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Research Paper

Influence of different moisture regimes and n-fertilization on electrochemical changes and some nutrients in the leachate solution during growing period of rice plants

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Abstract

A pot experiment was conducted in the greenhouse of NRC, Dokki, Giza, Egypt, using clay loam soil to study the effect of different moisture regimes (M1, M2 and M3) and fertilizer treatment(F0, F1, F2, F3, and F4) on electrochemical change and concentration of some nutrients in the leachate solution during growing period of rice plant (variety Sakha 102).
The important results could be summarized in the follows: PH values showed the highest decreases under all the fertilizer treatments when the moisture regime of M1 was used followed by M2 and M3 in descending order. Furthermore, pH values showed higher decreases when the fertilizer treatment of F3 was used followed by F4, F2, F1 and F0 in decreasing order.
Under all soil moisture regimes and fertilizer treatment Eh values sharply decreased during the 12 days after starting (DAS), then they decreased to the lowest values at 24 DAS. The soil moisture regimes decreased Eh values in soil solution during the growth period of rice plants. The highest decreases were obtained under soil moisture of M1 followed by M2 and M3 in descending order. The greatest decreases of Eh values were obtained by using the fertilizer treatment of F3 followed by F4, F2, F1 and F0 in descending order.
Results showed that , P, K+, Fe++ and Mn++ concentrations in soil solution were higher in the early stages of rice plans and reached a peak at 24 days after staring (DAS), then the concentrations of all the studied nutrients gradually decreased with increasing the growth period.
Inorganic N-fertilizer treatments (F1 and F2) gave higher nutrients concentrations under all soil moisture regimes as compared with N-organic fertilizer treatment alone (F4). Combination of organic and inorganic fertilizer (F3) gave the higher nutrients concentration in the leachate solutions followed by fertilizer treatments of F2, F1, F4 and F0 in decreasing order.
The highest values of , P, K+, Fe++ and Mn++ concentrations were obtained at 24 days after starting (DAS) by using the fertilizer treatment of F3 under soil moisture regime of M1 (F3 M1¬) followed by F3M2 and F3M3 in decreasing order, while the lowest values were obtained at 72DAS under soil moisture regime of M3 and unfertilized treatment F0 (M3F0).

Keywords: *Moisture Regimes; Nitrogen Fertilizers; Soil Solution; Rice Plants; Macro and Micronutrients; Submergence; Eh; Ph; Organic Fertilizers.*

1. Introduction

Soil, water and fertilizer management are considered the most important factors in rice production. Nitrogen is frequently the most limiting nutrient in rice production. It is usually low in most arias under arid conditions.
The main electrochemical changes in submerged soils that 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. Flooding (submergence) causes an increase in the content of NH_4^+, P, K^+, Ca^{++} and Mg^{++}. 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 looses 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 [1], [2], [3]. The supplementary and complementary use of organic manure and chemical fertilizers will augment the efficiency of both substances to maintain a high level of soil productivity and rice production [4]. The benefits of organic amendments for rice production have been reported by many workers [6]. There is, however, lake of knowledge on the effect of various organic amendments on the changes in the soil solution nutrient composition overtime of flooded soils. Such information would be extremely useful for developing suitable management practices for their efficient use in rice cultivation.

This experiment was conducted to study the influence of different moisture regimes and fertilizer treatments on electrochemical change and concentration of some nutrient in the leachate solution during growing period of rice plants.

2. Materials and methods

Pot experiment was conducted in the greenhouse of NRC, Dokki, Giza, Egypt, to study the influence of different moisture regimes and fertilizer treatment on electrochemical changes and concentration of some nutrients in the leachate solution during growing period of rice plants.

Soil samples at a depth of (0-30cm) from the surface layer of clay loam soil has a pH of 7.9; 1.9% O.M; 2.61% $CaCO_3$; 26.7% sand, 35.8% silt and 37.5% clay. A total of 45 plastic pots, containing air dried soil were arranged in a complete randomize design.

The irrigation treatments were used as follow: M_1, M_2 and M_3, watering at every 4, 6 and 8 days irrigation interval respectively and the fertilizer treatments were:

F_0: control (11.5kg N+ 3. 75kg P_2O_5 + 13kg K_2O /fed).

F_1: (46kg N + 15kg P_2O_5 + 52Kg K_2O/Fed).

F_2: (69kg N+ 15Kg P_2O_5 + 52 Kg K_2O/Fed.).

F_3: (23Kg N + 15Kg P_2O_5 +52Kg K_2O/ Fed + 1.5 ton chicken manure).

F_4: 3 ton chicken manure.

Four-week old seedling of Sakha 102 was transplanted at rate of nine plants per pot containing different treatments. Each treatment was replicated thrice:

Soil leachate solution were collected by gravity, in 250ml conical flasks under/ pravin soil for measurement of pH, Eh, NO_3^+, NH_4^+, P, K^+, Fe^{++} and Mn^{++} at the intervals of 0, 12, 24, 48, 72 and 96 days after starting (DAS).

All the leachate solutions were collected and all the previous nutrients were determined as described by [6], [7], and [8].

3. Results and discussions

3.1. Electrochemical changes

PH -values: Results in Table (1) show that the changes in pH in leachate solution during the experiment were closely related to fluctuation in the soil water regimes and the different fertilizer treatments. PH values decreased in the leachate solution under all the fertilizer treatments, and these decreases were more pronounced when the fertilizer treatment of F_3 (23kg N + 15Kg P_2O_5 + 52 Kg K_2O/Fed. + 1.5 ton chicken manure) was used as compared with the other fertilizers treatments. The decrease in pH was declined gradually for the F_3 treatment from pH 8.0 to 7.0, 7.4 and 7.6 at the day after starting (DAS) and the soil moisture of M_1, M_2 and M_3, respectively for rice variety of Sakha 102. Confirm these results Venterea, et al., [9] who stated that pH values of the soil solution followed similar trends, and decreased in the alkaline and calcareous soils with increasing soil moisture regimes. They attributed this effect to the respiration of aerobic bacteria, and production of organic acid from the decomposition of organic matter and also may be due to the changes in the partial pressure of CO_2 through the Na_2CO_3-H_2O-CO_2 and $CaCO_3$-H_2O-CO systems.

Data also reveal that pH values showed the highest decreases under all the fertilizer treatments when the moisture regime of M was used, followed by M_2 and M_3 in decreasing order and this mean that the M_1 treatment affected the pH values more than other two moisture levels (M_2 and M_3).

Concerning the fertilizer treatments, pH values showed higher decreases when F_3 was used followed by F_4, F_2, F_1 and F_0 in decreasing. Order and this mean that the organic fertilizer (F_3 and F_4) affected pH values in soil solution than those of inorganic fertilizers of F_1 and F_2. In this concern, Wade and Ladha [10] stated that the use of organic matter for rice growing has an advantage to improve the pH buffering capacity of soil and the nutrients availability and retention of soil, suggesting that it may be beneficial to lessen the effects of loss of soil water saturation. Results also 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., [11] who stated that pH values increased during days 1-4 and then was a sharp decline on days 4- followed by a gradually decline.

Eh (redox potential): Table (1) shows the changes 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. The lowest values were found at 24DAS. Eh values decreased to 10mv, 95mv and 123 mv by using the fertilizer treatment of F_3 under soil moisture regimes of M_1, M_2 and M_3 respectively.

Table 1: Changes in Ph Values and Redox Potenial (Eh) in Soil Solution during the Growth Period of Rice as Affected by Different N-Treatments and Soil Moisture Regimes.

Fertilizer Treatment	pH values Day after starting (DAS)						Redox potential Days after staring (DAS)					
	0	12	24	48	72	96	0	12	24	48	72	96
	M_1						M_1					
F_0	8.0	7.7	7.3	7.2	7.2	7.1	430	58	38	85	248	258
F_1	8.0	7.8	7.3	7.3	7.2	7.2	430	48	29	88	252	261
F_2	8.0	7.8	7.5	7.3	7.3	7.2	430	42	42	90	258	256
F_3	8.0	7.0	7.0	7.1	6.8	7.1	430	65	10	75	105	128
F_4	8.0	72	7.2	7.2	7.0	7.1	430	90	15	95	125	162
	M_2						M_2					
F_0	8.0	7.8	7.5	7.5	7.7	7.7	436	200	170	251	312	318
F_1	8.0	7.8	7.5	7.6	7.5	7.4	430	210	178	262	318	323
F_2	8.0	7.8	7.5	7.5	7.4	7.4	430	214	182	268	315	318
F_3	8.0	7.3	7.4	7.4	7.1	7.2	430	109	92	145	170	185
F_4	8.0	7.5	7.5	7.6	7.5	7.6	430	143	110	182	217	224
	M_3						M_3					
F_0	8.0	7.9	7.6	7.7	7.7	7.8	430	217	192	265	338	345
F_1	8.0	7.9	7.7	7.6	7.7	7.8	430	228	190	270	341	346
F_2	8.0	7.9	7.7	7.6	7.7	7.7	430	233	200	278	341	343
F_3	8.0	7.6	7.6	7.6	7.4	7.5	430	151	123	190	222	227
F_4	8.0	7.8	7.7	7.6	7.6	7.7	430	175	141	238	239	249

The moisture regimes, irrespective of fertilizer treatments decreased the Eh values in soil solution during the growth period of the rice variety Sakha 102. The highest decreased were obtained under soil moisture regime of M_1 followed by M_2 and M_3 in decreasing order. Results show also that, regardless of soil moisture regimes, the greatest decreased of Eh values were obtained by using the fertilizer treatment of F_3 followed by F_4, F_2, F_1 and F_0 in descending order. This mean that the addition of organic fertilizer treatments (F_3 and F_4) resulted in greater decrease of Eh as compared with inorganic fertilizer treatments (F_1 and F_2) and control one (F_0). This trend may be attributed to increased microbial respiration stimulated by organic matter (Michel, et al., [4], Sudhalakhsmi, et al., [12] and Kaleem and Almas, [14] or due to the release of reducing substances accompanying oxygen depletion before Mn (IV) and Fe (III) oxide hydrates can mobilize their buffer capacity (Ponnamperuma, [14] and Sahrawat, [15]. Confirm the previous results of Eh, Mohamed et al., [16] who reported that Eh values dropped sharply during the first and second week of prior flooding and were lowered at 30 days crop growth stage. The same author stated also that addition of organic matter caused a steep fall in Eh, because of the accumulation of reducing substances as a result of O_2 depletion.

3.2. Concentration of some nutrients in leachate solution

Ammonium Nitrogen (NH_4^+ -N) Results in Table (2) show that NH_4^+ -N concentration in soil leachate solution was higher in the early stages of the rice growth till 24 days after starting, then it gradually decreased with the growth period of rice plants. Concern the fertilizer treatments, NH_4^+ - N concentration increased in the leachate solution to a peak at 24 days after starting, but differ in their values as affected by fertilizer treatments, then declined to very low levels at about 96 days of starting (DAS). Confirm these results (Nagarajah et al. [17], Hanan [18] and Zhang et al., [19] who found that the decrease in NH_4^+ -N over the initial values at later stages was attributed to crop uptake, gaseous loss of NH_4^+ -N as NH_3 and incorporation into the body tissue of micro-organisms.

Inorganic fertilizer treatments (F_1 and F_2) gave higher NH_4^+ -N concentration under all soil moisture regimes as compared with organic fertilizer treatment alone (F_4). Combination of organic and inorganic fertilizer (F_3) gave the highest NH_4^+ -N concentration in the leachate solutions followed by fertilizer treatments of F_2, F_1, F_4 and F_0 in decreasing order. In this concern, Deka Medli et al., [20] indicated that organic matter had to undergo decomposition and mineralization, which increased the concentration of NH_4^+-N in soil solution during rice growth period.

Data also reveal that the rate of NH_4^+-N concentration in solution increased by using the higher level of soil moisture regimes (M_1) followed by M_2 and M_3 in descending order regardless the effect of fertilizer treatments.

Came to the same results, Sahrawat [15], reported that the loss of ammonium by leaching is more pronounced in water logged soil than in well drained soils. The obtained results concerning concentration of NH_4^+-N in soil leachate solution are in good agreement with those obtained by [21], [18]. Data also show that the concentration of NH_4^+-N reached to traces amounts under soil moisture M_3 at 96 DAS under all the used fertilizers.

Data in Table (2) reveal that the highest of NH_4^+-N concentration were obtained at 24 DAS by using the fertilizer treatment of F_3 under soil moisture regime of M_1 followed by F_3M_2 and F_3M_3 in decreasing order, while the lowest values were obtained at 72 DAS under the soil moisture regime of M_3 and unfertilized treatment F_0 (M_3F_0). The other NH_4^+-N concentration were fluctuated in between.

Nitrate Nitrogen (NO_3^--N): results presented in Table (2) show that NO_3^--N concentration in the leachate solution took the same trend of NH_4^+-N concentration while the highest peak of NO_3^--N concentration were obtained at day after starting, then decreased sharply with time. The highest peaks of NO_3^--N were obtained by using F_3 followed by F_2, F_1, F_4 and F_0 in decreasing order. This was true under all the soil moisture regimes. Regardless the effect of fertilizers treatments, the highest NO_3^--N concentration values were obtained under the highest level of soil moisture M_1 followed by M_2 and M_3 in decreasing order.

Table 2: Changes in Ammonium and Nitrate Nitrogen Concentration (Ppm) in Soil Solution during the Growth Period of Rice as Affected by Different N-Treatments and Soil Moisture Regimes.

Fertilizer Treatment	NH_4^+ concentration (ppm)						NO_3 concentration (ppm)					
	Day after starting (DAS)						Days after staring (DAS)					
	0	12	24	48	72	96	0	12	24	48	72	96
	M_1						M_1					
F_0	3	6.00	7.25	4.10	1.95	0.95	20	28	2.10	0.41	0.22	00
F_1	3	9.10	12.89	7.10	3.15	2.10	20	39	7.12	1.18	0.12	00
F_2	3	10.35	14.85	8.65	5.32	3.10	20	45	8.15	1.95	0.48	00
F_3	3	14.65	19.25	12.12	9.10	4.10	20	49	10.25	2.15	0.62	00
F_4	3	8.55	11.65	6.45	2.45	1.95	20	35	3.10	0.68	0.38	00
	M_2						M_2					
F_0	3	5.10	6.25	3.25	1.15	0.25	20	27	1.55	0.21	00	00
F_1	3	7.95	11.45	5.13	2.20	0.95	20	35	4.00	0.50	00	00
F_2	3	9.15	12.25	6.35	3.38	1.55	20	41	4.75	0.81	00	00
F_3	3	12.25	16.45	9.16	5.25	2.15	20	46	5.10	0.82	00	00
F_4	3	7.45	10.15	4.80	1.95	0.65	20	31	2.28	0.38	00	00
	M_3						M_3					
F_0	3	4.15	5.15	1.85	00	00	20	23	0.95	0.10	00	00
F_1	3	6.10	8.25	4.15	1.35	00	20	30	2.20	0.31	00	00
F_2	3	7.25	9.10	5.25	2.80	00	20	35	2.98	0.42	00	00
F_3	3	10.20	12.22	6.35	2.95	00	20	39	3.75	0.55	00	00
F_4	3	3.35	7.85	3.75	1.15	00	20	28	1.35	0.25	00	00

Results show that the lowest values of NO_3^--N in the soil solution under rice plants reached to the trace amounts at 96 DAS by using the soil moisture regimes of M_2 and M_3. In this concern, (Sheng-mao, et al. [22] and Zhang, et al., [19] found that under prolonged submergence in rice culture, nitrate leach out of the root zone and denitrify before the plants are able to utilize the nitrogen. This is due to the strong reductive conditions in flood rice cultures. Intensity of leaching depends also on the rate of percolation of water through the soil.

The interaction between fertilizer treatments and soil moisture regimes on NO_3^--N concentration throughout the growth period of the rice plants took the same trend of NH_4^+-N concentrations. The obtained results are in good harmony with those of [15], [18], [22], [19] who stated that intensity of nitrogen leaching depends on the rate of percolating of water though the soil. They also found that loss of NO_3^--N by leaching increased by increasing the amount of soil moisture levels, and the interaction of fertilizers (sources and rates) and water regimes gave a highly significant increase in total losses of NO_3^--N in the leachat solution.

Phosphorus: Regardless of the fertilizer treatments, results in Table (3) show that the highest P concentration was found under the soil moisture regime of M_1, followed by M_2 and M_3 in decreasing order. Phosphorus concentration in the soil leachate solution increased gradually and reached a peak at 24 day after starting (DAS), there after sharply decreased till 96 DAS. Conform these results Mukherjee and Mandal (1) who stated that the availability of P at all the stage crop growth decreased by increasing in soil water stress and the advancement in crop growth. Results show that the peak values varied with the fertilizer treatments.

The peak values under rice plants were as follows: F_3, F_2, F_1, F_4 and F_0 in decreasing order .Under soil moisture regime of M_1, the P concentration in solution under rice variety of Sakha102 reached the trace amounts by using the fertilizer treatments of F_0 and F_4 at 72 DAS, while it reached this level when the fertilizer treatment of F_1, F_2 and F_3 were used at 96 DAS at M_1 and M_2.

Under soil moisture regime of M_3 P concentration reached the trace amounts at 48 DAS by using F_0, while by using F_1, F_2, F_3 and F_4, P concentration reached to the same levels (trace amounts) at 72 DAS. These results mean that P concentrations in soil solution greatly affected by soil moisture stress (M_3) than the other two soils moisture regimes ($M_2$and M_1).

The increase in P-concentrations in soil solution from the zero time till 24DAS may be attributed to a) release of P from organic matter, b) increase in solubility of calcium phosphate associated with the decrease in pH caused by accumulation of CO_2 in soils [23]. And c) may be attributed to the Eh decrease upon [24].

Concerning P-concentration in the soil leachate solution for the used rice variety, the highest P-concentration value was occurred at 24DAS and under fertilizer with F_3 and using soil moisture M_1 (1.82 ppm), while the lowest P concentration values were obtained at 48 and 72DAS.

Potassium: Results in Table (3) reveal that K-concentration in soil solution increased under all the soil moisture regimes (M_1, M_2 and M_3) and reached a peak at 24DAS and declined there after with time till 96 DAS. Generally, regardless of the fertilizer treatments, all the K-concentration values were higher at soil moisture regime of M_1 than M_2 and M_3. Confirm these results Pratt [25], [26], [18] who reported similar results indicating that the constraint head of water on the soil surface resulted in greater downward percolation of soil solution in a waterlogged soil than in a well-drained soil, and they added that the losses of the cations (K, Ca and Mg) by leaching increased by increasing the amount of water added to the soil.

As regards to the effect of fertilizer treatments, the addition of F_3 treatment, caused the highest increase in K concentration values in the soil solution under the rice variety Sakha 102, followed by F_2, F_1, F_4 and F_6 treatments in descending order. This mean that F_2 and F_1 (inorganic fertilizer treatments) increased K-concentration in the soil solution than F_4 (organic fertilizer treatment). Data also show that addition of organic matter in combination with inorganic fertilizer (NPK) increased K-concentration in the soil solutions when compared with inorganic (F_1 and F_2) and organic (F_4) each alone. These increases in K-concentration in soil solution may be due to the higher increase in soil solution of Fe^{+2} and Mn^{+2} which caused by organic matter, which release K from the exchange complexes.

Table 3: Changes in Phosphorus and Potassium Concentration (Ppm) In Soil Solution during the Growth Period of Rice as Affected by Different N-Treatments and Soil Moisture Regimes.

Fertilizer Treatment	Phosphorus concentration (ppm) Day after starting (DAS)						Potassium concentration (ppm) Days after staring (DAS)					
	0	12	24	48	72	96	0	12	24	48	72	96
	M_1						M_1					
F_0	0.1	0.62	1.10	0.40	00	00	16	33	62	29	18	8
F_1	0.1	1.00	1.43	0.61	0.10	00	16	44	77	40	28	17
F_2	0.1	1.34	1.55	0.68	00	00	16	52	89	51	34	23
F_3	0.1	1.61	1.82	0.79	0.12	00	16	61	98	62	39	29
F_4	0.1	0.68	1.25	0.60	00	00	16	39	71	38	24	14
	M_2						M_2					
F_0	0.1	0.31	0.80	0.30	00	00	16	27	38	18	11	6
F_1	0.1	0.44	1.31	0.42	00	00	16	34	63	32	20	13
F_2	0.1	0.91	1.38	0.52	00	00	16	43	74	41	24	16
F_3	0.1	1.10	1.61	0.58	00	00	16	52	86	53	31	21
F_4	0.1	0.35	0.86	0.50	00	00	16	30	55	27	15	9
	M_3						M_3					
F_0	0.1	0.24	0.46	00	00	00	16	19	28	10	5	2
F_1	0.1	0.33	1.00	0.39	00	00	16	25	39	18	12	9
F_2	0.1	0.54	1.18	0.40	00	00	16	31	49	23	17	12
F_3	0.1	0.81	1.40	0.41	00	00	16	38	61	31	20	16
F_4	0.1	0.82	0.61	0.22	00	00	16	22	34	5	10	7

Data in Table (3) show that the highest K-concentration values in soil solution under rice plants as affected by the soil moisture regimes and fertilizer treatments were obtained by using soil moisture of M_1 and fertilizer treatment F_3 at 24

DAS (98 ppm), while the lowest ones were obtained by using soil moisture of M_3 and unfertilized (F_0) at 96DAS (2ppm).

Iron (Fe): Results presented in Table (4) show that Fe concentration in the soil solution under all fertilizer treatments and soil moisture regimes increased gradually and reached a peak at 24 DAS. Under soil moisture regime of M_1, Fe concentration decreased gradually after the peak till 72DAS then reached to the trace amounts at 96DAS. Under soil moisture regime of M_2, Fe concentration in soil solution under rice plants reached to the minimum levels at 48 DAS and 72DAS for the (F_0, F_1 and F_2) and (F_3 and F_4), respectively then they reached to the trace amounts at 72 and 96 DAS, respectively. Concerning Fe-concentration in soil solution values under soil moisture regime of M_3 and all the fertilizer treatments, they reached to the trace amounts after the peak, i.e. 48 DAS.

Results show that the highest F_2 concentration in soil solutions regardless the fertilizers treatments were obtained under soil moisture regime of M_1 followed by M_2 and M_3 in decreasing order. Furthermore.

Table 4: Changes in Iron and Manganese Concentration (Ppm) in Soil Solution during the Growth Period of Rice as Affected by Different N-Treatments and Soil Moisture Regimes.

Fertilizer Treatment	Iron concentration (ppm) Day after starting (DAS)						Manganese concentration (ppm) Days after staring (DAS)					
	0	12	24	48	72	96	0	12	24	48	72	96
	M_1						M_1					
F_0	0.3	2.3	2.8	0.8	0.3	00	0.1	1.2	1.8	0.4	00	00
F_1	0.3	2.4	3.0	1.3	0.6	00	0.1	1.3	1.9	0.7	00	00
F_2	0.3	2.6	3.2	1.5	0.8	00	0.1	1.4	2.1	0.8	00	00
F_3	0.3	16.2	19.2	8.1	2.6	00	0.1	2.1	3.2	1.7	00	00
F_4	0.3	8.8	11.6	4.3	1.7	00	0.1	1.8	2.5	1.4	00	00
	M_2						M_2					
F_0	0.3	1.3	1.6	0.3	00	00	0.1	0.6	1.1	00	00	00
F_1	0.3	1.5	1.9	0.7	00	00	0.1	0.7	1.4	00	00	00
F_2	0.3	1.6	2.0	0.8	00	00	0.1	0.7	1.5	00	00	00
F_3	0.3	6.2	9.4	3.1	1.5	00	0.1	1.0	2.5	00	00	00
F_4	0.3	3.7	6.2	2.2	1.0	00	0.1	0.8	2.0	00	00	00
	M_3						M_3					
F_0	0.3	0.6	0.7	00	00	00	0.1	0.3	0.4	00	00	00
F_1	0.3	0.7	0.9	00	00	00	0.1	0.5	0.7	00	00	00
F_2	0.3	0.8	0.90	00	00	00	0.1	0.6	0.8	00	00	00
F_3	0.3	4.2	2.8	00	00	00	0.1	0.9	1.6	00	00	00
F_4	0.3	1.4	1.7	00	00	00	0.1	0.7	1.0	00	00	00

Results show that the different fertilizer treatments greatly affected Fe concentration in soil solutions obtained throughout the growth period of rice plants. The highest Fe concentration in soil solution under all soil moisture regimes was found by using F_3 followed by F_4, F_2, F_1 and F_0 in decreasing order. This mean that the organic and inorganic fertilizer treatments F_3 and F_4 (organic treatment) affected the Fe concentration in soil solution than the inorganic fertilizer treatments (F_1 and F_2). These results of Fe were not identical with those obtained by NH_4^+, NO_3^- P and K concentrations in soil solution (Tables 2 and 3), which gave the highest values by using F_3 followed by F_2, F_1, F_4 and F_0 in decreasing order. Generally, the F_3 (organic in combination with inorganic fertilizers) was the best in affecting the concentration of the nutrients in soil solution. In this concern Deka Meldhi et al., [20] stated that the addition of organic matter particularly was reported to accelerate the process of reduction in soil, by decreasing the redox potential and increasing PCO_3.

Manganese (Mn): Results presented in Table (4) indicate that Mn concentration increased gradually and reached a peak at about 24 DAS. These results are true under the soil moisture regimes and all the fertilizer treatments. Under soil moisture regime of M_1, Mn- concentration in soil solutions for the rice plants, decreased after the peak and reached the minimum Mn concentration at 48 DAS, then reached to the trace amounts at 72 DAS. Under the soil moisture of M_2 and M_3, Mn-concentration in the soil solutions after the peak (24DAS) reached to the trace amounts at 48 DAS for all the fertilizer treatments. These results are in line with those of Deka Meldhi et al., [20] who stated that the kinetics of soil solution Mn^{+2} followed the same pattern as that of Fe^{+2}. The concentrations of soil solution Mn^{+2} increased to a peak at two weeks after flooding and decreased thereafter. The increases in soil solution Mn^{+2} on flooding were due to reduction of Mn^{+2} (Ponnamperuma, [23], whereas, the decrease thereafter was due to precipitation of Mn as $MnCO_3$, [27]. Reduction of Mn concentration in soil solution with time was mainly due to vigorous absorption and assimilation of nutrient by rice plants, [28].

Results show that Mn concentration was greatly affected with soil moisture regimes (M_1, M_2 and M_3). Regardless of fertilizers treatments, soil moisture M_1 gave the highest values of Mn concentrations in soil solutions throughout the growth period of the rice plants, followed by M_2 and M_3 in decreasing order.

Results also show that the different fertilizer treatments greatly affected Mn- concentration in soil solutions. The highest values of Mn concentration were obtained by using the fertilizer treatment F_3 followed by F_4, F_2, F_1 and F_0 in descending order. This means that the organic fertilizer affected Mn-concentration in soil solution than inorganic fertilizer as shown by Fe concentrations. Generally the concentration of Mn in soil solution under soil moisture regimes and different fertilizer treatments were lower than those obtained for Fe concentrations under the same conditions.
The highest values of Fe and Mn concentrations in soil solutions were obtained at 24DAS by using the fertilizer treatment of F_3 and soil moisture regime of M_1, while the lowest Fe and Mn concentration were at M_3 F_0. The obtained results of Fe and Mn concentrations are in good agreement with those reported by [27], [23], and [20] who stated that the increase of Fe^{+2} concentration in soil solution seems to relate to the organic carbon content of the soil. Thus reduction, which effect Fe^{+2} concentrations in soil solution, is enhanced by addition of organic substance in soil, especially those low in organic carbon content. The higher Fe^{+2} and Mn^{+2} concentrations in soil solution appeared to be due to the anaerobic microbial activity and chemical biological reduction. They added that the increase in the solubility of Fe and Mn under saturated moisture condition in the soil appeared to the largely influenced by a combination of low redox potential and low pH caused by the application of N and /or organic matter during the incubation period.

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