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Soil Element Assessment in Organic Paddy Fields in the Thung Kula Ronghai Zone, Thailand

Patarapong Kroeksakul[1]*, Kun Silprasit[1], Naphat Phowan[1], Arin Ngamniyom[1] and Pakjirat Singhaboot[2]

[1]*Faculty of Environmental Culture and Ecotourism, Srinakharinwirot University, Bangkok, 10110, Thailand*
[2]*Faculty of Agricultural Product Innovation and Technology, Srinakharinwirot University, Ongkharak, Nakhon Nayok, 26120, Thailand*

ABSTRACT

Organic rice production (ORP) has been promoted as a means of sustaining both farmers and the ecology of paddy fields, so this research aims to evaluate soil properties and soil elements in the ORP and general rice production (GRP) systems in the Thung Kula Ronghai (TKR) zone in Thailand. Soil samples were collected in Roi-et province from fields classified as ORP (5 fields) or GRP (4 fields), and interviews were also conducted with the field owner about rice yield and rice production. Data from the ORP and GRP groups were compared by *t*-test, and soil enhancement practices were measured by one-way analysis of variance (ANOVA) for variances. Results indicate there were 14 indicators of soil element control in the TKR. All indicators in the ORP and GRP systems were lower than the rate in soil that is suitable for rice production. The macroelement content in the TKR zone was total nitrogen > total potassium > phosphorus available at a ratio of 338: 3: 1, and the soil organic matter (SOM)/soil organic carbon (SOC) ratio is about 3.45. The soil improvement techniques used in the ORP systems—manure only and manure combined with green manure—have a higher pH value ($p < 0.05$) than the fertilizer only input but a lower TK value ($p < 0.05$) than the fertilizer only input. As a result, the ORP yield was higher than that of the GRP systems ($p < 0.05$), greatly affecting farmers' practices.

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E-mail addresses:
patarapong@g.swu.ac.th (Patarapong Kroeksakul)
kun@g.swu.ac.th (Kun Silprasit)
naphat@g.swu.ac.th (Naphat Phowan)
arin@g.swu.ac.th (Arin Ngamniyom)
pakjirat@g.swu.ac.th (Pakjirat Singhaboot)
* Corresponding author

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INTRODUCTION

The organic rice production (ORP) system in Thailand promotes farmers' health, increases the sustainability of ecological systems, and produces a higher value crop

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(Ueasangkomsate et al., 2018). In addition to being ecologically friendly, ORP can increase biodiversity in the fields (Avasthe et al., 2018; Rahmann, 2011; Reeve et al., 2016) because organic fertilizer and organic pesticides control rice production process (Lin & Fukushima, 2016). It is the reason the government is trying to include this system in its development program that aims to increase the ORP area in the country (Herique & Faysse, 2020). Thailand's rice-producing area is about 9.5 million ha, and 61% of paddy fields are in the country's northeast region, making this a significant area for rice production (Office of Agricultural Economics [OAE], 2019). ORP represents more than 80% of all rice grown in the northeast region of Thailand (Thuansri & Morathop, 2016).

The northeast region of Thailand is a major area of high-quality ORP. The Thung Kula Ronghai (TKR) zone is located on the Khorat plateau. It has an area of about 320,000 ha covering 13 districts in 5 provinces: (1) Phayakaphum Phisai district in Maha Sarakham province, (2) Champhonburi and Thatum districts in Surin province, (3) Phatumrat, Kasetwisai, Suwannaphumdi, Phonsai, and Nonghee districts in Roi-et province, (4) Sira-art, Rasisarai, and Yangchumnoi districts in Srisaket province, and (5) Khorwang and Mahachanachai districts in Yasothon province. Approximately 70%, or 224,000 ha, of the TKR zone is used for rice production, representing 3.96% of the country's northeast region. In the past, the TKR zone experienced problems with soil fertility because the soil in the region is sandy loam and silty clay; therefore, it does not retain moisture, rendering the soil less fertile (Loeffler et al., 1993; Sompob, 1986). However, the situation did not affect the quality of rice grown in the area (Saetung & Trelo-ges, 2017), and rice produced in TKR is well known domestically and internationally.

Considering how ORP affects the nutrient balance in the soil has led to the research question of whether there is a difference in soil element in the ORP and general rice production (GRP) systems in the TKR zone. The purpose of this study was to evaluate soil properties and soil elements in ORP and GRP systems to support continuing farmer discussions about selecting rice production systems in TKR. When evaluating soil elements in paddy fields, indicators should be considered. Soil organic matter (SOM) is one indicator of soil fertility, as are soil organic carbon (SOC), soil pH, carbon/nitrogen (C/N) ratio, nitrogen (N), phosphorus (P), available potassium (K), and electrical conductivity (EC) (Khaki et al., 2017; Supriyadi et al., 2017). This information can develop soil improvement techniques to increase ORP in the TKR zone.

MATERIALS AND METHODS

Soil Collection

The TKR study site in Roi-et province comprised nine plots distributed across two districts—five organic paddy fields in Phatumrat district and four general paddy fields in Kasetwisai district. The soil samples were collected from eight points in a Z shape (shown as red stars in Figure 1) for mixing and were placed in plastic bags for element analysis. Two levels of topsoil (0–5 cm and 5–20 cm) were used (shown as back dots in Figure 1) to measure bulk density and biomass. The soil was collected by soil core, stored in plastic bags, and kept in an icebox.

Field Study Experiment

TKR1 to TKR5 are organic fields fertilized with manure prior to plowing. Organic fertilizer was applied 2–5 weeks after rice planting and 12–16 weeks after planting. Farmers also used a bio-extract hormone supplement during the rice production process (spraying 7–12 weeks after planting). Different methods were used in the ORP system: TKR3, TKR4, and TKR5 were treated with green manure either after harvest or before planting, but TKR1 and TKR2 did not have the green manure input. Before plowing in the GRP system, farmers used cow and chicken manure in the fields. After planting, the farmer applied fertilizer twice: first, at the early rice-growing stage (about 4–6 weeks after broadcasting) using a formula of 16-16-8 (% of nitrogen [N], phosphorus [P], and potassium [K]) at a rate of 50 kg/ha; and second, at the early grain production stage (about 12–15 weeks after broadcasting) using a formula of 15-15-0 at a rate of 62.5 kg/ha. In addition, in TKR_1 and TKR_4, straw was burned after the rice was harvested.

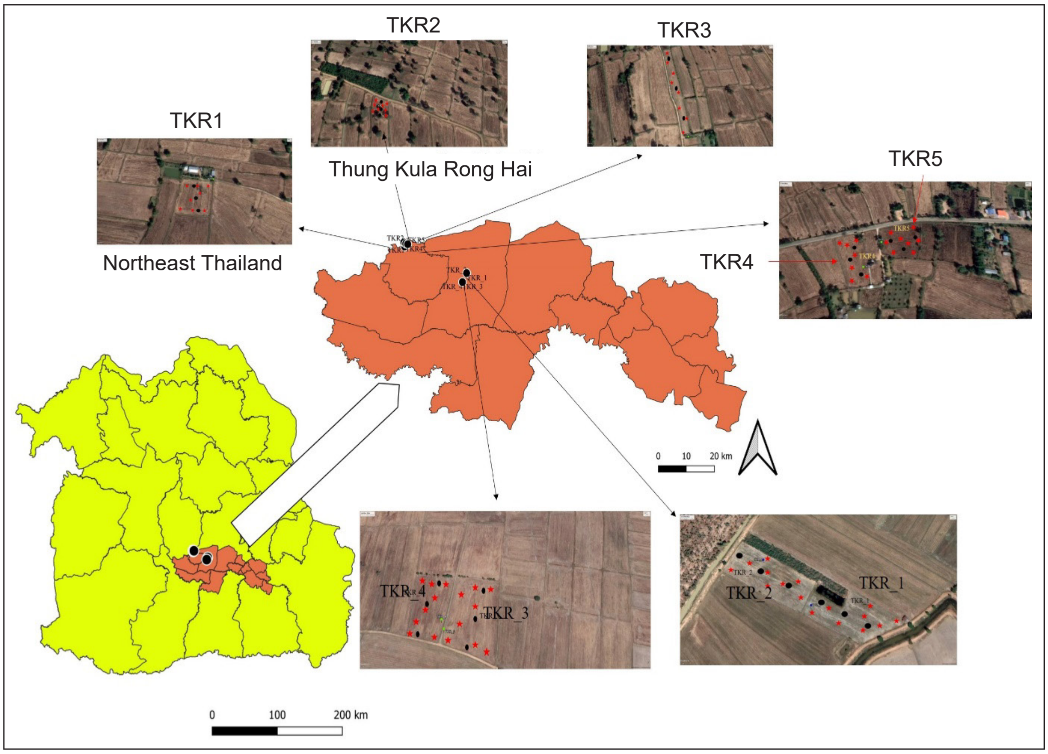

Figure 1. Study site and field plots where soil samples were collected

Physical Survey of Soil in the Field

Soil moisture levels were measured during the dry season in March 2021 using a Delta-T Devices series HH2 moisture meter (United Kingdom). This multi-sensor instrument auto-detects the amount of moisture in the soil (%), soil temperature, and soil EC as well as can measure the soil surface to a depth of 5 cm. It also determines soil color, which was used to confirm soil type using the Munsell Soil Color Book.

The pH value and sodium chloride (NaCl) content of the soil were tested using a solution technique. The soil sample was dissolved in water at a 1:2 ratio of 5 g of soil diluted in 10 mL of deionized water, and shaken for 30 min. After waiting an additional 30 min to allow for precipitation, the liquid was separated from the sample for pH and NaCl content checking using a Hach HQ40d portable multimeter (USA). EC was checked via a solution technique using electrochemistry instruments from the EUTECH CON700 series (USA).

Soil Extraction and Element Analysis

The collected soil samples were placed in plastic bags and kept in an icebox while transported from the field to the laboratory. The soil was dried in a 105°C oven for 72 hours, then ground using a mortar and pestle. Net No. 4 (10 mm) of sifted soil were selected and maintained in the refrigerator at a temperature of 4°C.

The soil extraction used in AAS analysis was a 2 g soil sample with concentrated nitric acid (HNO_3) and concentrated perchloric acid ($HClO_4$) (1:1) for 10 mL (United States Environmental Protection Agency [US EPA], 1996). It was then digested at about 500°C in the SpeedDigester K-425 BUCHI until dried (Switzerland). Each residue was rinsed with 1% HNO_3 then sieved through Whatman No.1 paper. The supernatant was then transferred to a 50 mL volumetric flask, and 1% HNO_3 was added for continued atomic absorption spectrophotometers (AAS) analysis (Thummahitsakul et al., 2018).

The analysis of nitrogen and carbon formed total nitrogen (TN) and total carbon (TC) in the samples analyzed by the LECO series CHN-628 CHN Analyzer (USA). Potassium (K) analysis was performed using AAS, an Agilent series 240AA instrument (USA). Mineral content analysis and the level of phosphorus (P) available in the soil content were analyzed using the Bray II method (Bray & Kurtz, 1945) and measured by spectrophotometers at a wavelength of 882 (nm).

Jenkinson and Powlson's (1976) technique was applied to prepare the soil for biomass analysis. A 20 g soil sample was incubated for about 72 hours in polyethylene bags, after which it was dried in a 105°C oven for 24 hours and placed into glass beakers (10 g) for fumigation with chloroform ($CHCl_3$) in desiccators for 72 hours. A CHN-628 CHN analyzer (USA) was used to analyze the percentage of carbon content in the soil.

Statistical Analysis

The data were analyzed by t-test in $p < 0.05$ using data components of the ORP and GRP systems in the TKR zone, such as rice yield production and quantity of element in the soil. However, the soil improvement practices were determined using one-way ANOVA for variances. In addition, differences in data were compared using post-hoc Tukey's honestly significant difference (HSD) in $p < 0.05$. Finally, all analyses used the SPSS V.22 and Sigmaplot 12.0 (free trial).

RESULTS

Soil Properties

The paddy fields of TKR are made up of sandy soil, as confirmed by the Munsell Soil Color Book. The soil contains the mineral goethite, its texture is very fine, and its color is different from the plots where the soil samples were collected so that the same sets of soils characteristic Ki series in the USDA classification are fine loamy and isohyperthemic typic natraqualfs types (Land Development Department, 2021). The soil pH of ORP systems averaged 5.6 ± 0.32, which is significant ($p < 0.01$), while the GRP systems had an average pH of 4.74 ± 0.26. However, the percentage of NaCl in the soil in ORP systems averaged 0.22% ± 0.12%; the percentage in GRP systems averaged 0.27% ± 0.31%. The EC in ORP systems averaged 252.74 ± 122.12, and the EC in GRP systems averaged 359.40 ± 297.28. The bulk density of the soil surface (0–5cm; BD5) in ORP systems averaged 0.39 ± 0.18 g/cm^3; GRP systems had an average bulk density of 0.27 ± 0.15 g/cm^3. At a depth of 6–20 cm (BD20), the soil bulk density averaged 0.99 ± 0.43 g/cm^3 in ORP systems and 0.80 ± 0.26 g/cm^3 in GRP systems.

Soil Moisture

In the field survey, dry conditions prevented the soil moisture volume from being collected; daytime temperatures reached a high of 35.56°C ± 2.53°C. However, collected soil samples dried in a 105°C oven for three days were found to have topsoil (0-5cm) moisture content of 1.46% ± 0.72%. At 6–20 cm soil depth, the soil had a moisture level of 3.67% ± 1.4%. In ORP systems, the average topsoil temperature was 35.72°C ± 3.74°C, and the soil moisture level averaged 1.81% ± 0.71% for topsoil and 4.37% ± 1.4% for soil at a depth of 6–20 cm. In GRP systems, the topsoil had an average temperature of 35.37°C ± 0.75°C and an average soil moisture level of 1.03% ± 0.69% for topsoil and 2.80% ± 0.81% for soil at a depth of 6–20 cm. Differences between the three indicators—temperature, soil moisture percentage of topsoil, and a soil moisture percentage of soil 6–20 cm deep—in the ORP and GRP groups were not significant, present in Table 1. The correlation between temperature and soil moisture at a depth of 6–20 cm ($r = 795$; $p < 0.05$) is shown in Figure 2. However, the soil moistures will decrease to temperature increasing (Tang & Chen, 2017) related to temperature are indicated with performing of agriculture yield production (Rahman et al., 2020), because the parameter has impacted to microorganism activity in the soil, so the soil moisture is better to microorganism activity has about 30-40% of soil moisture and temperature to better with microbial activity about 20-40°C (Cruz-Paredes et al., 2021).

Table 1
Soil moisture and temperature data from the field survey in TKR

Field	Pattern of rice production	% moisture of topsoil (0-5 cm)	% moisture of soil (6-20 cm)	Temperature (°C)
TKR1	ORP	2.32	2.40	30.1
TKR2	ORP	1.10	2.61	33.6
TKR3	ORP	2.18	5.21	38.3
TKR4	ORP	0.981	5.23	38.3
TKR5	ORP	2.46	6.40	38.3
	Average	1.81	4.37	35.72
	SD	0.710	1.77	3.74
TKR_1	GRP	1.74	2.38	34.5
TKR_2	GRP	0.211	1.99	35
TKR_3	GRP	0.740	2.96	36
TKR_4	GRP	1.45	3.86	36
	Average	1.03	2.80	35.37
	S.D.	0.693	0.81	0.75

Note. TKR = Thung Kula Ronghai; ORP = Organic rice production; GRP = General rice production; S.D. = Standard deviation

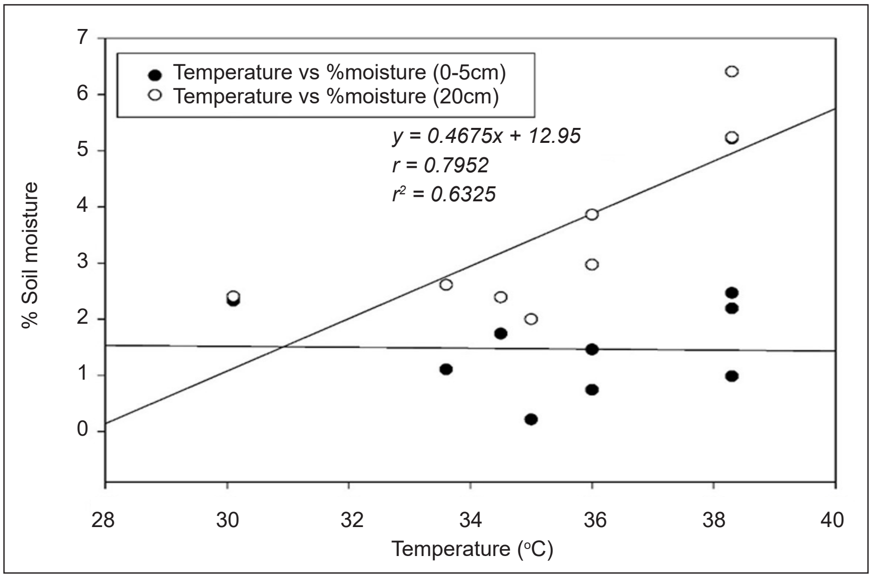

Figure 2. Correlation between soil surface temperature and soil moisture percentage at a depth of 6–20 cm in TKR during the dry season

Rice Yield Production in the Field Survey

Interviews with the paddy field owner found that between 2017 and 2020, the plot TKR5 had a higher yield production (3093.7 ± 759.4 kg/ha). In 2018, TKR1, TK2, and TK3 cannot be harvested because the dough affects the farmer's yield loss product. However, TKR5 was used for glutinous rice cultivation, while TKR 1, 2, 3, and 4 produced the Hom Mali 105 (jasmine rice) variety and the yield production of the present in Table 2. However, when considering with quantity, rice yield of ORP was found to average 507 (±127) kg/ha and the production of GRP average 238 (±51) kg/ha (Table 3), so that rice production yields for organic and general rice production were significant ($p < 0.01$), indicating that organic paddy fields produce higher yields than general paddy fields (Figure 3).

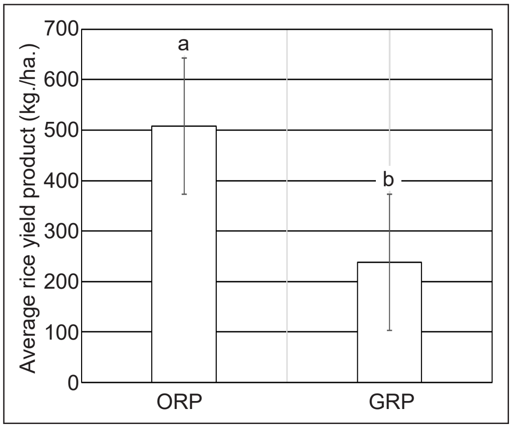

Figure 3. Average the rice yield production at the study site comparison of rice yield production among organic and general rice production systems in TKR ($p < 0.01$)

Table 2
Rice production quantities from 2017 to 2020 (kg/ha)

Year	TKR1	TKR2	TKR3	TKR4	TKR5	TKR_1	TKR_2	TKR_3	TKR_4	$\bar{X}$ of ORP	$\bar{X}$ of GRP
2020	2437	3409	4687	3333	3750	1562	1687	1015	1458	3523	1430
2019	3062	3409	4687	2500	3750	1770	1964	1273	1718	3481	1681
2018	0	0	0	2187	2500	1437	1517	1328	1302	937	1396
2017	2875	2272	2500	1968	2375	2187	1071	1406	1031	2398	1424
$\bar{X}$	2093	2272	2968	2497	3093	1739	1560	1255	1377	2585	1483
S.D.	1420	1607	2231	598	759	328	374	169	287	607	1215

Note. Fields TKR1, TKR2, and TKR3 to 2018 cannot be harvested due to drought; ORP = Organic rice production are field TKR1, TKR2, TKR3, TKR4, and TKR5.; GRP = General rice production are TKR_1, TKR_2, TKR_3, and TKR_4

Table 3
Compares rice quantity between organic and general rice production system in TKR

	t	df	Sig. (2-tailed)	Mean difference
Organic rice production systems	15.395	14	0.00	507.616
General rice production system	20.859	19	0.00	238.289

Note. The mean difference is significant at the p-value < 0.05 level

Element and Mineral Quantities in Organic and General Paddy Fields

The quantity of essential elements in the soil content in TKR is as follows: TN, approximately 210 mg/kg; TK, approximately 2.06 mg/kg; and available P, approximately 0.62 mg/kg. Therefore, the ratio of TN > TK > available P is 338:3:1. The ORP TN value averaged 209 ± 2.57 mg/kg, while the GRP value averaged 210 ± 2.40 mg/kg to compare the organic and general groups. Available P in ORP systems averaged 0.825 ± 0.391 mg/kg; available P in GRP systems averaged 1.76 ± 1.18 mg/kg. The TK level in GRP soil content averaged 2.65 ± 0.15 mg/kg, which is significant ($p < 0.01$), the TK level in ORP soil content averaged 1.47 ± 0.18 mg/kg, present in Table 4. The amounts of macroelements in ORP and GRP are illustrated in Figure 4. The soil element in assessing TKR is mineral content (TN, P available, and TK), soil pH, EC, percentage of sodium chloride, bulk density of topsoil, and soil deep 6-20 cm, soil organic matter, and soil organic carbon of topsoil and soil deep 6–20 cm is provided in Table 5.

Table 4
Soil element content and comparison of soil macro-elements between the organic production system and the general rice production system in TKR

Item	Unit	ORP	GRP	*t*	Sig.(2-tailed)
N	mg./kg	209 (±2.57)	210 (±2.40)	0.011	0.991
P	mg./kg	0.825 (±0.391)	1.76 (±1.18)	-1.189	0.319
K	mg./kg	1.47 (±0.186)	2.65 (±0.152)	-13.09	0.00

Note. The mean difference is significant at the *p*-value < 0.05 level.; P was determined to use the Bray II method. The phosphorus considered P available from potassium dihydrogen phosphate (KH_2PO_4), N was total nitrogen, and K was total potassium.; ORP = Organic rice production system; GRP = General rice production system

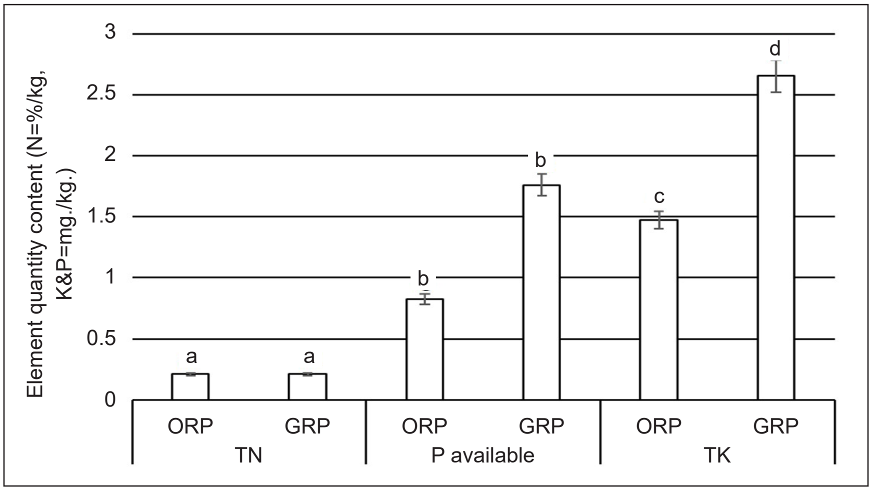

Figure 4. Quantity of macroelements comparison of ORP and GRP in TKR found to TK between ORP and GRP significant ($p < 0.01$)

Table 5
Volume of parameter of studies site of TKR

Item	Unit	TKR1	TKR2	TKR3	TKR4	TKR5	TKR_1	TKR_2	TKR_3	TKR_4	Average	SD	SE
TC	g/kg	3.23	2.21	2.21	2.21	6.75	3.61	3.66	6.26	1.68	3.53	1.82	.607
TN	g/kg	0.20	0.21	0.21	0.21	0.20	0.213	0.21	0.20	0.20	.21	.002	.001
P available	mg./kg	0.85	1.33	1.05	0.44	0.43	0.743	0.73	2.83	2.73	1.24	.919	.306
TK	mg./kg	1.59	1.40	1.18	1.65	1.53	2.8815	2.56	2.56	2.61	1.99	.643	.214
pH*		5.22	5.6	5.97	5.82	5.02	4.36	4.82	4.88	4.93	5.18	.523	.174
EC	(µS-1)	357	325	84	244	159	759	170	407	100	289	209	69.9
NaCl	%	0.2	0.16	0.4	0.12	0.09	0.73	0.09	0.21	0.05	.22	.214	.071
BD (5)	g/dm3	0.59	0.26	0.49	0.20	0.68	0.386	0.04	0.27	0.37	.36	.199	.066
BD (20)	g/dm4	0.55	0.75	1.54	1.13	2.12	0.591	0.56	0.96	1.08	1.03	.524	.174
C/N ratio		15.6	10.5	10.4	10.4	32.6	16.9	17.3	30.1	8.04	16.9	8.85	2.95
SOM (5)	mg./kg	1242	852	850	852	2598	1389	1408	2408	646	1360	701	233
SOC (5)	mg./kg	360.	247	246	247	753	402	408	698	187	394	203	67.7
SOM (20)	mg./kg	1002	642	650	592	2308	1149	1168	2168	406	1120	685	228
SOC (20)	mg./kg	290	186	188	171	669	333	338	628	117	325	198.	66.3

Note. * Testing in water soluble ; TC = Total carbon; TN = Total nitrogen; P available = Phosphorus available; TK = Total potassium; EC = Electrical conductivity; NaCl = Sodium chloride; BD (5) = Bulk density of top soil; BD (20) = Bulk density deep 20 cm.; C/N ratio = Ratio between carbon and nitrogen; SOM (5) = Soil organic matter of top soil; SOC (5) = Soil organic carbon of top soil; SOM (20) = Soil organic matter of soil deep 20 cm; SOC (20) = Soil organic carbon of soil deep 20 cm

Essential Soil Element Assessment in ORP Systems in TKR

The value of TN and available P in the paddy fields of TKR in ORP and GRP systems was not significant: TN was approximately 0.20 and 0.21 g/kg, respectively, and available P was approximately 0.825 and 1.762 mg/kg, respectively. The TK value in ORP was lower than ($p < 0.05$) that of the GRP system, at approximately1.473, and 2.655 mg/kg, respectively, so the value of essential elements in ORP and GRP systems in the TKR zone is less than the quantities detailed in Arunrat et al. (2020)'s report. This report found the following essential mineral content in paddy fields in the tropical monsoon region: TN, approximately 0.41 g/kg; available P, approximately 2.77 mg/kg; and TK, approximately 56.71 mg/kg. However, the quantity of essential elements in the soil content in ORP tends to be lower than in GRP. It is similar to Islam et al. (2017)'s and Kakar et al. (2020)'s findings that areas that use only organic manure (animal manure, sawdust, and vermicompost) have lower quantities of essential elements in the soil than areas that use chemical fertilizer or chemical fertilizer combined with organic fertilizer. Major natural sources of TK, such as humus or rice straw, can increase potassium levels, but their use should be limited to no more than 120 days (Li et al., 2014) because microorganisms will digest the raw material until it is changed to humus and potassium oxide (K_2O) or K in the soil. This technique for increasing K in the soil cannot be used in TKR because the dry climate and high temperature affect the ability of microorganisms and earthworms to digest humus (Möller, 2015; Pathma & Sakthivel, 2012), so the value of soil indicators present in Table 6.

Volume of Biomass Content in Organic and General Paddy Fields

The SOM content of the soil surface (SOM5) in ORP systems had an average value of 1279.3 mg/kg, and the GRP value averaged 1463.04 mg/kg. The value of SOM in SOM20 in ORP averaged 1039.30 mg/kg, and the value in GRP was approximately 1223.04 mg/kg; there were no significant differences ($p > 0.05$). The value of the SOC content of the soil surface (SOC5) in ORP averaged 340.99 mg/kg, and the value in GRP averaged 424.28 mg/kg. The value of SOC in SOC20 in ORP averaged 301.39 mg/kg, and the GRP value was approximately 354.68 mg/kg; there were no significant differences. The C/N ratio in ORP had an average value of 15.93, and the GRP value averaged 18.10. The SOM, SOC, and C/N ratio values are presented in Table 7.

Types of Soil-improving Activity

There were three methods of soil improvement used in the study: (1) manure only input, such as cow dung and chicken excrement; (2) manure combined with green manure input; and (3) fertilizer input. Of the 14 indicators—TC, TN, available P, TK, pH, EC, % NaCl, BD5, BD20, C/N ratio, SOM content of the soil surface at a depth of 0–5 cm (SOM5), SOC content of the soil surface at a depth of 0–5 cm (SOC5), SOM content of the soil surface at a depth of

Table 6
The value of soil indicators in ORP and GRP systems in TKR compared with soil conditions suitable for rice production

Indicators	Soil in paddy fields in TKR		Rate in soil suitable for rice production (Reference rate)	Reference of indicator
	ORP	GRP		
TN (g/kg)	0.209	0.210	0.93–0.52**	Araragi et al. (1978)
P available (mg/kg)	0.825	1.762	>15	Saenya et al. (2015)
TK (mg/kg)	1.473	2.655	>20	Saenya et al. (2015)
pH	5.526	4.747	>4.3	Saenya et al. (2015)
EC (μS^{-1})	234.038	359.402	<200	Saenya et al. (2015)
% NaCl	0.194	0.27		
Temperature (°C)	36.92	35.375	25–38	Saenya et al. (2015)
BD5 (g/cm^3)	0.450	0.268	1.1–1.2/1.6	Saenya et al. (2015); Zhou et al. (2014)
BD20 (g/cm^3)	1.223	0.801	1.1–1.4/1.6	Saenya et al. (2015); Zhou et al. (2014)
C/N ratio	15.937	18.101	11.18**	Araragi et al. (1978)
SOM5 (mg/kg)	1279.307	1463.048	14000–16000*	Saenya et al. (2015)
SOC5 (mg/kg)	370.999	424.283	2000–3000/>150	Ross (1993); Saenya et al. (2015)
SOM20 (mg/kg)	1039.307	1223.048	14000–16000*	Saenya et al. (2015)
SOC20 (mg/kg)	301.399	354.683	2000–3000*	Ross (1993)

Note. *Used similar rate to topsoil (0–5 cm) because Ross (1993) and Saenya et al. (2015) reported the SOC value of the soil surface at a depth of 0–20 cm; ** Using low humic gley soil; TN = Total nitrogen; P available = Phosphorus available; TK = Total potassium; EC = Electrical conductivity; %NaCl = Percentage of sodium chloride in soil; BD5 = Bulk density of top soil; BD20 = Bulk density deep 20 cm.; C/N ratio = Ratio between carbon and nitrogen; SOM5 = Soil organic matter of top soil; SOC5 = Soil organic carbon of top soil; SOM20 = Soil organic matter of soil deep 20 cm; SOC20 = Soil organic carbon of soil deep 20 cm

Table 7
The volume of SOM, SOC, and C/N ratio in ORP and GRP in TKR

Value	C/N ratio		SOM5 (mg/kg)		SOC5 (mg/kg)		SOM20 (mg/kg)		SOC20 (mg/kg)	
	ORP	GRP	ORP	GRP	ORP	GRP	ORP	GRP	ORP	GRP
$\bar{X}$	15.93	18.10	1279.30	1463.04	370.99	424.28	1039.30	1223.04	301.39	354.68
S.D.	9.61	9.07	756.69	723.09	219.44	209.69	728.17	723.09	211.17	209.69

Note. The value of C/N ratio, SOM5, SOC5, SOM20, and SOC20 indicators compares between ORP and GRP by *t*-test found to not significant ($p > 0.05$); C/N ratio = Ratio between carbon and nitrogen; SOM5 = Soil organic matter of top soil; SOC5 = Soil organic carbon of top soil; SOM20 = Soil organic matter of soil deep 20 cm; SOC20 = Soil organic carbon of soil deep 20 cm; ORP = Organic rice production; GRP = General rice production

6–20 cm (SOM20), and SOC content of the soil surface at a depth of 6–20 cm (SOC20) testing variances by one-way ANOVA in 3 were significant ($p < 0.05$): TK, pH, and BD20., this is shown in Table 8, and the correlation of all indicators found with the pH and TK values ($r = -0.855$; $p < 0.05$), and the soil temperature and BD20 ($r = 0.755$; $p < 0.05$), and EC and percentage of NaCl in soil ($r = 0.741$; $p < 0.05$), also the soil organic matter group are C/N ratio, SOC, and SOM of the soil surface and deep soil 6-20 cm, shown in Table 9.

Table 8
The value of indicator significance in soil improvement methods in TKR

Indicators	Manure	Manure + Green Manure	Fertilizer
TK (mg/kg)	1.498[a]	1.457[a]	2.65[b]
pH	5.41[a]	5.6[a]	4.47[b]
BD20	0.65[a]	1.6[b]	0.8[a]

Note. [a,b] = The mean difference is significant at the *p*-value < 0.05 level.

Effects of Burning Fields after Harvest

When rice fields burned after the harvest were tested using the *t*-test method, of the 14 indicators, the EC value was significant ($p < 0.05$) compared to the unburned fields. The EC value for burned fields averaged 583 ± 248 µS, while the value for unburned fields averaged 205 ± 106 µS. When considering the correlation of EC to other indicators in ORP and GRP, the EC value related to % NaCl ($r = 0.741$) in ORP was significant ($p < 0.05$), as presented in Figure 5. However, opposite results were observed for the EC value in GRP. There was no significant correlation between EC and other components in the soil in the TKR fields.

DISCUSSION

ORP Activities to Reduce Soil Salinity and pH

The EC value is an indicator of soil health (United States Department of Agriculture

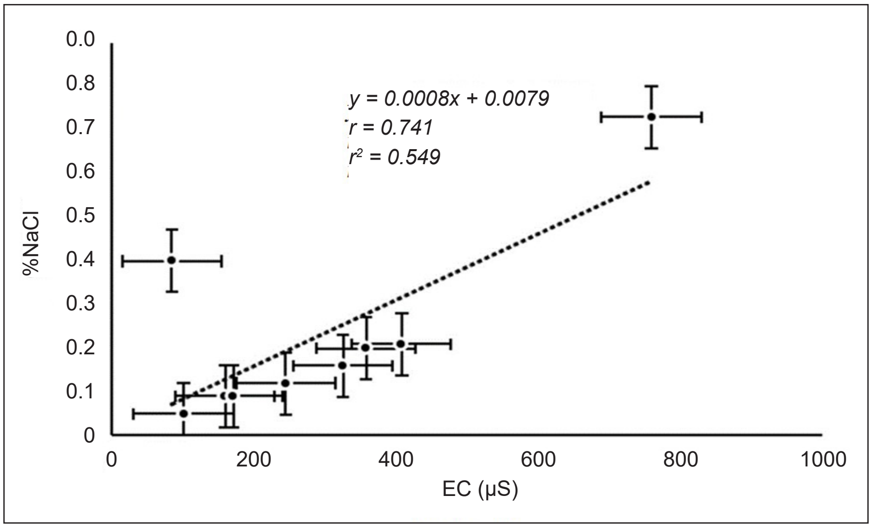

Figure 5. Correlation between EC and % NaCl in paddy field soil in ORP systems in TKR

Table 9
The correlation of soil parameters in TKR

	TC	TN	P	TK	pH	EC	NaCl	Temp.
TC	1	-.535	.010	.156	-.450	.176	-.041	.165
TN	-.535	1	-.299	.175	.099	.325	.546	-.244
P	.010	-.299	1	.422	-.198	-.072	-.193	-.244
TK	.156	.175	.422	1	-.855**	.456	.235	-.471
pH	-.450	.099	-.198	-.855**	1	-.550	-.281	.480
EC	.176	.325	-.072	.456	-.550	1	.741*	-.526
NaCl	-.041	.546	-.193	.235	-.281	.741*	1	-.208
Temp	.165	-.244	-.244	-.471	.480	-.526	-.208	1
BD5	.280	-.558	-.168	-.437	.052	-.042	.151	.433
BD20	.376	-.350	-.124	-.469	.316	-.527	-.229	.775*
C/N ratio	1.000**	-.550	.014	.146	-.442	.164	-.054	.173
SOM5	1.000**	-.535	.010	.156	-.450	.176	-.041	.165
SOC5	1.000**	-.535	.010	.156	-.450	.176	-.041	.165
SOM20	1.000**	-.532	.021	.154	-.446	.180	-.030	.154
SOC20	1.000**	-.532	.021	.154	-.446	.180	-.030	.154

	BD5	BD20	C/N ratio	SOM5	SOC5	SOM20	SOC20
TC	.280	.376	1.000**	1.000**	1.000**	1.000**	1.000**
TN	-.558	-.350	-.550	-.535	-.535	-.532	-.532
P avai.	-.168	-.124	.014	.010	.010	.021	.021
TK	-.437	-.469	.146	.156	.156	.154	.154
pH	.052	.316	-.442	-.450	-.450	-.446	-.446
EC	-.042	-.527	.164	.176	.176	.180	.180
NaCl	.151	-.229	-.054	-.041	-.041	-.030	-.030
Temp	.433	.775*	.173	.165	.165	.154	.154
BD5	1	.559	.290	.280	.280	.277	.277
BD20	.559	1	.384	.376	.376	.369	.369
C/N ratio	.290	.384	1	1.000**	1.000**	.999**	.999**
SOM5	.280	.376	1.000**	1	1.000**	1.000**	1.000**
SOC5	.280	.376	1.000**	1.000**	1	1.000**	1.000**
SOM20	.277	.369	.999**	1.000**	1.000**	1	1.000**
SOC20	.277	.369	.999**	1.000**	1.000**	1.000**	1

Note. * = Correlation is significant at the 0.05 level (2-tailed); ** = Correlation is significant at the 0.01 level (2-tailed); TC = Total carbon; TN = Total nitrogen, P avai.= Phosphorus available; TK = Total potassium; EC = Electrical conductivity; NaCl = Sodium chloride; BD5 = Bulk density of top soil; BD20 = Bulk density deep 20 cm.; C/N ratio = Ratio between carbon and nitrogen; SOM5 = Soil organic matter of top soil; SOC5 = Soil organic carbon of top soil; SOM20 = Soil organic matter of soil deep 20 cm; SOC20 = Soil organic carbon of soil deep 20 cm

[USDA], 2011) because it measures the salinity of the soil and is related to the ion exchange and soil pH. The study found that burning straw in the paddy fields after harvest influenced the EC value; the EC rate was higher in burned fields than in unburned fields ($p < 0.05$). The EC ratio of % NaCl in the soil ($r = 741$; $p < 0.05$) is presented in Table 7. Saline soil is a problem in the TKR zone (Secretariat of the Senate, 2001). Farmers in ORP systems use tilling or plowing straw as a soil improvement method. It is a technique for soil conservation (Freitas, 2000) that can lead to decreased soil erosion and increased organic carbon in the soil (Chen et al., 2019).

Assessment of the SOM/SOC Ratio in ORP Systems in TKR

The value of SOM can be attributed to major amendments in the soil (Swift, 1996) because SOM is related to microbial activity in the soil (Cynthia et al., 2016; Powlson et al., 2001). If the SOM in the soil is less than 1% (> 10 g/kg), fertilizer input should be used for soil amendment (Haque et al., 2021). The SOM5 value of the soil surface in the ORP and GRP systems in TKR averaged 0.13% and 0.15%, respectively, which is very low. GRP systems used manure combined with chemical fertilizer, while ORP systems used manure combined with green manure; however, soil element was not significantly improved in the ORP systems. In addition, the SOM value in ORP systems was below the ideal rate needed for rice production, about 14000–16000 mg/kg (Saenya et al., 2015). Therefore, the SOM value in GRP systems is suitable for rice production in the TKR zone.

SOM values are calculated using SOC content, which affects the indicators; the SOM/SOC ratio will consider the pedogenesis and degree of decomposition of organic and mineral soil substrate (Bianchi et al., 2008; Klingenfuß et al., 2014). In the paddy fields of TKR, the SOM/SOC ratio of topsoil is about 3.45/1. The convention factor of topsoil's SOM/SOC ratio should be more than 1.72, so its median value is 1.9 (Pribyl, 2010). The SOM/SOC ratio in TKR indicates that organic carbon levels in the soil are lower than what is suitable for growing rice (see Table 5), so farmers should adopt methods that increase organic carbon in the soil, such as including pasture in the fields or applying green manure to paddy fields.

Evaluation Including Paddy Field Element Between ORP and GRP System in TKR

The indicator of TN, P available, and TK in TKR found one element of significance is the TKR content in the soil of GRP high than ORP system ($p < 0.05$). Thus, in the ORP system will, the soil, improve by animal manure and green manure for adding TN and phosphorus to the soil (Durán-Lara et al., 2020; Kakar et al., 2020) effect on the content of the element is no different from the GPR system. However, the ORP system uses bio-extract to add TK, but it is inferior to the fertilizer in the GRP system. Therefore, the TK content in soil may be planted using for yield product (Atapattu et al., 2018), where the situation in TKR is the dough, and the high-temperature effect at the biodegradable microbial process in the soil cannot function effectively (Sarkar et al., 2017).

Rice Production Quantities in ORP Systems in TKR

The quantity of rice production in ORP systems in TKR is 2093–2968 kg/ha for Jasmine rice, so organic rice yields about 2090–2544 kg/ha (Panpluem et al., 2019; Suwanmaneepong et al., 2020). On the other hand, the GRP yield in TKR is about 1255–1739 kg/ha, which is below the average rice yield in the country's northeast region average of 1810 kg/ha (Suebpongsang et al., 2020). The rice yield quantity in ORP has affected rice growing methods (Jierwiriyapant et al., 2012) and farming practices in ways that can be classified as follows:

1. ORP uses transplantation for rice growing; this practice has a greater effect on rice yield quantities than broadcasting or drum seeding (Dendup et al., 2018). GRP uses broadcasting most frequently for rice growing.
2. In the TKR zone, the average size of paddy fields in ORP systems is 0.57 ha; it is about 1.2 ha in GRP systems. Smaller fields allow farmers to better care for their crops.
3. ORP includes labor-intensive activities, such as weed and pest control.

CONCLUSION

All indicators in ORP and GRP systems in the TKR zone are lower than the rate in soil that is suitable for rice production. In particular, the quantity of macroelements is TN > TK > TP at a ratio of 338:3:1. The quantity of TK in GRP is higher than in ORP, which is significant ($p < 0.05$). The value of SOM and SOC, including the C/N ratio, is not significant in either ORP or GRP, and the SOM/SOC ratio of 3.45 is higher than the reasonable rate of about 1.9. Soil improvement techniques in ORP systems—manure only and manure combined with green manure—have higher pH values ($p < 0.05$) than fertilizer only input, but the TK value in fields using manure only input and manure combined with green manure is lower ($p < 0.05$) than the fertilizer only input. Burning fields increases EC in the soil ($p < 0.05$), and the relationship of EC to % NaCl ($r = 0.741$) affects soil salinity levels. This study determined that ORP is a more effective system in the TKR zone because yields are impacted by farming practices different from the intensive farming methods used in GRP.

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