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Electrochemical Changes In Soil Solution As Affected By Soil Moisture Regimes And Soil Texture Through Growth Period Of Rice Plants

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Abstract: A Pot experiment was conducted in the greenhouse of the National Research centre, Cairo, Egypt, to study the influence of soil moisture regimes (M_1,:high moisture, M2: moderate moisture and M3: low moisture) on electrochemical changes (Eh and pH) in soil solutions collected from soils differ in their texture and fertility levels, through the growth period of rice plants. Each pot received a basic dressing of 11.5 Kg N as urea (46% N), 3.75 Kg P_2O_5 as superphosphate (15.5% P_2O_5) and 13 kg K_2O as potassium sulphate (48% K_2O).
Results show that pH values at all the different determination dates were higher when soil moisture regime of M_3 was used followed by M_2 and M_1 in decreasing order. these results were true under all the used soils. Different soils markedly influenced the pattern, velocity and magnitude of pH changes caused by using soil moisture regimes. Under all soil moisture regimes M1, M2 and M3, pH values of clayey soils L1 & L2 (Damietta and Karf-El-Sheikh soils) gradually decreased and reached their minimum values at 24 DAS, then they slightly increased till 96 DAS, pH values of clay loam soils L_3 and L_4 (Sakha and El-Kanater soils) under soil moisture regimes of M_1 and M_2 gradually decreased and reached their minimum values at 24 DAS and still fairly stable between 24 and 48 days after starting. Finally pH values slightly increased till 96 days after starting (DAS).
Also, results show that in silty loam soil (L5), sandy loam soils (L6 and L7), and loamy sand soil (L8), Eh values sharply decreased at 12 DAS, then they gradualy increased and reached their maximum values at 96 DAS. Eh values of soil L6 (sandy loam) were higher than those obtained in silty loam soil (L5). Furthermore, Eh values in calcareous loamy sand soil (L8) were higher than those obtained in calcareous sandy loam soil (L7). Generally Eh values at 96 DAS in all the used soils were lower than their corresponding values at 0 time (initial values).
Keywords : moisture regimes, soil texture, rice, solution, Eh, pH.

Introduction

Rice crop easily adapts to the environment. It can grow in types of soils under a wide range of climatic and soil moisture conditions. Rice can be grown with a thin film of moisture on the soil surface, to about 10-50 cm of standing water [1].

Submerging aerobic soils in water decreases its Eh that drops and stabilizes at a fairly stable range of +200 mV to -300 mV depending on soil, especially the content of organic matter and reducible species (nitrate, sulphate and ferric iron), particularly iron. But Eh of the surface water and the first few millimetres of top soil in contact with the surface water remain relativity oxidized in the Eh range of +300 to +500 mV. A range of Eh is encountered in various soils from well-drained, aerated to waterlogged conditions[2].

Also **Mitchel et al** [3] stated that redox potential (Eh) describes the electrical state as a matrix. In soils, Eh is an important parameter controlling the persistence of many organic and in organic compounds, on the other hand after the soil is flooded, regardless of its original pH before flooding, the pH will approach neutrality (pH 6.5 to 7.5). the pH of alkaline soils declines and the pH of acid soils increases. The change in pH upon flooding may take up to several weeks, depending on the soil type, organic matter levels, microbial population, temperature, and other soil chemical properties [4,5].

Sharma and Mishra [6], studied the changes in Eh and pH of soils of the Tarai and hill regions of Uttar Pradesh during submergence and rice growth. They found that Eh values of wet soils decreased rapidly during the first 10 days after submergence and slowly thereafter approaching values near –200 mv by 60^{th} day. The pH of alkaline soils decreased rapidly and that of acid soils increased during first 10 days. The NPK fertilizer application as well as rice planting caused a decrease in Eh and pH of the soils. Higher Eh values were generally associated with higher pH and vice versa.

This investigation was carried out to study the effect of soil moisture regimes on electrochemical changes in soil solutions collected from different soils varied their texture and level of fertility through the growth period of rice plants.

Materials and Methods

The soil moisture **regimes** were used as follows : M_1 : high level, watering at every 4 days irrigation intervals, M_2 : moderate, watering at every 6 days irrigation intervals, and M_3 : low level, watering every 8 days irrigation interval. In all the three moisture treatments (M_1, M_2 and M_3), submergence was raising to 5 cm at first month, 10 cm at the second month and 7 cm at the third month during irrigation.

The texture and the fertility levels of the used soils are presented in Tables 1 and 2. The used soils in this experiment were collected from the surface layer (0-3 cm), air dried, ground, to pass through a 2mm sive and were preserved in tight stopper plastic containers. Plastic pots (diameter 32, high 37 cm) were used and provided with a hole adjusted 5 cm from the bottom previous washed with diluted acid and distilled water. Pots were filled with 5 kg washed sand and gravels followed by 20 kg soil. Each pot received a basic dressing of 11.5 kg N as urea (46% N), 3.75 Kg P_2O_5 as superphosphate (15.5% P_2O_5) and 13 kg K_2O as potassium sulphate (48% K_2O) per feddan. One day after soil flooding, 15seedlings of 28 days old of Sakha 102 variety were transplanted in each pot. The pots were kept submerged under tap water.

The soil solutions were collected by gravity, in 250 ml conical flasks under pravin oil for measurement of Eh and pH at intervals of 0, 12, 24, 48, 72 and 96 days after starting (DAS). Soils and solution samples determinations were conducted as described by [7,8,9].

Table (1). Particle size distribution, $CaCO_3$, O.M% and pH values of the studied soils.

Soil location	Sand %	Salt %	Clay %	Texture class	$CaCO_3$ %	OM %	pH
	Alluvial soils						
L_1 Damietta	22.00	27.2	48.08	Clayey	1.66	3.40	8.10
L_2 Kafr El-Sheikh	30.00	28.0	41.00	Clayey	2.21	2.10	2.00
L_3 Sakha	26.70	35.8	37.05	Clay loam	2.61	1.91	7.90
L_4 El-Kanater	26.70	39.6	33.70	Clay loam Silty	2.70	1.80	7.96
L_5 El-Katiba	33.30	51.0	15.70	loam	2.90	1.36	7.80
L_6 El-Ga'faria	47.00	31.0	13.00	Sandy loam	3.60	1.10	7.90
	Calcareous soils						
L_7 Abo El-Matameer	78.00	9.60	12.40	Sandy loam	10.2	0.60	8.20
L_8 Janaklies	79.00	10.0	11.00	Loamy land	11.1	0.40	8.30

OM: organic matter

Table (2). Some chemical properties of the used soils

Soil location	E.C. ds/m	Available nutrients (ppm)			DTPA extractable (ppm)	
		NH_4^+	P	K	Mn	Fe
	Alluvial Soils					
L_1 Damietta	0.84	63.0	39.0	680	26.0	48.0
L_2 Kafr El-Sheikh	1.60	52.0	31.0	560	22.0	41.0
L_3 Sakha	0.83	36.0	27.0	490	14.0	35.0
L_4 El-Kanater	1.08	31.0	23.0	420	13.0	32.0
L_5 El-Katiba	1.35	19.0	14.0	310	7.8	19.0
L_6 El-Ga'faria	2.24	14.0	11.0	240	6.4	16.0
	Calcareous soils					
L_7 Abo El-Matameer	0.89	9.0	5.10	150	2.8	8.4
L_8 Janaklies	0.99	7.0	4.30	110	1.1	7.0

Results and Discussion

Effect of soil moisture regimes and different soils on changes in electrochemical properties in soil solution

Effect on pH :

Changes in pH values as affected with three moisture regimes and different soils are presented in Table (3) and illustrated in Fig. (1).

Results reveal that regardless the effect of soils, soil moisture regimes, M_1, M_2 and M_3 registered slight decreases in the pH of soil solution till 24 days from starting, then gradually increased till 96 days from starting. Generally, all the used soil moisture regimes (M_1, M_2 and M_3) decreased pH values after 96 days from starting to lower values than those of pH values at 0 time (initial values). The decrease in pH sharply after submergence is probably due to the accumulation of CO_2 produced by respiration of aerobic bacteria because CO_2 decreases the pH values even of acid soils [10,11]**.** They also stated that the pH values of flooded alkaline and calcareous soils after reduction can be explained by [5] showing the decrease in pH shortly after submergence is probably due to the accumulation of CO_2 produced by respiration of aerobic bacteria and also may be due to the changes in the partial pressure of CO_2 through of the following equilibria: Na_2 CO_3-H_2O-CO_2, $CaCO_3$-H_2O-CO_2; $MnCO_3$-H_2O-CO_2 and Fe_3 $(OH)_8$-H_2O-CO_2. Also, **Venterea et al.,** [12] who added that pH of alkaline soils is highly sensitive to changes in the partial pressure of CO_2 (P CO_2).

Table (3): Changes in pH in different soil solutions throughout the growth period of rice plants as affected by soil moisture regimes.

Soils Location		Days after starting (DAS)					
		0	12	24	48	72	96
				M_1			
L_1	Damietta	8.1	7.8	7.5	7.6	7.7	7.7
L_2	Kafr-El-Sheikh	8.0	7.7	7.4	7.5	7.6	7.7
L_3	Sakha	7.9	7.7	7.3	7.3	7.4	7.5
L_4	El-Kanater	7.96	7.6	7.2	7.2	7.3	7.4
L_5	El-Katiba	7.8	7.4	7.2	7.1	7.0	7.0
L_6	El-Ga'faria	7.9	7.5	7.3	7.2	7.1	7.1
L_7	Abo-El-Matameer	8.2	8.0	7.5	7.4	7.5	7.6
L_8	Janaklies	8.3	8.1	7.7	7.5	7.6	7.7
				M_2			
L_1	Damietta	8.1	7.9	7.6	7.7	7.7	7.8
L_2	Kafr-El-Sheikh	8.0	7.8	7.5	7.5	7.6	7.7
L_3	Sakha	7.9	7.8	7.4	7.4	7.5	7.6
L_4	El-Kanater	7.96	7.7	7.3	7.4	7.4	7.5
L_5	El-Katiba	7.8	7.5	7.3	7.2	7.1	7.2
L_6	El-Ga'faria	7.9	7.6	7.4	7.3	7.2	7.3
L_7	Abo-El-Matameer	8.2	8.0	7.6	7.5	7.6	7.7
L_8	Janaklies	8.3	8.1	7.8	7.6	7.7	7.8
				M_3			
L_1	Damietta	8.1	8.0	7.7	7.8	7.9	7.9
L_2	Kafr-El-Sheikh	8.0	7.9	7.6	7.7	7.8	7.9
L_3	Sakha	7.9	7.8	7.5	7.6	7.7	7.8
L_4	El-Kanater	7.96	7.8	7.4	7.5	7.6	7.7
L_5	El-Katiba	7.8	7.6	7.5	7.4	7.3	7.4
L_6	El-Ga'faria	7.9	7.7	7.6	7.5	7.4	7.5
L_7	Abo-El-Matameer	8.2	8.1	7.8	7.6	7.7	7.8
L_8	Janaklies	8.3	8.2	7.9	7.7	7.8	7.9

Data in Table (3) and Fig. (1) show that different soils markedly influenced the pattern, velocity and magnitude of pH changes caused by the used soil moisture regimes. Under all the soil moisture regimes M_1, M_2 and M_3, pH values of clayey soils L_1 & L_2 (Damietta and Kafr-El-Sheikh soils) decreased gradually to reach their minimum values after 24 days after submergence (DAS), then they increased slightly till 96 days after starting (DAS). pH values of clay loam soils L_3 and L_4 (Sakha and El-Kanater soils) under soil moisture regimes of M_1 and M_2 decreased gradually to reach their minimum values after 24 DAS and still fairly stable between 24 and 48 days after starting. Finally pH values increased slightly till 96 days after starting (DAS). Concerning soil moisture regime of M_3, pH values for both soils L_3 and L_4 decreased gradually to reach their minimum after 24 days then increased slightly till 96 days after starting (DAS). Concerning, silty loam and sandy loam soils (L_5 and L_6) the pH values decreased gradually under the three soil moisture regimes (M_1, M_2 and M_3) till 72 days after starting to reach their minimum values then still stable under M_1 to 96 days after starting and increased slightly under soil moisture regimes of M_2 and M_3 till 96 days after starting. Moreover, data show that pH values of sandy loam and loamy sand calcareous soils (L_7 and L_8), gradually decreased under the three soil moisture with time to reach their minimum values after 48 days then increased slightly after 96 days after starting. The subsequent increases in pH of the used soils may be due to the soil reduction as recommended by[13].

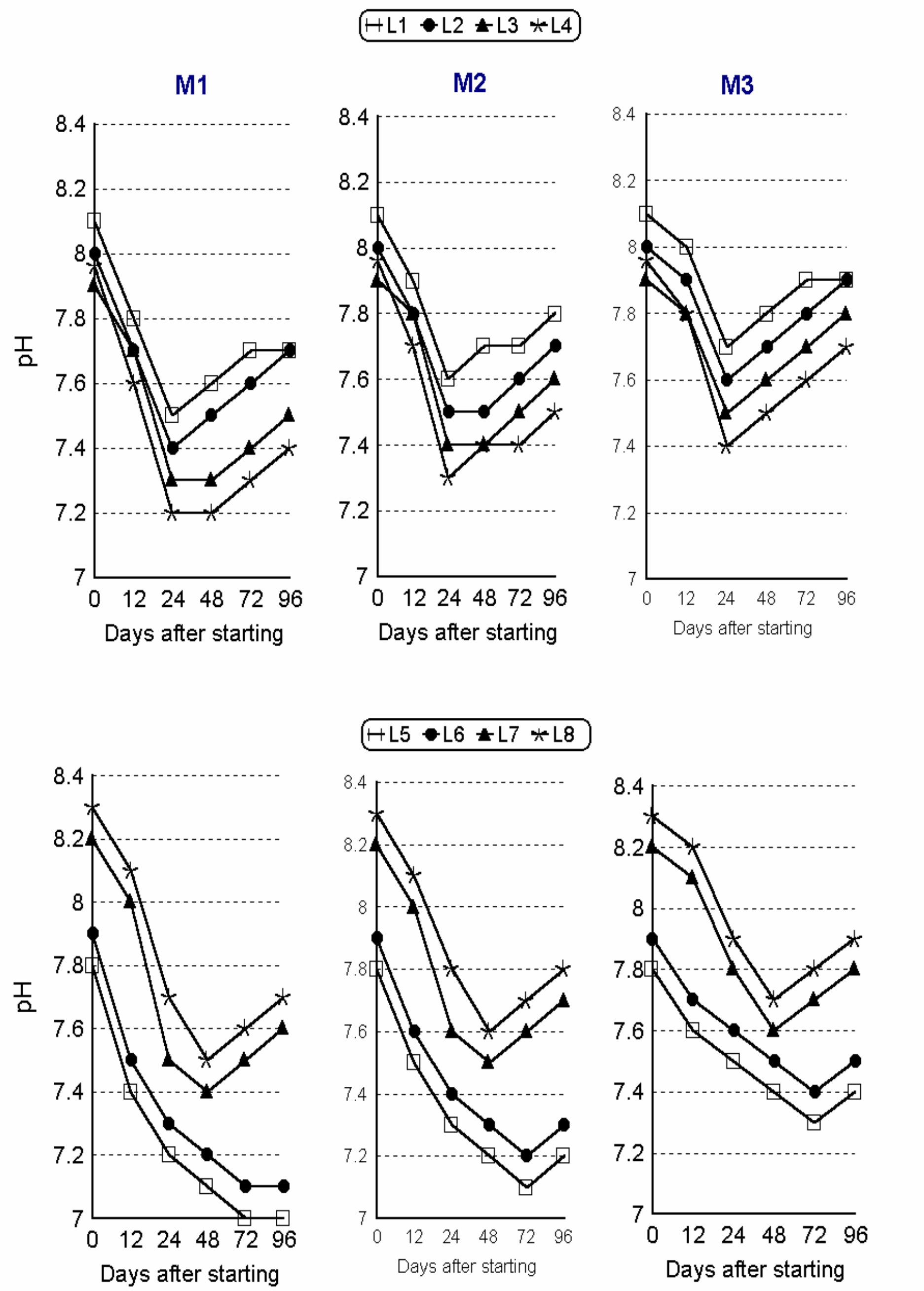

Fig. (1): Changes in pH in different soil solutions throughout the growth period of rice plants as affected by soil moisture regimes.

Generally, soils properties markedly influenced the velocity and magnitude of pH changes caused by submergence of the soils[6,14].

Results of the effect of submergence on pH values in this experiment are in full agreement with obtained by [15,16,17,5] who stated that when an aerobic soil is submerged its pH value decreased to their minimum values and then increased asymptotically to a fairly stable values a few weeks later.

Redox potential (Eh) :

The main electrochemical changes in submerged soils that influence the growth of rice are decrease in redox potential (Eh), and decrease in pH of alkaline soils. The extent of these changes is determined by the chemical and physical properties of the soil and by water regime.

Redox potential values of the soils under three soil moisture regimes were measured intervals throughout the growing period of rice plants. Data presented in Table (4) and illustrated in Fig. (2) show the effect of soil moisture regimes M_1, M_2 and M_3 on Eh values. Eh values were found under soil moisture regime of M_3 followed by M_2 and M_1 in decreasing order. This mean that the higher soil moisture regimes (M_3) increased the Eh values. As example, the Eh values for the calcareous loamy sand soil (L_8) in the collected samples taken at 0, 12,24,48,72 and 96 DAS (days after starting) were as follow, under soil moisture M_3; 411,200,228, 271,368,361mv, under M_2 were 411,140,152,210,299 and 294 mv, and under M_1 were 411,60,73,115,210 and 207 mv, respectively. Confirm these results, [18] stated that average redox potentials in clay loam soil through the season were + 598, +523 and-94 mv under the moist, wet and flooded condition, respectively. Corresponding redox potentials for the sandy loam soil were + 705, +398 and –21 mv, respectively.

Table (4): Changes in redox potential (m.v) in different soil solutions throughout the growth period of rice plants as affected by soil moisture regimes.

Soils Location		**Days after starting (DAS)**					
		0	**12**	**24**	**48**	**72**	**96**
				M_1			
L_1	Damietta	437	61	38	59	276	280
L_2	Kafr-El-Sheikh	451	90	65	85	310	318
L_3	Sakha	465	105	86	110	330	331
L_4	El-Kanater	473	125	105	120	345	349
L_5	El-Katiba	418	30	120	140	240	238
L_6	El-Ga'faria	425	41	132	155	270	263
L_7	Abo-El-Matameer	398	55	67	100	180	175
L_8	Janaklies	411	60	73	115	210	207
				M_2			
L_1	Damietta	437	145	113	135	310	314
L_2	Kafr-El-Sheikh	451	160	135	160	340	341
L_3	Sakha	465	178	156	178	358	363
L_4	El-Kanater	473	195	172	210	368	371
L_5	El-Katiba	418	90	180	195	322	313
L_6	El-Ga'faria	425	110	198	220	338	336
L_7	Abo-El-Matameer	398	125	138	190	285	280
L_8	Janaklies	411	140	152	210	299	294
				M_3			
L_1	Damietta	437	210	180	230	340	346
L_2	Kafr-El-Sheikh	451	235	225	280	371	373
L_3	Sakha	465	260	240	310	393	395
L_4	El-Kanater	473	281	263	405	405	409
L_5	El-Katiba	418	145	245	267	375	368
L_6	El-Ga'faria	425	156	263	286	384	378
L_7	Abo-El-Matameer	398	178	210	261	351	345
L_8	Janaklies	411	200	228	271	368	361

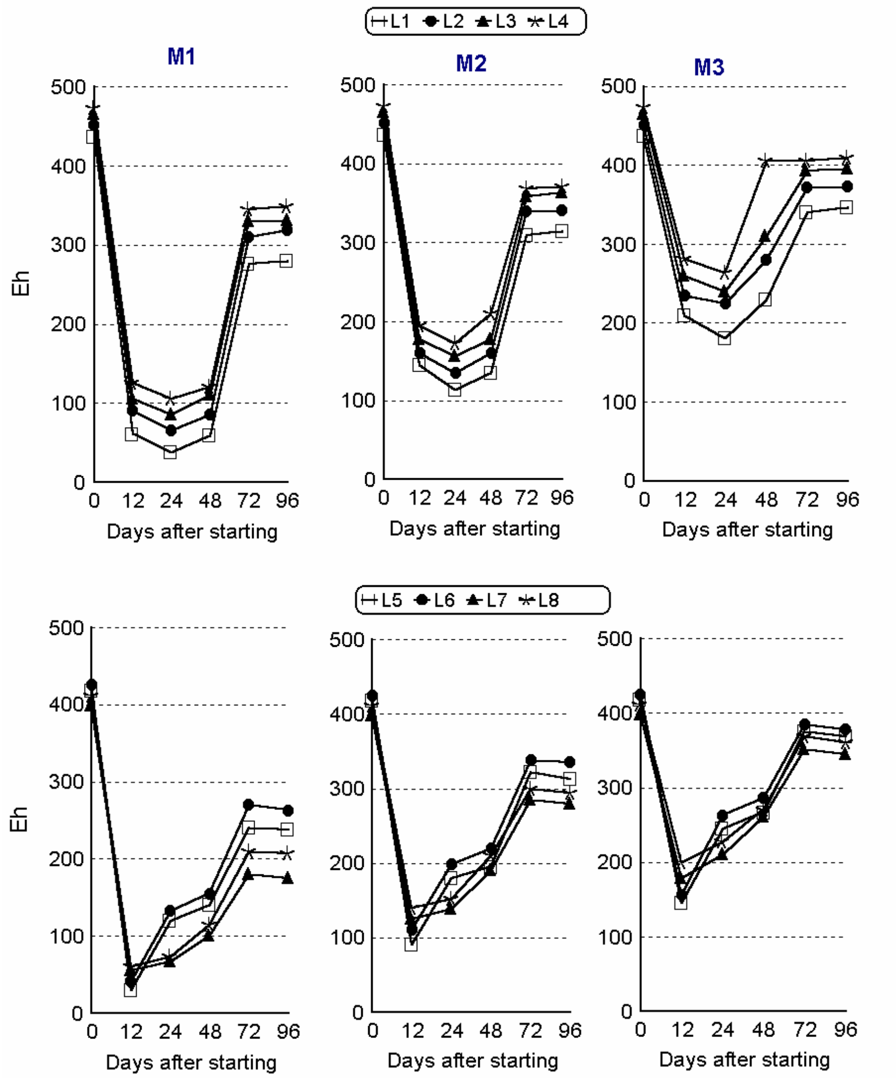

Fig. (2):Changes in redox potential(m.v) in different soil solutions throughout the growth period of rice plants as affected by soil moisture regimes.

The result are in good agreement with the finding of [3] 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.

Results also show that in silty loam soil (L_5), sandy loam soils (L_6 and L_7), and loamy sand soil (L_8), Eh values sharply decreased at 12 DAS, then they gradually increased and reached their maximum values at 96 DAS. Eh values of L_6 (sandy loam were higher than those obtained in silty loam soil (L_5). Furthermore, in calcareous soils the loamy sand (L_8) the Eh values were higher than those obtained in sandy loam soil (L_7). Generally Eh values at 96 DAS in all the used soils were lower than their corresponding values at 0 time (initial values).

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[10]**.**

In this concern, [19,20] 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.

Confirm the obtained results of Eh, [10,21,22, 23] who reported that, the Eh dropped sharply during the first and second week of prior-flooding and was lowest at that the 30 days crop growth stage and then increased. They added that the decrease of Eh values were greater in Sakha clay loam soil (-428 mv) than Mariout sandy clay loam soil (-398 mv) and Anshas loamy sand soil (-395 mv). This trend may be due to the higher organic matter content of Sakah soil (1.5%) than Mariout and Anshas soils (0.9%).

Furthermore, **Synder and Nathan** [24] found that the lower the redox potential (more negative), the more reduced (less O2) the soil is. If the soil O2 supply is deficient, soil bacria are forced to get O2 from other compounds in the soil in the following general ordr, form first to last : nitrate-nitrogen, manganese oxide (MnO2), iron hydroxyoxide (FeOOH), and sulphate-sulfur. If the functionality of these compounds is exhausted, microorganisms can use some of the energy stored in soil organic compounds and by fermenting organic matter to carbon dioxide (CO_2) and Methane (CH4).

Generally : The main electrochemical changes in submerged soils that influence the growth of rice are soil reduction or decrease in redox potential, increase in pH of acid soils, decrease in pH of alkaline soils increase in specific conductance ionc strength, ionic equilibrium and sorption and desorption.

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