EFFECT OF IRRIGATION REGIMES AND FERTILIZERS TO Eh IN THE PADDY SOIL OF THE RED RIVER DELTA, VIETNAM

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ABSTRACT

This paper presents the effects of different irrigation regimes and fertilizer to the oxidation-reduction potential (Eh) of soil. When dry soil is submerged, the Eh decreased rapidly within 2 weeks from 245 mV down to -220 mV. Then Eh slightly fluctuated except for withdrawal of water. Withdrawal water to the surface exposure or crack will increase the Eh from 105 to 150 mV. In field conditions, the soil was submerged before transplanting so Eh was low and ranged from -100 mV to -165 mV; except for withdrawal of water level Eh increases to 234 mV. Fertilizer organic or inorganic also affects the oxidation-reduction potential. The organic fertilizer decreases Eh more than the control and mineral fertilizer (urea). Beside of watering and fertilizer regime, the Eh also depends on the presence and growing period of rice plants.

Keywords: irrigation regime, rice, red river delta.

INTRODUCTION

Vietnam is a traditional agricultural country with rice cultivation, big amount of water proportion should be used for rice production. Submerge irrigation regime and not rational fertilization do not only waste natural resources but also change the soil oxidation-reduction potential (Ponnamperuma, 1985; Van Huy Hai, 1986; Yamane and Sato, 1970; and Yu-Tian-ren, 1985.), and create toxicants in soil such as methane (Yong-Kwang Shin *et al*., 1996), Fe and Mn (Нгуен Суан Хай, Нгуен Тхи Бич Нгует, 2011).

Within the scope of this paper, the irrigation and different types of fertilizers has studied in order to examine how changes in soil oxidation-reduction potential, from which propose suitable irrigation regime for rice cultivation in Red River Delta.

SUBJECTS AND METHODS

Study subjects

- Rice varieties: DT - 28. The rice growth, development and yield
- Red River alluvial soils with slight acidic - neutral reaction in Hoai Duc district, Ha Noi (Eutric Fluvisols)
- Irrigation regime
- Organic and inorganic fertilizers

Research methods

The experimental formula

The formula in the laboratory:

- **Formula-1** (CT1)**:** 5 kg soil, unfertilized, regularly irrigated.
- **Formula-2** (CT2)**:** 5 kg soil + 2.5 g urea, regularly irrigated.
- **Formula-3** (CT3)**:** 5 kg soil + 150 g compost + 2.5 g urea, regularly shallow irrigated.
- **Formula-4** (CT4)**:** 5 kg soil + 150 g organic + 5.43 g urea, shallow and exposure irrigated (after 29 days submerged, then shallow).
- **Formula-5** (CT5)**:** 5 kg soil + 150 g organic + 5.43 g urea, saturated moisture keeping.
- **Formula-6** (CT6)**:** 5 kg soil + 150 g straw + 5.43 g urea, irrigated regularly shallow.

The formula in the field experiment:

- **Control** (CT1)**:** regular shallow irrigation, inorganic + organic fertilizer;
- **Formula-2** (CT2)**:** shallow and exposure irrigated, inorganic + organic fertilizer;
- **Formula-3** (CT3)**:** watering saturated moisture, inorganic + organic fertilizers;
- **Formula-4** (CT4)**:** regular shallow irrigation, no fertilizer;
- **Formula-5** (CT5)**:** regular shallow irrigation, only organic fertilizers.

Description of formulas with experimental watering regimes

a) The control (CT1): Surface water layer in the fields of rice growing period is maintained as follows: green recovery phase cultures to maintain 20-30 mm deep layer of surface water, if raining- remove the water back 20-30 mm in 01 days. From shooting to ripening, maintaining 30-60 mm layer of water, having increased rainfall depth 60-90 mm, to dry naturally for 30-60 mm depth. 10-15 days before harvest water drained.

b) The formula shallow-exposure irrigation (CT2): Field of surface layers at different stages of growth is maintained as follows:

- Phase transplanted to green recovery: maintaining surface water layer 20-30 mm, having rain - draining back to 20-30 mm in one day.
- Shooting stage: from 30-60 mm field of surface layer, to dry naturally to reveal the ground 1-2 days,

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irrigation to 30-60 mm (if raining - also have to drain in 1 day), irrigation to 30-60 mm. The end of shooting: surface water draining 10-day field exposure.

- Phase to ear: 30-60 mm layer of surface water field, to drain a natural ground 1-2 days to 30-60 mm irrigation, rain having similar shooting.
- Flowering period: 30-60 mm layer of surface water field, to drain naturally, exposing the ground, irrigate immediately to 30-60 mm of rain have increased 60-90 mm depth to drain naturally, exposing ground, irrigate immediately to 30-60 mm.
- Green-ripe stage: 30-60 mm layer of the field, to drain naturally, exposing the ground 1-3 days, 30-60 mm irrigation on rain having similar shooting. 10-15 days before harvest draining fields.

c) Irrigation moisturizing formula (CT3): Maintain soil moisture in the growing period as follows:

- Phase transplanted to green recovery: maintaining surface water layer 20-30 mm field, having returned to remove rain water from 20 to 30 mm in one day.
- The phases shooting, ear and green-ripe, when soil moisture is reduced to the lower 60%, 70% and 80% of saturation, irrigate to increase soil moisture reached moisture saturation.
- Flowering period: maintain class 30-60 mm field of surface water to drain naturally then irrigate right to 30-60 mm (if rain having similar treatment of other formulas). Prior to harvest 10-15 days do not irrigate.

d) The formula CT4: CT4 regularly irrigated shallow, not fertilizer

e) The formula CT5: CT5 regularly irrigated shallow, only organic fertilizer.

Experimental conditions

The experimental formulas differ only in water regime (water level, irrigation volume and rate, and soil exposure time), the following factors: variety, crop, cultivation techniques, fertilizer regime are the same. Execution time was in 2010. The experiment repeated 3 times to get average values.

RESULTS AND DISCUSSIONS

Research results of experimental soil

Experimental zone located at agricultural meteorology station of Institute of meteorological science and the environment on Kim Chung commune, Hoai Duc district, 13 km West of Hanoi. This soil has large area and typical for the Red River Delta. Soil has a neutral reaction (pH = 6.8), humus content of 2.6% and 0.11% total nitrogen (Table-1). Soil cultivated 3 seasons in year: spring rice - summer rice - winter crops.

Quantitative analysis results showed that soil typically for the Red River alluvial with medium mechanical composition; neutral reaction; cation adsorption capacity and calcium, magnesium exchange high. The amounts of macronutrients (N, P, K) were from moderate to high, suitable for growth and development of rice plant.

Table-1. The agricultural chemical properties of experimental soil.

N	Parameters	Unit	Layer-1 (0-20cm)	Layer-2 (21-30cm)	Layer-3 (31-90cm)	Layer-4 (91-125cm)
1	Bulk density	g/cm^3	1.05	1.17	1.38	1.50
2	Soil density	-	2.46	2.47	2.55	2.68
3	Porosity	%	57.48	51.38	45.88	44.50
4	Humus	%	2.6	1.68	1.04	0.86
5	Total N	%	0.10	0.06	0.04	0.04
6	Total P_2O_5	%	0.11	0.09	0.08	0.08
7	Total K_20	%	1.8	1.47	1.55	1.60
8	pH_{KCl}	-	6.81	6.95	6.62	6.55
9	CEC	me/100g	19.8	18.2	18.5	18.5
10	Al^{3+}	me/100g	0.3	0.2	0.62	0.74
11	Ca^{++}	me/100g	12.5	13.4	11.8	12.2
12	Mg^{++}	me/100g	4.2	3.8	3.6	3.4
13	H^+	me/100g	0.15	0.05	0.20	0.30
14	Base saturation	%	84.34	94.51	83.24	84.32
15	Composition: sand silt clay	 % % %	 20.5 62.4 17.1	 18.8 66.5 14.7	 12 70.5 17.5	 21.2 63.7 15.1

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Soil Eh in laboratory experiment

Eh dynamics of the experimental formula is presented in Table-2 and Figure-1, with following comments were:

- In most of the experimental formula, Eh values decreased very sharply in the first 8 days submerged. After 8 days submerged Eh decreased from -174mV to -282mV. After 15 days of flooding, the measured Eh values ranging from -283 mV to -220mV (Table-2 and Figure-1).
- In the controls (CT1) and urea fertilizer (CT2) formulas, although the Eh decreased with the time, but not strongly decrease as in the other formula with organic fertilizers. Eh between the formulas for the value in the following order: CT1> CT2> CT3 ~CT4 ~ CT5 > CT6.

Eh values decreased "drop" at 8 days of flooding is also consistent with the results of Yamane and Sato (1970) Ponnamperuma (1978, 1985) and Van Huy Hai (1986).

Table-2. Eh dynamics of the formula laboratory experiments (mV).

Days after submerged	CT1	CT2	CT3	CT4		CT5	CT6
	Submerge 5cm			Water regimes		Saturate keeping	Submerge 5cm
1	245	250	201	Submerge 5cm	196	192	207
2	84	82	46	Submerge 5cm	40	28	-21
3	0	-44	-97	Submerge 5cm	-93	-103	-145
8	-174	-193	-228	Submerge 5cm	-218	-210	-282
15	-220	-231	-256	Submerge 5cm	-256	-258	-283
22	-195	-246	-266	Submerge 5cm	-287	-261	-300
29	-218	-225	-241	Exposing ground	-218	-150	-232
36	-215	-227	-245	Drained ground	105	50	-245
42	-214	-230	-249	Crack ground	150	91	-262
49	-248	-290	-287	Submerge 5cm	-101	164	-282
56	-210	-260	-275	Submerge 5cm	-252	230	-233
63	-211	-262	-273	Submerge 5cm	-240	202	-226

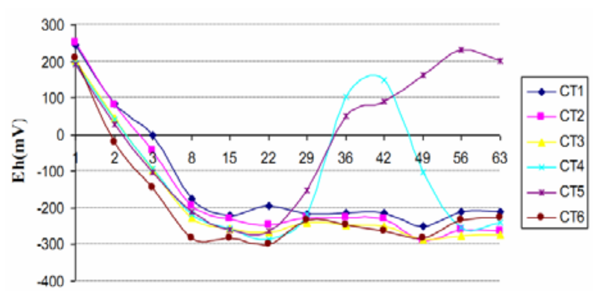

Figure-1. Developments of soil Eh in laboratory experiments.

The Eh decreased rapidly in the first week of flooding is explained as follows:

- Dry soil when submerged, soil air, including oxygen - an oxidant was displaced by water, creating anaerobic environment. Reduction reaction occurs and leads to the formation of a reducing agent, in other words, increasing concentrations of reagents as Eh decreases.

According to the Nernst equation (Latimer, 1964):

$$Eh = E_0 + \frac{0{,}059}{n} \lg \frac{Aox}{Ared} \quad (1)$$

where
Eh = Oxidation-reduction potential
E0 = Standard oxidation-reduction potential at 25^0C and pH = 0
n = Number of electrons participate in redox processes
A_{ox} = Oxidant activity
A_{red} = Reductant activity

According to Equation (1), when the dry soil submerged, the activity of reducing agents increases, Eh decreased.

- The early days submerged aerobic bacteria in the soil are not destroyed completely. In order to sustain for life, this bacteria try to get oxygen in the oxidizing substances and turn them into reducing. When submerged soil condition, anaerobic bacteria also begin to activate and joint into the reduction of chemical compounds in the soil, increasing reduction process. This is consistent with the findings of Yu-Tian-ren, (1985).

Compared with other formulas, the formula 6 (CT6) applying straw and inorganic fertilizers reduced Eh strongest. The cause of this phenomenon is explained in an overview of the research question is: when the resolution of organic matter, the following process occurs:

$(CH_2O)_x + O_2 = xCO_2 + xH_2O$

$2H_2O = O_2 + 4H^+ + 4e$

The presence of electron increased reduction process.

CT3 (fertilization regime in general and organic fertilizer) have 2nd lowest Eh, after fertilizer straw and inorganic fertilizers. The cause of this phenomenon is due to the influence of organic matter. When soil rich in organic matter or organic matter supply (fertilization) occurs, the stronger the depolarization. This phenomenon is explained similarly.

In contrast, particularly in CT2 (urea fertilizer), urea when applied into the soil will be resolved as NO_3^- and NH_4^+; NO_3^- is oxidant increases Eh. Thus, fertilization with organic fertilizers as inorganic fertilizer is not as strong reducing Eh as straw. But here Eh decreased markedly compared with other inorganic fertilizer only (CT2).

In formula CT5 (moisture keeping irrigation), Eh was not differs from submerged formula and with same fertilizer regime. This shows the difference in water level from 0 to 5 cm (in the first 22 days) did not significantly affect the dynamics of Eh. From day 29 onwards until the end of the experiment, the Eh values measured in the formula 4 and 5 has the vagaries. Eh values in the formula 4 increased to 150mV after the withdrawal of water exposed (ground cracking) and decreased gradually after the submerged again (day 49). The oxidation-reduction potential increases as the water regime to change from submerged to dry especially when the ground cracks. This is explained as follows: when submerged land turning into shallow water, oxygen will through capillary, cracks penetrate into the soil, the soil environment from reducing to oxidizing and Eh should be increased. After flooding back, Eh decreased.

In summary, Eh dynamics of an experimental model, in the formula submerged after 29 days, soil changes into wetland environment. Eh significantly decreased in the first week and reaching conditions for the formation of CH_4. Then Eh is the variation that can cause the anaerobic fermentation of organic matter in soil.

Dynamics of soil Eh in the experiments in this model also follows the rule that many authors as Yamane and Stator (1968, 1970), Ponnamperuma (1978, 1985) and Van Huy Hai (1986) were announced. Studies on the dynamics of soil Eh in the field experiments will strengthen above mentioned references.

After the soil to dry gradually, the measured results showed that Eh values irregular changes when submerged, most of the Eh values of the formula are increased. Thus, in wetland environment, water regimes strongly influence soil Eh.

Dynamics of Eh in the field experiments

Dynamics of Eh in the field experiments are shown in Table-3 and Figure-2. The Eh trend changes in time after 25 days of submerged rice similar experimental model in the laboratory (CT3). However, the Eh values of the experimental model in the laboratory higher levels and decrease faster than Eh in field experiments. The reason is that, laboratory experiments soil was dried before flooding. Soil in the field was not the same conditions as in the laboratory, the soil was wet, anaerobic bacteria were active, should reduce Eh not as strong as in the laboratory. The Eh was decreasing in 46 days (CT1, CT2, CT4, CT5), then gradually increase (due to withdrawal of water, or to dry naturally) in accordance with laboratory experiments.

The impact of rice to the Eh can be explained: at shooting stage of rice and milk-dough stage, the rice roots releases much of organic compounds (exudation processes) increases in soil organic matter, Eh decreased more than rice absence, this is consistent with results of Van Huy Hai (1986).

Table-3. The Eh dynamics of the formula in field experiments.

Growing periods	Time after implant (days)	CT1	CT2	CT3	CT4	CT5
Implantation - in green	4	-126	-157	-159	-120	-135
	11	-145	-144	-153	-126	-141
Shooting stage	18	-153	-154	-171	-135	-150
	25	-157	-162	-143	-146	-162
Panicle formation stage	32	-160	-92	-150	-157	-165
	46	-165	-175	-175	-165	-168
Phase of flowering	60	-100	-130	3	-70	-90
The milk-dough - hardening of the grains	81	-52	179	234	-15	-25

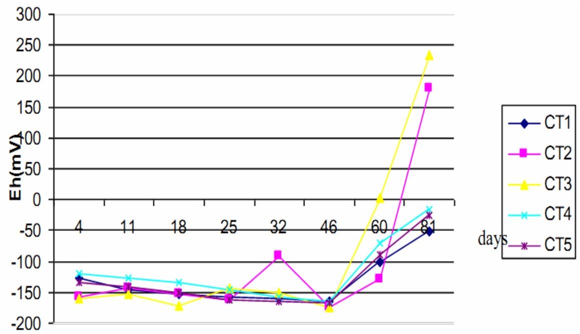

Figure-2. Development of Eh in field experimental formulas (days).

CONCLUSIONS

a) Irrigation regime strongly affects the soil oxidation-reduction potential. When dry soil submerged, Eh decreased rapidly in the first 2 weeks from 245 mV to -220mV. Then, the Eh slightly fluctuated, except for shallow water. As soil conditions of dry or cracked, the Eh will strongly increase from 105 to 150 mV. In field conditions due to the submerged land before implantation, Eh consistently lower and fewer variables from -100 mV to -165 mV, except exposed soil Eh will increase to 234 mV.

b) Applying organic fertilizer, the Eh decreased more sharply than in control or urea fertilizer.

c) In addition to water and fertilizer regime, Eh also depends on the presence and growth of rice plants. At the shooting stage of rice and milk-dough stage, the rice roots released organic compounds to increases organic matter so that soil Eh decreased more than rice absence formula.

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