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Redox Potential of Rice Field

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Abstract:

The work examines the main factors influencing the redox potential of soil fertility. In particular, the influence of flooding the soil of rice fields on its redox state was analyzed. The results of field experiments using drainage and waste water for rice irrigation and the dynamics of the redox potential of rice field soil are presented.

Keywords: lower reaches of the Amu Darya, sierozem-meadow and swamp-meadow soils, mineralized waters, rice field, oxidation and reduction processes, soil air regime, dissolved oxygen, soil water-air regime

The most important factor determining the changes and direction of soil processes and soil fertility is its oxidation-reduction potential (ORP). Based on many years of research, it has been established that when soil is flooded with water, its redox state changes sharply (Neunylov 1948; Mitsui, 1960; Black, 1973).

When flooded, oxygen gas is displaced from the soil along with air. Oxygen dissolved in water does not penetrate deep into the soil, but is intercepted by its surface layer. As a result of its consumption by microorganisms and plants, the amount of oxygen in the soil begins to noticeably decrease. Almost 5-8 days after flooding the soil, oxygen was not detected in the soil air. This leads to the fact that processes of a restorative nature begin to predominate in the arable soil horizon.

In this case, in a rice field flooded with water, several differently charged zones or layers appear: a layer of water with a positive ORP value, two layers of soil - the upper (several mm thick), in which oxidative processes predominate, and the lower, in which the entire arable layer restoration processes predominate. In the subsoil horizon, restoration processes are less pronounced and the ORP has a positive value. This is due to the different content of energy material for microorganisms between the arable and subsurface layers and the residual effect of trapped air in the subsurface layer.

In the rice rhizosphere, the restored environment of the arable horizon is penetrated by a dense network of oxidative microzones located along the rice roots, which protect them from the influence of toxic substances formed when the redox potential decreases.

The lowest ORP is characterized by long-term flooded soils of rice fields and swamp soils. In the root layer of old irrigated sierozem-meadow and swamp-meadow soils (at a groundwater depth of 1-2 m) during the cotton growing season, the ORP is favorable in the range from 300 to 400 mV. It has also been established that when the groundwater level is raised to the root layer of cotton, the ORP deteriorates due to the accumulation of ferrous forms of iron in the soil.

Studies conducted on swamp soils have revealed that when rice fields are flooded, the ORP indicator decreases. When the ORP value in irrigation water is 550 mV, in fluff it is 350 mV and in a 10 cm layer is 320 mV. A month after filling the checks, the ORP decreased to 440, 130 and 110 mV, respectively. During the period of rice irrigation, the ORP indicator along the profile sharply decreases, reaching a minimum in the gley horizon. In autumn, after water drains from the rice fields, it increases sharply.

Without going into details of the analysis of available data (Mitsui, 1960, Kovda, 1961, Zaitsev 1968, Muzaffarov, 1961, Umarov 1971, etc.), we note that until now, the quantitative values of redox potential, as an important factor determining physical and chemical processes in the soil for the conditions of the lower reaches of the Amu Darya in general and for the zone of development of rice cultivation, in particular, are practically not established.

To determine possible changes in ORP when using drainage and waste water for rice irrigation, determination of the ORP indicator, field experiments were carried out using the following options:

- irrigation with ordinary water (section 1);
- irrigation in the tillering phase with drainage and waste water (section 2);
- irrigation with drainage and waste water (section 3).

The data we obtained showed that in all variants the ORP indicator in water is higher than in soil (Table 1).

Table 1. The value of the redox potential of water and soil in a rice field

Options experiments	Place of determination		Deadlines for determination					
			If there is a layer of water in check I3/U.SH at 1130 hours.		After dumping water from the check after 18 hours. I4/U.SH at 10 oclock.		After the check was re-flooded, I5/U.SH at 11 a.m.	
			tº C	OVP indicator, mV	tº C	OVP indicator, mV	tº C	OVP indicator, mV
I	In the water (check)		22,0	153	-	-	32,0	208
	In the soil layer:	0-2 см.	22,0	-55	27,0	110	30,0	30
		2-10 см.	22,0	-60	26,9	30	29,0	10
		10-20 см.	22,5	-67	26,9	30	28,6	-30
II	In the water (check)		23,0	210	-	-	27,9	67
	In the soil layer:	0-2 см.	22,0	-120	30,0	70	27,9	40
		2-10 см.	22,0	-105	9,0	23	27,9	27
		10-20 см.	22,0	-110	28,6	10	27,9	27
III	In the water (check)		24,0	222	-	-	27,5	165
	In the soil layer:	0-2 см.	22,0	-110	34,0	30	27,8	-45
		2-10 см.	22,0	-140	32,0	15	27,9	70
		10-20 см.	22,0	-147	29,8	12	27,9	-95

If there is a layer of water in the check, a restoration process takes place in the soil, i.e. the ORP indicator has negative values. This process is most pronounced in variants II and III of the experiment, where the soil ORP indicator in the 0-20 cm layer, respectively, ranges from -105 to -120 mV and from -110 to -147 mV, versus -55 and -67 mV in the control.

After water is discharged from the checks, the air regime of the soil improves, the oxidation process intensifies, and the ORP indicator has a positive value. This process is most pronounced in option I, where rice was irrigated with ordinary water.

When the rice field is re-flooded with fresh water, which contained dissolved oxygen in the control of 10.2 mg/l, and in option II 8.4 mg/l, the oxidative process initially predominates and the ORP indicator has positive values. In the option of irrigating rice only with drainage water, which contained 6.3 mg/l of dissolved oxygen, this indicator has negative values, i.e. the recovery process predominates.

Observations of changes in ORP over time (from sowing to harvesting rice) showed that before the rice field is flooded with water, an oxidation process occurs in the soil. The ORP value in a soil layer of 0-2 cm at a temperature of 35-37.50C is 250-260 mV versus 210-235 mV in the lower layers (Table 2).

Table 2. Dynamics of redox potential of rice field soil

Options experiments	Place of determination	Deadlines for determination	Before the checks are flooded with water May 21st		At the end of the tillering phase, July 30		During the flowering phase, 24 August		After rice harvest, October 5	
			t° C	OVP indicator, mV	t° C	OVP indicator, mV	t° C	OVP indicator, mV	t° C	OVP indicator, mV
I Irrigation with regular water Section 1	In the water (check)		-	-	23,0	330	18,2	20		-
	In the soil layer:	0-2 см.	35,0	250	24,5	-20	19,3	-100	8	320
		2-10 см.	28,0	210	23,7	-67	20,0	-160	8	260
		10-20 см.	23,5	210	34,5	-85	19,8	-160	9	225
II Irrigation from the tillering phase with drainage water Cut 2	In the water (check)		-	-	27,0	300	19,0	280	-	-
	In the soil layer:	0-2 см.	34,0	260	26,0	-245	20,0	-100	9	360
		2-10 см.	28,5	235	25,2	-290	21,0	150	9	250
		10-20 см.	23,0	210	26,0	-305	20,5	160	10	245
III Irrigation with drainage and waste water Section 3	In the water (check)		-	-	26,2	370	20,9	330	-	-
	In the soil layer:	0-2 см.	37,5	250	26,2	-405	22,4	-320	9	335
		2-10 см.	29,0	230	25,0	-420	22,8	-330	9	258
		10-20 см.	24,5	220	26,0	-450	21,2	-340	10	238

After the checks are flooded with water, due to a change in the reaction of the environment (the prevalence of anaerobic conditions), the recovery process prevails, and the ORP indicator has negative values. A comparison of the data obtained in the context of experimental options shows that the restoration process is relatively less pronounced in the case of irrigation with ordinary water. The ORP indicator for this option ranges from -20 to -110 mV (layer 0-2 cm). In option III, where rice was irrigated only with drainage water, the ORP indicator is significantly higher, ranging from -320 to 405 mV (layer 0-2 cm) and from -340 to -450 mV (layer 10-20 cm). After water is discharged from the rice fields, the water-air regime of the upper soil layer changes radically and the oxidation process is clearly expressed with an ORP value of the order of -250 to -360 mV (layer

0-10 cm). The intensity of this process in the context of the studied rice irrigation options does not differ significantly.

The significance of iron and its compounds in the change and direction of the soil-forming process is undoubted. During the process of soil formation, some forms of iron are oxidized, others are reduced and migrate along the soil profile, accumulating in it under reducing conditions in oxide forms, and in oxidizing conditions - in oxide forms.

It was noted that the ratio of iron oxide and iron oxide in the hydromorphic soils of the sierozem belt varies greatly both by the seasons of the year and by the soil profile. It is less in the arable horizon and more in the lower layers. The seasons change - from autumn to winter and from winter to spring. The quantitative content of oxide oxide forms indicates the constant presence of mobile oxide forms in soils, and in many cases the quantitative predominance of their oxide forms. Due to the specificity of the soil water regime during rice sowing, when anaerobic conditions are created during the flooding period, the process of oxidation of iron compounds and the formation of mobile forms has a slightly different direction.

n irrigated swamp soils under rice crops, ferrous forms of iron from the fields of water discharge from the fields disappear at the end of autumn, and after flooding, in the summer, they appear again. As the recovery processes intensify, the intensity of accumulation of ferrous forms of iron in the soil increases.

Our observations have shown that in old irrigated meadow soils where rice has been cultivated as a monoculture for more than 10 years, the content of ferrous forms of iron (FeO) in the 0-30 cm layer ranges from 0.023 to 0.045 mg, and oxide forms (Fe2O3) from 0.024 to 0.028 mg. per 100 g of soil. Determinations of mobile forms of iron before flooding and after harvesting rice over a number of years showed that, in general, the content of oxide forms of iron in the soil does not undergo significant changes from spring to autumn. In some cases, there is even an increase in them compared to the spring period, which is due to the intensification of the oxidative process after the release of water from the rice fields.

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