Proceedings of the International Conference for Agricultural Machinery & Process Engineering
October 19-22, 1993, Seoul, Korea

MANAGING SALINITY PROBLEMS IN RICE FIELDS

K. Sani[1] and M. D. Daham[2]
[1]Agricultural Engineering Division
MARDI Rice Research Centre
P.O.Box 203, 13200 Kepala Batas, Seberang Perai, Malaysia
[2]Agricultural Engineering Division
MARDI, P.O.Box 12301, 50774 Kuala Lumpur, Malaysia

ABSTRACT

The response of salt affected rice soils to salinity reclaimation by flushings and chemical amelioration by lime and gypsum were evaluated. Soils with good drainage system responded well to simple reclaimation. The effects of seawater intrusion were reduced efficiently in a very short time. Yields of rice crops recovered to their potential level within one to two seasons of cropping. Soil profile strength was also improved under well drained areas. However, when drainage system was ineffective the problems of salinity and soil strength remained unsolved. Under both condition, water depth management played important role in the survival of rice crop under the saline soil condition.

Key Word: Salinity, Reclaimation, Soil strength

INTRODUCTION

Soil salinisation in the rice growing areas of Malaysia is one of the factors that lead to the reduction and instability of rice production. The effects of salinity on agriculture had been extensively reviewed by Richards (1969), Kovda et al. (1973), Akbar and Ponnamperuma (1982) and Ayers and Westcot (1985). Soils had been rendered unproductive when salinised due to the loss of soil fertility (Akbar and Ponnamperuma 1982), soil structure destruction (Rolston et al. 1984), and the crop inability to tolerate toxic condition under the saline environment (Robinson 1971, Sharma and De Datta 1985). Malaysian rice plants are known only to be moderately tolerant to salinity condition (Anon. 1986) and to increase their tolerance would take time (Dvorak and Ross 1986). Other non-crop means had to be used for salinity control and one such method is through soil and water management (Van Alphen 1984). This paper attempted to use the already proposed method of salinity management into the problem rice growing areas in Malaysia.

MATERIALS AND METHODS

Sites

Three sites were selected with one (15 ha) at Sg. Baru, Kerian, Perak. This project has a poorly developed system of irrigation and drainage. It has low canal density of less than 10 m/ha as compared to the targeted density of 25 m/ha (Abd. Wahab et al. 1990). It has a consistently high salinity level. The other two sites were at Kepala Tanjung (2 ha) and Padang Garam (15 ha), both were in the Muda Agricultural Develepement Authority (MADA), in Kedah. These two areas have canal densities of about 30 m/ha (Anon. 1991). All the sites were of the coastal marine alluvial soils especially suitable for rice cultivation (Paramananthan 1978). Padang Garam was constantly under the threat of sea water intrusion and during this study, the whole rice crop was totally destroyed by sea water intrusion during high tides.

Salinity reclaimation

Case A: Salinisation from seawater intrusion

Reclaimation on such soil at Padang Garam basically utilised the method of Van Alphen (1984). The seawater that flowed into the area had EC values of about 32.60 to 43.96 dS/m. Flushing was done without any land tillage to avoid salt movement into the deeper soil layer. Field perimeter bunds however were kept in good condition to provide field water retention. Two days were taken to fill up the field with fresh water. After this, the water was allowed to reside for three days and at the end of the third day of flooding, the water was immediately drained out of the field to remove all the standing water and the soluble salts. Three flushing cycles were carried out to achieve the target. Liming material was then applied to the field at 1 mt/ha at transplanting.

Rice seedlings were transplanted and in some plots broadcasting was done to evaluate the best method of planting. Field water during plant growth was maintained at about 5 cm deep and any drying was strictly avoided except when the field was about 20% ripe to facilitate grain harvesting.

Case B: Salinisation due to the underlying saline soil

The Kepala Tanjung soil has saturation extract EC values of about 6.55 dS/m at the 30 cm depth to 15.10 dS/m at 150 cm depth. The soil was prepared under dry condition for planting. Perimeter bunds were maintained at a hight of 30 cm. Once preparation was completed, fresh water was brought in to flood the field. Draining was done after two days of flooding. Seedlings were then transplanted into the field. Direct seeding was also done in some areas for comparision.

Lime was applied at the rate of 1 mt/ha at field preparation. For the duration of the growth period the water depth was maintained at about 5 cm. Field draining was done after the crop had reached 20 % ripening and also to facilitate crop harvesting.

Case 3: Salinisation due to soil logging The Sg. Baru area has a severely saline environment with poor drainage system. Its has about sea level elevation. The fields were prepared manually since no machines could go into the area. Since water table was high and drainage was poor, field drying mainly through evaporation. The soil was treated with lime (Ca-Mg CO_3) and gypsum ($CaSO_4$) at a rate of 1 mt/ha each to increase soil strength and flocculation. Field water depth was maintained at about 5 cm for the duration of plant growth. Transplanting and direct seeding were evaluated for crop establisment. For direct seeding, the field was sufficiently drained to facilitate seed broadcasting. However at 20 % grain ripening, water was drained out to speed up ripening and facilitate harvesting.

In all cases, the water and soil extract ECs were determined with a Hach 44600 Conductivity/TDS meter and the soil strength index were determined with a proving ring penetrometer with a base area of 6.45 cm^2 (Tada 1987; Shahrin et al. 1989). The investigation was conducted over a period of three years to monitor the effects of salinity reclaimation.

RESULTS AND DISCUSSION

Case A: Reclaimation from seawater intrusion

The reclaimation at Padang Garam was very successful. Salt water seepage into the deeper soil layer was very minimal. MADA water which was known to be of good quality (Sani 1991) was indeed effective for flushing the seawater from the affected areas. The changes in soil and water salinities are as shown in *Table 1*. After three cycles of flushing, the water EC was reduced from 2.13 dS/m to 0.25 dS/m and the saturation extract of soil was reduced from 8.02 to 3.67 dS/m. Yield from the plots of transplanted rice recorded an overall increase from zero in the previous season to 3.87 mt/ha (*Table 2*). This was about 73% of normal yield obtained from the unaffected areas.

Soil cone index readings at saturated condition are as shown in *Figure 1*. Machine mobility was possible on this area when soil was sufficiently dry .

Crop establishment under the direct seeding method did not performed very well because of the poor rate of germination. The drained soil aggravated the salinity condition to a level detrimental to seed germination. However, after the first crop establishment, the next crops fared better because of the the reducing salinity condition. Crop with lime treatment showed healthier appearance.

Case B: Reclaimation of soil with underlying saline layer
Simple flooding and flushing managed to reduce surface soil salinity with subsequently resulted in some increase in crop yield (*Table* 3). Water depth control had reduced leaves drying. Lime treated plots produced healthier and greener plants. The incidences of water logging was reduced on areas treated with lime. This could be due to the stabilising effects of calcium on the soil (Kamphorst 1990) that caused better aggregation and water movement.

Crop grown by transplanting method performed better after reclaimation. Direct seeding was possible after the soil salinity level was reduced to a safe range.

Case C: Reclaimation of salinity-logged areas
Salinity reclaimation for this logged area was not very effective. Soil salinity remained high (*Table* 4) even after three years of rice cultivation. The survival of this area depended so much on the availability of water for irrigation. The presence of sufficient water would ensure crop success and even a short period of water shortage, as had happened at the end of 1991, had caused total crop destruction and uneconomic return.

Good soil aggregation could not be achieved under this saline condition eventhough sufficient organic matter (3.60%) was present (Amrhein et al 1992). Poor organic matter decomposition under such condition had reduced the organic matter contribution (Chenu and Guerif 1991) to soil formation. The high soluble salts in the soil need to be drained off and replaced with structure-promoting elements to produce good soil formation (Weirzchos et al. 1992). For such purpose the use of gypsum had been reported to be beneficial in salinity reclaimation (Osipov and Sokolov 1978, Dexter and Chan 1991, Levy et al. 1993). However under poor drainage condition similar to that in Kerian, the benefits of using was not very encouraging. Moreover, gypsum was very expensive when compared to lime. Even if it had better solubility and efficiency for saline soil reclaimation (Lebedev and Lekhov 1990, Den Elshout and Kamphorst 1990, Armstrong and Tanton 1992, Arslan and Dutt 1993), the cost factor had put lime as the most logical choice to be use for salinity amelioration. Lime application had slightly improve soil strength (*Figure* 1) and its low cost justifies its continuous application.

Transplanting was the most appropriate method of planting under this situation, Direct seeding method could not be adopted due to the low survival rate under the high salinity condition.

CONCLUSIONS

Marine alluvial soils are very good rice soils but most of them that lie along the coast are threaten with high salinity problems. These problems could be contained with a cheap and simple method of flushing and soil improvement. In some areas some major upgrading of the drainage system need to be carried out to ensure better and effective soil reclaimation. Both methods, when properly implemented, could put more rice fields into operation, thus increasing the national rice production.

ACKNOWLEDGEMENTS

The authors are greatful to the Director General of the Malaysian Agricultural Research and Developement Institute (MARDI) for his permission to present this paper. This work was supported by the IRPA grant through the Ministry of Agriculture.

REFERENCES

1. Abd. Wahab, A. H., H. Zainal Abd., T. Omar, Y. H. Chen, N. Ahmad Puat, J. Mohd. Aris, D. Abu Hassan, H. Habibuddin and M. Azmi. 1990. In *Towards meeting regional technology requirements* (Marzuki, H. ed.) p. 39-58. Kepala Batas: MARDI

2. Akbar, M. and F. N. Ponnamperuma. 1982. Saline soils of South and Southeast Asia as potential rice lands. In *Rice research strategies for the future* p. 265-81. Los Banos: IRRI

3. Amrhein, C., J. E. Strong and P. E. Mosher. 1992. Effects of deicing salts on metal and organic matter mobilization in roadside soils. *Environ. Sci. Technol.* ***26(4):*** 703-6

4. Anon. 1986. *Rice Research Division Annual Report.* p. 67 Serdang: MARDI

5. Anon. 1991. *MADA Annual Report.* A. Star: MADA 40p.

6. Armstrong, A. S. B. and T. W. Tanton. 1992. Gypsum application to aggregated-saline sodic clay top soil. *J. Soil Sci.* ***43(2):*** 249-60

7. Arslan, A. and G. R. Dutt. 1993. Solubility of gypsum and its prediction in aqueous solution of mixed electrolytes. *Soil Sci.* ***155(1):*** 37-47

8. Ayers, S. and D. W. Westcot. 1985. *Water quality for agriculture* (FAO Irrig. Drain. Paper 29. Rev. 1) 174 p. Rome: FAO

9. Chenu, C. and J. Guerif. 1991. Mechanical strength of clay minerals as influenced by an absorbed polysaccharides. *Soil Sci. Soc. Am. J. 55:* 1076-80

10. Den Elshout, S. V. and A. Kamphorst. 1990. Suitability of coarse grade gypsum for sodic soil reclaimation : A laboratory experiment. *Soil Sci.* ***149(4):*** 228-38

11. Dexter, A. R. and K. Y. Chan. 1991. Soil mechanical properties as influenced by exchangable cations. *J. Soil Sci.* ***42:*** 219-26

12. Dvorak, J. and K. Ross. 1986. Expression of tolerance of Na^{+}, K^{+}, Mg^{2+}, Cl^{-}, and $SO_4{}^{2-}$ ions and seawater in the amphioploid of *Triticum aestivum* x *Elytrigia elongata*. *Crop Sci.* ***26:*** 658-60

13. Kamphorst, A. 1990. Amelioration of sodic clay soils by crack stabilization : An experimental laboratory simulation. *Soil Sci.* ***149(4):*** 218-27

14. Kovda, V. A., B. C. Van Den and R. M. Hagan. 1973. *Irrigation, drainage and salinity. A international source book.* 510 p. London: FAO/UNESCO

15. Lebedev, A. L. and A. V. Lekhov. 1990. Dissolution kinetics of natural gypsum in water at 5-25 °C. *Geochem. Int.* ***27:*** 85-94

16. Levy, G. H., H. Eisenberg and I. Shainberg. 1993. Clay dispersion as related to soil properties and water permeability. *Soil Sci.* ***155(1):*** 15-22

17. Osipov, V. I. and V. N. Sokolov. 1978. Structure formation in clay sediments. *Bull. Int. Assoc. Engng. Geol.* ***18:*** 83-90

18. Paramananthan, S. 1978. Rice soils in Malaysia. In *Soils and rice.* p. 87-98. Los Banos: IRRI

19. Richards, L. A. 1969. *Diagnosis and improvement of saline and alkaline soils.* Agric. Handbook 60 p. 83-147. Washington D. C.: USDA

20. Robinson, J. B. 1971. Salinity and the whole plant. In *Salinity and water* (Talsma, T. and J. R. Phillip. ed.) p. 193-206. New York: Wiley-Interscience

21. Rolston, D. E., J. W. Biggar and D. R. Nielsen. 1984. Effects of salt on soil. *Calif. Agric.* ***10:*** 11-3

22. Sani, K. 1991. Hydrochemistry of MADA irrigation water. *MARDI Res. J.* ***19(1):*** 143-58

23. Shahrin, M. Y., K. Ayob and O. Suhaimi. 1989. Soil drying requirement for mobility of heavy combine harvesters in rice fields. *MARDI Res. J.* **17(2)**: 296-301

24. Sharma, P. K. and S. K. De Datta. 1985. Puddling influence on soil, rice developement and yield. *Soil Sci. Soc. Am. J.* **49**: 1451-7

25. Tada, A. 1987. Bearing capacity. *In Physical measurement in flooded rice soils. The Japanese methodologies* (Tabuchi, T., S. Iwata, S. Hasegawa, T. Woodhead and E. Maurer eds.) Los Banos: IRRI

26. Van Alphen, J. G. 1984. Rice in the reclaimation of salt affected soils. *Food and Fertil. Tech. Centre Ext. Bull.* **204** 13 p.

27. Wierzchos, J., C. Ascaso Ciria and M. T. Garcia-Gonzalez. 1992. Changes in microstructures of soils following extraction of organically bonded metals and organic matter. *J. Soil Sci.* **43(3)**: 505-15

Table 1. Salinity changes at Padang Garam after reclaimation activities

Soil depth (cm)	Electroconduct. (dS/m)			
	Start	1st Flushg.	2nd Flushg.	3rd Flushg
Surface water	2.13	0.92	0.66	0.25
0 - 30	8.02	3.90	4.80	3.67
30 - 60	4.87	3.13	5.23	3.93
60 - 90	7.10	3.93	5.53	5.27

Table 2. Yield changes after reclaimation at Padang Garam

Plot status	Grain yield (mt/ha)					
	A	B	C	D	E	Av.
Saline	3.75	4.76	3.38	3.82	3.66	3.87
Control	5.73	4.00	5.47	5.54	5.76	5.30
S/C	0.65	1.19	0.62	0.69	0.63	0.73

Table 3. Changes in soil and water salinity and yield response after reclaimation at Kepala Tanjung

	Electroconduct. (dS/m)		Yield (mt/ha)	
Season	Water	Soil Ext.	Reclmn.	Control
MS 1	2.34	6.41	3.45	3.45
OS 2	1.15	4.08	3.88	3.73
MS 3	0.76	2.81	6.10	4.20
OS 4	0.86	2.97	3.20	4.00

Table 4. Changes in soil and water salinity and yield response to the condition at Sg. Baru, Kerian

Soil depth (cm)	Electroconduct. (dS/m)				
	90/1	90/2	91/1	91/2	92/1
Surface water	2.36	3.04	0.83	0.82	3.43
0 - 30	9.06	9.49	9.55	9.45	10.98
30 - 60	10.09	10.93	10.57	10.15	11.05
60 - 90	13.44	13.34	13.20	13.56	17.62
Yield (mt/ha)	2.80	5.30	6.09	3.55	3.71

Figure 1. Cone index readings for saline affected soils