CHINESE GEOGRAPHICAL SCIENCE
Volume 13, Number 2, pp. 171 – 174, 2003
Science Press, Beijing, China

SUSTAINABLE AGRICULTURE DEVELOPMENT IN SALINE-ALKALI SOIL AREA OF SONGNEN PLAIN, NORTHEAST CHINA

WANG Zhi-chun, LI Qu-sheng, LI Xiu-jun, SONG Chang-chun, ZHANG Guang-xin
(Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences, Changchun 130012, P. R. China)

ABSTRACT: There is great potential for agriculture in saline-alkali soil area in Songnen Plain, Northeast China. But the sustainable crop production in this area has been restricted by a few of main factors, such as less precipitation, higher evaporation and frequent drought, high salinity and alkalinity, high exchangeable sodium content and poor infiltration of the soil, and insufficiency and low availability in nutrition. It is also considered that there are a few of favorable conditions for agricultural development in this region, such as sufficient light and heat resources, rich ground water resources, plenty of manure produced by livestock, and so on. At the same time, scientific management and measurements have been employed; rational irrigation and drainage system has been established; reclamation, amendment and fertilization of soil, and suitable strategies of cropping practices have been made for the sustainable development of agriculture. Great progress has been made during 1996 – 2000.

KEY WORDS: sustainable agriculture development; saline-alkali soil; Songnen Plain

CLC number: S156.4 Document code: A Article ID: 1002-0063(2003)02-0171-04

1 INTRODUCTION

Songnen Plain is situated in Northeast China. It is the second largest plain after the Huang-Huai-Hai Plain in the central part, China. The area of saline-alkali soil reaches 3.42×10^6ha, occupying 14.4% of the total area of the plain (ZHANG *et al.*, 1997). These problem soils are mainly distributed in the west part of Jilin and Heilongjiang provinces. Also, it represents the typical saline-alkali soil in China. Sustainable development of agriculture in this area has been restricted for a long time due to drought, water shortage, and soil salinity and alkalinity. Research progress has been made for better management and exploitation of the saline-alkali soil over a decade. Taking Da'an of Jilin Province, an experimental area as an example, the average annual income per farmer increased from 265.5 yuan in 1989 to 1710.3 yuan in 1997 (HE and SONG, 2001). Research results and production practices indicated that the sustainable development of agriculture in the saline-alkali area in the plain is a complex system. It is necessary to break through the key problems and take a better way of assembling and integrating proper techniques.

2 MATERIALS AND METHODS

Da'an area, which is seated in the west part of Songnen Plain, Northeast China, was selected as an experimental area during 1996 – 2000. Soil samples from Chagan, Liuhetang, Xianfeng villages, as well as Dongdapao lowland in Da'an area were collected and analyzed. Analysis items include soil pH, total dissolved salts (TDS), electric conductivity (EC), exchangeable sodium percentage (ESP), bulk density, infiltration rate, and so on.

Received date: 2002-09-23
Foundation item: Under the auspices of the National Key Project (BA508 B05).
Biography: Wang Zhi-chun (1963 –), male, a native of Jilin Province, professor, specialized in soil salinity management and agricultural development.

3 FAVORABLE AND RESTRICTING CONDITIONS FOR SUSTAINABLE DEVELOPMENT OF AGRICULTURE

3.1 Restricting Conditions for the Sustainable Development of Agriculture

3.1.1 Low precipitation, higher evaporation and frequent drought

Da'an area is located in the semi-arid and arid climate region. Annual average temperature is 3 – 5℃, dryness degree is 1.3. Annual average precipitation is 350 – 450mm, of which 70% – 80% concentrates in July – September. The evaporation in this region reaches 1600 – 1800mm, as much as 4 – 5 times of its annual precipitation. Seasonal drought occurs frequently in spring and autumn, and nine-tenths of springs suffer from drought. In addition, the groundwater level change seasonally, as a result, salt accumulates in the soil profile.

3.1.2 High salinity and alkalinity, high exchangeable sodium content and poor infiltration of the soil

The soil type of Songnen Plain is mainly saline-alkali soil. The average total dissolved salt in the topsoil (0 – 30cm) is 0.5% – 1.1%, with Na_2CO_3 and $NaHCO_3$ as the main components. The soil shows alkali reaction, with pH 7.7 – 9.8 and ESP 10% – 45% or more, and poor physical properties. The bulk density is 1.4 – 1.5g/cm^3. The infiltration rate in the surface layer is 1 – 2mm/min, and falls down to 0.1 – 0.2mm/min in the alkali layer. These problem physical and chemical properties restrict the sustainability of regional agricultural development.

3.1.3 Insufficiency and low availability in nutrition

The soil is poor in nutrition, with 0.4% – 1.2% of organic matter content, 0.2 – 1.1g/kg of total nitrogen and 0.5 – 0.9g/kg of total phosphorus. High exchangeable sodium percentage (ESP) limits the fertility of soil and the availability of nutrition to plant (WRIGHT and RAJPER, 2000).

3.2 Favorable Conditions for the Sustainable Development of Agriculture

3.2.1 Sufficient light and heat resources

Songnen Plain is located in the west part of Northeast China. Total radiation of the sunshine is 525.5kJ/cm^2 annually, with the highest value of 64kJ/cm^2 in June. The sun shinning hours are 3014h per year, and active accumulated temperature of ≥ 10℃ is 2921.3℃. Usually the frost-free period is 137 days from early May to late September. Sufficient light and heat resources and simultaneous season of rain and heat can fully meet the requirements of annual crops here, providing a favorable condition for agricultural development.

3.2.2 Rich groundwater resources

Songnen Plain is rich in groundwater resources with a total storage of $9.15 \times 10^9 m^3$. Natural recharge to the groundwater is $3.40 \times 10^9 m^3/a$ and the pumping volume potential is $6.85 \times 10^9 m^3/a$. Groundwater used for irrigation comes from the confined aquifer (Q1 and Nt, 70 – 100m deep), with pH6.8 – 7.3, mineralization degree of 0.64 – 0.82g/L by HCO_3^--$Na^+ \cdot Ca^{2+}$. It meets the requirements of water quality for irrigation by national standard (TJ-24-79). But it is very important to manage the groundwater properly, avoiding its contamination and enhancing water use efficiency.

3.2.3 Plenty of manure produced by livestock

Songnen Plain is famous for animal husbandry industry because of its large area of grassland. Over 30% of the total agricultural output value comes from animal husbandry. Amounts of livestock in Baicheng City, Jilin Province are more than 1.0×10^6. Manure produced by these animals provides the local farmers with organic fertilizers, which can be used to fertilize the soil and change the physical and chemical properties of the soil. Study shows that manure application on the saline-alkali soil can activates N, P, K and other trace elements to be available to plants and becomes an economical practice reclaiming the problem soil.

4 KEY TECHNIQUES FOR SUSTAINABLE DEVELOPMENT OF AGRICULTURE

4.1 Establishing Proper Irrigation and Drainage System

Effective leaching and drainage were necessary for both paddy field and dry land (RICHARDSON and NARAYAN, 1995). In this region, growing rice was proved to be a suitable way to utilize the saline-alkali soil resources because the standing water that is necessary for leaching the salts causes chemical changes in the soil that benefit rice (TANJI, 1990). But well-established irrigation and drainage system is the precondition for rice farming in saline-alkali area. At the same time, field irrigation and drainage canals should be well organized. The irrigation and drainage for each plot must be separated, and the area of each plot should be less than 0.2ha. Standing water must be drained out of the field regularly to accelerate the desalinization.

Dry land with high salinity and alkalinity often suffers from drought or waterlogging. Pumping water from wells for irrigation can supplement water to plant, leach salts out of root zone and facilitate crop growth so that higher yield is expected. In addition, the semi-confined water level is reduced to some extent by pumping water from the ground and secondary salinization in soil is prevented. Because of poor infiltration and waterlogging in saline-alkali soil, effective drainage system is strongly recommended.

4.2 Amending and Fertilizing the Saline-alkali Soil

4.2.1 Covering saline-alkali soil with sand

Scientific research and production practices show that covering saline-alkali soil with sand is an easy and cheap way to improve the soil penetrability and other properties. The sand used for amendment exists in sand dunes nearby in a great deal. The sand volume applied varies from $300m^3/ha$ to $750m^3/ha$ usually, depending on soil salinity and alkalinity. Successive sand covering in the following years are needed to fully reclaim the soil even though higher grain yield is achieved in the second year after covering. Taking Liuhetang Village, Chagan Town, as examples, after 6 years amendment with sand, 7500kg/ha of rice yield was made on this problem soil in 2000 with the improvement in chemical characteristics (Table 1).

Table 1 Chemical characteristics of soil treated by sand covering (mg/kg)

Trials	CO_3^{2-}	HCO_3^-	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	NO_3^-	$K^+ + Na^+$	TDS	pH
S_1	0.00	146.40	35.07	18.24	79.88	1.24	40.00	48.13	367.96	7.21
S_2	0.00	256.20	30.06	27.36	115.38	4.80	30.00	98.90	562.70	7.36
S_3	0.00	256.20	40.08	9.12	124.25	5.12	20.00	123.97	578.74	7.60
CK	0.00	292.80	45.09	30.40	133.13	5.88	20.00	97.89	625.19	9.08

Note: S_1, S_2 and S_3 indicate the rate of sand covered, S_1: 750 – $1050m^3/(ha \cdot a)$, S_2: 300 – $750m^3/(ha \cdot a)$, S_3: 150 – 300 $m^3/(ha \cdot a)$, CK: no sand applied

4.2.2 Supplying organic materials

Organic materials suitably supplied to saline-alkali soil include farmyard manure, straw of crops and green manure plants. Organic matter increased by 40% and total dissolved salts decreased by 37.2% after continuous supplement of farmyard manure for three years. The analysis also showed that available N, P, K were enhanced to 47.0mg/kg, 19.3mg/kg and 90.4mg/kg, respectively. Farmyard manure of 1000kg supplied can bring 79.6-kg yield increase of rice.

4.2.3 Applying chemical amendments

The most common chemical amendment for saline-alkali soil is gypsum, a byproduct of chemical industry. It works very well because sodium in soil is exchanged by calcium in gypsum. But there is no commercial gypsum available in the region, gypsum is not in practical use. Elemental sulfur was used in the U.S. (SLATON *et al.*, 1996), but it is not easily available here in market. After 3-year tests, TC-1 amendment was developed for saline-alkali soil. The experiment showed that 15 000kg/ha was suitable rate and two times application significantly reduced the salt content, pH and exchangeable sodium in the topsoil (Table 2).

4.3 Crop Cultivation and Tillage Practices

4.3.1 Selecting salt tolerant crops (varieties)

Growing salt tolerant species or cultivars of plants can reduce the reclamation cost (PONNAMPERUMA, 1984). Salt tolerant species of plants in this area include sunflower, sugar beet, sorghum and sweet sorghum, etc. Sunflower grows well even in the soil with salinity of 0.1% – 0.5% and ESP of 10% – 37%, but without any amendment. Cotton is also a salt tolerant crop and can be grown in Songnen Plain. Grain Amaranth is newly introduced forage crop for salt tolerance.

Rice's salt and alkali tolerance varied among varieties representing by stand loss and yield decrease. The characteristics of rice salt-alkali tolerance include quick recovering after transplantation, high survival rate, more tillers and high grain yield. More than 50 rice varieties were introduced for salt-alkali tolerance selection. The total salt content and pH in the topsoil (0 – 17cm) for the selection were 0.38%, and 9.2, respectively. Ji 89-45, Jiyou 1, Huangjinlang and Jiudao 16 showed very good characteristics of saline-alkali tolerance (Table 3).

In fact, Ji 89-45, with highest yield, is getting in large demand in recent years because of its saline-alkali tolerance in this area.

4.3.2 Tillage practices

Precisely land leveling, shallow plowing and deep loosing are recommended for the tillage practices in allusion to restrictions of the soil in root zone. For rice field, plowing in autumn and re-plowing in next spring can loosen soil so that salts will be exchanged and leached out of the root zone more easily. These tech-

Table 2 Effect of TC-1 amendment on soil salinity (mg/kg)

	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$K^+ + Na^+$
CK	0	829.6	11.9	103.04	84	58.8	743.3
Treated	0	488.0	13.3	77.80	132	58.8	317.8
CK	21	1189.5	11.9	22.60	80	46.8	749.8
Treated	0	475.8	7.7		112	50.4	117.5

Note: CK indicates no amendment applied.

Table 3 Yield characteristics of saline-alkali tolerant rice varieties

Variety	Heads/hill	Seeds/panicle	Wt/thousand seeds (g)	Filled seeds(%)	Yield (kg/ha)
Ji 89-45	13.0	80.7	22.4	92.0	7131.2
Jiyou 1	15.2	73.4	20.4	91.0	6855.0
Huang jinlan	12.3	78.4	23.4	91.2	6777.9
Jiudao 16	12.4	79.6	23.6	87.6	6731.5
Nongda 8	13.5	79.3	21.1	90.1	6703.1
Nongda 10	12.5	81.9	22.8	85.7	6531.2
Fengyou 201	12.6	79.9	20.3	92.8	6241.8
Tong 211	12.5	88.0	18.8	90.0	6147.8
Tong 09	10.6	95.3	20.1	86.5	5766.3
Jiuxuan 1	13.3	69.9	20.4	92.2	5646.6
Tong 211	13.7	75.4	19.1	83.4	5300.3

niques are worth of extended intensively in the region.

4.3.3 Integrated anti-salt cultivation techniques

Anti-salt cultivation techniques for rice include nursing stronger seedling with proper broadcasting, flooding and leaching before transplantation, arranging rational stand density, balancing fertilization and managing irrigation(WANG, 1990). Every cultivation practice adopted should provide a favorable condition to rice planting, making rice stronger in vigor and soil less in salinity and alkalinity. For dryland crops, the emphasis should be given on germination (XIE *et al.*, 2000) because most crops are salt sensitive during seedling stage. Proper field management practices such as hoeing and plowing in time are also important for plant growth.

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