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Potential of Paddy Soils for Jasmine Rice Production in Si Sa Ket Province, Northeast Thailand

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ABSTRACT

A study was conducted to characterize seven areas of paddy soils in Si Sa Ket province, northeast Thailand and to evaluate their potential for jasmine rice production. Field soil survey, soil sampling with respect to genetic horizons and soil analyses were undertaken basing on standard procedures. All soils were Ultisols (Korat (Kt1, Kt2), Roi Et (Re1, Re2), Ubon (Ub) and Thatum (Tm) soil series) with one Alfisol (Phimai soil series, Pm). All soils were deep with poorly drained feature but varied in properties. Their suitability for paddy rice cultivation was moderately (Pm soil) to marginally suitable (Kt1, Re2, Ub and Tm soils) with Kt2 and Re1 soils, both being unsuitable but potentially suitable (N1sn). Soil texture(s) was the major restriction of most soils of which loamy sand to sandy loam topsoil induced rather rapid water infiltration rate and a risk of moisture shortage. There were no soils that had a salinity problem despite reports suggesting a stress induced by soluble salts in soils was essential for jasmine rice to produce fragrant substance. Basing on gained yield data collected which varied from 2.41-2.98 t ha^{-1}, all soils were tentatively suitable for jasmine rice, Khao Dok Mali 105 variety. The highest yield was in Pm soil that was slightly higher than that grown on Tm soils (2.94 t ha^{-1}). These amounts of yield were higher than the potential yield of this variety (2.28 t ha^{-1}). This might be due to the impact of management and it indicated that suitability assessment for paddy rice in general cannot be used to evaluate the potential of these paddy soils for growing jasmine rice. The tentative suitability class for this variety should be in better classes according to this study. Nonetheless, low soil moisture retention capacity in addition to low fertility status of the soils needs to be emphasized. Thus, these soil constraints should be designated in the suitability class for growing jasmine rice on these soils in order to provide basic information and sustainable use.

Key words: Jasmine rice, soil potential, coarse-textured soil, tropical paddy soil, soil suitability

INTRODUCTION

Khao Dawk Mali 105 (KDML105) variety, commonly known as jasmine rice, is a premium quality and very famous in the world market because of its unique long slender grain feature with white color. Moreover, the test is soft and smells like a natural fragrance after cooked (Kongsri *et al*., 2002). Thailand is the major producer of high-quality aromatic jasmine rice, which commands a premium price in the world market. In 2013, exported jasmine rice earned over

5.74 billion baht for Thailand (Maclean *et al.*, 2002; Vejpas *et al.*, 2005). The lower northeast Thailand sub-region contains nine provinces covering 8.4 million ha, with 17,357 villages and 11.5 million people. About 70% of the agricultural land belongs to the rainfed lowland rice ecosystem (DOA., 2002). Si Sa Ket, one of those provinces located in the region, is the important area for growing rice, mainly jasmine rice, in the country with the amount produced slightly over million ton per year. Jasmine rice is mostly grown under rainfed conditions in the north-east of the country, a region characterized by an undulating landscape with generally poor soils and erratic rainfall (Homma *et al.*, 2003). The salinity in salt affected soils is the major obstacle in achieving a better result (Cha-Um *et al.*, 2009; Cha-Um and Kirdmanee, 2011). All of these soil constraints caused stunted growth and have drastically reduced rice grain yield and average yields for Jasmine rice in north-east Thailand are about 2.33 t ha^{-1} (Maclean *et al.*, 2002), which is one of the lowest in the world, however, this average yield is slightly higher than that of the potential yield, which is 2.28 t ha^{-1} (Sri-Aun, 2005). Plant nutrients in soils and available water content during growth period have been listed as major biophysical constraints to increasing yields (Jearakongman *et al.*, 1995; Wonprasaid *et al.*, 1996; Fukai *et al.*, 1998; Khunthasuvon *et al.*, 1998). Besides, the increased aromatic fragrance has been reported (Yoshihashi *et al.*, 2004; Gay *et al.*, 2010; Kaewduang *et al.*, 2013). Although genetic factors play a major role in determining rice aroma (Bradbury *et al.*, 2008), environmental factors and cultivation practices have been shown to substantially affect the aromatic quality of rice. Drought and salinity (Dubey and Singh, 1999; Jedrum *et al.*, 2014; Wanichananan *et al.*, 2003) and soil with low level of availability nitrogen and phosphorus but with high sodium concentration may have a positive effect on the aromatic quality of rice.

In assessing the suitability of soils for crop production, soil requirement of crops must be known. Also, these entire requirements must be understood within the next context of limitations imposed by land forms and other features which do not form a part of the soil but may have a significant influence on use that can be made of the soil. Soil suitability classifications are based on knowledge of crop requirement, of prevailing soil conditions, qualifies in broad terms to what extent soil conditions match the areas. The suitability of soil for paddy rice based on FAO framework system is used in cases of growing long grain rice varieties but not specifically for jasmine rice. Jasmine rice has different characteristics from other long grain rice varieties; therefore it may need differences in land quality that is used in the FAO methodology for the assessment of suitability class. Therefore, this study on the vital soil characteristics of jasmine rice cultivated soils was required to evaluate their true potential for jasmine rice production. This result would be used as a basic knowledge for initiating proper soil management that can be implemented in these soils.

MATERIALS AND METHODS

Description of the study site: Si Sa Ket province is located in the southern part of the northeast, Thailand between latitude 14°20'-15°40'N and longitude 103°45'-104°55'E (Fig. 1). This province produces the largest amount of rice, mostly jasmine rice, accounting for more than 0.17 Mt. Traditionally, jasmine rice in this region could be grown under rainfed condition only one crop per year, from July to November.

Seven locations of jasmine rice, KDML 105, growing area in this province were representatively chosen (Fig. 1). The soils selected were in boundaries of Korat (Kt1, Kt2), Roi et (Rt1, Rt2), Ubon (Ub), Thatum (Tm) and Phimai soil series. These areas are under tropical savanna climate with annual rainfall and mean temperature between 2000-2012 being 1,480.4 mm and 27.8°C, respectively (World® Weather Online, 2014).

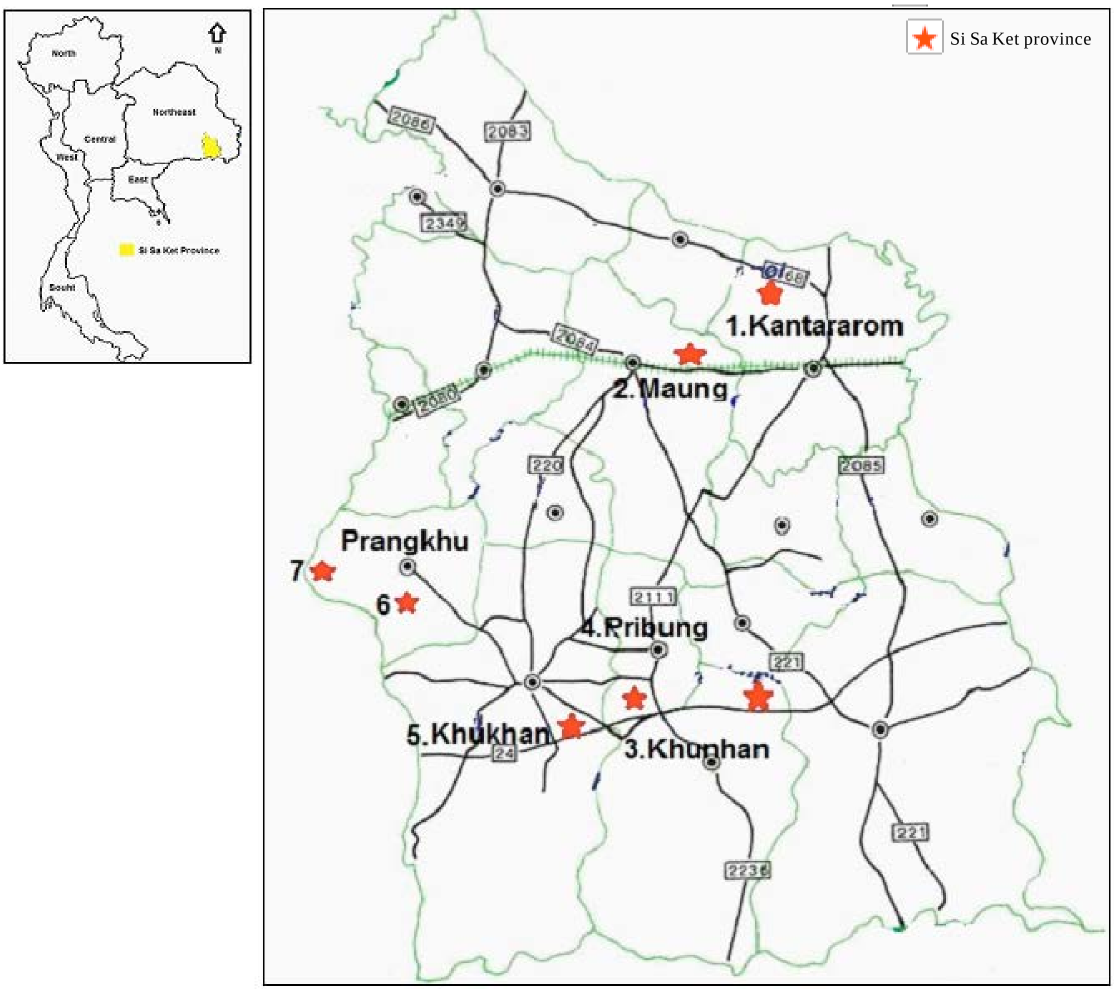


Fig. 1: Location of soil sampling sites (★) in the Si Sa Ket province

Field survey methods consisted of field investigation and soil sampling. Soil profile of each site was dug to the depth of 2 m, if it was able, in order to provide detail soil profile description and sample the soil from all genetic horizons using standard field study procedures and methods (Soil Survey Division Staff, 1993). Jasmine rice grain yield was measured at harvesting stage (110-120 days old) within the area of 4 m^2 in each site where soils and their samples were studied and collected.

Laboratory analyses: Laboratory analyses for soil physico-chemical properties were based on standard procedures. Soil samples were air-dried and crushed to pass through a 2 mm sieve and analyzed for the following parameters. The particle size distribution was determined by a combination of sieve and pipette analysis (Day, 1965). Bulk density was determined by a cold method (Blake and Hartge, 1986). Soil pH was determined for a saturation paste, 1:1 soil: water mixture with a pH-meter (National Soil Survey Center, 1996). Organic carbon was determined according to Walkley and Black wet oxidation procedure (Nelson and Sommers, 1996). Soil was extracted by the Bray II method and subsequently the available phosphorus content was determined by the molybdate blue method (Bray and Kurtz, 1945). Extractable Na, K, Ca and Mg were leached from soils with NH_4OAc pH 7.0 and their concentrations were measured by Atomic Absorption Spectrometry (AAS) (Peech, 1945). Electrical conductivity (ECe) of a saturation extract at 25°C was measured with an electrical-conductivity bridge (Richards, 1954). The calculation of Sodium Adsorption Ratio (SAR) was carried according to US Salinity Laboratory Staff (1954).

Soil suitability evaluation: Land suitability assessment of soils was done using the FAO framework method (Sys *et al*., 1991, 1993; FAO., 1976). Data for the requirements of jasmine rice was obtained through the review of various literatures on their morphological characteristics while water requirement and the soil physicochemical requirements of paddy rice were adapted basing on FAO (1976). The parameters used for the land quality assessment is shown in Table 1. The information for the soil unit's characteristics and crop requirements were matched for each quality to obtain suitability rating. The overall soil suitability classes were obtained using techniques including; principle of limiting condition and arithmetic procedures. Soils were first placed in suitability classes by matching their land characteristics with the agronomic requirements of rice (Table 1).

RESULTS AND DISCUSSION

Soil properties: The soils in this study were developed from different parent materials such as old and local alluvium; wash over residuum derived from siltstone and basalt on undulating surface with slope range of 0.5-5%. The soils were moderately deep to very deep and common profile developments were Apg-Btg and Apg-Btg-Btcg, representing clay accumulation in subsoil horizons (Fig. 2). A presence of indurate plinthite was found in Kt2 and Tm soils, indicating a long dry period over a year in the shallower zone of soils than that of the others. They had thin surface layer with the thickness of 12-21 cm. Soil permeability of these soils was low because of the presence of puddles. These soils had low chroma in matrix and mottles, indicating poorly drained feature and a long period of water logging. The level of ground water table at the time of sampling in dry season was deeper than 200 cm.

The soils had a wide range of textural classes from loamy sand to clay texture with the contents of sand, silt and clay particles ranging from 326-846, 69-339 and 99-378 g kg^{-1}, respectively (Table 2). High bulk density (1.8-2.0 Mg m^{-3}) and slow to moderately slow hydraulic conductivity (0.21-0.65 cm h^{-1}) of the layer directly underneath topsoil (Btg) in all soils reaffirmed that puddling was made in that layer to promote waterlogged condition for growing paddy rice. Most soils exhibited coarse textured characteristics in addition with thin topsoil layer that had insufficient moisture during the growth period of jasmine rice. It was shown by low amount of available water capacity, which accounted in the range between 3.5 and 10.9% by volume except for the Tm soil whose amount was medium (15.2% by volume). This result corresponded to the low content of available water capacity that led to low moisture holding capacity in the soils (Elder and Lal, 2008; Brady and Weil, 2008). This was clearly the major constraint for growing jasmine rice in the area.

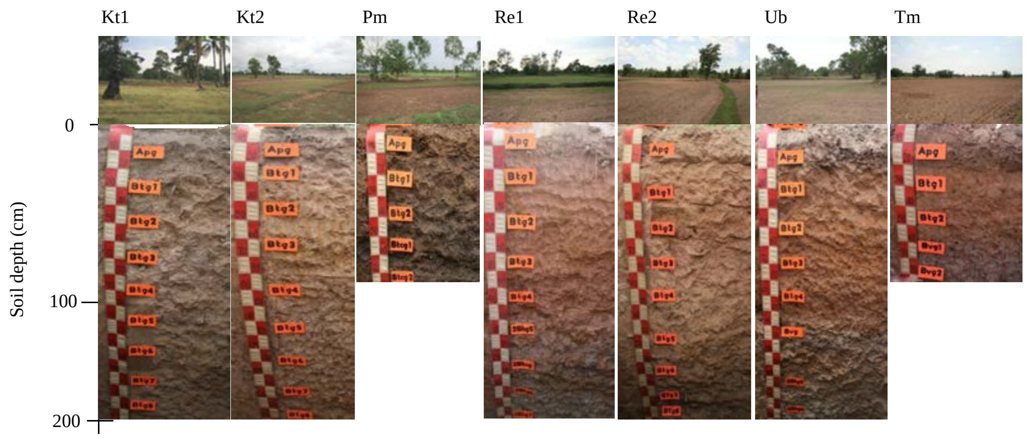
Chemical properties and plant nutrient status of the soils chosen were variable (Table 3). The soils were very strongly acid to slightly alkaline, having soil pH in the range of 4.5-7.4. Organic matter content varied between very low to high (0.34-31.99 g kg^{-1}), while total nitrogen contents being very low (0.04-0.52 g kg^{-1}). Phosphorus availability ranged from very low to high

Table 1: Soil and environmental conditions for paddy rice production

		Land suitability[1]				
Limitations	Symbol	S1	S2	S3	N1	N2
Mean rainfall for rainfed rice during growing season (mm)		>1400	>1000	>800	<800	<800
Mean temp. at crop development stage (°C)		24-36	18-42	10-45		any
Mean temp. at ripening stage (°C)		25-38	20-42	17-45		any
Mean minimum temp. at ripening stage (°C)		17-25	10-28	7-30		any
Average daily maximum temp. warmest month (°C)		30-40	26-45	21-50		any
Relative humidity at tillering (%)		55-90	any			
Relative humidity at vegetative stage (%)		50-90	any			
Growing season sunshine duration at ripening stage (h)						
Topography						
Slope (%)	t	0-4	4-8	8-12	12-25	>25
Wetness						
Flooding[2]	f	F0 to F32	F0 to F42	F0 to F43	F0 to F44	F0 to F45
Drainage	d	Imperfect	Poor to moderate	Poor to good	Poor to good	Very poor to good
Physical soil characteristics						
Textural-structural range[3]	s	C, SiC	SiCL, CL,	SiL, L,	Si, LS,	S
Texture (topsoil)			SC, SCL	SL	S	
Coarse fragments (topsoil) (%)		None	<15	<35	<35	>35
Texture (subsoil)		C, SiC	SiCL, CL, SC, SCL	SiL, Si, L, SL, LS	S	S
Coarse fragments (subsoil) (%)		None	<15	<35	<35	>35
Rockiness	r	0	<2	<10	<10	>10
Depth to impermeable layer (cm)	c	>90	>50	>20	>20	<20
$CaCO_3$ (%)		<6	<15	<25	<25	>25
Fertility limitations (cmol kg^{-1})	n	>16	>10-16	5-10	<5	
Base saturation (top soil) (%)		>50	>35-50	<35		
Organic carbon (top soil) (%)		>1.5	0.8-1.5	<0.8		
Available P (top soil) (mg kg^{-1})		>15	5-15	<5		
Available K (top soil) (mg kg^{-1})		>20	10-20	<10		
Salinity and soil reaction						
Ece (topsoil) (dS m^{-1})	x	<2	2-4	4-8	8-12	>12
Acidity (topsoil) (pH 1:1 H_2O)	a			4.0-4.5	<4.0	
Alkalinity (topsoil) (pH 1:1 H_2O)	k				>8.5	
Depth of jarosite (cm)	j	None	None	<100	<100	
Expected rice yield (t ha^{-1})		>4.7	3.3-4.7	1.9-3.3	1.4-1.9	>1.9

[1]S1: Suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Actually unsuitable but potentially suitable, N2: Actually and potentially unsuitable, [2]Flood sequence defined as duration and depth of flooding, i.e., F32: Flood duration class 3 and flood depth class 2. Tentative classes for duration of floods, class 1 = <2 month, class 2 = 2-3 month, class 3 = 3-4 month, class 4 = >4 month. Tentative flood depth classes, class 1 = <10 cm, class 2 = 10-20 cm, class 3 = 20-40 cm, class 4 = 40-80 cm, class 5 = >80 cm. Flooding depth was to be considered after leveling and grading. F0: No floods, [3]Textural class, C: Clay, SiC: Silty clay, SiCL: Silty clay loam, CL: Clay loam, SC: Sandy clay, SCL: Sandy clay loam, Si: Silt, SiL: Silt loam, L: Loam, SL: Sandy loam, LS: Loamy sand, S: Sand. Modified from Sys *et al*. (1991, 1993)

(0.16-36.64 mg kg^{-1}) whereas available potassium content varied between very low to low (1.43-43.98 mg kg^{-1}). The low amounts of three major plant nutrients show a need of careful



Physiography	Low terrace	Lower part of savanna plain	Middle part of savanna plain	Erosional surface of the upper part of savanna plain	Erosional surface of the upper part of savanna plain	Middle part of savanna plain	Middle part of savanna plain
Elevation (m MSL)	113	117	145	146	154	140	129
Parent material	Old alluvium	Local alluvium	Wash over residuum derived from siltstone	Wash over residuum derived from siltstone	Wash over residuum derived from siltstone	Wash over residuum derived from siltstone	Local alluvium over residuum derived from siltstone
Slope (%)	0.5	2	1	1	1	1	1
Runoff	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Permeability	Slow	Slow	Slow	Slow	Slow	Slow	Slow
Thickness of topsoil (cm)	18	20	12	12	18	18	21
Drainage condition	Poorly drained	Poorly drained	Poorly drained	Poorly drained	Poorly drained	Poorly drained	Poorly drained
Soil structure[1]							
topsoil	1,f, SAB	1,vf-f, SAB	2,f-m, SAB	1,vf-f, SAB	1,vf-f, SAB	1,vf-f, SAB	1,vf-m, SAB
subsoil	2-3,m-c, SAB	1,vf-f, SAB	2-3,f-m, SAB	1,vf-f, SAB	1-2,vf-m, SAB	1,vf-m, SAB	1-2,vf-c, SAB-SeSAB

[1]1 = weak, 2 = moderate, 3 = strong; vf = very fine, f = fine, m = medium, c = coarse, SAB = subangular blocky structure, SeSAB = semi- subangular blocky structure

Fig. 2: Soil profiles and environmental conditions of soils studied

fertilization management, especially nitrogen and potassium, when jasmine rice grown on these soils. Typically, the high contents of organic matter and plant nutrient were found in the topsoil and decreased with decreasing depth (Table 3). This was due to the residual effect of cultivation practices in these areas. The soils had very low to very high contents of extractable bases with Ca being a dominant base except for Re1, Re2, Ub and Tb that both Ca and Na were dominant (Table 3). Additionally, very low to very high CEC (0.25-20.75 $cmol_c\ kg^{-1}$) of soils was closely reflected by the amounts of clay and soil organic matter. This also expressed the soils having very low ability to retain plant nutrients. Values of electrical conductivity ranged from 0.89-0.45 $dS\ m^{-1}$ and sodium adsorption ratio was in the range of 0.3-19.8 (Table 3), indicating that salinity and sodicity were not a limiting factor for growing jasmine rice in these areas.

Soil classification: Basing on morphological, physical and chemical characteristics of the soils, most soils were classified as Ultisols (Kt1, Kt2, Re1, Re2, Ub and Tm soils) because of a presence of argillic horizon that had base saturation of lower than 35% at the defined depth (Soil Survey Staff, 2014). This was with the exception of Pm soil that fell into an Alfisol order, owing to base saturation in the argillic horizon of greater than 35%. The Pm soil had a redoximorphic feature throughout the soil profile with a presence of plinthite within 150 cm depth from the mineral soil surface; therefore it was classified into Typic Plinthaqualf at the subgroup level.

For Ultisols, the soils also had the redoximorphic feature and were saturated with water in all layers throughout the soil profile. Within 150 cm from the mineral soil surface with increasing

Table 2: Physical properties of soils selected

Pedon and depth (cm)	Horizon	Particle size distribution ($g\ kg^{-1}$) Sand	Silt	Clay	Textural class	Bulk density ($Mg\ m^{-3}$)	Hydraulic conductivity ($cm\ h^{-1}$)	Water content (% by vol.) At -33 kPa	At -1500 kPa
Kt1									
0-20	Apg	693	208	99	SL	1.6	0.82	16.3	13.2
20-37/48	Btg1	567	246	188	SL	1.8	0.21	15.2	7.9
48-63	Btg2	542	203	255	SCL	1.6	0.63	18.0	11.0
63-80	Btg3	513	241	247	SCL	1.6	0.66	17.4	11.0
80-99	Btg4	469	260	271	SCL	1.7	1.16	18.5	13.6
Kt2									
0-18	Apg	793	135	72	LS	1.4	1.83	12.9	4.2
18-35	Btg1	775	114	111	SL	1.4	0.65	10.1	2.9
35-53	Btg2	749	168	84	SL	1.5	0.27	10.0	2.6
53-80	Btg3	671	201	128	SL	1.7	0.97	14.0	5.0
80-105	Btg4	577	200	224	SCL	1.6	0.74	19.8	8.7
Pm									
0-12	Apg	643	198	160	SL	1.4	1.30	21.0	9.1
12-30	Btg1	604	177	219	SCL	1.9	0.52	22.8	11.5
30-48/52	Btg2	501	236	263	SCL	1.5	1.74	29.1	18.9
52-64	Btcg1	559	206	236	SCL	1.7	0.47	24.5	12.2
64-80+	Btcg2	468	255	278	SCL	1.7	1.21	29.9	22.0
Re1									
0-12	Apg	841	83	75	LS	1.4	1.78	7.3	2.8
12-34	Btg1	846	91	64	LS	1.7	0.71	6.9	2.5
34-65	Btg2	847	69	84	LS	1.7	2.36	7.7	2.3
65-76	Btg3	851	78	72	LS	1.8	0.40	7.7	1.9
76-96	Btg4	830	106	64	LS	1.8	0.39	8.1	2.2
Re2									
0-18	Apg	739	169	91	SL	1.3	3.43	10.6	3.8
18-40	Btg1	749	124	128	SL	1.8	0.57	18.2	10.7
40-59	Btg2	755	113	132	SL	1.7	0.61	9.5	4.2
59-84/93	Btg3	708	136	156	SL	1.7	0.88	13.5	4.6
93-109	Btg4	663	213	124	SL	1.9	0.13	13.5	4.6
Ub									
0-18	Apg	726	194	80	SL	1.5	4.26	12.5	7.2
18-41	Btg1	692	181	128	SL	2.0	0.46	18.6	4.6
41-60	Btg2	615	225	160	SL	1.5	1.63	21.5	8.4
60-76	Btg3	650	214	136	SL	1.5	1.25	20.3	6.0
76-99/110	Btg4	592	213	195	SL	1.7	0.64	23.1	7.7
Tm									
0-21	Apg	620	268	112	SL	1.3	1.2	22.4	7.2
21-36	Btg1	519	298	183	L	1.8	0.26	21.4	10.4
36-50/56	Btg2	457	339	203	L	1.7	4.21	26.7	11.8
56-73	Bvg1	351	283	367	CL	1.8	0.05	30.5	15.9
73-90+	Bvg2	326	296	378	CL	1.6	0.23	31.3	17.8

Scoring is used for the assessment of physical properties rating of soil according to Kanchanaprasert (1988): Bulk density ($Mg\ m^{-3}$): Low: <1.4, Medium: 1.4-1.8, High: >1.8, Hydraulic conductivity ($cm\ h^{-1}$): Slow: <0.5, Moderate: 0.5-12.5, Rapid: >12.5, Kti and Kt2: Korat, Pm: Phimai soil series, Re1 and Re2: Roiet, Ub: Ubon, Tm: Thatum

depth, there was no clay decrease of 20% or more (relative) from the maximum clay content and the soils had chroma of 3 or more in topsoil. As a result, Kt1, Kt2 and Re2 soils were classified as

Table 3: Chemical properties of selected soils

Pedon and depth (cm)	Horizon	pH	OM ($g\ kg^{-1}$)	Available ($mg\ kg^{-1}$) P	K	Extractable ($cmol_c\ kg^{-1}$) Ca	Mg	Na	CEC	BS (%)	EC ($dS\ m^{-1}$)	SAR
Kt1												
0-20	Apg	4.7	25.8	31.1	15.6	1.25	0.07	0.11	4.0	27.0	0.89	7.8
20-37/48	Btg1	4.7	7.2	2.5	3.9	2.17	0.04	0.31	2.7	33.7	0.15	1.0
48-63	Btg2	4.9	6.9	4.7	7.8	2.03	0.04	0.40	4.5	29.3	0.15	1.0
63-80	Btg3	5.2	8.3	3.0	7.8	2.64	0.06	0.77	3.7	36.7	0.06	1.0
80-99	Btg4	4.8	5.5	5.0	7.8	2.64	0.05	1.02	6.8	42.7	0.10	1.7
Kt2												
0-18	Apg	4.9	18.9	36.6	11.7	0.47	0.10	0.29	1.7	30.8	0.28	0.8
18-35	Btg1	5.9	1.0	3.3	3.9	1.28	0.18	1.07	1.7	29.8	0.18	3.8
35-53	Btg2	5.3	3.4	4.3	7.8	0.57	0.09	0.47	2.2	18.7	0.18	2.9
53-80	Btg3	4.9	2.8	0.9	3.9	1.39	0.29	0.66	2.5	37.1	0.23	1.9
80-105	Btg4	4.7	2.1	3.0	11.7	1.33	0.40	1.01	5.0	21.7	0.15	2.5
Pm												
0-12	Apg	5.3	32.0	22.3	11.7	5.10	2.44	0.80	1.0	43.2	0.23	0.8
12-30	Btg1	5.3	8.9	4.7	3.9	6.62	4.89	0.64	11.0	52.5	0.17	1.1
30-48/52	Btg2	5.3	4.5	1.4	3.9	7.87	7.77	1.54	14.7	58.9	0.15	1.2
52-64	Btcg1	5.6	3.4	4.3	23.4	7.24	7.70	0.51	14.2	56.4	0.10	1.3
64-80+	Btcg2	5.8	4.8	1.2	19.5	8.00	8.18	0.50	17.0	60.3	0.24	3.0
Re1												
0-12	Apg	5.5	12.7	7.6	3.9	0.28	0.06	0.38	0.8	42.5	0.16	4.4
12-34	Btg1	5.5	3.4	3.7	3.9	0.12	0.03	0.63	4.5	44.0	0.17	3.1
34-65	Btg2	5.6	1.0	2.0	1.56	0.13	0.03	0.11	0.3	21.0	0.10	2.5
65-76	Btg3	6.0	1.0	2.7	1.95	0.15	0.03	0.97	1.5	36.7	0.13	4.8
76-96	Btg4	6.2	0.3	1.7	1.95	0.18	0.03	0.59	1.2	44.5	0.17	6.7
Re2												
0-18	Apg	4.5	26.1	10.5	7.8	0.73	0.12	0.72	2.0	21.0	0.45	5.0
18-40	Btg1	4.5	2.8	10.5	7.8	0.85	0.13	0.77	2.5	37.1	0.38	4.4
40-59	Btg2	5.9	1.7	2.0	3.9	1.05	0.22	0.86	2.8	68.1	0.45	4.0
59-84/93	Btg3	6.5	1.4	0.5	3.9	1.63	0.46	0.41	2.2	29.5	0.16	2.9
93-109	Btg4	6.5	1.0	3.3	3.9	0.84	0.29	0.97	2.7	26.0	0.15	2.5
Ub												
0-18	Apg	5.6	25.8	6.3	42.9	0.81	0.12	0.39	4.0	16.9	0.23	3.2
18-41	Btg1	6.4	3.8	1.4	7.8	1.27	0.07	0.85	3.5	52.5	0.35	2.2
41-60	Btg2	6.6	3.1	0.8	7.8	2.03	0.05	0.86	4.5	37.1	0.19	3.5
60-76	Btg3	6.7	3.1	4.7	7.8	1.58	0.04	0.81	5.3	32.8	0.17	9.9
76-99/110	Btg4	6.3	3.1	4.7	7.8	2.64	0.05	1.34	4.0	40.3	0.14	19.8
Tm												
0-21	Apg	5.7	0.7	4.0	27.3	0.79	0.13	0.70	3.5	17.5	0.35	2.8
21-36	Btg1	6.3	0.4	4.0	7.8	1.30	0.25	0.69	3.5	24.4	0.24	2.3
36-50/56	Btg2	6.8	0.3	2.0	15.6	1.16	0.26	0.65	12.0	23.2	0.20	2.1
56-73	Bvg1	6.9	0.3	1.4	19.5	0.59	0.13	0.62	9.5	9.0	0.13	3.1
73-90+	Bvg2	4.6	0.3	0.5	19.5	0.48	0.09	0.74	7.8	8.9	0.12	3.3

Scoring is used for the assessment of chemical properties rating of soil according to Land Classification and FAO Project (FAO., 1973): Organic matter content ($g\ kg^{-1}$): Low: <15, Medium: 15-35, High: >35, Available P ($mg\ kg^{-1}$): Low: <10, Medium: 10-25, High: >25, Available K ($mg\ kg^{-1}$): Low: <60, Medium: 60-90, High: >90, Extractable Ca ($cmol_c\ kg^{-1}$): Low: <5, Medium: 5-10, High: >10, Extractable Mg ($cmol_c\ kg^{-1}$): Low: <1, Medium: 1-3, High: >3, Extractable Na ($cmol_c\ kg^{-1}$): Low: <0.3, Medium: 0.3-0.7, High: >0.7, CEC ($cmol_c\ kg^{-1}$): Low: <10, Medium: 10-20, High: >20, BS (%): Low: <35, Medium: 35-75, High: >75

Table 4: Land suitability assessment of soils selected for paddy rice production

Soil series	Soil taxonomy	Suitability class for paddy rice production	Yield of jasmine rice grow on the soils (t ha^{-1})	Tentative suitability class for jasmine rice
Kt1	Aeric paleaquult	S3s	2.58	S2sn
Kt2	Aeric paleaquult	N1sn	2.81	S3sn
Pm	Typic plinthaqualf	S2s	2.98	S2n
Re1	Arenic paleaquult	N1sn	2.59	S3dn
Re2	Aeric paleaquult	S3s	2.81	S2sn
Ub	Typic plinthaquult	S3s	2.41	S2sn
Tm	Typic plinthaquult	S3s	2.94	S2s
Potential yield of Jasmine rice, KDML105			2.28	-

Aeric Paleaquults with the exception of the Re1 soil that had sandy particle size class throughout a layer extending from the mineral soil surface to the top of the argillic horizon, therefore this soil fell into an Arenic Paleaquult. In the case of Ub and Tm soils, plinthite was found within 150 cm depth from the mineral soil surface; hence they were classified as Typic Plinthaquults (Table 4). However, the plinthite had no part in impeding the growth of jasmine rice root because it was formed in the depth far below rooting zone.

Land suitability classification for jasmine rice production: Sri Sa Ket province is under tropical Savanna climate where the average mean rainfall and temperature over 10 years during the growing season (July-November) of 918.7 mm and 27.6°C, respectively (World® Weather Online, 2014). Therefore, climate, soil depth and ground water table were optimum for growing rice in the study area. Most soils had low fertility status in both topsoil and subsoil mainly due to their low organic matter content, phosphorus and potassium availabilities, low base saturation and low CEC (Table 5), the result was consistent with several reports (Oberthuer and Kam, 2000; Haefele *et al.*, 2006; Boling *et al.*, 2008; Haefele and Konboon, 2009). They also showed poor soil fertility status in northeast Thailand, resulting from low inherent nutrient contents and the dominance of sandy soils.

Most soils (Kt1, Re2, Ud, Tm) were marginally suitable with unfavorable texture (S3s) as strongly limited by predominant sandy particle size class (Table 2). This coarse texture (s) induced rather rapid water infiltration rate and moisture deficiency during growing season. Nonetheless, Pm soil (S2s) was found to be the most suitable for growing rice using normal technology of soil and fertilizer managements with respect to soil and environmental conditions for paddy rice production as shown in Table 1. In some cases as of Kt2 and Re1 they were actually unsuitable but potentially suitable (N1sn) for rice production due to very high sand content in the soils with low nutrient status (n). Regarding slightly undulating surface (2-5% slope), paddy floor must be smoothly graded and high bund was needed for steadily prolonged water storage. This must be taken care very closely and suitably. Although, the nature of soil texture that induced moisture shortage during growing period and reportedly had the adverse effect on reduced yield of jasmine rice, yield survey showed otherwise. Yield data recorded from 7 locations revealed that jasmine rice, KDML 105, grown on all sites chosen gave the yields 3-27% higher than that of yield potential of this rice variety with the yield obtained from Ub soil being the lowest. This indicated that these soils selected were suitable, to some degree, for growing jasmine. This is because jasmine rice is an indigenous variety that is tolerant to doughtiness (Mackill *et al.*, 1996) and barely responds to managements (Bradbury *et al.*, 2008). Ragland and Boonpuckdee (1987, 1988) and Ragland *et al.*

Table 5: Fertility assessment of soils selected using some chemical properties of soil in major rooting zone (0-30 and 30-60 cm for topsoil and subsoil, respectively)

Pedon and depth (cm)	OM[a] (g kg^{-1})	Score	BS[a] (%)	Score	CEC[a] (cmol$_c$ kg^{-1})	Score	Avail. P[a] (mg kg^{-1})	Score	Avail. K[a] (mg kg^{-1})	Score	Total score	Fertility[b]
Kt1												
0-30	16.5	2	30.3	1	3.4	1	16.8	2	9.9	1	7	Low
30-60	7.6	1	33.0	1	4.1	1	3.8	1	7.6	1	5	Low
Kt2												
0-30	10.0	1	30.3	1	1.7	1	20.0	2	8.4	1	6	Low
30-60	3.1	1	27.9	1	2.4	1	2.6	1	7.0	1	5	Low
Pm												
0-30	20.5	2	47.9	2	6.0	1	13.5	2	9.0	1	8	Medium
30-60	4.0	1	57.6	2	14.5	2	2.9	1	14.3	1	7	Low
Re1												
0-30	8.1	1	43.2	2	2.6	1	5.6	1	4.3	1	6	Low
30-60	1.0	1	28.9	1	0.9	1	2.3	1	1.7	1	5	Low
Re2												
0-30	14.4	1	29.0	1	2.2	1	10.5	2	8.2	1	6	Low
30-60	1.5	1	48.8	2	2.5	1	1.2	1	4.2	1	6	Low
Ub												
0-30	14.8	1	43.2	2	3.8	1	3.9	1	26.3	1	6	Low
30-60	3.1	1	35.0	2	4.9	1	2.7	1	7.9	1	6	Low
Tm												
0-30	0.6	1	21.0	1	3.5	1	4.0	1	18.1	1	5	Low
30-60	0.3	1	16.1	1	10.8	1	1.7	1	18.4	1	5	Low

[a]OM (g kg^{-1}): <15 = 1, 15-35 = 2, >35 = 3, Avail. P (mg kg^{-1}): <10 = 1, 10-25 = 2, >25 = 3, Avail. K (mg kg^{-1}): <60 =1 , 60-90 = 2, >90 = 3, CEC (cmol$_c$ kg^{-1}): <10 = 1, 10-20 = 2, >20 = 3, BS (%): <35 = 1, 35-75 = 2, >75 = 3, [b]Fertility rating: Sum of scores from OM, Avail. P, Avail. K, CEC and BS: <7= Low, 8-12 = Medium, >13 = High

(1987) reviewed a number of trials, concluding that, with few exceptions, fertilizer response was abnormally low. Wade *et al.* (1999) compared fertilizer responses across several countries and found the poorest response at sites in northeast Thailand.

Haefele and Konboon (2009) studied the nutrient management for rainfed lowland rice in northeast Thailand and concluded that soil characteristics between lower and upper fields revealed significantly higher soil fertility for lower fields (higher pH, total organic carbon, total soil nitrogen, CEC, clay and silt content; lower sand content). Across seasons and treatments, grain yields were higher in the valley bottom (2.82 t ha^{-1}) than on upper and middle terraces (1.68 t ha^{-1}). This coincided with surveyed yield of this study (Table 5) that the soils (Kt2, Pm and Tm) located in the lower part of the landscape tended to give a better yield. These yields obtained were higher than that of the reported potential grain yield of jasmine rice, KDML 105 (2.28 t ha^{-1}), therefore, the modification of the suitability assessment specifically for jasmine rice is needed. The tentatively modified class is shown in Table 5. Most studied soils should be placed into at least the second suitability class with suffix indicating some soil constraints such as either fertility limitation (n), drainage (d) or topsoil texture (s). However, there are other soils in this region that could be placed into lower class or in the other word, possess lower potential. Such soils are salt affected soils (saline, sodic and saline sodic soils) that distribute extensively in the area. Reports showed that much lower yields of jasmine rice (0.5-1.1 t ha^{-1}) was obtained by Jedrum *et al.* (2014) when grown this rice variety on these soils. However, application of crops residues was recommended to improve soil moisture retention and fertility status. These management practices will increase the suitability of theses soils for higher yield and quality in rainfed sustainable production of jasmine rice production in the study area. In contrast, Willet (1995) and Boling *et al.* (2008) reported a limited and inconsistent yield response to inorganic fertilizer. Contrary to these findings, a large FAO study reported a normal to high fertilizer response (FAO., 1984). Likewise, Khunthasuvon *et al.* (1998) and Homma *et al.* (2007) found good responses to inorganic and organic fertilizers.

CONCLUSION

Seven paddy soils in Si Sa Ket province were chosen for this study. Those were lowland paddy soils with soil colours being indicative of water stagnant. Most soil properties indicated low level of soil quality paddy rice production. There had low fertility status with regard of the contents of organic matter, available phosphorus and potassium, base saturation and CEC. Soil suitability assessment reveled theses soils were moderately to actually unsuitable but potentially suitable with major limitations such as coarse-texture (s) soils in addition with low nutrient status (n). However, the suitability class of these soils did not represent the actual obtainable jasmine rice (Khao Dok Mali 105 variety) yield as shown by the yield surveyed data. All yields obtained were higher than the potential yield of this rice variety, which might be due to cultivating management and the variety being indigenous that subsequently responds differently to soil and environmental conditions as used for the suitability assessment of paddy rice production in general. Improved suitability classes were provided in this study, nonetheless, soil constraints such as risk of water deficit during growing period and lack of plant nutrient reserve along with low ability to retain plant nutrients still remained as a problem that needs to be addressed when grown jasmine rice on these soils.

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