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Research paper

Soil layer displacing plough — Part 1: Cernozem soil☆

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ABSTRACT

Chernozem is a soil group with calcium carbonate which is found extensively throughout the Heilongjiang province of the People's Republic of China. As one of the main corn belts in the world, the area has continuous planting of corn every year, but that lead to continuous cropping injury. Many corn stalks remain on the soil surface in autumn, so these corn stalks should be buried into the subsoil to retain rainwater underground. This can be accomplished with a special plough which we newly designed and built in this paper. The results show that when the corn stalk length was less than 1000 mm, a smooth burial took place. A total draught of this plough was measured at about 35 kN.

1. Introduction

Chernozem, which is a special soil group characterized by calcium carbonate, $CaCO_3$, is widely distributed in the Heilongjiang province of the People's Republic of China near the border with Russia (Gongzitong, 1999; Tseng et al., 1963). The annual precipitation there is only about 700 mm.

Fig. 1 shows a typical chernozem of a cultivated field in Anda, Heilongjiang (latitude: 46°24′28″ N, longitude: 125°19′28″ E). The first horizon (Ap) is a black and gray soil with humus (8%–10%) that is suitable for plant growth and has a thickness of about 100 mm. The second horizon (A) is a calcareous and impermeable soil (clay) with less organic matter and a thickness of about 150 mm. The third horizon (Bca) is calcareous and impermeable parent material (clay, thickness about 150 mm). The fourth horizon (Cca) below about 400 mm depth is calcareous and impermeable gleyed soil (clay) with rust spots (Zhao, 1992).

With the impermeable A, Bca and Cca horizons, plants suffer from both drought and excess moisture. The soil hardness (penetration resistance) of the A, Bca and Cca horizons is more than 5.0 MPa (cone penetrometer, 30° cone angle, 16 mm base diameter). Roots of plants cannot penetrate into the A, Bca and Cca horizons.

This area is one of the main corn (maize) belts in the world, and the corn here is continuously planted every year, which triggers continuous cropping injury. Hence, the corn yield is declining, and its quality is also becoming poor (Gao et al., 2012).

It is firstly recommended that the top soil (the 0–200 mm depth layer with margin) and the subsoil (the 200–400 mm depth layer) should be displaced to eliminate the continuous cropping injury, and the top soil should be left for about five years (resolution period) underground (Gao et al., 2012).

After corn is harvested, the stalks are left on the soil surface (Fig. 2). Corn is generally harvested by hand here; the corn stalks are cut by using a sickle. They are gathered and used as a fuel in winter. However, a lot of the corn stalks remain on the soil surface unused (Fig. 2). They are then burnt away in autumn, causing terrible air pollution.

It is also recommended that these corn stalks should be buried into the subsoil to retain rainwater underground.

In order to improve a heavy clay soil (meadow soil), we have already tried this; trash such as corn stalks remaining on the soil surface in autumn were gathered and buried into subsoil (Zhang & Araya, 2001a, 2001b; Zhang et al., 2001) with a three-stage soil layer mixing plough developed by us. With this method, we achieved proper results on the meadow soil conditions, and we felt this method can be adapted to the chernozem soil conditions, too. However, this plough cannot be directly adapted for improvement

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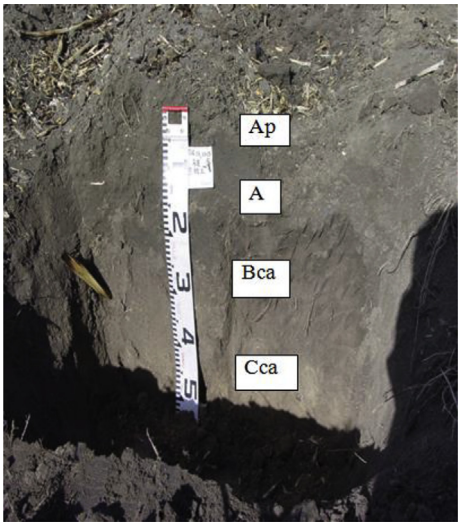

Fig. 1. Typical chernozem at a crop field in Anda, Heilongjiang, P. R. of China. Ap horizon, calcareous blocking structure with abundant organic matter; A horizon, calcareous and impermeable soil with less organic matter and few roots; Bca horizon, calcareous and impermeable parent material with a significant concentration of Fe–Mn; Cca horizon, calcareous and impermeable gleyed soil with rust spots.

of the fields with continuous cropping injury because this plough does not interchange the top soil and subsoil.

We newly designed and built a special plough (soil layer displacing plough with a corn stalk collector) which consists of three plough bodies (Fig. 3). This plough (length: about 2000 mm; weight: about 150 kg) is much simpler than the previous three-stage soil layer mixing plough (Zhang et al., 2001; length: about 3000 mm; weight: about 500 kg) and can be effectively used for the fields with the continuous cropping injury. This paper deals with that plough configuration (Fig. 3).

2. Principle of soil layer displacing plough with a corn stalk collector

In order to displace the top soil (0–200 mm layer, Ap and a part of A horizons) and the subsoil (200–400 mm layer, a part of A and Bca horizons), 400 mm deep layer can be tilled by a single huge mould plough (Bowser & Cairns, 1967), but a huge traction force is required (Jia et al., 1998a).

Hence, we designed and built a special plough (Figs. 3 and 4) which consisted of three plough bodies. The first and third plough

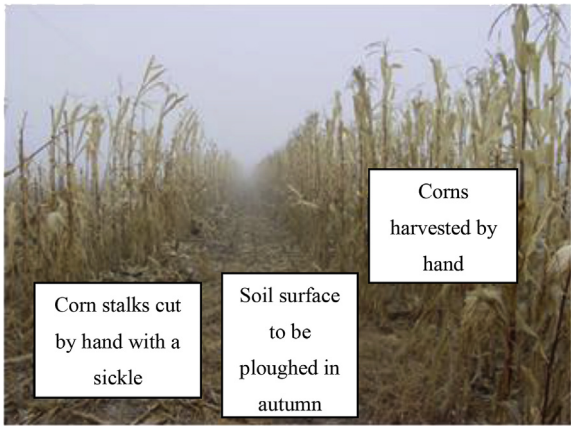

Fig. 2. Corn field after harvesting (right), after sickling by hand (left) and after cut corn stalks are carried out (center).

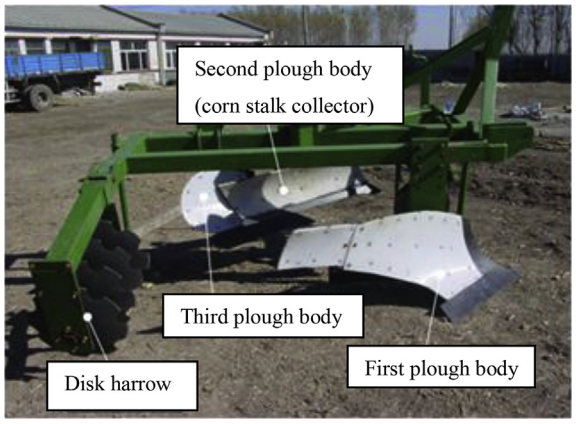

Fig. 3. Soil layer displacing plough with a corn stalk collector.

bodies each till the 200 mm depth layer (Gao et al., 2012; Araya et al., 2013a, 2013b, 2013c). The shape and configuration of the second plough body is due to the previous reports (Jia et al., 1998b; Zhang & Araya, 2001b). The trash collector of the previous three-stage soil layer mixing plough is just used here as the second plough body (corn stalk collector) of the present soil layer displacing plough with a corn stalk collector (Fig. 3).

Fig. 5 shows schematic diagram of the displacing process of the Ap and Bca horizons (mainly) and the burying process of corn stalks into subsoil with four stages.

With the first plough body, the Bca horizon (200–400 mm layer) is raised up to 200 mm and is inverted on the right side of the plough body. As the same time, a ditch is constructed (Stage 1). The right wheels run in the furrow.

The second plough body runs on the soil surface in the next and adjacent furrow. It gathers the corn stalks distributed on the soil surface and drops them into the ditch made by the first plough body (Stage 2).

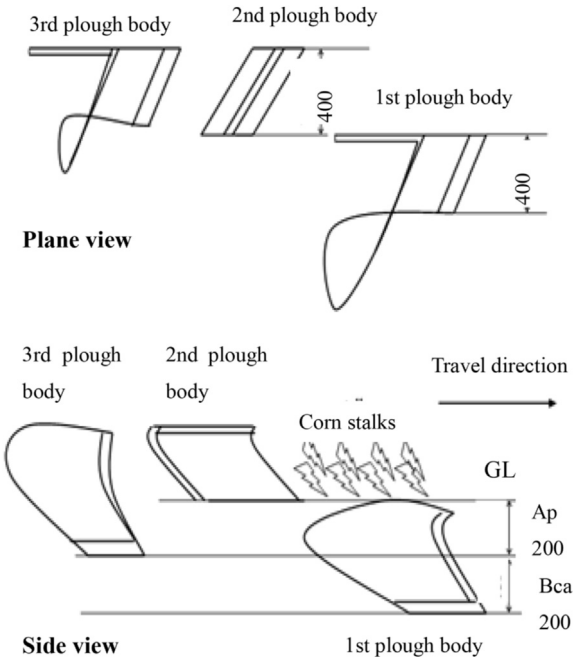

Fig. 4. Schematic diagram of soil layer displacing plough with a corn stalk collector (2nd plough body). All dimensions are in mm; GL = ground level.