Plant Archives Vol. 19 No. 1, 2019 pp. 1965-1973 e-ISSN:2581-6063 (online), ISSN:0972-5210

A REVIEW OF ELECTROCHEMICAL CHANGES IN SUBMERGED SOILS

Hanan S. Siam[1], Safaa A. Mahmoud[1], A.S. Taalab[1] and G.W. Ageeb[2]

[1]Plant Nutrition Department and [2] Soils and water use Department, Agriculture and Biological Division, National Research Centre, 33El Buhouth St., 12622, Dokki, Cairo, Egypt.

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 (Sangita *et al.,* 2013).

Flooded soil causes changes in the properties of the soil because of physical reactions between the soil and water and the biological and chemical process set in motion as a result of excess water. However rice (*Oryza sativa* L.) root systems play an important role in uptake of water and nutrients from soil (Yang *et al.,* 2004). Soil reduction resulting from flooding can change availability of nutrients to plants via change in chemical species (e.g., increasing solubility of Fe) (Pierce *et al.,* 2010). The most important change is the conversion of the root zone from an aerobic environment to an anaerobic or near-anaerobic environment.

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 nutrients availability and retention of soil. Furthermore, the addition of organic fertilizer decreases of Eh as compared with inorganic fertilizer and control (Siam *et al.,* 2015). 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.

The reduction of Mn and Fe is one of the most important chemical transformations that occur in waterlogged soils. Previous studies indicated that water logging significantly increased water soluble Mn^{2+} and Fe^{2+} ions and concentrations in soils (Favre *et al.,* 2002 and Grybos *et al.,* 2009) Who stated that, in wetlands, large quantities of dissolved organic matter (DOM) are solubilized under reducing conditions. Which the following processes account for this phenomenon. Release of organic matter (OM) from Mn-and Fe- ox hydroxides that undergo reductive did dilution; and iii) desorption of OM from soil minerals due to PH changes. Also, Egrinya Eneji *et al.,* (2001) studied the effect of some animal manures on rice yield and micro nutrients, the manure application increased grain yield and concentration of Fe^{2+} and Mn^{2+}. Furthermore, Siam *et al.,* (2015) in their study on the advantages of organic fertilizer treatment under soil moisture regime of (23Kg N + 15kg P_2O_5 + 52kg K_2O/Fed + 1.5ton chicken manure) at watering at every 4 days irrigation (M1) recorded the highest values of concentration of Fe^{2+} and Mn^{2+} in soil solution.

The most characteristic management practice in paddy rice cultivation is water logging, or submergence of the land surface. This brings about anaerobic conditions in the soil, due to the very slow diffusion rate of oxygen through water. Biologically, after the oxygen reserve in the soil is exhausted and aerobic microorganisms have all died, facultative anaerobes dominate for some time. As the anaerobic conditions continue, these microorganisms are gradually replaced by obligate or strict anaerobes.

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 millimeters of top soil in contact with the surface water remain relativity oxidized in Eh range of + 300 to +500 mV. A range of Eh is encountered in various soils from well-drained, aerated, to waterlogged conditions (Sahrawat, 2005).

Also, Mitchel *et al.,* (2004) 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 (PH6.5 to 7.5), the PH of alkaline soils declines and the PH of acid soils increases. Sahrawat (2005) and Siam *et al.,* (2015) studied 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.

All these biochemical changes occur vigorously for the first month after submergence, when readily decomposable organic matter, the energy source for microorganisms, is abundantly available. Past this stage, there will be e period when the supply of oxygen by diffusion, though extremely slow, exceeds its consumption at the soil/water interface. As all the oxygen is trapped by such reduced substances as ferrous and manganese ions at the interface, a thin oxidized, orange colored layer (normally a few millimeters thick) is differentiated from the underlying bulk of the strongly reduced, bluish-gray plow layer. The great environmental difference between the oxidized and the reduced layers exerts a profound influence on nitrogen transformation in the later stages of paddy soil management, as will be explained below.

Chemical transformation that occurs in waterlogged soils have been extensively reported by (Bovin *et al.,* 2002; Favre *et al.,* 2002) Larson *et al.,* 1991; and Scatenghe *et al.,* 2002). Many studies have dealt with the electrochemistry, solution chemistry, and nutrition status of paddy soils in relation to redox reaction induced by water logging (Narteh and Sahrawat, 1999).

As a result, the entrained oxygen is quickly exhausted. The lack of free oxygen or anaero-biosis causes soil reduction and sets in motion a series of physical, chemical and biological processes. The influence of flooding on physical, chemical and electrochemical properties of soil has been comprehensively researched and reviewed from time to time.

The main electrochemical changes in submerged soils that influence the influence the growth of rice are: soil reduction or decreased in redox potential, increase in PH of acid soils, decrease in PH of alkaline soils, increase in specific conductance ionic strength, ionic equilibrium and sorption and desorption. The oxidation-reduction conditions of soil, growing with rice change due to change in soil water level. Due to change in chemical kinetics in aerobic and anaerobic soils, the availability of nutrients also changes. Besides, the applied fertilizer, particularly nitrogen, may incur losses due to changes in water stress, and its use efficiency may also differ. Rice growing under different soil water level prevailing under rain fed conditions has largely been ignored (Mitchel *et al.,* 2004 and Sangita *et al.,* 2013). This A-review was conducted to study the influence of different moisture regimes and fertilizer treatments on electrochemical change.

Electrochemical changes in submerged soils

Flooding a soil sets in motion a series of physical, chemical and biological processes. Changes in flooded soil are triggered by lack of oxygen in the flooded soil-system. The soil gets reduced lower Eh; see tables 1 and 2, for which energy is provided by mineralization organic carbon. The reduction process is regulated by the presence and availability of electron acceptors (mainly ferric iron and sulphate) and electron donors (organic matter. Soil reduction is accompanied by changes in the PH, Eh, specific conductance, sorption-desorption, ion exchange and exchange equilibrium, which in turn greatly influence the availability of plant nutrients, uptake and utilization by wetland rice (Sahrawat, 2005).

Soil redox potential

The change in soil the course rate and magnitude of Eh decrease depend on the kind and the amount of organic matter, the nature, and the contents of electron acceptors, temperature and the duration of submergence (Michel *et al.,* 2004).

Table 1: Oxidation-reduction potential found in rice soils ranging from well-drained to submerged conditions

Soil water condition	Redox potential (mv)
Aerated or well-drained	+700 to + 500
Moderately reduced	+ 400 to $^+$200
Reduced	+ 100 to – 100
Highly reduced	-100 to -300

The changes may affect the rice plant directly or indirectly through their influence on release and loss of nutrients, uptake of water, nutrients, formation and destruction of oxins.

Table 2: Redox potentials in which the main oxidized components in submerged soils become unstable

Reaction	Redox potential (mV)
O_2 –H_2O	+ 380 to + 320
NO_3 – N_2, Mn^{4+} – Mn^{2+}	+ 280 to + 220
Fe^3+ Fe^{2+}	+ 180 to + 150
SO_4^{2-} - S^{2-}	- 120 to – 180
CO_2 – CH_4	- 200 to – 280

Holah *et al.,* (2015). Revealed that after 10 days the addition of organic matter to the studied soils under submergence and incubation at 30°C+-, reduced Eh values faster and sharper as they compared with those under submergence treatments alone then the values Eh slightly increased with increasing submergence period till 30 days from submergence, They added also 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 low as 83 mV for sandy calcareous soil, 103 mV for clay loam soil (Sakha soil), 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.

Also, they added the presence of native or added organic matter sharpened and hastened the first minimum. In this concern Kaleem and Almas (2012) 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. Holah *et al.,* (2015) revealed 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.

Also, Siam *et al.,* (2015) stated that in redox potential in soil leachate solutions as affected by different fertilizer treatments and soil moisture regimes (M_1, M_2 and M_3). Results show that the Eh values falls sharply during the 12 days after starting (DAS) under all soil moisture regimes and fertilizer treatments, then they decreased to the minimum. Also, they added the highest decreases were obtained at 24 days and Eh values lowest decreased to 10 mV, 95 mV and 123 mV by using fertilizer treatment of (23Kg N + 15kg P_2O_5 + 52kg K_2O/Fed+1.5ton chicken manure) under soil moisture of Ml (at watering at every 4 days irrigation) followed by M2 (at watering at every 6 days irrigation) and M3 (at watering at every 8 days irrigation) in descending order,

Generally, the influence of soil factors on Eh changes have been summarized by (Ponnampruma, 1965) 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 (Sudhalakhsmi *et al.,* 2007 and Peng *et al.,* 2006).

Concerning the effect of submergence and organic matter on Eh values in different soils are in good agreement with those obtained by (Holah, 1989).

In this concern, Abd-ElMoez *et al.,* (2015) reported that Eh values of (sandy loam) were higher than those obtained in silty loam soil. Furthermore, in calcareous soils (loamy sand) the Eh values were higher than those obtained in sandy loam soil, generally Eh values at 96 DAS in all the used soils were lower than their corresponding values at 0 times (initial values). In this concern, silty loam soil, sandy loam soils and loamy sand soil, Eh values sharply decreased at 12 days, and then they gradually increased and reached their maximum values at 96 days.

Also, Sudhalakhsmi *et al.,* (2007) 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 direct seeding; limited irrigation and cono-weeding practices have resulted in substantial increase in the redox potential while green manuring has considerably reduced the redox potential of the rhizosphere region.

Submerging aerobic soils in water decreases its Eh that drops and stabilizes at a fairly stable range of +200m V to-300m V depending on the 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 millimeters of top soil in contact with the surface water remain relatively oxidized in the Eh range of +300 to + 500mV. A range of Eh is encountered in various soils from well-drained, aerated to waterlogged conditions, table 3. (Mitsch and Gosselink, 1993) and Sahrawat, 2005). Also, Siam *et al.,* (2015) the highest decreases were obtained under soil moisture of Ml (at watering at every 4 days irrigation) followed by M2 (at watering at every 6 days irrigation) and M3 (at watering at every 8 days irrigation) in descending order.

Mitchel *et al.,* (2004) stated that redox potential (Eh) describes the electrical state of a matrix. In soils, Eh is an important parameter controlling the persistence of many organic and inorganic compounds.

Table 3: The most important redox pairs and the approximate redox values at the ocourrence of transitions at the reference PH of 7.0 (Mitsch and Gosselink, 1993)

Chemical property	Oxidized form	Reduced form	Approximate Eh at transformation (mV)
Oxygen	O_2	H_2O	+600 to + 400
Nitrogen	NO_3^-	N_2O, N_2, NH_4^+	250
Manganese	Mn^{2+}	Mn^{2+}	225
Iron	Fe^{2+}	Fe^{2+}	+100 to – 100
Sulfur	$SO_4^=$	$S^=$	-100 to – 200
Carbon	CO_2	CH_4	Less than – 100

Synder and Nathan (2002) found that the soil O_2 status can be measured using specialized electrodes and is termed the redox potential. The redox potential is measured in millivolts. The lower the redox potential (more negative), the more reduced (less O_2) the soil. If the soil O_2 supply is deficient, soil bacteria are forced to get O_2 from other compounds in the soil in the following general order, from first to last: nitrate - nitrogen, manganese oxide (MnO_2) iron hydroxyoxide (FeOOH), and sulfate-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 (CH_4).

Oxygen levels

When a soil is flooded (anaerobic conditions), microorganisms use the available soil O_2 to survive. Free O_2 in the soil is usually depleted within a couple of days after flooding. The longer the soil is flooded, the lower soil O_2 levels become (more reduced). Some O_2 movement dose from the air, through the floodwater into about the upper 1/4 to 1/2 of soil (Synder and Nathan, 2002). They added that the deeper the flood, the less O_2 can move from the air into the soil. Most upland crops cannot tolerate prolonged saturation or flooding. In contrast, rice has the ability to transport O_2 from the leaves and stems to the roots. The area immediately around rice roots is usually oxygenated compared to the rest of the soil.

Soil PH

Soil properties markedly influenced the velocity and magnitude of PH changes caused by submergence of the soils, (Sahrawat 2004a and Bahmaniar *et al.,* 2008). In this concern Siam *et al.,* (2015) show that PH values decreased gradually after 45 day after starting (DAS) till the end of the rice-growing period, and these decrease were also in very little range and varied with the moisture regimes. These results are in good agreement with those obtained by (Kumar *et al.,* 1995) who stated that PH values increased during days 1-4 and then was a sharp decline on days 4- followed by a gradually decline.

After a 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.

The pH values of Sakha clay loam and El-Noubaria sandy calcareous soils decreased on flooding (Holah *et al.,* 2015). The rate of PH decrease after the first 10 days was more pronounced. 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 after10 days from submergence date).

Also, Holah *et al.,* (2015) indicated that PH values of the clay loam and calcareous soils decreased after 10 days from submergence and then increased gradually till 30 days after submergence. The combined effect of OM and water logging decreased PH values of the studied soils after 10 days from submergence and then they slightly increased till 30 days after submergence.

They added that, the decrease in PH shortly after submergence is probably due to the accumulation of CO_2 produced by respiration of aerobic bacteria, because CO_2 decreases the PH even of acid soils (Siam *et al.,* 2015). 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 (Venterea *et al.,* 2005). They added that PH of alkaline soils is highly sensitive to changes in the partial pressure of CO_2 (PCO_2) 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 equilibrium: 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. (Yang Chang *et al.,* 2004).

Furthermore, Abd El-Moez *et al.,* (2015) indicated that PH values of clay 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 under different soil moisture regimes of 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).

Also, they added that, silty loam and sandy loam soils the PH values decreased gradually under the three soil moisture regimes (M_1 (watering at every 4 days irrigation), M2 (watering at every 6 days irrigation), and M_3 (watering at every 8 days irrigation), 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 soils moisture regimes of M_2 and M3 till 96 days after starting. Moreover, the PH values of sandy loam and loamy sand calcareous soils, 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 (Ponnamperuma, 1966).

The PH of acidic soils decreases following submergence because under anaerobic conditions, ferric iron is used as an electron-acceptor for oxidizing organic matter and during this process acidity is neutralized:

$$Fe_2O_3 + 1/2\ CH_2O + 4H^+ = 2Fe_2^+ + 5/2\ H_2O + 1/2\ Co_2 \ldots (1)$$

In these redox reactions, ferric iron (from amorphous ferric hydroxides) serves as an electron-acceptor and organic matter (CH_2O) as the electron-donor. This reaction results in the neutralization of acidity and increase in PH. A decrease in PH of alkali or calcareous soils is the result of accumulation of carbon dioxide in flooded soil, which neutralizes alkalinity. Moreover, carbon dioxide produced is retained in the flooded soil due to restricted diffusion through standing flood-water layer on the soil surface. This allows large quantities of carbon dioxide to accumulate and form mild acid, which help in neutralizing alkalinity in the soil-floodwater system (see eq. 2 and 3). Moreover, submerged soil provides an ideal environment for reaction between carbon dioxide-generated acid (carbonic acid) and alkalinity.

$$CO_2 + H_2O = H2_CO_3 \quad \ldots\ldots\ldots (2)$$

$$H_2CO_3 = H^+ + HCO_3 \quad \ldots\ldots\ldots (3)$$

Furthermore the addition of OM to the submerged soils clearly decreases PH values after 10 days from submergence, and 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, studied indicate that all PH values under the combination of submergence and OM addition were lower than those obtained under submergence alone (Xie *et al.,* 2012).

Sahrawat (2004a) pointed out, thus accumulation of large amounts of carbon dioxide in submerged soils acts as an ameliorating agent by neutralizing the alkalinity. Adding organic carbonaceous materials, which would generate extra carbon dioxide on decomposition, can enhance the generation of carbon dioxide, especially in soil low in organic matter. However, if the carbon dioxide produced is allowed to escape from the soil-water system, it would result in increasing the PH of the soil-water system. Thus iron reduction and carbon dioxide concentration in submerged soils play a key role in controlling the pH of submerged soils. This, of course, requires optimum temperature (between 25 and 35^{o}C) and availability of easily decomposable organic matter, reducible iron and other electron acceptors such as sulphate and carbon dioxide.

Influence of organic matter

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 (Holah *et al.,* 2015).

In this concern, El- Ashry *et al.,* (2008) found that, with the coast of chemical fertilizers as agriculture all inputs, chicken manure produced the highest uptake of the essential nutrients. Also, found that mixing chicken manure with could low the C/N Ratio and pointed out that N, P, K, Ca and Mg of soil ware increased by application of chicken manure.

Also, urea plus FYM treatment recorded maximum grain yield of wheat. Agronomic efficiency (AE) of N in rice doubled in saturated moisture regime compared to intermittent wetting and drying with application of urea. When a part of N was provided through FYM, this increase was 25% (Pathak *et al.,* 2010).

The balanced application of mineral fertilizers and farm yard manure is very important to protect soil and underground water from potential NO_3^- N pollution while sustaining high productivity in the oasis agro-ecosystem (Sheng-mao *et al.,* 2006).

Furthermore, Siam *et al.,* (2016) pointed out the highest concentration and uptake values of N, P and K were obtained under different soil moisture regime and using fertilizer treatment of : F3: (23 kg N+ 15 kg $P0_5$ + 52 kg K_20/fed + 1.5 ton chicken manure).

The effects of submergence and OM addition on PH values are in full agreement with those obtained by (Grybos *et al.,* 2009 and Neubauer *et al.,* 2013). The presence of native or added organic matter sharpened and hastened the first minimum. Also, in this concern Kaleem and Almas (2012) confirmed the previous results and stated that nitrate abolishes the first minimum decrease. The rapid initial decrease of Eh values was apparently due to release of reducing substances accompanying oxygen depletion before Mn (IV) and Fe (III) oxide hydrates can mobilize their buffer capacity.

Also, Siam *et al.,* (2015), pointed out that PH values showed higher decreases under soil moisture regime fertilizer treatment if compared to the control (without organic matter) when the fertilizer treatment of: (23Kg N + 15kg P_2O_5 + 52kg K_2O/Fed+1.5ton chicken manure) and the greatest decreases of Eh values also were obtained by using the fertilizer treatment of: (23Kg N + 15kg P_2O_5 + 52kg K_2O/Fed+1.5ton chicken manure) if compared to control (inorganic fertilizer alone).

Due to change in chemical kinetics in aerobic and anaerobic soils, the availability of nutrients also changes. Besides, the applied fertilizer, particularly nitrogen, may incur losses due to changes in water stress, and its use efficiency may also differ. Rice growing under different soil water level prevailing under rain fed conditions has largely been ignored (Michel *et al.,* 2004, and Sangita *et al.,* 2013).

Also, Siam *et al.,* (2015) indicated that the organic fertilizer (23Kg N + 15kg P_2O_5 + 52kg K_2O/Fed+1.5ton chicken manure) and (3ton chicken manure) affected PH values in soil solution than those of inorganic fertilizers treatments. In this concern Wade and Ladha (1995) stated that the use of organic matter for rice growing has an advantage to improve the PH buffering capacity of soil, the nutrients availability and retention of soil, suggesting that in may be beneficial to lessen the effects of loss of soil water saturation.

Holah *et al.,* (2016) the highest values of the yield (roots, straw and grain), concentration and the total uptake of Fe and Mn obtained by using the fertilizer treatment of (organic and inorganic in combination) followed by the two rates of inorganic fertilizer treatments.

Furthermore, the reduction of Mn and Fe is one of the most important chemical transformations that occurs in waterlogged soils. Previous studies indicated that water logging significantly increased water soluble Mn^{2+} and Fe^{2} ions. Concentrations in soils Larson *et al.,* (1991) and Favre *et al.,* (2002), they stated that, in wetlands, large quantities of dissolved organic matter (DOM) are solubilized under reducing conditions, which the following processes account for this phenomenon, release of organic matter (OM) from Mn-and Fe-ox hydroxides that undergo reductive did dilution; and iii) desorption of OM from soil minerals due to PH changes. Also, Egrinya Eneji *et al.,* (2001) studied the effect of some animal manures on rice yield and micro nutrients, the manure application increased grain yield and concentration of Fe^{2+} and Mn^{2+}. Furthermore, Siam *et al.,* (2015) revealed that, the advantages of organic fertilizer treatment under soil moisture regime of (23Kg N + 15kg P_2O_5 + 52kg K_2O/ Fed+1.5ton chicken manure) at watering at every 4 days irrigation (M1) recorded the highest values of concentration Fe^{2+} and <n^{2+} in soil solution.

Also, Siam *et al.,* (2016) pointed out the interaction between soil moisture regimes and fertilizer treatments (mineral and chicken manure fertilizer) significantly affected the yield of rice plants, concentrations and the total uptake of N, P and K by the two rice varieties. The highest concentration and uptake values were obtained under soil moisture regime of M1 (at watering at every 4 days irrigation) and using fertilizer treatment of (23Kg N + 15kg P_2O_5 + 52kg K_2O/Fed+1.5ton chicken manure)

In this concern, Watanabe (1984) reported that green manure is bio resource for sustainable agriculture. The relatively lower redox potential under green manuring practice would have attributed to the accumulation of organic metabolism including volatile fatty acids, tartaric acid, phenolic acids like p-hydroxybenzoic, vanilic resulting in reduced conditions in the soil system. The current research reveals that direct seeding, limited irrigation and conoweeding practices can contribute to action of the soil under submerged ecosystem resulting in oxidation of the rhizosphere region and to protect the roots from accumulation of toxic metabolites.

Also, Sahrawat (2005) the decomposition of soil or added organic matter is relatively fast under aerobic conditions where oxygen is the electron acceptor. However, under submerged conditions the supply of free oxygen is low or absent and the decomposition of organic matter depends on the availability of electron acceptors such as ferric iron or sulphate. Moreover, the alternate electron- acceptors (ferric hydroxides or sulphate) are inefficient in the destruction of organic matter compared to oxygen. Consequently the decomposition of organic matter is comparatively slow, inefficient and incomplete under flooded or anaerobic soil conditions. Coupled with retarded rates of organic matter decomposition in submerged soils, the higher primary productivity of wetlands, contribution by biological nitrogen fixation and decreased humification of organic matter lead to preferential (compared to aerobic counterpart soils) accumulation of organic matter in wetland soils and sediments (Sahrawat, 2004b).

Also, Sahrawat (2004b) cites several examples, which show that accumulation of organic C and N in submerged soils is significant in wetland rice double-

Table 4: Changes in organic matter and availability of plant nutrients in soils following their submergence under water (Sahrawat, 2005)

Chemical property	Change (s) following soil submergence
PH	Favours convergence to neutral pH
Organic matter	Favours accumulation of organic C and N
Ammonium-N	Release and accumulation of ammonium favoured
P	Improves P availability, especially in soils high in Fe and Al oxides
K	K improves through exchange of K
Ca, Mg, Na	Favours release of Ca, Mg and Na solution
S	Sulphate reduction may reduce sulphur availability
Fe	Iron a availability improves in alkali and calcareous soils, but Fe Fe toxicity may occur in acidic soils high in reducible Fe
Al	Al toxicity is generally absent, except perhaps in acid sulphate soils
Cu, Zn and Mo	Improves availability of Cu and Mo but not of Zn
Reduction products	Production of supplied and organic acids, especially in degraded soils may cause toxicity or injurious effects to growing plants

cropping, even during short-term experiments. The use of an planted crop in the crop sequence with wetland rice resulted in decreased organic C and total N.

Relatively higher accumulation of organic matter (organic C and total N) in wetland soils makes them attractive for sequestration of C for increasing the fertility of wetland soils and at the same time mitigating greenhouse emissions (Bouchard and Cochran, 2002). Unlike in aerobic soils, such effects can be significant during relatively short periods. For example, Witt *et al.,* (2000) conducted a two-year experiment under irrigated condition to study the effects of crop rotation and residue management on C sequestration and N accumulation, and rice productivity. They found that compared to the rice-rice system replacement of dry-season rice by maize caused a reduction in soil C and N sequestration due to a 33 – 41% increase in the estimated amount of mineralized C and less input from biological N fixation during the dry-season maize crop. There was 11–20% more C sequestration and 5–12% more N accumulation in soils continuously cropped with wetland rice, than in maize-rice rotation with greater amounts in N-fertilized treatments. These results demonstrate the capacity of continuous, irrigated rice systems to sequester C and accumulate N during relatively short time-periods.

As rice straw and other soil organic matter decompose in submerged soil, a sequence of reduction-oxidation (redox) reaction occur that are driven by a variety of microbes. This sequence of microbially mediated reactions is shown as a redox ladder (Suduan *et al.,* 2003), they stated that the oxygen sufficiency of an environment can be indicated by its redox status, which can be roughly indexed by redox potential (Eh) as measured by a platinum and reference electrodes. A high Eh represents oxic (oxygen-rich) conditions and a low Eh represents anoxic (oxygen-poor) conditions. Redox status can also be classified into oxic, sulfidic and methanic status, as different redox reactions occur that correspond to decrease in Eh. They, also metioned that microbes decompose organic matter to obtain energy, and they need oxygen or other oxidized substances such as nitrate (NO_3), manganese [Mn (IV or III)], iron [Fe(III)], sulfate (SO_4^{++}) or carbon dioxide (CO_2) to serve as electron acceptors. In submerged paddy soil, the decay of organic matter will initially consume the dissolved oxygen in water. Dissolved oxygen (O_2) which as an electron-poor substance is reduced to an electron-rich substance (H_2O) because it serves as the electron acceptor while organic matter is being oxidized. (This is an example of a redox reaction). Table 4. When oxygen is depleted, microbes reduce nitrate to nitrogen gas (N_2) (denitrification), and convert the soil from oxic to post-oxic status. In post-oxic status, organic matter continues to decay and oxidized manganese and iron present in solid phases are reduced to soluble manganous (Mn^{++}) and soluble ferrous (Fe^{++}) ions. The continuous decay of organic matter leads to sulfidic conditions, and microbes reduce sulfate to sulfice. Under highly reducing condition (Fig. 2) microbes (methanogens) reduce carbon dioxide to produce methane. This process is defined as methanogenesis and the resulting condition is termed "methanic status". Under post-toxic conditions, soluble manganous and soluble ferrous ions are produced; under sulfidic conditions, dissolved hydrogen sulfide (mainly as HS^-) is produced, when sulfides accumulate, they may precipitate out as ferrous and manganous sulfides (such as FeS and MnS), reducing the accumulation of soluble sulfides to very low concentrations. But if soluble ferric and manganic sources are depleted, sulfidic may accumulate. As a result, sulfidic accumulation and toxicity to rice plants may occur only under specific environmental conditions.

Conclusion

The main electrochemical change that influence the chemistry and fertility of submerged soils and growing of crops such as werland rice include. A decrease in Redox potential (Eh) or reduction of the soil. An 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.

We must recommended that it is better to give rice plants organic and inorganic fertilizer in combination, and use the submergence treatment as the best soil moisture regime to obtain the highest yield of rice.

References

Abd El-Moez, M.R., Sh. Sh. Holah, S.T.Abou Zeid and S. Hanan Siam (2015). Electrochemical changes in soil texture through growth period of rice plants. *International Journal of Chem Tech Research,* **8(6)**: 496-504.

Bahmaniar, M.A. (2008). The influence of continuous rice cultivation and different waterlogging periods on the properties of paddy soils. *Pochvoedenie,* **(1)**: 95-101.

Bouchard, V. and M. Cochran (2002). Wetland and carbon sequestration in Encyclopedia of Soil Science (ed. Lal, R.), Marcel Dekker, New York, pp. 1416-1419.

Bovin, P., F. Favre, C. Hammeeker, J.L. Maeght, J. Delariviere, J.C. Poussin and M. Wopereis (2002). Processes deriving soil solution chemistry in a flooded rice-cropped vertisol: Analysis of long-time monitoring data. *Geoderma,* **110**: 87-107.

Egrinya Eneji, A., T. Honna and S. Yamamoto (2001). Manuring effect on rice grain yield and extractable trace elements in soils. *J. of Plant Nutrition,* **24(7)**: 967-977.

El-Ashry, S.M., S. Siam Hanan and M.R. Abd El-Moez (2008). Ameliorative effect of organic fertilizers in the presence of Mineral fertilizers on lettuce and sorghum and their components. *Australian Journal of Basic Applied Sciences,* **2(4)**: 1246-1257.

Favre, F., D. Tessier, M. Abdelmoula, J.M. Genin, W.P. Gates and P. Bovin (2002). Iron reduction and changes in cation exchanges capacity in intermittently waterlogging soil**.** *Eur. J. Soil Sci.,* **53**: 175-183.

Grybos, M., M. Davranche, G. Gruau P. Petitjean and M. Pedrot (2009). Increasing pH drives organic matter solublilization from wetland soils under reducing conditions. *Geoderma,* **154(1-2)**: 13-19.

Hanan, S. Siam, M.R. Abd El-Moez, S.H. Holah amd S.T. Abou Zeid (2016). Effect of fertilizers treatments and soil moisture regimes on Rice plants (*Oryza sativa* L.) Macro Nutrients by different rice parts of two varieties at harvest. *International Journal of Chem Tech Research,* **9(5)**: 43-59.

Hanan, S. Siam., A.L. Saleh, M.R. Abd El-Moez, Sh.Sh. Holah, and S.T. Abou Zeid (2015). Influence of different moisture regimes and N-fertilization on electrochemical change and some nutrients in the leachate solution growing period of rice plants. *International J. of Basic and Aapplied Science,* **4(3)**: 303-309.

Holah, Sh.Sh. (1989). Effect of silicon on the chemical composition of rice plants. *J. Agric. Sci. Mansoura Univ.,* **14(2)**: 923-934.

Holah, Sh. Sh., S.T. Abou Zeid, M.R. Abd El-Moez and S. Hanan Siam (2016). Effect of fertilizer treatments and soil moisture regimes on Rice plants *(Oryza Sativa* L.) Iron and Manganese Content (mg/pot) by different rice parts of two varieties at harvest. *International Journal of Chem Tech Research,* **9(5)**: 60-71.

Holah, Sh.Sh., S.T. Abou Zeid, S. Hanan Siam and M. Abdel-Hady (2015). Effect of waterlogging and organic matter addition on water soluble Si, PH and Eh values. *International Journal of Chem Tech Research,* **8(4)**: 1557-1562.

Kaleem, A. and K. Almas Microbial (2012). Biomass carbon and nitrogen transformations n a loam soil amended with organic- N sources and their effect on growth and N-uptake in maize. *Ecological Engineering,* **39**, 123-132**.**

Kumar, D., A. Swarup and V. Kumar (1995). Journal of Agricultural Science,125(1)95-98. http://dx. Doi.org/ 10.1017/soo21859600074542.

Larson, K. D., D.A. Graetz and B. Schaffer (1991). Flooded-induced chemical transformation in calcareous agricultural soils of South Florida. *Soil Sci.,* **152**: 33-40.

Michel, V., G. Harm, G. Van der Geest; Daan van Marum, Kess Wattel and J.P. Hijackers Herman (2004). Automated and contimuous redox potential measurements in soil. *Environ. Qual.,* **33**: 1562 – 1567.

Mitsch, W. J. and J.G. Gosselink (1993ed.). Wetlands. 2nd. Van Nostrand Reinhold, New York.

Narteh, L.T. and K.L. Sahrawat (1999). Influence of flooding on electrochemical and chemical properties of West African soils. *Geoderma,* **87**: 179 – 207.

Neubauer, E., W.D.C. Schenkeveld, K.L Plathe, C. Rentenberger, and F. von der Kammer (2013). Hofmann T, The influence of pH iron speciation in podzol extracts: Iron complexes with natural organic matter and iron mineral nanoparticles. *Science of the Total Environment,* **461-462**: 108-116.

Pathak, H., A. Bhatia and N. Jain (2010). Yield and N-use efficiency in rice-wheat system with different soil moisture regimes and fertilizer management. *Current advance in Agricultural Sciences;* **2(2)**:74-76.

Peng, S.B., R.J. Buresh, J.L. Huang, J.C. Yang, Y.B. Zou, X.Y. Zhong, G.H. Wang and F.S. Zhang (2006). Strategies for overcoming low agronomic nitrogen use efficiency in irrigated rice systems in China. *Field Crops Res.,* **96(1)**: 37-47. (doi: 10.1016/J.for. 2005.004.).

Pierce, S.C., M.T. Moore, D. Larsen and S.R. Pezeshki (2010). Macronutrient (N, P, K) and redoximorphic metal (Fe, Mn) allocation in Leersia oryzoides (rice cutgrass) grown under different flood regimes. *Water, Air, and Soil Pollution,* **207(1/4):** 73-84.

Ponnamperuma, F.N., E. Martinez and T. Loy (1966). Influence of redox potential and partial pressure of carbon dioxide on pH values and the suspension effect of flooded soils. *Soil Science,* **101(6)**: 421-431.

Ponnamperuma, F.N. (1965). In "The Mineral Nutrition of the Rice Plant," pp. 295-328 Johns Hopkins Press, Baltimore, Maryland.

Sahrawat, K.L. (2004a). Organic manure accumulation in submerged soils. *Adv. Agron,* **81**: 169-201.

Sahrawat, K.L. (2004b). Ammonium production in submerged soils and sediments. The role of reducible iron. Commun. *Soil Sci. Plant Anal.,* **35**: 399 – 411.

Sahrawat, K.L. (2005). Fertility and organic matter in submerged rice soils. International Crops Research Institute for the Sem-Arid Tropics. *Atancheru,* 324- 502, India.

Sangita, M., A. Nayakak Kumar, P. Tripathi, R. Shahid, P. Bhattacharyya, R. Raja and D.D. Panda (2013). Carbon and nitrogen mineralization kinetics in soil rice-rice system under long term application of chemical fertilizers and farmyard manure. *European Journal of Soil Biology,* **58**: 113-121.

Scalenghe, R., A.C. Edwards, F. Ajmone Marsan and E. Barberis (2002). The effect of reducing conditions on the solubility of phosphours in a diverse range of European agricultural soils. *Eur. J. Soil Sci.,* **53**: 439 – 447.

Sheng-mao, Y., L. Feng-min, S. Dong-rang, G. Tian-wen, W. Jian-guol, S. Bingling and J. Shao-ling (2006). Effect of long term fertilization on soil productivity and nitrate accumulation in Gansu Oasis. *Agric. Sci. In China,* **5**: 57-67.

Sudhalakhsmi, C.V. Velu and T. M. Thiyagarajan (2007). Redox Potential in the Rhizosphere Soil of Rice Hydrid as Mediated by Crop Management Options. *Research Journal of Agriculture and Biological Science,* **3(4)**: 299 – 301.

Suduan, Gao, K. Tanji Kenneth and C. Scardaci Steven (2003). Incorporating straw may induce sulfide toxicity in paddy rice (http: danr, ucop. Edu/calag).

Synder, C.S. and S. Nathan (2002). Effect of soilo flooding and drying on phosphorusre actions. News and Views. A regional newsletter published by the Potash & Phosphate Institute (PPI) and the Potash & Phosphate Institute of Canada (PPIC).

Venterea, R.T., M. Burger and K.A. Spokas (2005). Nitrogen oxide and methane emissions under varying tillage and fertilizer management. *J. Environ. Qual.,* **9: 34(5):** 1467-1477.

Wad, LJ. and J.J. Ladha (1995).The fate of organic matter and nutrients in lowland rice systems. In: SOIL Organic Matter Management for Sustainable Agriculture, ACIAR/ Proceeding, No., 56. Pp: 115-119 Canberra ACT. Australia.

Watanabe, I. (1984). Use of green manures in North East Asia. In: *Organic matter and rice IRRI,* Manila, Philippines. **99**: 22-234.

Witt, C., K.G. Cassman, D.C. OIK, U. Biker, S.P. Liboon, M.I. Samson and J.G. Ottow (2000). Crop rotation and residue management effects on carbon sequestration, nitrogen cycling and productivity of irrigated rice systems. *Plant Soil,* **225**: 263 – 278.

Xie, J., D. Wang, J. van Leeuwen, Y. Zho, L. Xing and Ch. W.K. Chow (2012). PH modeling for maximum dissolved organic matter removal by enhanced coagulation. *Journal of Environ. Sci.,* **24(2)**: 276-283.

Yang Chang, Ming Yang, Lin hang Yang, Yang Xing and Ouyang Zhu (2004). Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agricultural Water Management,* **70**: 67-81.