Interaction Effect between the Applied Phosphorus and Selenium with Time on Their Availability in Three Different Soil Types.

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Abstract

A laboratory experiment was conducted to evaluate the interaction effect of phosphorus and selenium application rates on their availability in three different soil types with time. The soil samples were collected from the surface layers "0-30 cm" of three different sites. Four levels from Se were used as followed 0.0 – 0.5 - 1.0 and 2.0 mg Se kg $^{-1}$ soil as sodium selenate while P was used as mono super phosphate at rates of 0.0 – 3.225 – 6.45 and 12.9 mg P kg^{-1} soil and they were incubated with soil for one month. Results revealed a positive and significant correlation between Se and P application rates as well as time of incubation on soil available Se; where soil available Se content was increased with increasing the application rate of Se especially when P was also added at high rates as time of incubation was passed. The highest soil available Se values were obtained when Se and P were added at rates of 2 and 12.9 mg kg^{-1} soil, respectively especially in the case of soil 3 (clayey soil). Results also showed that soil available phosphorus was positively but not significant affected with increasing the application level of both Se and P, but it was negatively affected as the time of incubation was increased.

Key words: selenium, phosphorus, soil types, incubation.

Introduction

The element selenium (Se) was discovered by Swedish chemists J. J. Berzelius and J. G. Graham in 1817, who named it after the Greek moon goddess *Selene*. Although Se is not classified as an essential micronutrient for higher plants; selenium (Se) is considered as an essential micronutrient for humans and animals, but it is deficient in at least a billion people worldwide. Its deficiency in food can cause cancer, cardiovascular and other diseases in humans and animals, so it is used as a nutritional additive for livestock and poultry **(Birringer et al., 2002).**

Besides native substrate, amount of rainfall plays an important role in determining selenium content in soil. In regions with less than 500 mm of rain, the soil formed from rocks with a high Se content contains potentially toxic Se concentrations. The same kind of soil formed in humid regions typically contains high amounts of Se, but it is bound to iron in a poorly soluble complex. When the substrate is low in selenium, the soil forming on it will have a low Se concentration regardless of climate **(Fleming, 1980).**

Whereas some soils of the world are seleniferous, most are considered deficient. Soil is the major source of Se supply to humans and animals through food chains. The flux of Se from soil to humans is, to a large extent, determined by the content and availability of Se in the soils **(Hartikainen, 2005).** However, selenium reactivity, distribution and bioavailability depend not only on its total content in soil but also on its chemical forms and some soil factors such as soil reaction, soil salinity, calcium carbonate content, cation exchange capacity, organic matter content, aeration, contents of clay, the identity and concentration of competing ions, redox potential, content of sesquioxides and microbiological activity **(Kabata-Pendias, 2001).**

Selenium behavior in soils has received much attention in recent years. Selenium exists in the soil environment in four oxidation states: selenide, elemental selenium, selenite and selenate. Selenate is the predominant form of selenium in calcareous soils and under alkaline conditions but selenite is the predominant form in acidic soils **(Kabata-Pendias and Mukherjee, 2007)**.

Because selenium can be in several interactions in the environment, its sorption behavior differs among soils, where the soil management or production systems are different **(Lopes et al., 2017).**

Vouri et al., (1989) noted that, 7 days after adding 5 mg Se kg^{-1} soil as selenate, as much as 25% of the selenate was sorbed and that the amount was positively correlated with sulfuric acid-extractable phosphorus. **Neal and Sposito (1989),** however, did not find positive selenate adsorption onto four soils from the San Joaquin Valley, California.

Guo et al., (2000) found that transformation of Se was less affected by soil water content at ≥21.5%, but was distinctively faster under anaerobic conditions where O_2 was displaced with N_2 gas. They also reported that during the incubation period of 49 to 52 d, between 27.9 and 74.9% of the total selenium, initially present as selenate, was reduced to elemental or organic Se species.

El-Ghanam, (2004) found that soil available Se was significantly increased as the levels of selenium and phosphorus increased; the highest increase in soil available Se was occurred during the first period of incubation (15 days) where it amounted 35.3 and 130.8 %, as compared with P_0 and Se_0 treatments, respectively. Also, the soil available P was markedly increased with increasing the application rates of P and Se, but it decreased as the incubation period increased**.**

Most studies such as **Nakamaru et al., (2006)** and **Nakamaru and Sekine (2008)** showed that Se becomes more plant available following phosphate addition, i.e. Se sorption decreases as phosphate increases.

El-Ramady et al., (2014) showed that sandy soils have lower Se contents compared to organic and calcareous soils.

Li et al., (2016) showed that the change of soil available Se in all tested soils divided into two phases: rapid decrease at the initial time (42 days) and slow decline thereafter. The second order equation could describe the decrease processes of available Se in tested soils during the entire incubation time ($R2 > 0.99$), while parabolic diffusion equation had less goodness of fit. These results indicated that Se aging was controlled not only by diffusion process but also by other processes such as nucleation/precipitation, adsorption/ desorption with soil component, occlusion by organic matter and reduction reaction. Soil available Se fractions tended to transform to more stable fractions during aging.

Materials and Methods

A laboratory experiment was conducted to evaluate the interaction effect of phosphorus and selenium application rates on Se availability in three different soil types with time**.** The soil samples were collected from the surface layers "0-30 cm" of three different sites i.e. soil (1) was presented from El-Areesh Agricultural Research Station, North Sainai governorate, Egypt, soil (2) was collected from El-Nobarya Agricultural Research Station, Al-Behaira governorate, Egypt and soil (3) was presented from Bahteem Agricultural Research Station, El-Qalubia governorate, Egypt. Soil samples were air dried at room temperature and grounded to pass through a 2mm sieve. Four levels from Se were added as followed 0.0 – 0.5 - 1.0 and 2.0 mg Se kg $^{-1}$ soil as sodium selenate while P was used as mono super phosphate at rates of 0.0 – 3.225 – 6.45 and 12.9 mg P kg^{-1} soil which equivalent 0.0 – 119 – 238 and 476 kg fertilizer ha^{-1}. Plastic cubs were filled with the sieved soils at a rate of 300 g from soil (1) and 200 g from both of soils (2) and (3). Super phosphate was added and mixed with soil in each cub then selenium solution was added at a rate of 80% from field capacity of each soil type. The experiment was conducted for one month, through this period soils were kept moisted to 80% of the field capacity by adding the distilled water. Each treatment was represented by five replicates which were arranged in a completely randomized design (CRD); one of them was taken after one day, three days, one week, two weeks and the last one was taken after one month from the beginning of the experiment.

Table 1. Characteristics of the soils used in the study.

Soil (1)										
Sand	Silt	Clay	Texture class	pH (1:2.5)	EC (1:5) dS m^{-1}			Organic matter	CaCO$_3$	
	%							g kg^{-1}		
94.6	4.1	1.3	Sandy	7.65	0.17			5.2	16.1	
Soluble ions (mmole L^{-1}) and SAR									Available elements (mg kg^{-1})	
Ca^{++}	Mg^{++}	K^+	Na^+	HCO_3^-	CO_3^{--}	Cl^-	SO_4^{--}	SAR	P	Se
0.42	0.23	0.12	0.82	0.10	Nil	0.67	0.82	1.44	6.47	0.038
Soil (2)										
Sand	Silt	Clay	Texture class	pH (1:2.5)	EC (1:5) dS m^{-1}			Organic matter	CaCO$_3$	
	%							g kg^{-1}		
62.7	24.3	13.0	Sandy clay loam	8.47	1.07			7.1	257.0	
Soluble ions (mmole L^{-1}) and SAR									Available elements (mg kg^{-1})	
Ca^{++}	Mg^{++}	K^+	Na^+	HCO_3^-	CO_3^{--}	Cl^-	SO_4^{--}	SAR	P	Se
3.32	2.36	1.42	3.22	0.20	Nil	7.84	2.28	1.91	5.66	0.064
Soil (3)										
Sand	Silt	Clay	Texture class	pH (1:2.5)	EC (1:5) dS m^{-1}			Organic matter	CaCO$_3$	
	%							g kg^{-1}		
7.3	20.2	72.5	Clay	7.55	0.23			18.4	26.4	
Soluble ions (mmole L^{-1}) and SAR									Available elements (mg kg^{-1})	
Ca^{++}	Mg^{++}	K^+	Na^+	HCO_3^-	CO_3^{--}	Cl^-	SO_4^{--}	SAR	P	Se
0.58	0.32	0.36	0.65	0.10	Nil	1.21	0.60	1.56	15.73	0.068

The soils chemical analyses were performed according with the methodology by **Sadzawka et al., (2004).** Briefly, soil pH was assayed by potentiometer in a 1:2.5 (w/v) soil/distilled water suspension. Electrical conductivity EC (dSm^{-1} at 25 C) was determined in 1:5 (soil/water) extract, using EC meter, as described by **Jackson, (1973).** Organic matter was determined by wet digestion with a modified **Walkley and Black** method. Soluble ions and calcium carbonate content were determined as described by **Page et al., (1982)**. Available phosphorus was extracted by the Olsen bicarbonate method and analyzed colorimetrically using ascorbic acid according to **Murphy and Riley, (1962)** as modified by **John, (1970).** Available selenium was extracted using ammonium bicarbonate - DTPA solution as described by **Soltanpour and Workman, (1980)** and measured by Atomic Absorption Spectrophotometry – Hydride Generation coupled (AAS-HG) according to **Kumpulainen et al., (1983).**

Results and Discussion

Soil available selenium.

Data presented in table 2 revealed that there were no significant differences between treatments in available Se values, where the available Se was increased with increasing Se application rates especially when Se was added at a rate of 2 mg kg^{-1} soil, but this increasing was not significant. These results were in accordance with those of **El-Ghanam, (2004)** who reported that soil available Se was six fold increased at 10 mg Se kg^{-1} soil compared with 0 level, then increased to thirteen fold as Se level was increased to 40 mg Se kg^{-1} soil.

Table 2. AB-DTPA extractable Se (mg kg^{-1}) as affected by selenium and phosphorus application rates as well as incubation periods.

Phosphorus rates (mg kg^{-1})	Selenium rates (mg kg^{-1})	Soil (1) sandy					
		Time					
		T1	T 2	T 3	T 4	T 5	Mean
P 1 (0.00)	Se 1 (0.0)	0.038	0.034	0.036	0.040	0.038	0.037
	Se 2 (0.5)	0.062	0.066	0.070	0.072	0.076	0.069
	Se 3 (1.0)	0.094	0.104	0.108	0.110	0.114	0.106
	Se 4 (2.0)	0.126	0.130	0.138	0.134	0.138	0.133
Mean		0.080	0.084	0.088	0.089	0.092	
Grand mean of phosphorus rates		0.087					
P 2 (3.225)	Se 1 (0.0)	0.052	0.052	0.054	0.056	0.062	0.055
	Se 2 (0.5)	0.086	0.090	0.092	0.088	0.092	0.090
	Se 3 (1.0)	0.122	0.125	0.126	0.130	0.138	0.128
	Se 4 (2.0)	0.168	0.170	0.174	0.182	0.184	0.176
Mean		0.107	0.109	0.112	0.114	0.119	
Grand mean of phosphorus rates		0.112					
P3 (6.45)	Se 1 (0.0)	0.066	0.068	0.072	0.072	0.074	0.070
	Se 2 (0.5)	0.088	0.094	0.096	0.096	0.097	0.094
	Se 3 (1.0)	0.156	0.162	0.171	0.174	0.176	0.168
	Se 4 (2.0)	0.174	0.174	0.178	0.182	0.184	0.178
Mean		0.121	0.124	0.129	0.131	0.133	
Grand mean of phosphorus rates		0.128					
P 4 (12.9)	Se 1 (0.0)	0.072	0.075	0.080	0.082	0.086	0.079
	Se 2 (0.5)	0.094	0.096	0.102	0.105	0.109	0.101
	Se 3 (1.0)	0.172	0.178	0.180	0.184	0.190	0.181
	Se 4 (2.0)	0.196	0.198	0.194	0.196	0.201	0.197
Mean		0.134	0.137	0.139	0.142	0.147	
Grand mean of phosphorus rates		0.140					
Grand mean of selenium rates		Se 1	Se 2	Se 3		Se 4	
		0.043	0.089	0.139		0.190	
Selenium rates (mg kg^{-1})		T1	T 2	T 3	T 4	T 5	
Se 1 (0.0)		0.041	0.043	0.044	0.045	0.042	
Se 2 (0.5)		0.088	0.092	0.090	0.086	0.092	
Se 3 (1.0)		0.136	0.140	0.141	0.137	0.142	
Se 4 (2.0)		0.190	0.192	0.182	0.192	0.195	
Grand mean of time		0.113	0.116	0.114	0.115	0.118	
LSD at 5%							
Selenium rates (Se)				0.0004			
Phosphorus rates (P)				0.0004			
Interaction (Se x P)				0.0007			
Time (T)				0.0004			
Interaction (Se x T)				0.0008			
Interaction (P x T)				0.0008			
Interaction (Se x P x T)				0.0016			

T1 = one day T2 = three days T3 = one week T4 = two weeks T5 = one month

Table 2. cont.

Phosphorus rates (mg kg^{-1})	Selenium rates (mg kg^{-1})	Soil (2) sandy clay loam					
		Time					
		T1	T 2	T 3	T 4	T 5	Mean
P 1 (0.00)	Se 1 (0.0)	0.043	0.044	0.046	0.044	0.046	0.045
	Se 2 (0.5)	0.074	0.074	0.078	0.080	0.084	0.078
	Se 3 (1.0)	0.132	0.134	0.134	0.138	0.140	0.136
	Se 4 (2.0)	0.146	0.147	0.151	0.154	0.157	0.151
Mean		0.099	0.100	0.102	0.104	0.107	
Grand mean of phosphorus rates		0.102					
P 2 (3.225)	Se 1 (0.0)	0.064	0.066	0.070	0.076	0.082	0.072
	Se 2 (0.5)	0.090	0.094	0.096	0.098	0.104	0.096
	Se 3 (1.0)	0.150	0.154	0.152	0.156	0.160	0.154
	Se 4 (2.0)	0.188	0.192	0.196	0.204	0.211	0.198
Mean		0.123	0.127	0.129	0.134	0.139	
Grand mean of phosphorus rates		0.130					
P3 (6.45)	Se 1 (0.0)	0.080	0.084	0.082	0.086	0.094	0.085
	Se 2 (0.5)	0.094	0.098	0.104	0.107	0.110	0.103
	Se 3 (1.0)	0.164	0.166	0.172	0.182	0.186	0.174
	Se 4 (2.0)	0.220	0.226	0.228	0.234	0.236	0.229
Mean		0.139	0.144	0.147	0.152	0.156	
Grand mean of phosphorus rates		0.148					
P 4 (12.9)	Se 1 (0.0)	0.084	0.085	0.088	0.092	0.096	0.089
	Se 2 (0.5)	0.106	0.111	0.116	0.122	0.124	0.116
	Se 3 (1.0)	0.182	0.184	0.188	0.190	0.196	0.188
	Se 4 (2.0)	0.242	0.246	0.254	0.266	0.274	0.256
Mean		0.154	0.157	0.162	0.168	0.173	
Grand mean of phosphorus rates		0.163					
Grand mean of selenium rates		Se 1	Se 2	Se 3		Se 4	
		0.052	0.106	0.152		0.232	
Selenium rates (mg kg^{-1})		T1	T 2	T 3	T 4	T 5	
Se 1 (0.0)		0.048	0.051	0.052	0.054	0.056	
Se 2 (0.5)		0.161	0.095	0.091	0.092	0.094	
Se 3 (1.0)		0.153	0.155	0.143	0.153	0.155	
Se 4 (2.0)		0.223	0.230	0.237	0.244	0.251	
Grand mean of time		0.146	0.132	0.130	0.135	0.139	
LSD at 5%							
Selenium rates (Se)				0.0004			
Phosphorus rates (P)				0.0004			
Interaction (Se x P)				0.0007			
Time (T)				0.0004			
Interaction (Se x T)				0.0008			
Interaction (P x T)				0.0008			
Interaction (Se x P x T)				0.0016			

T1 = one day T2 = three days T3 = one week T4 = two weeks T5 = one month

High significant differences in available Se were observed in the case of soil3 (clay) when it was compared with the two other used soils. This may be due to its highly content of clay and consequently its high cation exchange capacity. These findings were in agreement with the results obtained by **El-Ramady et al., (2014)** who mentioned that sandy soils have lower Se contents compared with organic and calcareous soils; and **Lessa, et al., (2016)** who found that the Se adsorption was greater in the clayey soils compared with sandy ones due to its high content of clay and consequently high cation exchange capacity.

With respect to phosphorus application rates, results also revealed that there were no significant differences between treatments in available Se values where the available Se was increased with increasing the application rate of P, especially when P was added at a rate of 12.9 mg kg^{-1} soil however this increasing was not significant. These results were in agreement to some extent with those of **El-Ghanam (2004)** who showed that AB-DTPA extractable Se increased significantly with increasing P application rate. Also, the increase in available Se may be ascribed to that certain anions such as phosphate, silicate, citrate, molybdate, carbonate, fluoride and sulfate which are compete with selenate for adsorption sites and reduce its fixation in soils. **Masanza et al. (2016)** also reported that phosphorus ions in the soil solution are readily adsorb on the sorptive surface of soil colloidal particles thus decreasing the sorption of Se on the soil surface and increasing the bioavailability of Se.

Regarding to the interaction between Se and P, the obtained results showed that there were a positive and significant correlation between Se and P application rates on available Se, where its available content was increased with increasing the application rate of Se especially when P was also added at high rates. The highest soil available Se value was obtained when Se and P were added at rates of 2 and 12.9 mg kg^{-1} soil, respectively. The highly available Se value was obtained with soil 3, this may as previously mentioned be resulted from its highly clay content and high CEC of it compared with the two other used soils as mentioned previously by **(El-Ramady et al., 2014).**

Table 2: con.

Phosphorus rates (mg kg^{-1} soil)	Selenium rates (mg kg^{-1} soil)	**Soil (3) clay** Time					
		T1	T 2	T 3	T 4	T 5	Mean
P 1 (0.00)	Se 1 (0.0)	0.068	0.074	0.070	0.074	0.074	0.072
	Se 2 (0.5)	0.124	0.130	0.132	0.136	0.134	0.131
	Se 3 (1.0)	0.178	0.186	0.190	0.186	0.190	0.186
	Se 4 (2.0)	0.242	0.250	0.254	0.262	0.266	0.255
Mean		0.153	0.160	0.162	0.165	0.166	
Grand mean of phosphorus rates		0.161					
P 2 (3.225)	Se 1 (0.0)	0.080	0.084	0.084	0.090	0.096	0.087
	Se 2 (0.5)	0.136	0.136	0.142	0.146	0.150	0.142
	Se 3 (1.0)	0.182	0.186	0.190	0.194	0.190	0.188
	Se 4 (2.0)	0.250	0.260	0.266	0.274	0.270	0.264
Mean		0.162	0.166	0.170	0.176	0.177	
Grand mean of phosphorus rates		0.170					
P3 (6.45)	Se 1 (0.0)	0.094	0.098	0.104	0.106	0.112	0.103
	Se 2 (0.5)	0.130	0.134	0.132	0.136	0.144	0.135
	Se 3 (1.0)	0.186	0.190	0.194	0.198	0.194	0.192
	Se 4 (2.0)	0.256	0.270	0.274	0.274	0.286	0.272
Mean		0.166	0.173	0.176	0.179	0.184	
Grand mean of phosphorus rates		0.176					
P 4 (12.9)	Se 1 (0.0)	0.104	0.112	0.114	0.118	0.118	0.113
	Se 2 (0.5)	0.138	0.142	0.146	0.150	0.154	0.146
	Se 3 (1.0)	0.190	0.194	0.201	0.204	0.208	0.199
	Se 4 (2.0)	0.269	0.276	0.290	0.290	0.304	0.286
Mean		0.175	0.181	0.188	0.191	0.196	
Grand mean of phosphorus rates		0.186					
Grand mean of selenium rates		Se 1	Se 2	Se 3		Se 4	
		0.074	0.130	0.190		0.269	
Selenium rates (mg kg^{-1})		T1	T 2	T 3	T 4	T 5	
Se 1 (0.0)		0.072	0.077	0.072	0.072 q	0.076	
Se 2 (0.5)		0.127	0.131	0.128	0.130 l	0.133	
Se 3 (1.0)		0.184	0.189	0.191	0.193 f	0.193	
Se 4 (2.0)		0.252	0.264	0.271	0.275 b	0.282	
Grand mean of time		0.159	0.165	0.166	0.167 b	0.171	
LSD at 5%							
Selenium rates (Se)				0.0004			
Phosphorus rates (P)				0.0004			
Interaction (Se x P)				0.0007			
Time (T)				0.0004			
Interaction (Se x T)				0.0008			
Interaction (P x T)				0.0008			
Interaction (Se x P x T)				0.0016			

T1 = one day   T2 = three days   T3 = one week   T4 = two weeks   T5 = one month

For time, our results showed that available Se was increased with time passed this may be due to replacement of Se with P on the exchangeable sites of all the three soils used in the study. This process may be made Se more labile and consequently more available in soil solution. This is in accordance with results of **El-Ghanam, (2004)** who mentioned that the available Se was significantly increased prolonging the incubation periods 15 to 30, 30 to 45 and 45 to 60 days by 28.6, 47.1 and 74.2%, respectively.

With respect to the interaction between time and Se application rate the obtained results revealed that available Se was increased with increasing Se application rates and time; where available Se was increased in the end of the experiment, i.e. after one month according to **(Masanza et al., 2016).**

Regarding to the interaction effect of phosphorus application rates and time on the availability of selenium, the obtained data showed that the available Se was increased with increasing P application rate and also with time passed. This may be as previously mentioned due to replacement process between P and Se on the exchangeable sites especially in the case of the second soil (sandy clay loam) due to its high content from calcium carbonate and consequently high CEC when compared as previously mentioned with the two other soils used in the study.

Finally, regarding to the interaction effect between phosphorus and selenium application rates and time, the obtained results showed that the availability of Se was increased with increasing P and Se application rates as well as with time passed due, as previously mentioned, to replacement of Se with P on the soil adsorption sites especially in the case of the second soil. These findings were in agreement with results of **Eich-Greatorex et al., (2010)** who reported that available Se was increased with increasing the application rates of both Se and P prolonging the period of incubation especially in silty clay loam soil due to adsorption of P immediately on the surface of colloidal particles of soil thus render Se more free in soil solution. They also mentioned that after 60 days of incubation approximately 95% of the applied P was adsorbed on soil surface and gradually rendered the free Se available in soil solution.

Soil available phosphorus.

Results presented in table 3 revealed that there was significant effect of P application rate on the available phosphorus. This finding was in accordance with the results of **El-Ghanam**, **(2004)** who mentioned that available P was increased with increasing P application level compared with control treatment.

The obtained results also showed that available phosphorus was increased with increasing selenium application level especially when Se was added at a rate of 2 mg kg^{-1} but generally this increasing was not significant. These results were in accordance with those of **Eich-Greatorex et al., (2010)** who reported that Se addition, especially in form of selenate resulted in a higher release of phosphate from soils with high P saturation values compared to low levels.

With regard to the interaction effect between Se and P application rates on available phosphorus, results showed that available P was positively but not significant affected with increasing the application level of both Se and P. These results agree well with those obtained by **El-Ghanam**, **(2004)**.

Regarding to time, the obtained results revealed that available P was decreased with time pass, this may be as expected due to fixation and precipitation processes which converted the available P to unavailable form with time; this was more clearly in the case of soil 2 where its content of calcium carbonate was high compared with the two other used soils. These are similar to those of **El-Gala et al., (1998)** who found that soil available P was decreased with increasing incubation time in calcareous soil.

The interaction effect between P application level and time reflected the decreasing in available P values with time even though when P was added at high rate i.e. 12.9 mg kg^{-1} soil. This may be confirm the fact that phosphorus converted to unavailable form with time pass as a result to fixation and precipitation processes as previously mentioned according to **Eich-Greatorex et al., (2010).**

Concerning the interaction effect between Se and time on available P, results showed that available P was increased with increasing selenium application rate but it decreased with increasing the period of incubation, but it was increased again genteelly in the end of experiment i.e. after one month from the beginning of the incubation trial. These results were in accordance with these obtained by **El-Ghanam**, **(2004)** who reported that soil available P was markedly increased with increasing Se application level, but this increase was decreased with prolonging the incubation periods from 15 to 30 days, while it was almost resembling at periods of 45 to 60 days.

Finally, with concern to the interaction between all of Se, P and time, results revealed that available P was positively correlated with both Se and P but negatively affected as the time of incubation was increased. These are similar to those of **El-Ghanam**, **(2004)** who reported that soil available P was markedly increased with increasing Se and P application levels, but this increase was decreased with time prolonging the incubation periods from 15 to 30 days; where the reduction percentage caused by prolonging time from 15 to 30, 30 to 45 and 45 to 60 days were 6.43, 12.06 and 10.46%, respectively.

Table (3). Soil available P (mg kg^{-1}) as affected by selenium and phosphorus application rates as well as incubation periods.

Phosphorus rates (mg kg^{-1})	Selenium rates (mg kg^{-1})	Soil (1) Sandy Time					
		T1	T 2	T 3	T 4	T 5	Mean
P 1 (0.00)	Se 1 (0.0)	6.80	6.40	6.00	6.40	6.40	6.40
	Se 2 (0.5)	6.80	6.40	6.00	6.00	6.40	6.32
	Se 3 (1.0)	7.20	6.40	6.00	6.40	6.00	6.40
	Se 4 (2.0)	7.60	6.40	6.00	6.40	6.20	6.44
Mean		7.10	6.40	6.00	6.30	6.20	
Grand mean of phosphorus rates		6.50					
P 2 (3.225)	Se 1 (0.0)	7.60	6.80	6.40	6.00	6.40	6.64
	Se 2 (0.5)	7.60	6.80	6.00	6.40	6.80	6.72
	Se 3 (1.0)	8.80	7.60	6.80	6.40	6.80	7.28
	Se 4 (2.0)	9.20	8.00	7.20	6.40	7.60	7.68
Mean		8.30	7.30	6.60	6.30	6.90	
Grand mean of phosphorus rates		7.08					
P 3 (6.45)	Se 1 (0.0)	8.00	7.20	6.80	6.40	6.80	7.04
	Se 2 (0.5)	9.20	8.40	7.60	6.80	7.20	7.84
	Se 3 (1.0)	11.2	10.0	9.20	8.40	9.20	9.60
	Se 4 (2.0)	11.6	10.4	9.30	8.40	8.80	9.71
Mean		10.0	9.00	8.23	7.50	8.00	
Grand mean of phosphorus rates		8.55					
P 4 (12.9)	Se 1 (0.0)	8.80	8.00	7.60	7.20	6.80	7.68
	Se 2 (0.5)	10.0	9.20	8.40	7.60	7.60	8.56
	Se 3 (1.0)	12.4	11.2	9.20	8.70	9.60	10.2
	Se 4 (2.0)	13.2	11.2	9.60	8.80	9.20	9.80
Mean		11.1	9.90	8.70	7.30	8.30	
Grand mean of phosphorus rates		9.07					
Grand mean of selenium rates		Se 1	Se 2	Se 3		Se 4	
		6.94	7.36	8.42		8.45	
Selenium rates (mg kg^{-1})		T1	T 2	T 3	T 4	T 5	
Se 1 (0.0)		7.80	7.10	6.72	6.50	6.60	
Se 2 (0.5)		8.40	7.70	7.00	6.70	7.00	
Se 3 (1.0)		9.90	8.80	7.80	7.48	8.10	
Se 4 (2.0)		10.4	9.00	8.03	6.75	8.20	
Grand mean of time		9.13	8.15	7.39	6.86	7.48	
LSD at 5%							
Selenium rates (Se)				0.2093			
Phosphorus rates (P)				0.2093			
Interaction (Se x P)				0.4186			
Time (T)				0.2340			
Interaction (Se x T)				0.4680			
Interaction (P x T)				0.4680			
Interaction (Se x P x T)				0.9361			

See footnotes of table (2)

Table 3: con.

Phosphorus rates (mg kg^{-1})	Selenium rates (mg kg^{-1})	Soil (2) sandy clay loam					
		Time					
		T1	T 2	T 3	T 4	T 5	Mean
P 1(0.0)	Se 1 (0.0)	6.00	5.60	5.20	5.60	6.40	5.76
	Se 2 (0.5)	6.40	5.60	5.20	6.00	6.40	5.92
	Se 3 (1.0)	6.80	6.00	6.00	6.40	6.40	6.32
	Se 4 (2.0)	7.20	6.40	6.40	6.00	6.40	6.48
Mean		6.60	5.90	5.70	6.00	6.40	
Grand mean of phosphorus rates		6.12					
P 2 (3.225)	Se 1 (0.0)	7.20	6.40	6.00	6.00	6.80	6.48
	Se 2 (0.5)	7.60	6.80	6.00	6.40	6.80	6.72
	Se 3 (1.0)	8.40	7.20	6.40	6.80	7.20	7.20
	Se 4 (2.0)	9.20	8.00	6.80	6.00	6.80	7.36
Mean		8.10	7.10	6.30	6.30	6.90	
Grand mean of phosphorus rates		6.94					
P3 (6.45)	Se 1 (0.0)	7.60	6.80	6.40	6.00	6.80	6.72
	Se 2 (0.5)	8.80	7.60	6.80	6.40	7.20	7.36
	Se 3 (1.0)	10.0	8.40	7.20	6.40	7.60	7.92
	Se 4 (2.0)	12.4	11.2	9.20	8.00	8.40	9.84
Mean		9.70	8.50	7.40	6.70	7.50	
Grand mean of phosphorus rates		7.96					
P 4 (12.9)	Se 1 (0.0)	8.40	7.20	6.40	6.80	7.20	7.20
	Se 2 (0.5)	9.60	8.40	7.20	7.60	8.00	8.16
	Se 3 (1.0)	11.6	9.20	8.00	7.20	7.60	8.72
	Se 4 (2.0)	13.6	12.4	11.2	10.0	10.4	11.5
Mean		10.8	9.30	8.20	7.90	8.30	
Grand mean of phosphorus rates		8.90					
Grand mean of selenium rates		Se 1	Se 2	Se 3		Se 4	
		6.54	7.04	7.54		8.80	
Selenium rates (mg kg^{-1})		T1	T 2	T 3	T 4	T 5	
Se 1 (0.0)		7.30	6.50	6.00	6.10	6.80	
Se 2 (0.5)		8.10	7.10	6.30	6.60	7.10	
Se 3 (1.0)		9.20	7.70	6.90	6.70	7.20	
Se 4 (2.0)		10.60	9.50	8.40	7.50	8.00	
Grand mean of time		8.80	7.70	6.90	6.73	7.28	
		LSD at 5%					
Selenium rates (Se)				0.0456			
Phosphorus rates (P)				0.0456			
Interaction (Se x P)				0.0912			
Time (T)				0.0509			
Interaction (Se x T)				0.1020			
Interaction (P x T)				0.1020			
Interaction (Se x P x T)				0.2040			

See footnotes of table (2)

Table 3: con.

Phosphorus rates (mg kg^{-1})	Selenium rates (mg kg^{-1})	**Soil (3) clay** Time T1	T 2	T 3	T 4	T 5	Mean
P 1 (0.00)	Se 1 (0.0)	15.60	15.20	16.00	15.20	15.60	15.52
	Se 2 (0.5)	15.20	14.40	14.00	15.80	15.20	14.92
	Se 3 (1.0)	15.20	14.40	14.00	14.80	15.20	14.72
	Se 4 (2.0)	14.40	14.00	13.60	14.40	15.20	14.32
Mean		15.10	14.50	14.40	15.05	15.30 I	
Grand mean of phosphorus rates		14.87					
P 2 (3.225)	Se 1 (0.0)	18.80	17.20	18.00	18.40	18.40	18.16
	Se 2 (0.5)	18.00	16.80	17.60	18.00	18.40	17.76
	Se 3 (1.0)	17.20	16.40	16.80	17.20	17.60	17.04
	Se 4 (2.0)	16.40	15.60	16.40	16.80	17.20	16.48
Mean		17.60	16.50	17.20	17.60	17.90	
Grand mean of phosphorus rates		17.36					
P3 (6.45)	Se 1 (0.0)	19.60	18.80	18.40	18.80	18.80	18.88
	Se 2 (0.5)	19.20	18.00	18.00	18.40	18.40	18.40
	Se 3 (1.0)	18.00	17.20	16.80	17.60	18.00	17.52
	Se 4 (2.0)	17.20	16.40	16.80	17.20	17.60	17.04
Mean		18.50	17.60	17.50	18.00	18.20	
Grand mean of phosphorus rates		17.96					
P 4 (12.9)	Se 1 (0.0)	21.20	19.20	18.80	18.80	19.20	19.44
	Se 2 (0.5)	20.00	19.20	18.40	18.00	18.80	18.88
	Se 3 (1.0)	19.60	18.80	18.00	18.40	18.80	18.72
	Se 4 (2.0)	18.40	17.60	17.20	17.60	18.40	17.84
Mean		19.80	18.70	18.10	18.20	18.80	
Grand mean of phosphorus rates		18.72					
Grand mean of selenium rates		Se 1	Se 2	Se 3		Se 4	
		18.00	17.49	17.00		16.42	
Selenium rates (mg kg^{-1})		T1	T 2	T 3	T 4	T 5	
Se 1 (0.0)		18.80	17.60	17.80	17.80	18.00	
Se 2 (0.5)		18.10	17.10	17.00	17.55	17.70	
Se 3 (1.0)		17.50	16.70	16.40	17.00	17.40	
Se 4 (2.0)		16.60	15.90	16.00	16.50	17.10	
Grand mean of time		17.75	16.83	16.80 d	17.21	17.55	
			LSD at 5%				
Selenium rates (Se)				0.0905			
Phosphorus rates(P)				0.0905			
Interaction (Se x P)				0.1810			
Time (T)				0.1012			
Interaction (Se x T)				0.2024			
Interaction (P x T)				0.2024			
Interaction (Se x P x T)				0.4047			

See footnotes of table (2)

Conclusion

As a final massage, the further understanding of selenium behavior in soils to predict its availability for crops in different systems will be a significant approach in future studies to establish form and safe doses of Se to be added in fertilizers.

The obtained results support the idea that adding Se to the soil is a good strategy to increase Se levels in food crops (agronomic bio-fortification), especially when crops are grown in soils that have been cultivated over the time due to their low Se adsorption capacity.

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تأثير التداخل بين الفوسفور والسيلينيوم المضافين مع الوقت علي تيسرهم في ثلاث أنواع مختلفة من الأراضي.

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أقيمت تجربة معمليه لتقييم تأثير التداخل بين معدلات إضافة كلاً من الفوسفور والسيلينيوم علي حركيتهم وتيسرهم في ثلاث أنواع مختلفة من الأراضي مع مرور الوقت. حيث تم جمع عينات من الطبقة السطحيه من صفر – 30 سم من ثلاث مواقع مختلفه وتم استخدام السيلينيوم بأربع معدلات وهي صفر– 0.5 – 1.0 و 2.0 ملليجرام سيلينيوم /كجم تربه في صورة سيلينات الصوديوم. كما تم اضافة الفوسفور أيضا بأربع معدلات وهي صفر –3.225 – 6.45 و 12.9 ملليجرام فوسفور/كجم تربه في صورة سوبر فوسفات أحادي, وتم تحضينهم مع التربه لمدة شهر. فأوضحت النتائج وجود ارتباط إيجابي ومعنوي بين معدلات إضافة كلاً من الفوسفور والسيلينيوم علي محتوي السيلينيوم الميسر في التربه , حيث أن السيلينيوم الميسر ارتفع بزيادة معدلات إضافة السيلينيوم خاصة عند إضافة الفوسفور بمعدل مرتفع, حيث كان أعلي محتوي للسيلينيوم الميسر في التربه عندما أضيف كل من السيلينيوم والفوسفور بمعدلات 2.0 و 12.9 مجم / كجم تربة لكلاً من العنصرين علي التوالي, وخاصة في حالة التربة الثالثة, وكذلك ارتفع السيلينيوم الميسر في التربة بمرور وقت التحضين. كما أوضحت النتائج أن الفوسفور الميسر في التربه ارتفع أيضا بزيادة معدل إضافة العنصرين كما في حالة السيلينيوم ولكنه تأثر سلبيا بمرور الوقت.