Research article

Using Vermitechnology in Soil Rehabilitation for Rice Production in Salt-affected Area of Northeast Thailand

CHULEEMAS BOONTHAI IWAI*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: chuleemas1@gmail.com

AJCHARAWADEE KRUAPUKEE
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

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Abstract Soil degradation resulting from salinity is a major obstacle to the optimal utilization of land resources. In Northeast Thailand, approximately 17% of the land is salt-affected due to salt bearing rocks, predominantly in Nakhon Ratchasima, Khon Kaen, Roi-Et and Mahasarakham provinces. The present extent of salt-affected soils in the Northeast already substantially restricts crop production in many areas especially rice production. This study aims to study using vermitechnology to rehabilitate saline paddy soil for rice production. The experiments were conducted to study the influence of earthworm and their activity on soil properties, production and growth of rice variety (Pathumthani 1) under the influence of salt. The results found that Activities of earthworms encourage the release of available plant nutrient, especially when associated with the utilization of organic matters. Applying 1% of biochar per 1 kg of dry soil, 650 kg of rice straw per Rai, and 1,000 kg of vermicompost per Rai can significantly increase organic carbon in soil in deteriorated paddy soil (EC= 0.08 – 0.13dS/m), slightly saline paddy soil level 1 (EC= 1.56 – 1.71 dS/m), and moderately saline paddy soil level 2 (EC= 2.90 – 3.47 dS/m). Moreover, the amount of total nitrogen, exchangeable sodium, exchangeable calcium, and exchangeable magnesium in soil also increased under all soil salinity level. The experiment under control condition indicated that activities of earthworms associated with the utilization of biochar, rice straw, and compost produced by earthworm enhanced the availability of plant nutrients. Furthermore, earthworms are soil organisms that benefit to soil property rehabilitation such as improving physical properties of soil by assisting on soil inversion. The burrowing by earthworm loosens the soil causing well drainage and aeration and improving water holding capacity. Activities of earthworms associated with the utilization of biochar, rice straw, and vermicompost in different soil salinity level under control condition enhanced growth rate of rice that increases rice productivity.

Keywords earthworm, rice production, salt-affected area, amelioration

INTRODUCTION

Soil degradation resulting from salinity is a major obstacle to the optimal utilization of land resources. Salt-affected soils are widely distributed throughout the world, with around 20% of the world's cultivated land affected (Sumner, 2000). In Northeast Thailand, approximately 17% of the land is salt-affected due to salt bearing rocks (Land Development Department, 1991), predominantly in Nakhon Ratchasima, Khon Kaen, Roi-Et and Mahasarakham provinces (Department of Mineral Resources, 1982). The salinization of soils in Northeast Thailand has several unique characteristics, and has been accelerated by human activities such as improper land management practices, deforestation, irrigation, salt-making, and construction of roads and reservoirs (Mitsuchi et al., 1986). All of these human activities except salt-making are believed to promote salinization by causing the level of saline groundwater to rise towards the surface. Eventually, low-lying paddy fields become subject to rapid salinization. The present extent of salt-affected soils in the Northeast already substantially restricts crop production in many areas. Concerns regarding the potential future expansion of areas of salt-affected soils and their effects on land and water resources have been reported to be one of the most important issues for farmers who live in affected areas (Kohyama and Subhasaram, 1993; Topark-Ngarm, 2010).

Soil salinity has become a serious threat to crop productivity. Many previous studies (Keren, 2000; Levy, 2000; Liang et al., 2003; Sardinha et al., 2003) have reported on the adverse effects of excessive amounts of salts on the physical and chemical properties of soils and on plant growth and yield. Salt-affected soils exhibit unique structural problems resulting from soil physical processes such as slaking, swelling, and dispersion of clay, which in turn cause degradation of soil structure (Boivin et al., 2004; Tejada and Gonzalez, 2005). These structural changes can affect water and air movement, plant available water holding capacity, root penetration, seedling emergence, and runoff and erosion, as well as tillage and sowing operations (Oster and Jayawardane, 1998). Salinity also affects soil chemical properties through the presence of high soluble salt concentrations (Sumner, 2000). This alters the osmotic and matric potential of the soil solution, thereby adversely affecting soil microbial communities and their activity (Zahran, 1997; Sardinha et al., 2003; Rietz and Haynes, 2003). This in turn can have a negative influence on plant growth and yield (Marschner, 1995). In addition, changes in the proportions of exchangeable ions in the soil solution have osmotic and ion-specific effects that can produce imbalances in plant nutrients, including deficiencies of several nutrients, or conversely high levels of $Na+$ (Grattan and Grieve, 1999; Mengel and Kirkby, 2001). In order to solve such problems, expansion of amelioration actions and improved management practices are needed to reclaim salt-affected soils (Qadir et al., 2001; Suarez, 2001; Barrett-Lennard, 2002).

The amelioration of salt-affected soils can be accomplished through many effective methods, such as water leaching, chemical remediation, and phytoremediation (Sharma and Minhas, 2005; Qadir et al., 2007). The amelioration of salt-affected soils using chemical agents, including gypsum, calcite, calcium chloride and organic matter (farmyard manure, green manure, organic amendments, and municipal solid waste), is a successful approach that has been implemented worldwide (Mitchell et al., 2000; Hanay et al., 2004; Sharma and Minhas, 2005; Tejada et al., 2006). According to Melero et al. (2007), the application of organic matter conditioners has become a common practice in salt-affected areas in the last several decades and constitutes an important method of soil regeneration and fertility enhancement. The application of organic matter for soil remediation is considered essential for sustainable land use and crop productivity.

Vermitechnology has been developed as a means of using earthworm converting wastes into value-added products which can be utilized for improving soil structure and fertility. Agro wastes could effectively be tapped for resource recovery through vermicomposting technology to produce a product for use in land rehabilitation. Adding compost or vermicompost to soils can help to replenish soil organic carbon which can help to improve soil health and promote further primary productivity (Iwai et al., 2010; 2011; Lal, 2004;).

Earthworms are known to have beneficial effects on the physical, chemical and biological properties of soils, and thereby contribute to increased plant growth and crop yields in both natural and managed ecosystems (Edwards and Bohlen, 1996; Edwards, 1998). Their beneficial effects have been attributed to improvements in soil properties and structure, greater availability of mineral nutrients to plants (Gilot, 1997), and enhanced microbial populations and activity, thereby producing biologically active metabolites such as plant growth regulators (Doube et al., 1997).

OBJECTIVE

The objective of this study was to investigate the effectiveness of vermitechnology for alleviating salt-affected soils, and to determine the effect of these amendments on the rice production in Northeast of Thailand.

METHODOLOGY

Preparation of Soil and Vermicompost

An experiment was carried out to investigate the effects of vermicompost produced on soil properties of different level of saline soils on the growth of rice under greenhouse conditions at Khon Kaen University, Thailand, during the rainy season of 2015. The soil was air-dried and passed through a 2 mm mesh to remove stones and other debris. The initial physical and chemical properties of the soils before the start of the experiment are shown in Table 1. Vermicompost were prepared in a laboratory of the Land Resources and Environment Department, Faculty of Agriculture, Khon Kaen University. They were produced from cassava waste materials incubated for two months in black plastic pots. The earthworm species used to produce the vermicompost was Eudrilus eugeniae. The chemical properties of the vermicompost used are shown in Table 1.

Table 1 Chemical characteristic of soil, biochar and vermicompost used for experiments

Parameter	Soil	Biochar	Vermicompost
Soil texture	loam	-	-
Sand (%)	49.9	-	-
Silt (%)	38.1	-	-
Clay (%)	12.0	-	-
OM (%)	0.63	16.40	8.37
EC (dS/m)	0.09	2.85	2.20
pH (1:5)	6.32	6.34	6.84
Total N (%)	0.059	0.16	0.77
Extractable P (ppm)	2.94	2,543.53	2,309.52
Exchangeable K^+ (ppm)	56.14	5,886.65	7,683.94
Exchangeable Na^+ (ppm)	48.89	113.45	142.34
Exchangeable Ca^{2+} (ppm)	930.90	3,084.95	13,675.76
Exchangeable Mg^{2+} (ppm)	81.38	669.86	1,992.63

Experimental Design

The experiments were conducted to study the influence of earthworm and their activity on soil properties, production and growth of rice variety (Pathumthani 1) under the influence of salt. The experiment was laid out in a completely randomized design (CRD) with three replications. Three level of saline soils were used, in deteriorated paddy soil (EC= 0.08 – 0.13dS/m), slightly saline paddy soil level 1 (EC= 1.56 – 1.71 dS/m), and moderately saline paddy soil level 2 (EC= 2.90 – 3.47 dS/m). Seven treatments were compared: T1 = control; T2 = biochar (BC1%); T3 = biochar (BC1%)+earthworms (20 individuals pot-1); T4 = rice straw 650 kg/rai; T5 = rice straw 650 kg/rai)+earthworms (20 individuals pot-1); T6 = vermicompost (VMC) 1,000 kg/rai; T6 = earthworms (20 individuals pot-1). Seven kilograms of 2 mm sieved air-dried soil were placed in each black plastic pot of 30 cm height and 25 cm diameter for each treatment.

Table 2 The results of vermitechnology with different amendments on Rice production in deteriorated paddy soil (EC= 0.08 – 0.13 dS/m)

Treatments	Spikelet number	Yield)kg./Rai(	1000 grain weight)g)
Soil	12.33	816.00 ab	25.40 ab
soil add earthworm (EW)	13.67	849.20 ab	26.87 a
soil add biochar (BC)	11.33	705.10 bc	25.90 a
soil add BC and EW	14.33	1,000.51 a	26.77 a
soil add rice straw	12.00	512.09 c	23.33 b
soil add rice straw and EW	13.33	599.47 bc	26.23 a
soil add vermicompost (VMC)	14.67	817.12 ab	26.37 a
soil add VMC and EW	16.00	1,024.38 a	27.17 a
f-test	ns	**	**
CV %	20.18	14.27	4.04

Note: Values are mean ± standard deviation. Means with the same letter in the same column are not significantly different (P>0.05)

Table 3 Results of vermitechnology with different amendments on Rice production in slightly saline paddy soil level 1 (EC= 1.56 – 1.71 dS/m)

Treatments	Spikelet number	Yield)kg./Rai(	1000 grain weight)g)
Soil	7.33	496.00 bc	24.60
soil add earthworm (EW)	8.67	593.90 abc	26.30
soil add biochar (BC)	6.33	482.85 bc	25.30
soil add BC and EW	9.33	751.44 ab	26.43
soil add rice straw	7.00	385.21 c	23.80
soil add rice straw and EW	8.33	635.48 abc	26.53
soil add vermicompost (VMC)	9.67	763.06 ab	26.67
soil add VMC and EW	11.00	878.00 a	27.07
f-test	ns	**	ns
CV %	32.11	21.06	5.02

Note: Values are mean ± standard deviation. Means with the same letter in the same column are not significantly different (P>0.05)

Plant Data Collection

The growth and rice production were measured.

Soil Analyses

Triplicate soil samples were collected at a depth of 0–10 cm by taking a soil core from each pot at the end of the experiment. The soil samples were analyzed for soil physical and chemical properties at the laboratory of the Land Resources and Environment section, Faculty of Agriculture, Khon Kaen University. Soil texture was determined by a hydrometer (Bouyoucos, 1951). Soil pH was determined in a 1:2.5 soil to water solution by a pH meter. Electrical conductivity (ECe) in saturated paste extracts was measured following the method described by the United States Department of Agriculture (USDA, 1954). Cation exchange capacity (CEC) was determined by the 1 N ammonium acetate method (Black, 1965), and total soil organic carbon (SOC) was determined by the method of Walkley and Black (1934). Total nitrogen (TN) was measured by the Kjeldahl method (Bremner, 1960). Extractable phosphorus (Extr. P) was determined by the Bray II method (Bray and Kurtz, 1945). Exchangeable potassium (Exch. K+), sodium (Exch. Na+), calcium (Exch. Ca2+) and magnesium (Exch. Mg2+) were extracted with 1 N ammonium acetate (pH 7.0) (Schollerger and Simmon, 1945). The concentrations of K+ and Na+ from these extracts were analyzed by flame photometry, while those of Ca2+ and Mg2+ were analyzed by atomic absorption spectrometry following a standard procedure.

Statistical Analysis

The data collected were analyzed statistically using analysis of variance (ANOVA) techniques. Treatment means were compared by the Least Significant Difference (LSD) method at the 5% level. All data analysis was done using Statistix 8.0 (Analytical Software, 2003).

RESULTS AND DISCUSSION

The results found that Activities of earthworms encourage the release of available plant nutrient, especially when associated with the utilization of organic matters. Applying 1% of biochar per 1 kg of dry soil, 650 kg of rice straw per Rai, and 1,000 kg of vermicompost per Rai can significantly increase organic carbon in soil in deteriorated paddy soil (EC= 0.08 – 0.13dS/m), slightly saline paddy soil level 1 (EC= 1.56 – 1.71 dS/m), and moderately saline paddy soil level 2 (EC= 2.90 – 3.47 dS/m). Moreover, the amount of total nitrogen, exchangeable sodium, exchangeable calcium, and exchangeable magnesium in soil also increased under all soil salinity level. The experiment under control condition indicated that activities of earthworms associated with the utilization of biochar, rice straw, and compost produced by earthworm enhanced the availability of plant nutrients.

Table 4 The results of vermitechnology with different amendments on Rice production in moderately saline paddy soil level 2 (EC= 2.90 – 3.47 dS/m)

Treatments	Spikelet number	Yield)kg./Rai(	1000 grain weight)g)
Soil	5.33	314.56	22.50
soil add earthworm (EW)	6.67	460.41	23.90
soil add biochar (BC)	4.33	457.14	23.37
soil add BC and EW	6.67	480.00	23.57
soil add rice straw	5.00	400.54	23.07
soil add rice straw and EW	5.00	459.32	23.43
soil add vermicompost (VMC)	6.33	521.36	23.20
soil add VMC and EW	8.00	535.51	24.53
f-test	ns	ns	ns
CV %	37.63	18.41	3.44

Note: Values are mean ± standard deviation. Means with the same letter in the same column are not significantly different (P>0.05)

CONCLUSION

The above results showed the beneficial effects of earthworm and vermicompost application in increasing the rice growth and production. The results of soil analysis showed that application of vermicompost significantly increased soil organic carbon, CEC and soil N, P and K contents. Organic amendments can thus serve as a source of essential nutrients for plants as well as contributing to improved soil properties. In addition, these amendments increased exchangeable K+, Ca2+ and Mg2+ while decreasing exchangeable Na+ in the saline soil, thereby reducing soil salinity. These results suggest that the use of earthworm and vermicompost is likely to be helpful for both alleviating salinity and improving crop productivity in salt-affected areas. The addition of earthworms as soil conditioners can also contribute to improved physical, chemical and biological properties of the soil and thereby increase its nutritive value for plants.

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