).

Table 14. Transfer factor of Zn to potato tubers as affected by fertilization treatments and irrigation water regimes.

Water regime (W) Etc	N Type (N)	N Rates ® kg ha^{-1} 0	150	90	Mean W.N	Mean of water regime
	Urea	0.6	0.4	0.8	0.6	
100%	A. phosphate	0.7	0.8	0.9	0.8	
	Mean W.R	0.65	0.60	0.85		0.7
	Urea	0.7	0.6	0.7	0.70	
60%	A. phosphate	0.8	0.6	0.5	0.6	
	Mean W.R	0.75	0.60	0.60		0.65
Mean of rates			0.60	0.72	0.66	
Mean of	Urea	0.6	0.5	0.7	N1	0.6
N.R	A. phosphate	0.8	0.7	0.7	N2	0.7

The soil-to-crop transfer of heavy metals might pose a potential health risk to the local residents (Bi, *et al*., 2006).

In general, Ezzat, *et al*., (2011) reported that micronutrients uptake by potato tubers were significantly affected by nitrogen application rate and irrigation intervals. They observed the highest values of Fe, Mn and Zn with 26 days irrigation intervals combined with 360 kg N ha^{-1}.

Ma and Zheng (2018) attributed the reason for the suppressive effects of N on maize stover Zn, Mg and Fe concentrations to the increased remobilization and translocation of Zn, Mg and Fe from vegetative tissues to the grain, as evidenced by the increased HI values, with increasing N rates. They speculated that the increased grain yields under high N supply must be supported by higher rates of translocation of several mineral elements from shoots to the developing kernels, resulting in mineral concentrations being lower in the stover but higher in the grain (Riedell *et al*. 2009).

In addition, high N supply may have made Cu and Zn more available to the crop as N fertilization leads to the acidification of the soil (Divito *et al*. 2011). A small change in soil pH can significantly affect solubility and crop uptake of

Zn, Cu, Mn, and Fe (Khoshgoftarmanesh *et al*. 2010). The enhanced root growth and greater release of organic acids from root exudates of highly N-fertilized maize may have indirectly promoted the formation of Cu^{2+}, which could become available for uptake by plant roots (Fageria 2001; Riedell 2010). Soil acidification may have also increased Zn bioavailability, as illustrated in wheat (Cakmak 2008) and maize (Divito *et al*. 2011).

Thus, it can be concluded that zinc element was more accumulated in tuber than other elements and highly transferred to plants that fertilized with ammonium phosphate comparing to urea form. Tested micronutrients were differentially affected by N forms and rate and water regimes. According to TF values, we suggest that, under such given conditions, more attention should be paid for zinc status in the soil and risk assessment may be considered.

REFERENCES

Allen, R. G.; L. Pereira S.; Raes D. and Smith M. (1998). Crop evapotranspiration: guidelines for computing crop water requirements, FAO Irrigation and Drainage Paper 56: 300.

Apau J., Acheampong A., Appiah J.A., and Ansong E. (2014). Levels and Health Risk Assessment of Heavy Metals in Tubers from Markets in the Kumasi Metropolis, Ghana. International Journal of Science and Technology Volume 3 No. 9, 534-539.

Bi, X., Feng, X., Yang, Y., Qiu, G., Li, G., Li, F., Liu, T., Fu, Z. and Jin, Z. (2006). Environmental contamination of heavy metals from zinc smelting areas in Hezhang County, western Guizhou, China. Environment International 32: 883890.

Cakmak I. (2008). Enrichment of cereal grains with zinc: agronomic or genetic biofortification? Plant Soil 302:1-17.

Carter, M.R. and Gregorich, E.G. (2008). "Soil Sampling and Methods of Analysis". (2nd ed.), CRC Press Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL, p. 1224.

Chary, N.S., Kamala, N.C., and Raj, D.S.S. (2000). Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer., Ecotoxicology and Environmental Safety, 69(3), 513-524.

Ciampitti, I.A., and Vyn, T.J. (2013). Maize nutrient accumulation and partitioning in response to plant density and nitrogen rate: II. Calcium, magnesium and micronutrients. Agron J., 105:1645-1657.

Codex (1995). General Standard for Contaminants and Toxins in Food and Feed, Codex Stan 193.

Divito G.A., Sain Rozas H.R., Echeverría H.E., Studdert G.A., and Wyngaard N. (2011). Long term nitrogen fertilization: soil property changes in an Argentinean Pampas soil under no-tillage. Soil Tillage Res 114:117-126.

Doorenbos, J. and Kassam A. H. (1979). Yield response to water. FAO Irrigation and Drainage Paper No. 33. Rome, FAO.

Estefan, G., Sommer, R. and Ryan, J. (2013). "Methods of soil, plant and water analysis: A manual for the West Asia and North Africa regions". International Center for Agricultural Research in the Dry Areas (ICARDA), 3 Ed.

Ezzat A. E. S., El-Awady A. A. and Ahmed H. M. I. (2011). Improving nitrogen utilization efficiency by Potato (*Solanum tuberosum* L.) B. Effect of irrigation intervals, nitrogen rates and veterra hydrogel on growth, yield, quality, nutrient uptake and storability. Nature and Science, 9(7): 34-42.

Fageria V.D. (2001). Nutrient interactions in crop plants. J Plant Nutr 24:1269-1290.

Faostat. (2013). Food and Agricultural Organization of the United Nations. – http://faostat.fao.org [last accessed 23.08.2016].

Feil, B., Moser, S.B., Jampatong, S., and Stamp, P. (2005). Mineral composition of the grains of tropical maize varieties as affected by preanthesis drought and rate of nitrogen fertilization. Crop Sci 45:516-523.

Janmohammadi, M., Pornour, N., Javanmard, A., and Sabaghnia, N. (2016). Effects of bio-organic, conventional and nanofertilizers on growth, yield and quality of potato in cold steppe. Bot. Lith., 22(2): 133–144.

Jolly, Y. N., Islam, A. and Akbar, S. (2013). Transfer of metals from soil to vegetables and possible health risk assessment. Springer Plus 2: 385

Khoshgoftarmanesh, A.H., Schulin, R., Chaney, R.L., and Daneshbakhsh, B. (2010). Micronutrient-efficient genotypes for crop yield and nutritional quality in sustainable agriculture-a review. Agron Sustain Dev 30:83–107.

Kloke, A., Sauerbeck, D. C. and Vetter, H. (1984). The contamination of plants and soils with heavy-metals and the transport of metals in terrestrial food chains. in: Nriagu, J. O. (ed), Changing metal cycles and human health. Dahlem Konferenzen, Berlin. p.113-141.

Lokeshappa, B., Shivpuri, K., Tripathi, V.and Dikshit, A.K. (2012). Assessment of Toxic Metals in Agricultural Produce. Food and Public Health, 2(1): 24-29.

Ma, B-L. and Zheng, Z. (2018) Nutrient uptake of iron, zinc, magnesium, and copper in transgenic maize (*Zea mays*) as affected by rotation systems and N application rates. Nutr Cycl Agroecosyst, 112:27-43.

Mirecki, N., Agič, R., Šunić, L., Milenković, L., and Ilić, Z. S. (2015). Transfer factor as indicator of heavy metals content in plants. Fresenius Environmental Bulletin 24: 4212-4219.

Olowoyo, J.O., van Heerden, E., Fischer, J.L. and Baker, C. (2010). Trace metals in soil and leaves of *Jacaranda mimosifolia* in Tshwane area, South Africa. Atmospheric Environment 44: 1826-1830.

Pobereżny J., Wszelaczyńska, E., Wichrowska, D., and Jaskulski, D., (2015). Content of nitrates in potato tubers depending on the organic matter, soil fertilizer, cultivation simplifications applied and storage. Chilean Journal of Agricultural Research, 75(1): 42-49.

Rangnekar, S. S., Sahu, S. K., Pandit, G. G., and Gaikwad, V. B. (2013a). Study of uptake of Pb and Cd by three nutritionally important Indian vegetables grown in artificially contaminated soils of Mumbai, India. International Research Journal of Environmental Sciences 2: 1-5.

Rangnekar, S. S., Sahu, S. K., Pandit, G. G., and Gaikwad, V. B. (2013b). Accumulation and translocation of nickel and cobalt in nutritionally important Indian vegetables grown in artificially contaminated soil of Mumbai, India. Research Journal of Agricultural and Forest Sciences 1: 15-21.

Riedell, W.E. (2010). Mineral-nutrient synergism and dilution responses to nitrogen fertilizer in field-grown maize. J Plant Nutr Soil Sci 173:869-874.

Riedell, W.E., Pikul, J.L., Jaradat, A.A., and Schumacher, T.E. (2009). Crop rotation and nitrogen effects on soil fertility, maize mineral nutrition, yield, and seed composition. Agron J 101:870-879.

Saif El-Deen, U. M., Gouda, A. E. A. I., and Badawy, A.S. (2015). Effect of foliar spray with some micronutrients and slow release nitrogen fertilizers rates on productivity and quality of sweet potato (*Ipomea batats* L.). J. Plant Production, Mansoura Univ., Vol. 6 (8): 1277 - 1291.

Sajjad, K., Farooq, R., Shahbaz, S., Khan, M.A., and Sadique, M. (2009). Health risk assessment of heavy metals for population via consumption of vegetables. World Applied Sciences Journal 6(12): 1602-1606.

SAS, (2002) The SAS System for Windows. Release 9. 0. SAS Inst. Inc., Cary, NC.

Smical, A.I., Hotea, V., Oros, V., Juhasz, J., and Pop, E. (2008). Studies on transfer and bioaccumulation of heavy metals from soil into lettuce. Environmental Engineering and Management Journal 7: 609-615.

تأثير نوعية السماد النيتروجيني ومعدلاته مع الحمية المائية على امتصاص العناصر الصغرى بواسطة البطاطس النامية على أرض رملية

محمد عدلي السيد سليمان
قسم الأراضي، كلية الزراعة ، جامعة دمياط ـ مصر

أقيمت تجربة حقلية على أرض رملية لتقييم عائد التفاعل ما بين مصادر الآزوت ومعدلاته مع حمية مياه الري على امتصاص العناصر الصغرى بواسطة محصول البطاطس. سمدت البطاطس بسمادي اليوريا وفوسفات الأمونيوم بمعدلات 150، 90 كجم للهكتار بالإضافة الى معاملة شاهد غير مسمدة. تم تقسيم معدلات الاضافة الى جرعتين متساويتين حيث أضيفت الأولى عند اليوم العشرين من الزراعة بينما أضيفت الجرعة الثانية بعد 25 يوم من الجرعة الأولى. رويت النباتات تحت ظروف حميتين مائيتين تمثلان 100% ، 75% من البخر-نتح لمحصول البطاطس. تأثر امتصاص كل من الحديد والمنجنيز والنحاس والزنك في معظم الأحيان بالحمية المائية. فيما عدا النحاس، تراكمت العناصر الأخرى بصورة معنوية أعلى تحت 60% بخر- نتح عنها في حالة 100% بخر- نتح. محتوى الحديد والمنجنيز في الدرنات كان أعلى في حالة اليوريا عنها مع فوسفات الأمونيوم المضافتين بمعدل 150 كجم للهكتار مقارنة مع معدل 90 كجم للهكتار. قيم النحاس في الدرنات لم تتأثر معنويا بكل من الحمية المائية أو المعدل الآزوتي بينما تفوقت تلك القيم في حالة اليوريا عنها في حالة فوسفات الأمونيوم. من ناحية أخرى، تراكم الزنك معنويا بصورة أكبر في حالة التسميد بفوسفات الأمونيوم المضافة بمعدل 90 كجم للهكتار تحت حمية مائية 60% بخر- نتح مقارنة مع المعاملات الأخرى. انتقال الحديد من التربة الى الدرنات بدى قليل جدا. انتقال المنجنيز الى الدرنات كان متوسطا. النحاس انتقل الى الدرنات بقيمة متوسطة الى عالية متأثرا بعوامل الدراسة. بدى أن درنات البطاطس مراكمات للزنك حيث ان معامل الانتقال كان عاليا وقريبا من الواحد الصحيح. ظهر أن التسميد بفوسفات الأمونيوم شجع انتقال الزنك مقارنة مع اليوريا. كما زاد معامل الانتقال مع معدل 90 كجم للهكتار مقارنة مع المعدل 150 كجم للهكتار. لم تكن هناك فروق معنوية فيما بين الحميات المائية تحت الدراسة.