Research Paper

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Deep Tillage Plough down to 600 mm for Improvement of Salt-affected Soils*

-Part 1: Configuration of Plough for Production of Large Soil Clods in Subsoil-

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Abstract

A method is proposed for soil improvement of salt-affected soils. Soil clods of desired size are produced in subsoil by deep tillage to cut off capillarity from groundwater and to prevent the rise of salts to the soil surface. In this paper, the plough configuration to produce soil clods with the proper size by brittle fracture was analysed in an indoor soil bin. The results showed that when brittle fracture (tensile failure) took place in the soil, a horizontal crack in the soil was produced at the tip of the plough blade, followed by an another upward crack toward the soil surface with the angle of about 40°. A short blade length (50 and 80 mm) and deep ploughing (150 and 200 mm) of the deep tillage plough generated unwanted huge soil clods of about 25 kg. In order to generate proper soil clods, the ideal rake angle should be 20°, and the ideal blade length was 130 mm.

[Keywords] salt-affected soils (solonchak and solonetz), soil improvement, subsoil, soil clods, plough configuration

I Introduction

Salt-affected soils are formed in arid areas in the world. In the previous paper (Guo *et al*., 2006), a method of soil improvement was discussed for salt-affected soils with sufficient rainfall to percolate into subsoil in summer; a coarse layer was provided below the subsoil (B horizon). It was demonstrated with indoor soil column experiments that the capillary water from groundwater could be cut off at the coarse layer, thus preventing the rise of dissolved salts to the soil surface. The salts normally accumulating in the topsoil (Ap horizon) leaches out by every rainfall, which then makes pH values to decrease.

In order to cut the capillarity, deep ploughing has been previously performed (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, such ploughing was performed by a back-hoe (Cairns, 1962) or a single mouldboard plough (Bowser & Cairns, 1967), and so every soil horizon was evenly mixed. The Ap horizon contains a fair amount of organic matter and is fertile, so it 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 ploughing.

Deep ripping (subsoiling) is a method to loosen the soil without mixing of soil horizons (Bole, 1986; Wetter *et al*., 1987; Mathison *et al*., 2002), but the effect of improvement of the salt-affected soils is poorer than by deep ploughing. In particular, the zones between shanks are hardly improved (Rasmussen *et al*., 1972; Alzubaidi & Webster, 1982).

We developed a four-stage subsoil plough (Fig. 1, Araya *et al*., 1996a; 1996b; 1996c; Guo *et al*., 2002), which tilles the layers down to 600 mm (to the C horizon) and retains the topsoil (Ap horizon). The plough consistes of four plough bodies. The first plough body is a conventional mouldboard

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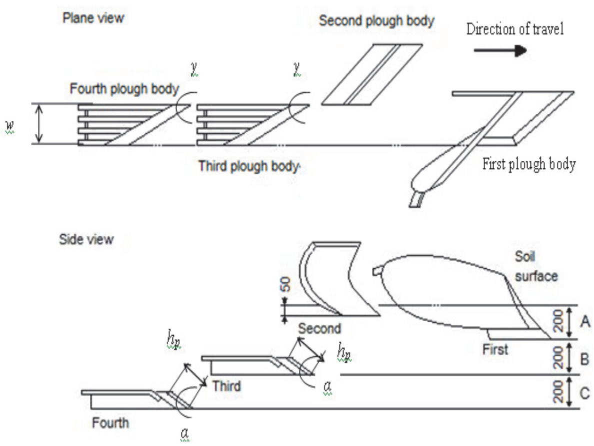

Fig. 1 Schematic diagram of plough bodies of a four-stage subsoil plough for improvement of salt-affected soils. The third and fourth plough bodies are identical. A, B and C are soil horizons; all dimensions are in mm.

plough which tills and inverts the Ap horizon at a depth of 0-200 mm. When there is efflorescence (alkali spots) on the soil surface, the second plough body skims an adjacent furrow on the land side which runs next to the first, third and fourth plough bodies, precisely 50 mm deep below the surface of the Ap horizon and transfers this thin soil slice to the preceding furrow onto the third plough body. The B horizon (200-400 mm) is then tilled by the third plough body, and the soil clods are produced here in the B horizon. The C horizon (400-600 mm) is then tilled by the fourth plough body, and soil clods are produced also in the C horizon. Subsequently, the first mouldboard plough body tills the remainder of the Ap horizon, inverting the Ap furrow slice, thus covering the tilled soil in the preceding furrow (Guo *et al*., 2002). In the present paper, the plough configuration of the third or fourth plough body (identical) to till the subsoil was analysed in an indoor soil bin to produce soil clods with proper size in the subsoil.

The purpose of tillage is generally for preparation of seedbeds, and an aggregate clod size range of 1-5 mm is required (Ojeniyi & Dexter, 1979). For this purpose, shearing failure in soil should be induced by tillage tools to cause soil to crumble into small pieces. However, tensile failure (brittle fracture) should take place here in the soil to obtain the desired soil clods of 100-140 mm (Araya *et al*., 2010). The size of clods produced by brittle fracture is much larger than those by shear failure, and there is negligible deformation in the soil clods (Aluko & Seig, 2000). For this purpose, the configuration of the third or fourth plough body (rake angle, length of plough blade, and operating depth) to induce brittle fracture and to produce soil clods was analysed (Fielke, 1996; Natsis *et al*., 1999; Hemmart *et al*., 2007).

When the soil water content is near the plastic limit (PL),

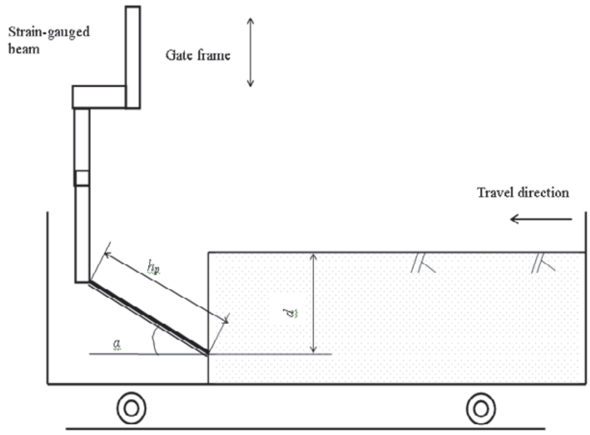

Fig. 2 Schematic diagram of the test apparatus. The soil bin is 1.8 m long, with a transparent side. d, operating depth; h_p, length of plough blade; α, rake angle.

it is found that soil is easily pulverized by tillage (Ojeniyi & Dexter, 1979; Braunack & McPhee, 1991; Lyles & Woodruff, 1962; Adam & Erbach, 1992). The salt-affected soils in this study are located in dry areas and are generally dry except in rainy seasons, and the measured soil water content of the subsoil is generally about 10% d.b. [dry base, =100 g kg^{-1}(dry soil)], which is much less than the plastic limit, so soil tended to cohere (Sun *et al*., 2007; Zhu *et al*., 2007).

II Materials and Methods

1. Soils in this study

The test site was in Japan. The previous paper (Guo *et al*., 2004) has reported that the subsoils of salt-affected soils [saline soil (slonchak) and sodic soil (solonetz)] are heavy clay soil, and the distribution of their soil particle-size is

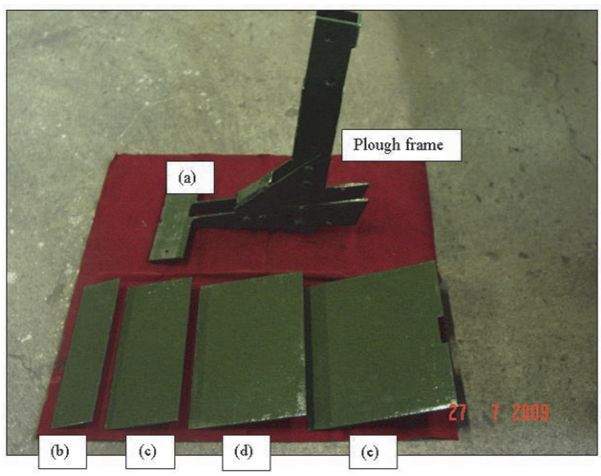

Fig. 3 Model blades of deep tillage plough (plough blades). Width of plough blade w=300 mm; (a) Blade length h_p=50 mm; (b) h_p=80 mm; (c) h_p=130 mm; (d) h_p=200 mm; (e) h_p=250 mm; rake angle α can be adjusted by the plough frame.