Control of Secondary Salinization in Soils through Effective Microbes

X. H. Shao[1], D. Y. Liu[1], P. Jiang[2] and W. L. Cao[2]

Hohai University of Water Conservancy& Hydro-power Engineering ,Nanjing 210098,P.R China[1]
Division of Agriculture Water Conservancy, Zhejiang Provincial Bureau of Water Resources , Hangzhou,310009,P.R China[2]

Abstract *: There have existed wide areas of soil secondary salinization in the western districts and coastal zones in China due to non-reasonable irrigation without good drainage systems. Secondary salinization of soils causes lower productivity of crops because of high salinity and poor structure .In order to ameliorate these saline-alkaline soils, EM technology combined with subsurface drainage is applied in the rice production in Ningxia and Zhejiang provinces. The results are summarized as follows (1) EM Bokashi with subsurface drainage treatment is the most effective in controlling the secondary salinization and raising rice grain yield and quality compared with other treatments; (2) EM technology can also increase soil organic substance content, improve soil porosity and permeability and raise soil available nutrients; (3)EM technology can evidently reduce amount of chemical fertilizers application, thereby improving the agriculture environment.*

Introduction

Through the establishment of drainage-irrigation system combined with biological engineering measures,the salt-affected soils in China are gradually ameliorated and controlled. However, there are still secondary salinization soils of 36.9 million ha., of which cultivated ones mainly occur in the Huang-Huai-Hai plain as well as a small part of eastern coast with a total area of 6.24 million ha., taking up about 7% of the country's cultivated land(Gong and Luo, 1997). These cultivated lands affected by salts are mostly formed due to irrigation with neglect of the drainage system notably in the (semi) arid region which are great obstacles to the development of agriculture.

Use of beneficial and effective microorganisms as microbial inoculants in agriculture is a promising new technology(Shao *et al.*, 2001). It has been shown to be effective in improving soil health and quality, and raising the growth, yield and quality of crops (Li *et al.*, 1999). However the research is conducted considering the amelioration of salt-affected soils by use of EM technology. In this paper, EM technology combining with subsurface drainage is applied in the rice production in the Autonomous Region of Ningxia and Zhejiang provinces to see the effectiveness of EM in controlling the secondary salinization.

Materials and Methods

1. Preparation of EM Bokashi

EM Bokashi is an organic fertilizer prepared by adding water (500ml), molasses (8ml) and effective microorganisms (EM) (8ml) to a thoroughly mixed material of rice bran and animal manure (4.7Kg) then anaerobically fermented for 2 weeks. Equal amount of rice bran and animal manure without addition of EM was also fermented to produce traditional Farmyard Manure (FYM). The chemical properties of EM Bokashi used are presented in Table 1.

2. Description of the Field Experiment

The field experiments were conducted from 2000 to 2001 in the saline soils of Qianjin Farm in the Autonomous Region of Ningxia and Baiquan town, Zhoushan city in Zhejiang Province respectively. Qianjin Farm is situated in arid area with the average annual rainfall of 186mm, whereas Baiquan town is located at the coastal humid zone with the average annual precipitation of around 1200mm. The experiment consisted of two blocks with and without the field sub-drainage system. The sub-drainage system used PVC tubes of 5.5cm diameter with the depth of 1.1m and the spacing of 15m respectively. Total eight plots (each of size 100mx30m) were given separately at two blocks of both sites. The following treatments were applied to designated plots each year in rice production: 1) Chemical fertilizer (N, P) without sub-drainage; 2) Farmyard manure (10t ha^{-1}) + Chemical fertilizer (N, P) without sub-drainage; 3) EM Bokashi (10t ha^{-1}) + Chemical fertilizer (N, P) without sub-drainage; 4) EM Bokashi (20t ha^{-1}) without sub-drainage; 5) Chemical fertilizer (N, P) with sub-drainage; 6) Farmyard manure (10t ha^{-1}) + Chemical fertilizer (N, P) with sub-drainage; 7) EM Bokashi (10t ha^{-1}) + Chemical fertilizer (N, P) with sub-drainage; 8) EM Bokashi (20t ha^{-1}) with sub-drainage.
Chemical fertilizer was applied according to local recommendations as basal and dressing applications. Farmyard manure and EM Bokashi were applied as basal and mixed well in the soils up to 15cm depth. Each treatment was adjusted to contain almost equal amount of N and P nutrients at each site.
The physio-chemical properties of soils tested are also listed in Table 1.

Table 1. Some Properties of Tested Soils (0-20cm) and EM Bokashi

	Soils		EM Bokashi
	Qianjin Farm	Baiquan Town	
Carbon (g Kg^{-1})	14.5	32.4	483.2
Nitrogen (g Kg^{-1})	1.2	2.3	24.5
C/N ratio	12.1	14.1	19.7
pH (H_2O)	8.0	7.2	5.5
EC (ds m^{-2})	5.5	3.5	4.8
Alkaline N (mg Kg^{-1})	26.0	101.2	982
Available P (mg Kg^{-1})	8.9	17.2	653
Total salt content (g Kg^{-1})	12.1	3.3	4.7
Bulk density (g cm^{-3})	1.70	1.47	-
CEC (Cmol Kg^{-1})	3.2	9.8	-
Texture	heavy clay soil	loam clay soil	-

Rice and soils were managed based on the local methods and traditions. Underground water table, soil moisture and EC of 0-100cm soil profiles, water irrigated and drained were measured in each treatment by use of the observing well, neutron probe and salt sensor as well as water gauge in the field. Laboratory analysis and measurement of coefficients related to soils and rice crop were strictly based on the methods of soil physico-chemistry analyses (Agriculture Press, 1989).

Results and Discussion

1. Effect of EM Bokashi on Soil Properties

Soil samples were collected from both experimental sites in the autumn of 2000 and 2001 just after rice harvest. Effect of application of EM Bokashi, FYM and chemical fertilizer on soil properties were compared. Table 2 listed the average values of 2000 and 2001 for different treatments at two field experimental sites. It could be seen from Table 2 that treatments received EM had a higher microbial biomass level, organic matter, alkaline N and available P than chemical fertilizer treatment as well as FYM + chemical fertilizer treatment whether with sub-drainage or without sub-drainage. The lowest soil bulk densities in both experimental sites occurred at 0-20cm where the soils were treated with 20t ha^{-1} EM Bokashi with sub-drainage system. Generally, highly productive agricultural soils have bulk densities of less than 1.4g cm^{-3} which have a well-developed structure, better porosity and permeability. Results showed that bulk densities of saline soils had reduced to less than 1.40g cm^{-3} after two years of amelioration with application of 20t ha^{-1} EM Bokashi. Therefore, EM Bokashi was very effective in raising the salt-affected soil fertility both physio-chemically and biologically.

Table 2. Effect of EM Bokashi, FYM and Chemical Fertilizer on Soil Properties at Depth of 0-20cm in Qianjin farm(1) and in Baiquan town(2)

Treatments	Bulk density (g cm^{-3})		Organic matter (g Kg^{-1})		Alkaline N (mg Kg^{-1})		Available P (mg Kg^{-1})		Micro-biomass (mg Kg^{-1})	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	1.68	1.46	8.2	17.2	27.2	99.5	9.0	16.8	305	482
2	1.60	1.40	10.5	18.5	33.6	112.4	10.2	17.6	421	509
3	1.53	1.37	12.3	18.6	46.2	130.2	11.3	18.4	501	601
4	1.42	1.32	15.6	20.3	72.1	150.5	13.9	20.3	612	722
5	1.62	1.46	8.0	16.9	26.8	97.3	8.8	17.0	312	491
6	1.56	1.39	9.7	17.8	35.3	109.3	10.1	18.1	453	537
7	1.50	1.35	12.1	17.9	47.2	135.2	11.9	19.2	518	623
8	1.38	1.30	14.9	20.1	70.5	149.8	14.0	21.3	654	756

2. Effect of EM Bokashi on Control of Secondary Soil Salinization

Secondary soil salinization is mainly caused by the irrational irrigation which results in rising of salty underground water table under poor drainage condition. Field sub-drainage systems are demonstrated to be very effective in controlling the occurrence of secondary soil salinization (Shao et al., 2000). In this paper, the fluctuation of soluble salt and desalinization degree were compared for different treatments of both experimental sites shown in Table 3. Before field experiments, the threats of secondary salinization existed in both locations with total soluble salt contents of 1.21%, 0.98%, 0.33% and 0.28% respectively at depths of 0-20cm and 0-100cm. The dates of July and Sept in 2000 represented the processes of leaching just after irrigation and movement upwards of the salt during drainage respectively. The results showed EM Bokashi with subsurface drainage treatment was the most effective in controlling the secondary salinization with maximum desalinization degrees at depths of 0-20cm and 0-100cm in both experimental sites. Sub-drainage system had no doubt predominant contribution to depressions of total soluble salt content. Nevertheless, EM Bokashi also played greater roles in the control of secondary salinization compared with chemical fertilizer treatment. The reasons were possibly that application of EM Bokashi improved the permeability and aeration capacity of soils which increased the leaching of salts.

3. Effect of EM Bokashi on Yield and Quality of Rice Grain

The effect of EM Bokashi, FYM and chemical fertilizer on the grain yield and quality of rice in two experimental sites was reported in Table 4. It could be seen from Table 4 that the highest rice grain yields, crude protein contents and crude fat contents were obtained with EM

Table 3. Effect of EM Bokashi and Subdrainage on Total Soluble Salt Content and Desalinization Degree at Experimental Sites of Qianjin Farm and Baiquan town

Treatments	Total Soluble Salt Content (%)								Desalinization degree (%)	
	July, 2000		Sept., 2000		Nov., 2000		Oct., 2001			
	0-20cm	0-100cm	0-20cm	0-100cm	0-20cm	0-100cm	0-20cm	0-100cm	0-20cm	0-100cm
Qianjin farm										
1	1.08	1.20	1.42	1.19	1.07	0.96	1.05	0.94	13.2	4.1
2	1.02	1.12	1.38	1.15	1.05	0.93	1.01	0.90	16.5	8.2
3	0.98	1.07	1.25	1.08	1.01	0.90	0.98	0.82	19.0	16.3
4	0.95	0.99	1.19	1.05	0.93	0.89	0.90	0.80	25.6	18.4
5	0.64	0.78	0.70	0.80	0.39	0.36	0.30	0.29	75.2	70.4
6	0.57	0.70	0.60	0.73	0.30	0.28	0.27	0.24	77.7	75.5
7	0.55	0.68	0.58	0.70	0.28	0.24	0.20	0.18	83.5	81.6
8	0.46	0.60	0.46	0.60	0.25	0.20	0.18	0.15	85.1	84.7
Baiquan town										
1	0.28	0.30	0.40	0.28	0.27	0.28	0.26	0.27	21.2	3.6
2	0.26	0.28	0.36	0.26	0.25	0.26	0.24	0.26	27.3	7.1
3	0.24	0.27	0.30	0.25	0.22	0.24	0.21	0.22	36.4	21.4
4	0.22	0.27	0.27	0.20	0.20	0.21	0.19	0.20	42.4	28.6
5	0.18	0.22	0.20	0.23	0.15	0.21	0.12	0.17	63.6	39.3
6	0.16	0.20	0.18	0.21	0.14	0.20	0.10	0.15	69.7	46.4
7	0.15	0.19	0.17	0.20	0.13	0.19	0.09	0.14	72.7	50.0
8	0.13	0.18	0.13	0.19	0.10	0.16	0.07	0.13	78.8	53.6

Bokashi treatments under sub-drainage conditions. Besides drainage, 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. It could be also seen from the data in Table 4 that EM technology had allowed the farmers to make a successful transition from chemical-based rice production to non-chemical, organic farming systems, and with considerably less environmental risk caused by chemical fertilizers.

Table 4. Effect of EM Bokashi on the Grain Yield and Quality of Rice (average values of 2000 and 2001)

Treatments	Yields (t ha^{-1})		Crude protein (%)		Crude fat (%)	
	Qianjin Farm	Baiqua town	Qianjin Farm	Baiquan town	Qianjin Farm	Baiquan town
1	5.0	4.5	10.6	9.1	4.2	3.7
2	5.4	4.8	10.8	9.3	4.3	3.9
3	5.8	5.0	11.0	9.5	4.5	3.9
4	6.0	5.5	11.5	10.0	4.8	4.1
5	6.0	5.7	13.5	11.4	4.7	4.2
6	6.2	6.0	14.2	12.3	4.9	4.5
7	7.0	6.5	14.7	12.8	5.1	4.6
8	7.5	7.0	15.2	13.5	5.3	4.9

Conclusions

The obtained analytical results lead to the following conclusions:

- EM Bokashi treatments evidently increased soil fertility by increasing soil organic matter content and available nutrients, by improving soil porosity and permeability and by increasing the micro-biomass of soils.
- EM Bokashi with subsurface drainage treatments were the most effective in controlling the secondary salinization of soils and raising rice grain yields and quality compared with FYM and chemical fertilizer treatments.
- EM technology could sufficiently reduce or stop the amount of chemical fertilizers application, thereby improving the agricultural environment and guaranteeing the sustainable development of agriculture.

References

Gong, Z.T. and G.B. Luo. 1997. The human-induced soil degradation in China. In: Cao,Z.H(Editor), International Symposium on Soil, Human and Environmental Interactions, China Science & Technology Press, 152-157.

Li, W.J., Q.L. Sun, H. Umemura, H. Cai, L.A. Niu and Y.Z. Ni. 1999HH. Application of EM technology for intensive organic recycling, soil quality, crop yield and quality, and environmental protection. In: Xu,H.L(Editor), Nature Farming and Sustainable Environment, 137-148.

Shao, X.H., D.Y. Liu, L. Zhu and H. Wang. 2001. Prospect of EM treatment techniques of organic waste water for agricultural irrigation. Advances in Science and Technology of Water Resources 21(1), 16-19.

Shao, X.H., J.B. Wang, C.L. Lin and X.R. Liu. 2000. Discussion on criterion for waterlogging reduction of winter wheat and barley in lower reach of Yangtze River. Journal of Hydraulic Engineering 8, 65-69.