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Improvement of Salt-affected Soils by Deep Ploughing*

— Part 1: Plot Field Tests in a Saline Soil (Solonchak) Region —

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Abstract

A method was investigated for improvement of salt-affected soils in regions where a sufficient amount of rainfall to percolate into subsoil occurs in summer. A coarse layer is provided in the subsoil by deep tillage, making soil clods to cut off the capillary rise from groundwater. This paper deals with plot test fields constructed by hand in a saline soil (solonchak) region. The results showed that the deep tillage to the subsoil was beneficial for the improvement of the solonchak soil. Where the Ap horizon (topsoil) alone was tilled, the vegetation was poor because the capillary rise was not perfectly cut off. Reduction of the pH from about 9.5 to 8.5 was obtained. The EC value decreased from about 0.5 dSm^{-1} to 0.2 dSm^{-1}. From these results, we determined that the tillage should be deeper to intercept the capillary rise at the subsoil.

[Keywords] saline soil (solonchak), salt-affected soil, soil improvement, deep ploughing

I Introduction

Salt-affected soils are formed in arid areas of the world and are widely distributed in Europe (Hungary and Russia), North America (USA and Canada), South America (Argentina and Paraguay), Asia (India, Iran and China) and Australia (Abrol *et al*., 1988). In this paper, the reclamation of the saline soil (solonchak) in salt-affected soils distributed in the People's Republic of China is firstly discussed.

This soil is called whitish oasis soil (Fig. 1). It is found on the Hebei and Inner Mongolia provinces (about 350 Gm^2). It contains calcium carbonate ($CaCO_3$), and belongs to the saline soil group (solonchak) according to pedological classification (Dudal, 1969; Scheffer & Schachtschabel, 1976; Abrol *et al.,* 1988; Cardon & Mortvedt, 2001).

In the previous paper (Guo *et al*., 2006), a method of soil improvement was discussed for the salt-affected soils with sufficient rainfall to percolate into subsoil in the summer season; a coarse layer was provided below the Bca horizon (subsoil) in this region. We demonstrated with soil column experiments that the capillary water from groundwater could be cut off, thus preventing the rise of dissolved salts to the soil surface. The salts accumulating in the topsoil (Ap horizon)

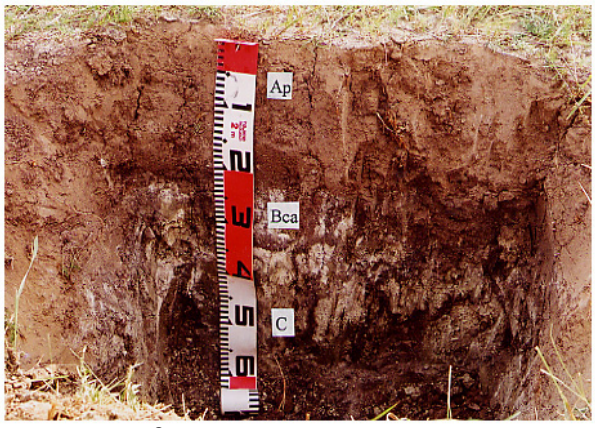

Fig. 1 Typical saline soil (solonchak) in Shangyi County, Hebei Province, P. R. of China. Ap horizon, humic soil with organic matter; Bca horizon, whitish, hard and impermeable soil; C horizon, hard parent material.

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were otherwise leached out by every rainfall, which then made the pH values to decrease.

For this purpose, deep ploughing had been achieved (Antipov, 1954; Botov, 1959; Fesko & Strugeleva, 1959; Maksimyuk, 1958; Rasmussen *et al*., 1972; Cairns, 1962; 1976a; Bowser & Cairns, 1967; Karkanis & Cairns, 1981; Buckland & Pawluk, 1985). However, above deep ploughing was performed by a back-hoe (Cairns, 1962) or a single mouldboard plough (Bowser & Cairns, 1967), and so every soil horizons were perfectly mixed. The Ap horizon in Fig. 1 contains pretty amount of organic matter and are fertile, and should not be mixed into the lower infertile horizons (Guo *et al*., 2002). Antipov & Pak (1965) and Cairns (1976b) also reported that the Ap horizon should be retained on the surface during deep ploughing.

We envisaged a four-stage subsoil plough which tilled the subsoil up to 600 mm deep, retaining the Ap horizon and was modified from the plough for improvement of planosol (Guo *et al*., 2002).

In the current paper, in order to verify this concept of capillarity interception, the plot test fields were prepared in a local spot by hand, and we determined that the solonchak soil could be improved by what kind of deep tillage. In 2004, three plot test fields were constructed, and their vegetation and soil properties were investigated in 2005, 2006 and 2007.

II Materials and Methods

1. Chemical properties of solonchak soil

Figure 1 shows a typical solonchak from a cultivated field in Sangyi County, Hebei Province where no irrigation system is applied. The Ap horizon (pH 8.9) is a 200 mm layer of humic, brown soil which contains organic matter suitable for plant growth. The Bca horizon (pH 9.4) is a 300 mm layer of accumulated $CaCO_3$ and whitish soil. The C horizon (pH 9.7) is the white and brown parent material. The Bca and C horizons were extremely hard, and the soil penetration resistance (cone penetrometer, 30° cone angle and 16 mm base diameter) was more than 5 MPa.

Fig. 2 Bare land in Dayingpanxiang, Shangyi County, Hebei Province. Efflorescence (alkali spots) are found on the soil surface.

Table 1 Chemical properties of solonchak in Shangyi County, Hebei Province

	Values for soil horizons		
	Ap	Bca	C
pH (H_2O)	8.9	9.4	9.7
Electrical conductivity EC, dSm^{-1}	0.25	0.37	0.688
Exchangeable sodium percentage ESP, %	1.8	6.7	9.9
Cation exchange capacity CEC, meq kg^{-1}	152	139	326
Humus, %	3.1	3.1	1.7
Exchangeable sodium Na_2O, mg kg^{-1}	113	391	1348
Available phosphate P_2O_5, mg kg^{-1}	40	10	20
Exchangeable calcium CaO, mg kg^{-1}	10500	10920	5670
Exchangeable magnesium MgO, mg kg^{-1}	2480	4090	11240
Exchangeable potassium K_2O, mg kg^{-1}	450	248	371
Available nitrogen N, mg kg^{-1}	52	42	29

Table 1 shows the chemical properties of this solonchak soil. The pH value of every horizon is about 9.0 (strongly alkaline) because of the accumulation of $CaCO_3$. If this soil is left undisturbed for a long time, white crystals of efflorescence (alkali spots) accumulate on the soil surface, and no plants can survive here (Fig. 2).

A pH value more than 8.5 is for the sodic soil group (solonetz) which is mainly due to Na_2CO_3, and that less than 8.5 is for the saline soil group (solonchak) which is mainly due to $CaCO_3$ (Abrol *et al*., 1988; Cardon & Motvedt, 2001). The soil in this study has a pH value that nearly overlaps both of these soil group designations.

The EC value less than 4 dSm^{-1} is for the solonetz group, and that more than 4 dSm^{-1} is for the solonchak group (Abrol *et al*., 1988; Cardon & Motvedt, 2001). The ESP value less than 15% is for the solonchak group, and that more than 15% is for the solonetz group (Abrol *et al*., 1988; Cardon & Motvedt, 2001). Taking into account all values of pH, EC, ESP and $CaCO_3$, we determined that the soil in this study belongs to the solonchak group on the whole.

The CEC values of the upper layers (Ap and Bca horizons) of the soil in this study were small because soil particles of the topsoil were coarse (Guo *et al*., 2004) and had little humus. The CEC value of the subsoil (C horizon) was a little higher because of heavy clay content (Fujiwara *et al*., 2003).

The humus content in the Ap horizon (topsoil) of the soil in this study was about 3%, and that in the C horizon (subsoil) was about 2%. In the planosol which is distributed in the Heilongjiang Province, the humus content in the topsoil was about 5%, and that in the subsoil was about 1% (Araya, 2001). In the meadow soil, which is also distributed in Heilongjiang Province, the humus content was about 20% in the topsoil and about 3% in the subsoil (Zhang *et al*., 2000). The humus