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Effect of waterlogging and organic matter addition on water soluble Si, pH and Eh values

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Abstract: A pot experiment was conducted at the greenhouse at NRC, to study three soils namely, sandysoil from El-GabalEl-Asfar,clay loam from Sakhaand calcareous soil from El-Nobaria were used in this experiment. These samples were transplanted to 50 ml- plastic centrifuge, and flooded with 25 ml of distilled water, then incubated in the dark at 30±2 ^{o}C. Half of the samples of each soil type received 3% organic matter (starch). The replicated were taken after 0 (dry soil), 10, 20 and 30 days after flooding and centrifugated. Available Si in sandy soil and calcareous soils increased after 10 days from submergence as affected by waterlogging alone then decreased gradually with time under incubation at 30 ^{o}C and the available Si in clay loam soil increased from 0.0 times and decreased the maximum between 10 and 20 days from submergence date, then decreased after 30 days. Addition the organic matter increased the available Si in all the studied soils as compared with waterlogging treatment alone. The highest values of Si were obtained in sandy soil followed by clay loam and calcareous soil in decreased order.

pH values of the clay loam and calcareous soils decreased after 10 days from submergence and then increased gradually till 30 days after submergence. Values of pH the sandy soil increased gradually from 0 times to 30 days after submergence data. The combined effect of OM and waterlogging decreased pH values of the studied soils after 10 days from submergence and then they slightly increased till 30 days after submergence.

Values of Eh decreased in all studied soils and reached the minimum after 30 days from submergence date. After 10 days, the addition of the OM to the studied soils under submergence and incubation at 30^{o}C±, reduced Eh values faster and sharper as they compared with those under submergence treatments alone. Then, the values of Eh slightly increased with increasing submergence period till 30 days from submergence.

Keywords: Soils, incubated, flooding, organic matter, pH, Eh.

Introduction

Rice is the second cash crop in Egypt. More than million feddans are cultivated annually with rice. The production of rice consumes much more water than those other crops. Rice growing under different soil water level prevailing under rain-fed condition has largely been ignored[1].

It is the second most abundant element in the soil.Silicon (Si)exists mainly as monosilicilc acid (H_4 SiO_4) at concentrations ranging from 0.1 to 0.6 mM in the soil solution and the concentration of the soluble SiO_2 in the extracts always well flew solubility of amorphous silica[2], which is taken up by plants in this form[3]. After the uptake, Si accumulates in the epidermis of varioustissues, mainly as polymer of hydrated amorphous silica.

Flooding a soil sets in motion a series physical, chemical and biological processes of oxygen in the flooded soils are triggered by lack of oxygen in the flooded soils system, the soil gets reduced for which energy is provided by mineralization of organic carbon. The reduction process is regulated by the presence and availability of electron acceptors (mainly Fe^{+3} and $SiO_4^{=}$) and electron donors (OM) . soil reduction is accompanied by change in the pH, Eh, specific conductance , sorption, desorption, ion exchange and exchange equilibria, which in turn greatly influence the availability of plant nutrients , uptake and utilization by wetland rice[4].

Organic fertilizer affected pH values in soil solution than of inorganic fertilizers. Also, use of organic matter for rice growing has an advantage to improve the pH buffering capacity of soil and nutrients availability and retention of soil. Furthermore, the addition of organic fertilizer decreases of Eh as compared with inorganic fertilizer and control[5]. They added also that pH values decreased gradually after 45 days after starting (DAS) till the end of rice growing period and these decrease were also in very little range and varied with the moisture regimes.

Sudhalakhsmi et al [5] reported that the oxidation reduction (Eh) system is a chemical reaction in which electrons are transferred from a donor to an acceptor which is an important index for characterizing the degree of oxidation or reduction of soil and reflects the equilibrium position between various redox systems. The results revealed that the direct seeding limited irrigation and cono-weeding practices have resulted in the substantialincrease in the redox potential while green manuring has considerably reduced the redox potential of the rhizosphere region.Furthermore,Mitchel et al [6] stated that redox potential (Eh) describe the electrical state of matrix.In soils, Eh is an important parameter controlling the persistence of many organic and inorganic compounds.

This research was conducted to study the effects of flooding and organic matter on Si availability, pH and Eh values in different soils.

Materials and Methods

Three soil samples namely, clay loam from Sakha, sandy soil from El-Gabal El-Asfar and calcareous soil from El-Noubaria were selected. Ten gm of 2 mm sieved samples of each soil types was transferred to 50 ml plastic centrifuge tubes, and flooded with 25 ml of distilled water, then incubated in the dark at 30 ± 2 °C.Half of the samples of each soil type received 3 % organic matter (starch). The replicated were taken after 0 (dry soil), 10, 20, and 30 days after flooding and centrifuged. The supernatants were analyzed for silica colorimetrically[8]. Values of pH and redox potential (Eh) were measured in separate samples using glass and platinum electrodes, respectively.

Results and Discussion

Effect on water soluble Silicon

Table (2) Effect of waterlogging and organic matter addition on water soluble Si, pH and Eh values

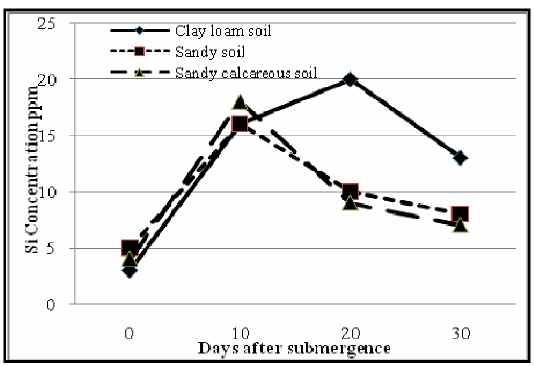
Place	Sakha			El-Gabal El-Asfar			El-Noubaria		
Soil texture	Clay loam soil			sandy soil			Sandy calcareous soil		
Submergence periods (days)	WL	WL+OM	Increase %	WL	WL+OM	Increase %	WL	WL+OM	Increase %
	Si ppm								
0	3.0	3.0	0.0	5.0	5.0	0.0	4.0	4.0	0.0
10	16.0	40.0	150.0	16.0	49.0	206.3	18.0	30.0	66.7
20	20.0	27.0	35.0	10.0	41.0	310.0	9.0	13.0	44.4
30	13.0	20.0	53	8.0	35.0	337.5	7.0	11.0	57.1
	pH values								
0	8.0	8.0		6.7	6.7		8.2	8.0	
10	7.3	6.1		7.3	4.9		7.3	6.9	
20	7.7	7.3		7.5	5.3		7.4	7.2	
30	7.8	7.4		7.6	6.3		7.4	7.9	
Maximum ΔpH	-0.2	-0.6		0.9	-0.4		-0.8	-0.3	
	Eh values								
0	433	433		453	453		456	456	
10	153	103		253	143		183	83	
20	103	93		213	193		113	93	
30	93	113		193	243		93	103	

WL :WaterloggingOM : Organic matter.

The effect of waterlogging and organic matter (OM) addition on Si concentration in the percolation solutions of different incubated soils at 30 $^{o}C \pm$ for 30 days are presented in table (2) and Figure (1; 2). Data reveal that available Si in percolation solutions of the sandy soil of El-Gabal El-Asfar and the sandy calcareous soil of El-Noubaria increased from 5 ppm (0 time) to 16 ppm and from 4 ppm (0 time) to 18 ppm, respectively, after 10 days from submergence date. Si concentration of both studied soils then decreased gradually and reached to 8 and 7 ppm for sandy and sandy calcareous soils, respectively. Data also show that Si concentration in the percolation solutions of the alluvial clay loam of Sakha soil gradually increased from 3 ppm (0time) to 20 ppm after 20 days. Generally, upon flooding, silica increased in sandy soil and sandy calcareous soils after 10 days from submergence, while in clay loam soil Si increased during the first 10-20 days, and then decreased in all the studied soils till 30 days from submergence. These results are in full agreement with those obtained by[10,11].

Data also reveal that addition of OM to the three soils clearly increased the water soluble Si in percolation solutions more than Si values obtained under submergence alone. These results confirm those of [12,13].

The highest values of water soluble Si as affected by waterlogging and OM together (Table 2 and Fig. 2) were obtained in sandy soil of El-Gabal El-Asfar followed by Sakha clay loam soil and sandy calcareous soil of El-Noubaria in decreasing order. These results may be due to the high OM content of El-Gabal El-Asfar soil and very low OM content of the calcareous soil (Table 2). In this connection, also [14] stated that soils having the highest content of OM also showed the highest level of soluble silicon. He found a positive correlation between OM content and both soluble and amorphous silicon in different soil samples.



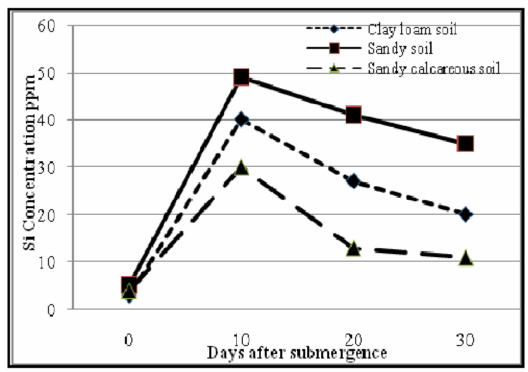


Fig. (1) The effect of waterlogging on the concentration of Si of the studied soils.

Fig. (2) The effect of waterlogging and organic matter on the concentration of Si of the studied soils.

Effect on pH values:

Soil properties markedly influenced the velocity and magnitude of pH changes caused by submergence of the soils. Sahrawat[15]and Bahmaniar[16].Data presented in table (2) and illustrated in Figures 3 and 4 show that the ph values of Sakha clay loam and El-Noubaria sandy calcareous soils decreased on flooding. The rate of pH decrease after the first 10 days was more pronounced. In Sakha clay loam soil, pH decreased from 8.0 (0time) to 7.3 and in sandy calcareous soil from pH 8.2 (0 time) to 7.3 after 10 days from the submergence date. The values of pH of the slightly acid soil (El-Gabal El-Asfar sandy soil) increased by 0.6 unit (from pH 6.7 at 0 time to 7.3 after 10 days from submergence date). pH values of clay loam and sandy calcareous soil increased gradually as the submergence period increased and reached to 7.8 and 7.4 after 30 days from the submergence date, respectively. Moreover, data show that pH values of the moderately acid soil of El-Gabal El-Asfar increased gradually with time and reached to 7.6 after 30 days from submergence date. The lower pH values of this soil may be due to the high OM content (Table 2) [16, 17].

The decrease in pH shortly after submergence is probably due to the accumulation of CO2 produced by respiration of aerobic bacteria, because CO_2 decreases the pH even of acid soils[5]. The subsequence increase in pH value of sandy soil of El-Gabal El-Asfar may be due to soil reduction. The pH values of submerged calcareous and sodic soils are lower than those of aerobic soils because of accumulation of CO_2[18]. They added that pH of alkaline soils is highly sensitive to changes in the partial pressure of CO_2 (P_{CO2}). They also stated that the ph values of flooded alkali, calcareous soils and acid soils after reduction can be explained quantitatively by one or more of the following equilibria: Na_2CO_3-H_2O-CO_2, $CaCO_3$-H_2O-CO_2, $MnCO_3$-H_2O, -CO_2, $Fe_3(OH)_8$-H_2O-CO_2.[19]

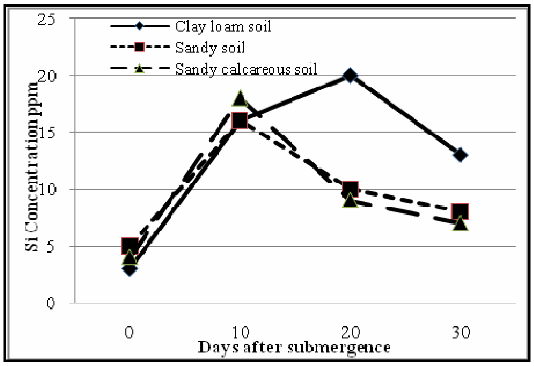


Fig. (1) The effect of waterlogging on the concentration of Si of the studied soils.

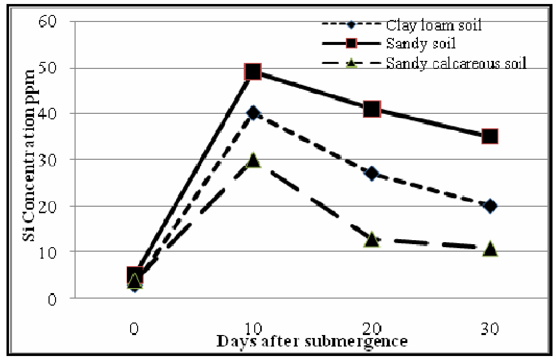


Fig. (2) The effect of waterlogging and organic matter on the concentration of Si of the studied soils.

Data presented in Table (2) and Fig. 4 show that the combined effect of OM and submergence decreased pH values of all used soils, from 8.0 to 7.4, from 6.7 to 6.3 and from 8.2 to 7.9 for clay loam, sandy and sandy calcareous soils, respectively. In this respect [10] revealed that OM magnifies the decrease in pH of sodic and calcareous soils. The addition of OM to the submerged soils clearly decrease pH values after 10 days from submergence, then they slightly increased till 30 days. The pH values of the all studied soils after 30 days were low than those of ph values at (0) time. Generally, data indicate that all pH values under the combination of submergence and OM addition were lower than those obtained under submergence alone[20].

Results of the effect of submergence and OM addition on pH values in this experiment are in full agreement with those obtained by[21, 22, 23].

c) Effect on Eh values:

Data presented in table (2) and illustrated in figs (5 and 6) show the effect of submergence and organic matter addition on Eh values of three different soils, incubated at 30 $^{o}C\pm 2$ for 30 days. Data reveal that the Eh values decreased in all studied soils after 10 days from submergence from 433,453 and 456 mV and reached 93,193,93 mV after 30 days for clay loam, sandy and calcareous soils, respectively .when 3%organic matter (starch) was added to the different submerged soils as a source of actively decomposing organic matter fig. (6), the reduction of waterlogged soils and change of Eh values were faster and sharper compared with those under submergence treatment alone (Fig.5) especially after 10 days from submergence date. They slightly increased with increasing submergence period (Fig.6).

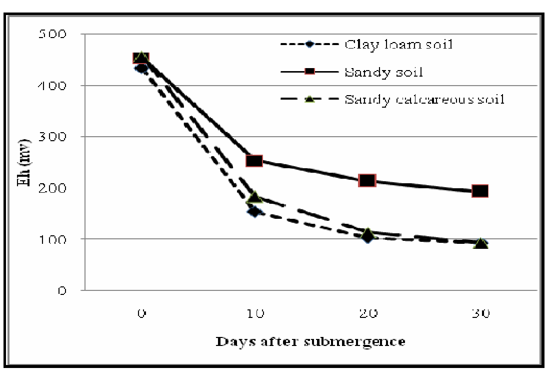


Fig. (5) The effect of waterlogging on the Eh values of the studied soils.

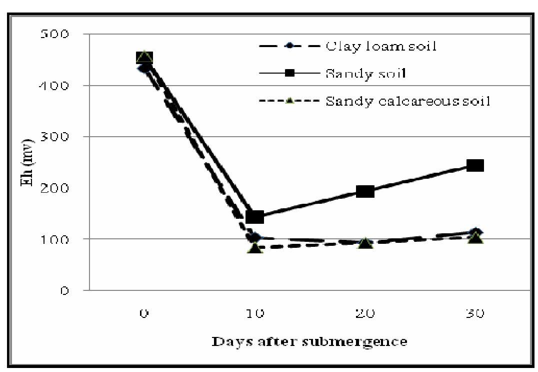


Fig. (6) The effect of waterlogging and organic matter on the Eh values of the studied soils.

The result are in good agreement with the finding of [7]who stated that the course, rate and magnitude of Eh decrease depend on the kind and the amount of organic matter, the nature, and the content of electron acceptors, temperature and the duration of submergence.

The presence of native or added organic matter sharpened and hastened the first minimum (Table 2 and Fig 6). In this concern,[24, 25] confirmed the previous results and stated that nitrate abolishes the first minimum decrease. The rapid initial decrease of Eh values was apparently due to the release of reducing substances accompanying oxygen depletion before Mn (IV) and Fe (III) oxide hydrates can mobilize their buffer capacity.

Data presented in table (1) and Figs 5 and 1 also show that the decrease in Eh values varied with the different soils. The lowest Eh values were obtained in sandy calcareous and clay loam soils and the highest values were obtained in sandy soil of El-Gabal El-Asfar. The first minimum potential can be as low as 83 mV for sandy calcareous soil, 103 mV for clay loam soil (Sakhasoil).And 143 mV for sandy soil of El-Gabal El-Asfar. The first minimum potential can be as low as -0.42 V and can be accompanied by the evolution of hydrogen.

Generally, the influence of soil factors on Eh changes have been summarized by [26] as follows : a)soils high in nitrate (more than 275 ppm NO^-_3) have positive potentials for several weeks after submergence; b) soils low in organic matter (less than 1.5%) or high in Mn (more than 0.2%) maintain positive potentials even 6 months after submergence, c)soils low in active Mn and Fe (sandy soils) with more than 3% organic matter attain Eh values of -0.2 to -0.3 V within 2 weeks of submergence, and d)the fairly stable potentials reached after several weeks of submergence lie between 0.2 and -0.3 V.[6, 27].

Table (1) : Mechanical analysis, $CaCO_3$, organic matter contents, and the pH values of the studied soils.

Soil sample No.	Location	Sand %		Silt %	Clay%	Texture	$CaCO_3$ %	OM%	pH value
		Coarse	Fine						
1-	Sakha	11.1	18.9	30.00	40.00	Clay loam	4.00	1.60	8.0
2-	El-Nobaria	17.26	22.09	10.28	50.37	Clay	13.00	1.50	8.1
3-	El-Gabal-El Asfar	50.00	39.76	5.74	4.50	Sand	0.008	6.00	6.7

By (Jackson 1982).

Results in this experiment concerning the effect of submergence and organic matter on Eh values in different soils are in good agreement with those obtained by[10].

Conclusion

The main electrochemical changes that influence the chemistry and fertility of submerged soils and growing of crops such as wetland rice include.A decrease in Redox potential (Eh) or reduction of the soil.An increase in Ph of acid and a decrease in pH of alkaline soils, and changes in flooding may take up to several weeks, depending on the soil type, OM levels, microbial population, and other soil chemical properties.Changes in organic matter and availability of plant nutrients in soils following their submergence under water could be as follow: i) Favours convergence to neutral pH, ii) Favours accumulation of organic carbon and nitrogen, and iii) Improve Si.

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