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Effect of EM Bokashi application on control of secondary soil salinization

Shao Xiaohou*[1, 2], Tan Min[1], Jiang Ping[3], Cao Weiling[3]

1. *College of Agricultural Engineering, Hohai University, Nanjing 210098, P. R. China*
2. *Key laboratory of Irrigation–Drainage and Agricultural Water and Soil Environment in Southern China, Ministry of Education, Hohai University, Nanjing 210098, P. R. China*
3. *Central Station of Rural Water Conservancy, Zhejiang Provincial Bureau of Water Resources, Hangzhou 310009, P. R. China*

Abstract: In order to ameliorate saline-alkaline soil, EM Bokashi has been applied to rice production in conjunction with subdrainage in Ningxia Autonomous Region and Zhejiang Province. The preliminary results can be summarized as follows: EM Bokashi can increase soil organic matter content, improve soil porosity and permeability, and raise the soil's levels of available nutrients; and EM Bokashi combined with subdrainage treatment is more effective in controlling secondary soil salinization and raising the grain yield and quality than other treatments. The results suggest that EM Bokashi can reduce the necessary amount of chemical fertilizer application, thereby improving the agricultural environment, and that the introduction of EM Bokashi into systems of secondary soil salinization control systems has resulted in significant benefits.

Key words: *EM Bokashi*; *secondary salinization control*; *soil amelioration*; *grain yield and quality*; *subdrainage*; *agricultural environment*

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1 Introduction

The use of beneficial and effective microorganisms (EM) as microbial inoculants in agriculture is a promising new technology. It has been shown to be effective in improving soil health and quality, inevitably raising the yield and quality of crops. Currently, EM technology has been applied in more than 90 countries and regions, including Japan, the United States, France, Austria and North Korea. Employing EM composting fertilizer and EM-activated liquid has been shown to promote root growth and improve the germination potential and germination rate. Spraying rice seedlings with EM liquid causes an increase in the leaf area, stem thickness and chlorophyll content. Meanwhile, effective control of the wilting of rice seedlings can be achieved (Melloni et al. 1995; Jowett and McMaster 1995; Mosbæk et al. 1988).

There are 369 000 km^2 of soils experiencing secondary salinization in China, including 62 400 km^2 of cultivated soils, making up about 7% of the country's cultivated lands. They are mainly found on the Huang-Huai-Hai Plain, on the western plain of Northeast China, near the

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*Corresponding author (e-mail: *shaoxiaohou@163.com*)
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Great Bend of the Yellow River, in inland areas of Northwest China, and along a small part of the eastern coast. These cultivated lands, mostly affected by salt through irrigation with neglect of the drainage system, notably in the (semi-) arid regions, are great obstacles to the development of agriculture (Shao et al. 2001). EM technology was introduced in China in 1992. It has been proven through research and demonstration tests to be effective in agricultural and environmental protection (Gunapala and Scow 1998). The technology has been used in the cultivation of plants with EM fertilizer, EM spray fertilizer, and EM-soaked roots, but little research has been conducted on the amelioration of salt-affected soil with EM technology, either in China or in other countries. In this study, EM Bokashi was applied to rice production in conjunction with subdrainage in Ningxia Autonomous Region and Zhejiang Province in order to investigate the effectiveness of EM in controlling secondary soil salinization.

2 Materials and methods

2.1 Experimental sites

The field experiments were conducted in the saline soils of Qianjin Farm in Ningxia Autonomous Region and in Baiquan Town of Zhoushan City in Zhejiang Province. The physical and chemical properties of tested soils at a depth of 0-20 cm are listed in Table 1.

Table 1 Properties of tested soils and EM Bokashi

Item	C (g/kg)	N (g/kg)	C/N ratio	Organic matter (g/kg)	pH	EC (dS/m)
Soil of Qianjin Farm	14.5	1.2	12.1	8.2	8.0	5.5
Soil of Baiquan Town	32.4	2.3	14.1	16.9	7.2	3.5
EM Bokashi	483.2	24.5	19.7		5.5	4.8
Item	Alkaline N (mg/kg)	Available P (mg/kg)	Total salt content (g/kg)	Bulk density (g/cm^3)	CEC (cmol/kg)	Texture
Soil of Qianjin Farm	26.0	8.9	3.6	1.70	3.2	heavy clay soil
Soil of Baiquan Town	101.2	17.2	1.8	1.47	9.8	loam clay soil
EM Bokashi	982.0	653.0	2.7			

Qianjin Farm is situated in an arid area with an average annual precipitation of 186 mm, whereas Baiquan Town is located in the coastal humid zone with an average annual precipitation of about 1200 mm. The saline soil of Qianjin Farm is a heavy clay soil, with a structural soil profile of clay. There is little rainfall in this dry climate, but the annual evaporation has amounted to more than 1800 mm. Strong evaporation of groundwater increases the concentration of salt particles substantially, and causes the salt particles to rise to the surface and rapidly accumulate in the soil. Secondary soil salinization occurs due to unreasonable irrigation without good drainage systems. The saline soil of Baiquan Town is a loam clay soil, and the structural soil profile shows loam at the top and clay at the bottom. The secondary soil salinization occurs due to the high salinity of irrigation water, unreasonable chemical fertilizer application, and strong surface evaporation (Shi et al. 2003).

2.2 Preparation of EM Bokashi

EM Bokashi is an organic fertilizer prepared by adding water (500 mL), molasses (8 mL) and EM (8 mL) to a mixture of rice bran and animal manure (4.7 kg), and then allowing the mixture to anaerobically ferment for two weeks. An equal amount of rice bran and animal manure without EM was also fermented to produce traditional farmyard manure (FYM). The chemical properties of EM Bokashi are presented in Table 1.

2.3 Design of the field experiments

The experiments conducted from 2000 to 2001 consisted of two blocks, one with the field subdrainage system and one without. The subdrainage system utilized 5.5 cm-diameter PVC tubes with depths of 1.1 m and spacing of 15 m. A total of eight plots (each with a size of 100 m × 30 m) containing single replicates of each treatment, were set up for both blocks (Huang et al. 2003).

The following treatments were applied to designated plots each year during rice production:

(1) Chemical fertilizer (N, P) without subdrainage,

(2) FYM (1 000 t/km^2) and chemical fertilizer (N, P) without subdrainage,

(3) EM Bokashi (1 000 t/km^2) and chemical fertilizer (N, P) without subdrainage,

(4) EM Bokashi (2 000 t/km^2) without subdrainage,

(5) Chemical fertilizer (N, P) with subdrainage,

(6) FYM (1 000 t/km^2) and chemical fertilizer (N, P) with subdrainage,

(7) EM Bokashi (1 000 t/km^2) and chemical fertilizer (N, P) with subdrainage, and

(8) EM Bokashi (2 000 t/km^2) with subdrainage.

Chemical fertilizer treatment consisted of basal and topdressing applications according to local recommendations. FYM and EM Bokashi were applied as basal and mixed well into the soil to a depth of up to 15 cm (Li et al. 2003). Each treatment was adjusted to contain an almost equal amount of N and P nutrients at each site. Rice and soil were managed based on local methods and traditions. The water table, soil moisture and electrical conductivity (EC) of 0-100 cm soil profiles, as well as irrigated and drained water were measured with an observation well, neutron probe, salt sensor, and water gauge in the field. Laboratory analysis and measurement of coefficients relating to soil and rice crops were strictly based on the *Analytical Methods for Soil and Agricultural Chemistry* (Lu 1999).

3 Results and discussion

3.1 Effects of EM Bokashi application on soil properties

Soil samples were collected from both experimental sites in the autumns of 2000 and 2001, just after the rice harvest. The effects of application of EM Bokashi, FYM and chemical fertilizer on soil properties were compared. Tables 2 and 3 list the average values for different treatments at the two field experimental sites from 2000 and 2001.

Table 2 Effects of EM Bokashi, FYM and chemical fertilizer on soil properties at a depth of 0-20 cm at Qianjin Farm

Treatment	Bulk density (g/cm^3)	Organic matter (g/kg)	Alkaline N (mg/kg)	Available P (mg/kg)	CEC (cmol/kg)	Microbial biomass (mg/kg)
1	1.68a	8.2d	27.2bc	9.0a	3.3e	305e
2	1.60b	10.5bc	33.6bc	10.2a	5.6d	421d
3	1.53c	12.3b	46.2b	11.3a	6.8bc	501bc
4	1.42d	15.6a	72.1a	13.9a	9.2a	612a
5	1.62ab	8.0d	26.8c	8.8a	3.2e	312e
6	1.56bc	9.7cd	35.3bc	10.1a	6.0cd	453c
7	1.50c	12.1b	47.2b	11.9a	7.0b	518b
8	1.38d	14.9a	70.5a	14.0a	9.9a	654a

Note: Numbers in the same column followed by the same letter are not significantly different according to the DMRT (Duncan's multiple range test) method ($P<0.05$), where P is the probability.

Table 3 Effects of EM Bokashi, FYM and chemical fertilizer on soil properties at a depth of 0-20 cm at Baiquan Town

Treatment	Bulk density (g/cm^3)	Organic matter (g/kg)	Alkaline N (mg/kg)	Available P (mg/kg)	CEC (cmol/kg)	Microbial biomass (mg/kg)
1	1.46a	17.2b	99.5cd	16.8a	9.5d	482c
2	1.40ab	18.5ab	112.4c	17.6a	10.7c	509c
3	1.37bc	18.6ab	130.2b	18.4a	12.5b	601b
4	1.32cd	20.3a	150.5a	20.3a	14.6a	722a
5	1.46a	16.9b	97.3d	17.0a	9.7d	491c
6	1.39b	17.8b	109.3cd	18.1a	10.9c	537c
7	1.35bcd	17.9b	135.2b	19.2a	13.1b	623b
8	1.30d	20.1a	149.8a	21.3a	15.2a	756a

Note: Numbers in the same column followed by the same letter are not significantly different according to the DMRT method ($P<0.05$).

It can be seen from Tables 2 and 3 that treatments of EM corresponded with higher levels of microbial biomass level, alkaline N, available P and cation exchange capacity (CEC) than treatments of chemical fertilizer or FYM and chemical fertilizer, either with subdrainage or without subdrainage. The lowest soil bulk densities at both experimental sites occurred at 0-20 cm, where the soils were treated with EM Bokashi (2 000 t/km^2) combined with a subdrainage system. EM Bokashi (1 000 t/km^2) and FYM with chemical fertilizer resulted in lower bulk densities than chemical fertilizer alone. Generally, highly productive agricultural soils have bulk densities of less than 1.40 g/cm^3, a well-developed structure, and better porosity and permeability. Results showed that bulk densities of saline soils were reduced to less than 1.40 g/cm^3 after two years of amelioration with application of EM Bokashi (2 000 t/km^2). Therefore, EM Bokashi is very effective in physically, chemically and biologically raising the fertility of salt-affected soil.

3.2 Effects of EM Bokashi application on yield and quality of grain

The effects of EM Bokashi, FYM and chemical fertilizer on the yield and quality of rice at the two experimental sites are reported in Table 4. It can be concluded that the highest yield, crude protein contents and crude fat contents were obtained with EM Bokashi treatments under subdrainage conditions. Besides subdrainage, EM was responsible for much of the yield increase and quality improvement, possibly due to increased availability of plant nutrients or direct beneficial effects on plant growth, health and protection (Bevacqua and Mellano 1994; Stolze et al. 2000). The results in Table 4 also show that EM technology has allowed farmers to make a successful transition from chemical-based conventional rice production to non-chemical, organic farming systems, and with considerably less environmental risk from chemical fertilizers.

Table 4 Effects of EM Bokashi on the grain yield and quality of rice (average values from 2000 and 2001)

Treatment	Yield (10^2 t/km^2)		Crude protein (%)		Crude fat (%)	
	Qianjin Farm	Baiquan Town	Qianjin Farm	Baiquan Town	Qianjin Farm	Baiquan Town
1	5.0f	4.5f	10.6c	9.1c	4.2e	3.7e
2	5.4e	4.8ef	10.8c	9.3c	4.3de	3.9de
3	5.8d	5.0e	11.0c	9.5c	4.5cde	3.9de
4	6.0cd	5.5d	11.5c	10.0c	4.8bc	4.1cde
5	6.0cd	5.7cd	13.5b	11.4b	4.7bcd	4.2bcd
6	6.2c	6.0c	14.2ab	12.3ab	4.9abc	4.5abc
7	7.0b	6.5b	14.7ab	12.8a	5.1ab	4.6ab
8	7.5a	7.0a	15.2a	13.5a	5.3a	4.9a

Note: Numbers in the same column followed by the same letter are not significantly different according to the DMRT method ($P < 0.05$).

3.3 Effect of EM Bokashi application on control of secondary soil salinization

Secondary soil salinization is mainly caused by excessive irrigation which results in the rising of salty underground water under poor drainage conditions. Field subdrainage systems have been demonstrated to be very effective in controlling the occurrence of secondary soil salinization (Shao et al. 2000a, 2000b). The total soluble salt content of soil can be obtained from the EC recorded by salinity sensors buried in soil. The relationships between the EC of the salinity sensor (x) and total soluble salt content (y) are expressed as follows:

$$y = 0.02817x + 0.0027 \text{ (Baiquan Town, } n = 9, r = 0.962^{**})$$

$$y = 0.05867x + 0.0573 \text{ (Qianjin Farm, } n = 10, r = 0.895^{**})$$

where n is the number of the correlative analysis, r is correlation coefficient, and ** indicates that the correlation coefficient is very significant.

The desalinization degrees at depths of 0-20 cm and 0-100 cm at both experimental sites are calculated based on the following formula: Desalinization degree = (total soluble salt content of soil before experiment – total soluble salt content of soil in October 2001) / total soluble salt content of soil before experiment.

The fluctuation patterns of soluble salt and desalinization degree with different treatments at both experimental sites were compared, and are shown in Tables 5 and 6. The sample dates of July and September in 2000 represent the processes of salt leaching just after irrigation and the surface accumulation of salt during transpiration, respectively. Before field experiments, the threats of secondary salinization did exist at both locations, with total soluble salt contents at depths of 0-20 cm and 0-100 cm, respectively, of 12.1 g/kg and 9.8 g/kg at Qianjin Farm, and 3.3 g/kg and 2.8 g/kg at Baiquan Town. The results in Table 5 and Table 6 show that EM Bokashi with subdrainage treatment is most effective in controlling the secondary salinization with maximum desalinization degrees at depths of 0-20 cm and 0-100 cm at both experimental sites. Subdrainage systems no doubt made the predominant contribution to depressions of total soluble salt content. Nevertheless, EM Bokashi played a greater role in the control of secondary salinization than chemical fertilizer treatment. The reason was that the application of EM Bokashi improved the permeability and aeration capacity of soil, which increased the leaching of salts (Zhang et al. 2005; Hussain et al. 2003).

Table 5 Effects of EM Bokashi and subdrainage on total soluble salt content and desalinization degree at Qianjin Farm

Treatment	Total soluble salt content (g/kg)								Desalinization degree (%)	
	Jul. 2000		Sep. 2000		Nov. 2000		Oct. 2001			
	0-20 cm	0-100 cm	0-20 cm	0-100 cm	0-20 cm	0-100 cm	0-20 cm	0-100 cm	0-20 cm	0-100 cm
1	10.8a	12.0a	14.2a	11.9a	10.7a	9.6a	10.5a	9.4a	13.2b	4.1d
2	10.2a	11.2a	13.8a	11.5a	10.5a	9.3a	10.1a	9.0a	16.5b	8.2cd
3	9.8a	10.7a	12.5a	10.8a	10.1a	9.0a	9.8a	8.2a	19.0b	16.3cd
4	9.5a	9.9ab	11.9a	10.5a	9.3a	8.9a	9.0a	8.0a	25.6b	18.4c
5	6.4b	7.8bc	7.0b	8.0b	3.9b	3.6b	3.0b	2.9b	75.2a	70.4b
6	5.7b	7.0c	6.0b	7.3b	3.0b	2.8b	2.7b	2.4b	77.7a	75.5ab
7	5.5b	6.8c	5.8b	7.0b	2.8b	2.4b	2.0b	1.8b	83.5a	81.6ab
8	4.6b	6.0c	4.6b	6.0b	2.5b	2.0b	1.8b	1.5b	85.1a	84.7a

Note: Numbers in the same column followed by the same letter are not significantly different according to the DMRT method ($P<0.05$).

Table 6 Effects of EM Bokashi and subdrainage on total soluble salt content and desalinization degree at Baiquan Town

Treatment	Total soluble salt content (g/kg)								Desalinization degree (%)	
	Jul. 2000		Sep. 2000		Nov. 2000		Oct. 2001			
	0-20 cm	0-100 cm	0-20 cm	0-100 cm	0-20 cm	0-100 cm	0-20 cm	0-100 cm	0-20 cm	0-100 cm
1	2.8a	3.0a	4.0a	2.8a	2.7a	2.8a	2.6a	2.7a	21.2e	3.6d
2	2.6a	2.8ab	3.6ab	2.6ab	2.5a	2.6ab	2.4a	2.6a	27.3de	7.1d
3	2.4ab	2.7abc	3.0bc	2.5ab	2.2ab	2.4ab	2.1a	2.2ab	36.4cd	21.4c
4	2.2ab	2.7abc	2.7cd	2.0b	2.0abc	2.1abc	1.9ab	2.0abc	42.4c	28.6bc
5	1.8bc	2.2bcd	2.0de	2.3ab	1.5bcd	2.1abc	1.2bc	1.7bc	63.6b	39.3b
6	1.6c	2.0cd	1.8e	2.1ab	1.4cd	2.0bc	1.0c	1.5bc	69.7ab	46.4ab
7	1.5c	1.9d	1.7e	2.0b	1.3cd	1.9bc	0.9c	1.4c	72.7ab	50.0ab
8	1.3c	1.8d	1.3e	1.9b	1.0d	1.6c	0.7c	1.3c	78.8a	53.6a

Note: Numbers in the same column followed by the same letter are not significantly different according to the DMRT method ($P<0.05$).

The traditional practices for controlling secondary salinization in soil are water conservation, agricultural, biological and chemical measures (Bhatti et al. 2005). This study combined water conservation measures and biological measures to raise the salt-affected soil fertility physically, chemically and biologically with EM Bokashi and subdrainage treatment. Subdrainage treatments were most effective in controlling the secondary salinization of soil and raising grain yield and quality. Meanwhile, EM Bokashi is also a good microbial carrier for use in promoting settlement of the microorganism and creating a useful soil environment.

4 Conclusions

The analytical results lead to the following conclusions:

(1) EM Bokashi treatments increased soil fertility by increasing CEC and available nutrients, by improving soil porosity and permeability due to a significant soil bulk density decrease, and by increasing the microbial biomass of soil.

(2) EM Bokashi combined with subdrainage treatments were more effective in controlling the secondary salinization of soil and raising grain yield and quality than FYM and chemical fertilizer treatments. A balance of water and salt can be achieved by a combination of EM Bokashi and subdrainage treatment.

(3) These are two typical soils experiencing secondary salinization with large geographical differences. The conclusion was the same in the two different regions, suggesting that EM technology can sufficiently reduce the amount of chemical fertilizer application, thereby improving the agricultural environment and guaranteeing the sustainable development of agriculture through control of secondary soil salinization.

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