Research article

Earthworm Communities and Activities in Rice Ecosystem under Different Soil Salinity Levels in Northeast Thailand

AJCHARAWADEE KRUAPUKEE
Land Resources and Environment Division, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

CHULEEMAS BOONTHAI IWAI*
Integrated Water Resource Management Resource and Development Center in Northeast Thailand, Khon Kaen University, Khon Kaen, Thailand
Email: chulee_b@kku.ac.th

NARUMOL KAEWJAMPA
Faculty of Forestry, Kasetsart University, Bangkok, Thailand

Received 16 January 2016 Accepted 10 November 2016 (*Corresponding Author)

Abstract Soil salinity is one of the most serious agricultural problems. This problem generates low soil productivity and soil ecosystem. Earthworms are one of the most important soil organisms in soil ecosystem (maintaining soil structure and the fertility of soil). Soil salinity has become one of the major determinants of crop productivity in Northeast Thailand. The aim of present study was size and composition of earthworm communities on related soil properties and rice growth under different soil salinity; 2 levels 1) low soil salinity (EC 2-4 dS/m) and 2) moderate soil salinity (EC 4-8 dS/m). Soil and earthworm cast were collected to analyze for soil chemical properties. The results showed that there was significant difference between density and size of different species of earthworms in different level of soil salinity. In rice ecosystem in moderate salt-affected area the earthworm species *Drawida beddardi* was the only one found at 95 days after rice sowing, while in low salt affected area the earthworm species, *Glyphidrilus chiensis* and *Drawida beddardi* were the most common species found at 45 days after rice sowing. Earthworms improve soil properties and rice growth rate. *Oryza sativa L.* (Khao Dawk Mali 105 and RD6) growth decreased with increasing levels of soil salinity.

Keywords earthworm, rice ecosystem, salt-affected area

INTRODUCTION

Increasing soil salinity is a serious land degradation issue worldwide. Thailand salinization is amongst the major degradation processes endangering the potential use of Northeast Thailand soils. Despite of the naturally occurring salinization, deicers for removal from salt-bearing rocks (Land Development Department, 1991) in the Nakhon Ratchasima, Khon Kaen, Roi-Et and Mahasarakham provinces (Department of Mineral Resources, 1982). Salts have negative effects on ecosystem and environments have appeared increasingly. Sodium chloride (NaCl) from salt-bearing rocks is responsible for the increased salinity of soil surface and ground waters. Chloride accumulation can compromise soil structure and increase soil erosion, reduce soil fertility, and have an effect on soil chemistry. Salts negatively affect environmental ecosystems crop yield (Grewal, 2010; Li et al. 2010; Zhang et al. 2010), soil microorganisms (Yuan et al., 2007; Ibekwe et al., 2010), plants (Gadallah and Ramadan, 1997; Joutti et al., 2003; Ruhland and Krna, 2010), and soil organisms (Owojori et al., 2008). There has been a growing concern of the environmental effects resulting from deicing.

Earthworms are soil engineers, they have potential to improve soil properties, physical, chemical, and biological (Jouquet et al., 2009). Earthworm cast is usually chemical and physically protected and stabilizes aggregate and SOM in soil and (Bossuyt et al., 2005; Jouquet et al., 2008a; Chutima et al., 2010). There is also the positive influence of earthworms on soil structure (Mackay and Kladivko, 1985; Ketterings et al., 1997) and plant growth and yield (Scheu, 2003; Eisenhauer et al., 2009). Although, most of the published works which reported earthworm aerobic ecosystems, very few studies were carried out in partially or totally flooded environments, such as paddy fields. Flooding events are considered as adverse periods limiting the activity of macrofauna such as earthworms (Schütz et al., 2008; Chutima et al., 2010).

OBJECTIVE

The aim of this paper was to monitor the diversity and size of earthworm species in rice ecosystem and influences of earthworm on soil properties and rice growing in salt-affected area.

METHODOLOGY

Study Site

Studied in paddy field salinity area Phai district, Khon Kaen province during rainy season 2014, were selected area from map of the distribution of saline soil Land Development Department 5 Khon Kaen, two levels salinity, 1) low soil salinity (EC 2-4 dS/m) and 2) moderate soil salinity (EC 2-4 dS/m). These are areas sowing jasmine rice 105 and sticky rice RD 6, samples of soil rice growing and earthworms in three replicates.

Statistical Analyses

The data collected were statistically analyzed using analysis of variance techniques. Statistical analysis was performed employing Statistics 8.0 (Analytical Software, 2003). Mean comparisons of different treatments were done by least significant difference (LSD) and standard error of the difference (SED).

RESULTS AND DISCUSSION

Distribution of Earthworm

Distribution of earthworm population is highest on low salinity area (EC 2-4 dS/m^{-1}) about 280 (Juvenile and Adult) earthworm number per m^2 (Table 1), found earthworm activities *Glyphidrilus chiensis* and *Drawida beddardi* species (Fig. 1) at 45 days after rice sowing. Moderate soil salinity (EC 2-4 dS/m) *D*. *beddardi* is found only specie in this area about 20 (Adult) earthworms per m^2, they had activity at 95 days after rice sowing. Chanaban et al. (2013) have discovered a new earthworm species in the genus Glyphidrilus in paddy fields Northeast of Thailand. Earthworm species is most commonly found in paddy soil. Ivask and et al. (2007) study of earthworm's community in coastal areas and grasslands, flooded areas has lower earthworm's species. Thibaud et al (2003) reported factors that have influence on earthworm diversity environmental conditions, physical and chemical properties of soil, topography, climate and humans (agriculture and pollution).

Table 1 Diversity of earthworms in rice ecosystem under different soil salinity levels in Banpai district, Khon Kaen province

Rice ecosystem under different soil salinity levels	Species	Stage of earthworm	
		Juvenile	Adult
		(Number/ m^2)	
Low soil salinity - found earthworm activities at 45 days after rice sowing	*Glyphidrilus chiensis* *Drawida beddardi*	196 ±13.2 48 ± 4.4	28 ±3.1 8 ±2.1
Moderate soil salinity - found earthworm activities at 95 days after rice sowing	*Glyphidrilus chiensis* *Drawida beddardi*	- -	- 20 ±2.1

Mean (n=3)

Fig. 1 Earthworm species *Glyphidrilus chiensis* and *Drawida beddardi* in rice ecosystem under different soil salinity levels

Earthworm Activities on Soil Properties

The results of earthworm activities on soil chemical properties showed OM, pH, total N, available P and K in cast were increased. Earthworm activities have decreased soil EC (Table 2). Soil salinity reduces soil fertility, to have an effect on soil chemistry. Salts negatively affect environmental ecosystems crop yield (Grewal, 2010; Li et al. 2010; Zhang et al. 2010), soil microorganisms (Yuan et al., 2007; Ibekwe et al., 2010), plants (Gadallah and Ramadan, 1997; Joutti et al., 2003; Ruhland and Krna, 2010) and soil organisms (Owojori et al., 2008). Earthworms decompose organic matter and release plant nutrients into the soil such as ammonium nitrate, exchangeable potassium etc. and plant growth hormones and vitamins.

Table 2 Earthworm cast properties in rice ecosystem under different soil salinity levels in Banpai district, Khon Kaen province

Rice ecosystem under different soil salinity levels		OM	pH	EC	Total N	Avai P	K
		%	(1:5)	(dS/m)	%	ppm	ppm
low soil salinity	soil	0.84	6.6	0.29	0.1	5.39	42.83
(EC = 2-4 dS/m)	cast	2.08	7.5	0.11	0.4	11.58	139.68
moderate soil salinity	soil	0.78	6.4	0.65	0.1	2.62	31.17
(EC = 4-8 dS/m)	cast	1.88	7.1	0.46	0.4	5.12	100.37

Mean (n=3)

Earthworm activities on rice growth under different soil salinity levels

Statistical analyses showed that the influence of earthworm activity with earthworm cast and salinity levels on rice number per m^2 and height of rice (Table 3) Jouquet et al. (2008b) showed that casts produced by *Glyphidrilus* sp. can be considered as patches of nutrients in paddy fields in Northeast

Thailand. In Africa, Owa et al. (2003) also observed faster rice development and greater productivity when earthworm casts were associated to rice plants.

Table 3 The growth of rice ((*Oryza sativa* L.) KhaoDawk Mali 105 and RD6) under different soil salinity levels

Rice ecosystem under different soil salinity levels	Number of plant (m^2)	Height of plant flowering stage (cm)
Low soil salinity growing KhaoDawk Mali 105	35.32	92.13 abc
Low soil salinity growing RD6	30.00	103.07 a
Moderate soil salinity growing KhaoDawk Mali 105	19.00	81.63 c
Moderate soil salinity growing RD6	24.64	97.20 ab
F-test	ns	*
C.V. (%)	48.11	8.11

Remark: Mean (n = 3) in the same column followed by the same lower case letters are not significantly different at |p| ≤ 0.05 (LSD)

CONCLUSION

Within the rice ecosystem in low salt affected area (EC 2-4 dS/m), the earthworm species, *Glyphidrilus chiensis* and *Drawida beddardi* were the most common species found at 45 days after rice sowing (280 earthworms per m^2), while in moderate salt-affected area (EC 4-8 dS/m) the earthworm species *G. chiensisis* was the only specie found at 95 days after rice sowing (20 number of earthworm per m^2). *Oryza sativa* L. (Khao Dawk Mali 105 and RD6) growth decreased with increasing levels of soil salinity. Soil salinity influences the distribution of earthworm and rice growth. In salt-affected area earthworms play a main role on maintaining soil fertility, soil chemical properties, soil microbial communities and soil physical properties.

ACKNOWLEDGEMENTS

This study is supported by Integrated Water Resource Management and Development Center in Northeast, Thailand, Khon Kaen University, Thailand. Special thanks to the Research Developing and Learning Centre on Earthworm for Agriculture and Environment for facilities provided. Thanks, are extended to the Division of Land Resource and Environment, Faculty of Agriculture, Khon Kaen University for the support of equipment for laboratory testing.

REFERENCES

Analytical Software. 2003. Statistix 8. User's Manual. Analytical Software, Tallahasse.

Bossuyt, H., Six, J. and Hendrix, P.F. 2005. Protection of soil carbon by microaggregates within earthworm casts. Soil Biol. Biochem., 37, 251-258.

Chanabun, R., Sutchari, C., Tongkerd, P. and Panha, S. 2013. The semi-aquatic freshwater earthworms of the genus Glyphidrilus Horst, 1889 from Thailand (Oligochaeta, Almidae) with re-descriptions of several species. ZooKeys, 265, 1-76.

Chutinan, C., Jouquet, P., Hanboonsong, Y. and Hartmann, C. 2010. Effects of earthworms on soil properties and rice production in the rainfed paddy fields of Northeast Thailand. Appl. Soil Ecol., 45, 298-303.

Department of Mineral Resources. 1982. Geologic map of Thailand. Department of Mineral Resources, Bangkok.

Eisenhauer, N., Milcu, A., Nitschke, N., Sabais, A., Scherber, C. and Scheu, S. 2009. Earthworm and belowground competition effects on plant productivity in a plant diversity gradient. Oecologia, 161, 291-301.

Gadallah, M.A.A. and Ramadan, T. 1997. Effects of zinc and salinity on growth and anatomical structure of Carthamus tinctorius L. Biologia Plantarum, 39 (3), 411-418.

Grewal, H.S. 2010. Water uptake, water use efficiency, plant growth and ionic balance of wheat, barley, canola and chickpea plants on a sodic vertosol with variable subsoil NaCl salinity. Agricultural Water Management, 97 (1), 148-156.

Ibekwe, A.M., Poss, J.A., Grattan, S.R., Grieve C.M. and Suarez, D. 2010. Bacterial diversity in cucumber (Cucumis sativus) rhizosphere in response to salinity, soil pH, and boron. Soil Biology and Biochemistry, 42 (4), 567-575.

Ivask, M., Truu, J., Kuu, A., Truu, M. and Leito, A. 2007. Earthworm communities of flooded grasslands in Matsalu, Estonia. European Journal of Soil Biology, 43, 71-76.

Jouquet, P., Bottinelli, N., Podwojewski, P., Hallaire, V. and Duc, T.T. 2008a. Chemical and physical properties of earthworm casts as compared to bulk soil under a range of different land-use systems in Vietnam. Geoderma, 146, 231-238.

Joutti, A., Schultz, E., Pessala, P., Nystén, T. and Hellstén, P. 2003. Ecotoxicity of alternative deicers. Journal of Soils and Sediments, 3 (4), 269-272.

Ketterings, Q.M., Blair, J.M. and Marinissen, J.C.Y. 1997. Effects of earthworm on soil aggregate stability and carbon and nitrogen storage in a legume cover crop agroecosystem. Soil Biol. Biochem., 29, 401-408.

Land Development Department. 1991. Distribution of salt-affected soil in the northeast region 1:100,000 map. Department of Land Development, Bangkok.

Li, L.Z., Zhou, D.M., Peijnenburg, W.J.G.M., Wang, P., van Gestel, C.A.M., Jin, S.Y. and Wang, Q.Y. 2010. Uptake pathways and toxicity of Cd and Zn in the earthworm Eisenia fetida. Soil Biology and Biochemistry, 42 (7), 1045-1050.

Mackay, A.D. and Kladivko, E.J. 1985. Earthworm and rate of breakdown of soybean and maize residues in soil. Soil Biol. Biochem., 17, 851-857.

Owa, S.O., Oyenusi, A.A., Joda, A.O., Morafa, S.O.A. and Yeye, J.A. 2003. Effect of earthworm casting on growth parameters of rice. Afr. Zool., 38, 229-233.

Owojori, O.J., Reinecke, A.J. and Rozanov, A.B. 2008. Effects of salinity on partitioning, uptake and toxicity of zinc in the earthworm Eisenia fetida. Soil Biology and Biochemistry, 40, 2385-2393.

Owojori, O.J., Reinecke, A.J., Voua-Otomo, P. and Reinecke, S.A. 2009. Comparative study of the effects of salinity on life-cycle parameters of four soil dwelling species (Folsomia candida, Enchytraeus doerjesi, Eisenia fetida and Aporrectodea caliginosa). Pedobiologia, 52, 351-360.

Ruhland, C.T. and Krna, M.A. 2010. Effects of salinity and temperature on Deschampsia antarctica. Polar Biology, 33 (7), 1007-1013.

Scheu, S. 2003. Effects of earthworms on plant growth, Patterns and perspectives. Pedobiologia, 47, 846-856.

Schütz, K., Nagel, P., Dill, A. and Scheu, S. 2008. Structure and functioning of earthworm communities in woodland flooding systems used for drinking water production. Appl. Soil Ecol., 39, 342-351.

Thibaud, D., Fabrice, B. and Pierre, M. 2003. Earthworm communities in a wet agricultural landscape of the Seine Valley (Upper Normandy, France). Pedobiologia, 47, 479-489.

Yuan, B., Li, Z., Liu, H., Gao, M. and Zhang, Y. 2007. Microbial biomass and activity in salt affected soils under arid conditions. Applied Soil Ecology, 35, 319-332.

Zhang, J.L., Flowers, T.F.J. and Wang, S.M. 2010. Mechanisms of sodium uptake by roots of higher plants. Plant and Soil, 326 (1-2), 45-60.