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Energy consumption in cultivating and ploughing with traction improvement system and consideration of the rear furrow wheel-load in ploughing

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ABSTRACT

Soil tillage in conventional tillage systems is one of the most energy consuming processes. The paper deals with the influence of working width of mouldboard ploughs (mounted: 2 × 3, 2 × 5 and semi-mounted: 2 × 7) at the working depth of 25 cm and T-trailed cultivator (3 bars; row spacing: 27 cm; 18 tines; tine spacing; 27 cm, working width: 500 cm) at the working depth of 15 and 25 cm on field capacity, fuel consumption, slip and specific energy consumption. The experiments were conducted on the arable fields at the experimental farm Gross Enzersdorf (Lower Austria) of the University of Natural Resources and Life Sciences (BOKU) Vienna. For measuring of the vehicle and wheel speed (parameters for slip calculation), the tractors (4-WD 59 kW for 2 × 3 reversible plough and 4-WD 160 kW for 2 × 5 and 2 × 7 reversible plough and cultivator) were equipped with a radar and wheel hub sensor. The fuel consumption was measured for each trial volumetrically. The results show, that the technical field performance increases with the working width of the plough: 0.5 ha/h for 2 × 3, 1.9 ha/h for 2 × 5 and 2.3 ha/h for 2 × 7. The fuel consumption for 2 × 3 and 2 × 5 mouldboard plough is on the same level (20.3 and 20.5 l/ha) and decreases to 14.9 l/ha for 2 × 7. The high fuel consumption of 20.5 l/ha with 2 × 5 is explained by the luxury engine power in the 2 × 5 mouldboard plough-tractor combination. The increase of the working depth from 15 cm to 25 cm for the cultivator rises the fuel consumption by 70% and the slip by 265%, whereas the specific fuel consumption is on the same level. The Traction Control system in ploughs reduces fuel consumption between 10.0 and 11.5%. With increasing working width of the plough the potential of subsoil compaction is increasing, because of risen load of the rear furrow wheel. On-land ploughing is one technical solution to prevent subsoil compaction.

1. Introduction

Soil tillage, especially ploughing is one of the most energy consuming process in plant cropping. The intensity of soil tillage depends on the number of soil tillage operations, kind of device (active driven by PTO or passive by drawbar power), implement geometry and depth of operation (Loibl, 2006; Godwin, 2007). Fuel consumption of soil tillage is correlated with intensity of soil tillage. In the energy flow from engine to implement, there are efficiency losses in the engine, transmission and wheel–soil interface (Schreiber et al., 2004; Jahns and Steinkampf, 1982). Moreover slippage, which is an expression of the traction efficiency, effects the field performance and the fuel consumption. Additional the soil is stressed by shearing and kneading. Conventional ploughing is done with driving of two wheels on the furrow ground with potential contribution to subsoil compaction. Consequently, the formation of a plough pan with a platy structure affects the physical, chemical and biological processes of the deeper soil profile (Horn et al., 2003; Peth et al., 2006). Investigations by Peth et al. (2006) show, that the plough pan are more rigid under conventional management than in "relictic" plough layer under conservation management. Schäfer-Landefeld et al. (2004) found that using present-day heavy agricultural equipment does not necessarily lead to severe subsoil compaction in soils where a compacted plough pan already exists. There are many technical solutions to reduce the risk of subsoil compaction e.g. increasing the wheel/soil contact area with dual wheels, tandem wheels, rubber tracks adjusted tyre inflation

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pressure (Keller et al., 2002; Keller and Arvidsson, 2004; Arvidsson and Keller, 2004). On-land ploughing may reduce the risk for subsoil compaction compared to conventional ploughing within furrows (Keller et al., 2002).

The paper deals the influence of working width of reversible mouldboard plough (mounted and semi-mounted) and T-trailed cultivator (3 bars; row spacing: 27 cm; 18 tines; tine spacing; 27 cm, working width: 500 cm) on field capacity, fuel consumption, slip and specific energy consumption. The furrow wheel load in conventional ploughing is calculated for analysing the potential risk of subsoil compaction. Additional a traction increasing system in ploughing was analyzed regarding slip, fuel consumption and additional rear furrow wheel load.

Fig. 1. Full mounted 2 × 3 mouldboard plough with 59 kW 4-WD tractor.

2. Materials and methods

2.1. Experimental site

The field experiments took place at the experimental farm of the University of Natural Resources and Life Science (BOKU) in Gross Enzersdorf (Lower Austria; 48°15′ N/16°37′ E). The climate at the experiment site is characterized with an average temperature of 9.8 °C and rainfall of 546 mm respectively, which is typical for semiarid regions. The soil (silty loam of Chernozem) is well suited for arable cropping with a measured dry bulk density (0–25 cm) of 1.57 g/cm^3. The top soil (0–25 cm) has a humus content between 2.5 and 3.2%. At the time of investigation, the average gravimetric water content (0–25 cm) was 11.8%.

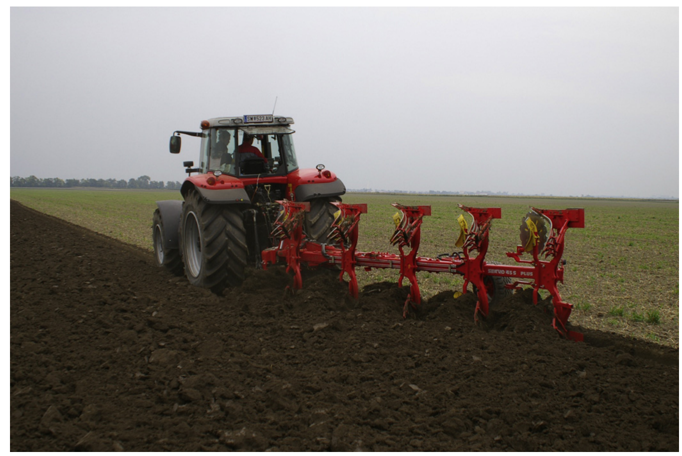

Fig. 2. Full mounted 2 × 5 slatted mouldboard plough with 160 kW 4-WD tractor.

2.2. Tractor-implement combinations

In Table 1 the analyzed tractor-implement combinations for the tillage operation are shown.

The mean working depth of the mouldboard plough (Pöttinger, Austria) was set by measuring the vertical distance between furrow ground and unploughed soil surface. For the semi mounted T-trailed cultivator (Pöttinger, Austria) the mean working depth was calculated by the difference between the vertical distance of the implement-frame to the soil surface in the tillage process and the vertical distance of the implement-frame to a concrete surface (Figs. 1–3).

The 2 × 5 mouldboard mounted plough and the 2 × 7 mouldboard semi-mounted plough were equipped with the Traction Control (TC) system. The additional hydraulic cylinder (Fig. 4) results in case of applying oil pressure (between 0 and 180 bar) in an increase of axle load of the rear wheel, because of the dynamic load transfer from plough and front axle of the tractor. In contrast to 2 × 7 semi-mounted plough, the 2 × 5 mouldboard plough is connected to the tractor with the three point linkage. For analyzing the effect of the Traction Control system, the investigation were done without usage of the Electronic Linkage Control (ELC) (Fig. 5).

The effect of the Traction Control system is to reduce wheel slip and fuel consumption (Moitzi et al., 2012).

The axle/wheel load was measured with two wheel load scales (platform 900 mm × 500 mm, weighing range 0–10,000 kg, resolution 5 kg) from AGRIS®. The shift in the axle loads are shown in Table 2.

Fig. 3. Semi-mounted 2 × 7 mouldboard plough with 160 kW 4-WD tractor.

2.3. Used tractors and measurement equipment

A four wheel driven tractor (Steyr 8090, CNH, St. Valentin, Austria) with an engine power of 59 kW (4 cylinder) was used for ploughing with the 2 × 3 mouldboard plough. The wheel

Table 1
Tractor-implement combinations.

Tractor	Implement	Working width (cm)	Working depth (cm)
59 kW 4-WD tractor	2 × 3 Mouldboard plough – three-point hitch	99 (3 cm × 33 cm)	25
160 kW 4-WD tractor	2 × 5 Mouldboard[a] plough[b] – three-point hitch	250 (5 cm × 50 cm)	25
160 kW 4-WD tractor	2 × 7 Mouldboard plough[b] – semi mounted	350 (7 cm × 50 cm)	25
160 kW 4-WD tractor	T-trailed cultivator – semi mounted	500	25
160 kW 4-WD tractor	T-trailed cultivator – semi mounted	500	15

[a] With slatted body.
[b] Equipped with Traction Control (TC) system.