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Technical paper

Soil layer displacing plough — Part 3: Black and brown soils☆

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ABSTRACT

Black soil and brown soil are special soil group containing clay and sandy loam respectively in the P. R. of China. As one of the main corn (maize) and peanut belts in the world respectively, the areas suffer from continuous cropping injury due to continuous planting. To improve conditions, it is recommended that the top soil and subsoil should be displaced and crop residue on the soil surface should be buried into the subsoil to retain the rainwater. These can be accomplished with a special plough which we designed and built. The results show that after operation, about 70% of the dark top soil fell down to the 700 mm depth. The crop residue was buried at a depth of 300–400 mm. A total draught of this plough was measured at 39.5 kN on the black soil field and 29.8 kN on the brown soil field including the tractor running resistance.

1. Introduction

Black soil, which is a special soil group with clay in the subsoil, 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 about 700 mm.

Fig. 1 shows a typical black soil of a cultivated (corn) field in Yian, Heilongjiang (latitude: 47°53′36″ N; longitude: 125°17′54″ E). The first horizon (Ap) is a black and gray soil with humus and granular structure that is suitable for plant growth and has a thickness of about 100 mm where plant roots are found. The second horizon (A) is an impermeable soil (clay) with less organic matter and a thickness of about 100 mm. The third horizon (AB) is an impermeable parent material with Fe–Mn concretion (clay, thickness of about 200 mm). The fourth horizon (B) below about 400 mm depth is a blocking structure and particles of SiO_2 are found (Zhao, 1992).

With the impermeable A, AB and B horizons, plants suffer from both drought and excess moisture. The soil penetration resistance (hardness) of the A, AB and B horizons is more than 3.0 MPa (cone penetrometer, 30° cone angle, 16 mm base diameter). Roots of plants cannot penetrate into the A, AB and B horizons.

This area is one of the main corn 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).

Brown soil, which is a special soil group with sandy loam, is widely distributed in the Liaoning province of the People's Republic of China (Gongzitong, 1999; Tseng et al., 1963). The annual precipitation in this area is only about 400 mm and concentrated in June to August.

Fig. 2 shows a typical brown soil of a cultivated (peanut) field in Taoli village, Fuxin district, Liaoning (latitude: 41°44′ N, longitude: 121°01′ E). The soil texture down to 500 mm depth is sandy loam (University of Florida, 2003). All of its horizons lack organic matter. The first horizon (Ap) is a dark brown soil with a plate structure and has a thickness of about 100 mm where a few plant roots are found. The second horizon (AB) is brown soil with a nucleus structure and

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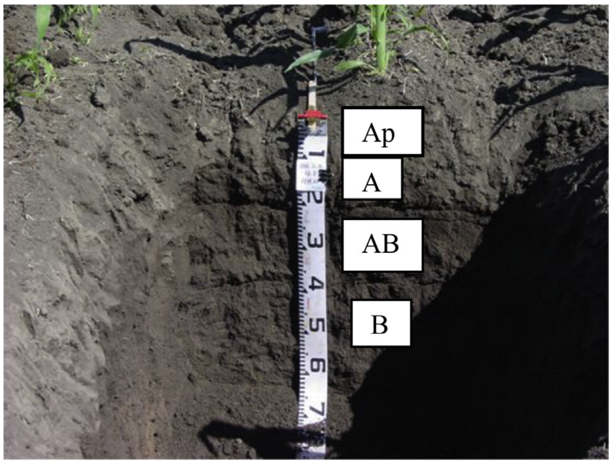

Fig. 1. Typical black soil in a corn field in Yian, Heilongjiang, P. R. of China. Ap horizon, granular structure with organic matter and plant roots are found; A horizon, impermeable soil with less organic matter and few roots; AB horizon, Fe–Mn concretion and impermeable layer; B horizon, blocking structure and SiO_2 particles are found.

few plant roots are found (thickness of about 200 mm). The third horizon (B) is also brown soil with a nucleus structure and a few rust spots (thickness of about 200 mm). The fourth horizon (C) below about 500 mm depth is a sand layer with considerable rust spots (Zhao, 1992).

This area is one of the main peanut belts in the world, and the cultivated area for peanuts is 66 Mm^2 of the total cultivated fields (80 Mm^2) in this region. The remaining 14 Mm^2 is used for corn, hence crop rotation cannot be applied, and peanuts have been continually planted in the same field every year for more than 15 years. These results in continuous cropping injury in which the size of peanut bean becomes small and its yield gets poor (Gao et al., 2012). The original peanut yield prior to 15 years ago was 0.45 kg m^{-2}, but the present yield has declined to 0.37 kg m^{-2} (80%).

With less precipitation, plants suffer from drought in both areas. Especially, the rainfall in spring seeding season is decreasing year after year in both areas and droughts in spring are frequent.

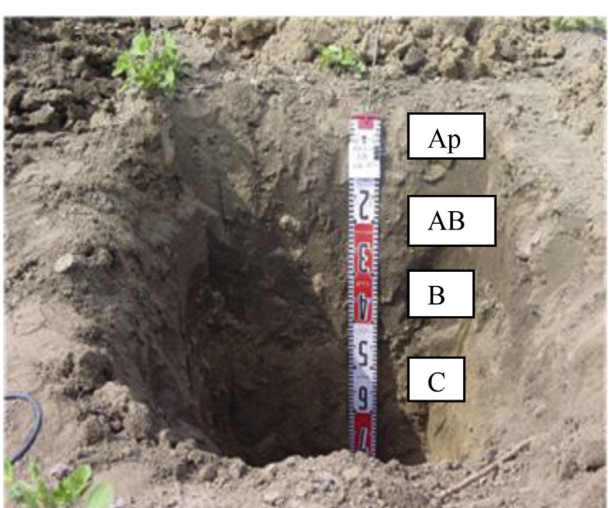

Fig. 2. Typical brown soil in a peanut field in Taoli village, Fuxin district, Liaoning province, P. R. of China. Ap horizon, plate structure and a few roots; AB horizon, nucleus structure and few roots; B horizon, a few rust spots and nucleus structure; C horizon, considerable rust spots and sand layer.

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

It is also recommended that crop residue remaining on the soil surface in autumn should be buried into the subsoil to retain rainwater underground. If the crop residue is corn stalks, their treatment before operation is required. The length of corn stalks must be less than 500 mm which can be performed with a straw crusher (Araya et al., 2015).

A special plough which consists of three plough bodies (Fig. 3) was newly designed and built by us. This plough was originally developed for improvement of chernozem soil conditions (Araya et al., 2015). This plough can be adopted to the black and brown soil conditions, too, so the similar tests as in the chernozem soil field were carried out in the black and brown soil fields, too.

The principle of the soil layer displacing plough with a crop residue collector (Fig. 3) was reported in the previous paper (see Araya et al., 2015).

The improved soil conditions (soil water content, soil temperature and crop yield) with this plough will be reported in the subsequent paper.

2. Materials and methods

2.1. Soil section

Soil sections of 1000 mm × 1000 mm × 700 mm depth (Figs. 1, 2 and 5) were prepared at the test field. The soil horizon, soil texture and depth of root penetration were subsequently determined.

2.2. Soil penetration resistance

Soil penetration resistance (soil hardness) was determined by a cone penetrometer (30° cone angle and 16-mm base diameter). Three penetrations were performed in different places and then averaged.

2.3. Traction test

The plough in Fig. 3 was mounted on a tractor which was used to support the plough but did not provide power (second tractor). This was drawn by another tractor (first tractor) through a traction

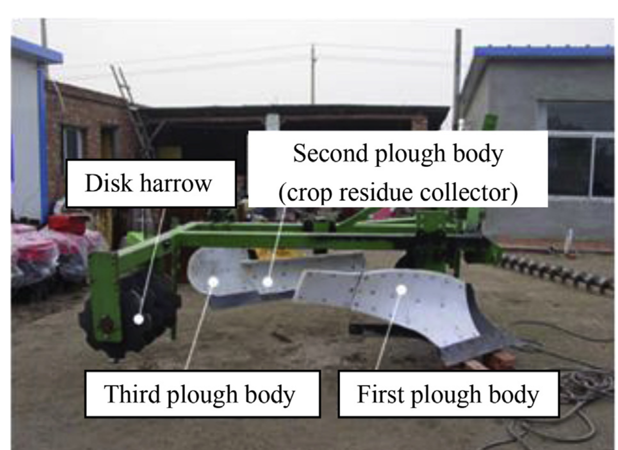

Fig. 3. Soil layer displacing plough with a crop residue collector.