E C O M I T

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POTENTIAL OF LOW GROUND PRESSURE FOR HARVESTING MACHINERY IN A CONTROLLED TRAFFIC FARMING SYSTEM IN ORGANIC AGRICULTURE.

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Abstract
Seasonal controlled traffic farming (SCTF), i.e. CTF without using the permanent traffic lanes for harvesting and primary soil tillage, leads to improved soil structure, higher crop yields, significant reduction of the emission of nitrous oxide and increased uptake of methane. Improved timeliness of operations, easier mechanical weed control and favourable returns on investments are considered practical advantages of SCTF. Further improvements, including reduced tillage, seem possible by avoiding overcompaction of the soil in the cropping beds during harvesting. The objective of the research was to find out what ground pressures can be applied without compromising soil structure and subsequent growth of a green manure crop, i.e. without tilling the topsoil after compression. No driving over the beds (ground pressure = 0) and simulation of harvesting with equipment requiring tyre inflation pressures of respectively 40, 60 and 80 kPa were investigated. Under dry or moist (field capacity) soil conditions support of harvesting machinery on the planting bed with tyres inflated to 0.4 bar did not lead to severe compaction and subsequent yield reductions.

Introduction
Innovative management of arable soils is necessary to improve the general sustainability of farming. One option for improved soil management is the adoption of controlled traffic farming (CTF), a system with permanent traffic lanes and wide, untrafficked cropping beds. Seasonal controlled traffic farming (SCTF), i.e. CTF without using the permanent lanes for harvesting and primary soil tillage, has been adopted by several organic farmers in the Netherlands. Vermeulen & Mosquera (2008) have shown that, compared to conventional organic farming, SCTF leads to improved soil structure, higher crop yields, significant reduction of the emission of nitrous oxide and increased uptake of methane. Improved timeliness of operations, easier mechanical weed control and favourable returns on investments are considered practical advantages of SCTF.
Further improvement seems possible by avoiding overcompaction of the soil during harvesting. Potential improvements include further improvement of soil structure, reduced soil tillage, savings on energy and cost, better possibilities for soil coverage by crops in winter to preserve N and avoid water logging and soil slaking. However, CTF harvesting equipment for most crops grown in organic farming is not available and the development poses technical and economic challenges. The technical challenge is to support the high vehicle loads of current, high-capacity harvesters on narrow running gear, suited for the traffic lanes. Even when the soil is wet, machinery should not slide off the lanes. The economical challenge is to realize a sufficiently large area under CTF to ensure a high yearly usage of the specialized machinery and, therefore, reach acceptable cost per ha.
One option to possibly overcome the harvesting problem in SCTF is to support part

of the machinery load on the cropping beds. In that case the ground pressure on the cropping bed should be low enough to avoid compaction of the soil under all circumstances. Experiments with low ground pressures during harvest in SCTF, ranging from 0 to 60 kPa on dry soil in 2005 and 2006 (Vermeulen & van der Wel, 2006; 2007) showed no significant negative effects on soil structure. The treatments had also no effect on the growth and dry matter yield of a green manure crop grown on the compressed soil without soil tillage other than making a seedbed. An inventory of equipment available for low ground pressures (Vermeulen & Verwijs, 2007) showed that presently developed rubber track systems allow the practical application of very low ground pressures combined with relatively high machinery loads. The objective of the experiment described in this paper was to investigate the effects of applying low ground pressures during moist harvesting conditions on the cropping beds in a SCTF system on soil structure and subsequent growth of a green manure crop without tilling the topsoil.

Materials and Methods

The experiment was conducted on a SCTF farm in a crop of Basil (*Ocimum basilicum*), harvested without compressing the soil. The soil was a loam soil with a clay content of about 22%. The treatments were: no driving over the beds (ground pressure = 0) and harvesting with equipment requiring relatively low, but attainable tyre inflation pressures of respectively 40, 60 and 80 kPa. For this purpose, a tractor (Fendt Farmer 310LSA) was loaded to the maximum allowable load (rear axle) at the specified tyre inflation pressures (Table 1). The plots were covered with wheel ruts by driving to and fro over the plots with the tractor (Figure 1). In this way the complete surface of the plots was compressed twice, simulating the passage of two large volume tyres under a harvester. The soil was irrigated 2 days before the ground pressure treatments to create moist (top)soil, simulating average harvesting conditions. The plots were 3.15 m wide and 5 m long. The number of replications was 4. The ground pressure treatments were given on 24 August 2007.

Table 1. Allowable wheel loads and actually applied loads on the tyres of the tractor used in the experiment for inflation pressures of 40, 60 and 80 kPa.

Tyre	Type of load	Tyre inflation pressure (kPa)		
		40	60	80
Rear: Michelin XM27	Allowable at 30 km/u (kg)	2740	3790	4200
800/65R32	Actually applied (kg)	2801	3790	4187
Front: Goodyear	Allowable at 30 km/u (kg)	1400 [1])	1765	1980
540/65R28	Actually applied (kg)	914	1206	1038

[1]) Use of the tyres at 40 kPa inflation pressure not recommended by manufacturer.

Thirteen days after the simulated harvest with 0, 40, 60 and 80 kPa tyre inflation pressure, respectively, the field was sown with white mustard (*Sinapsis alba*) without ploughing the field. Tillage was restricted to one passage with a CTF seedbed combination, cutting off the roots of the Basil stubble with sweep cultivators in the front hitch, making a 5-cm-deep seed bed with a rotary harrow and sowing white mustard at a rate of 25 kg ha^{-1} (Figure 2). Therefore, the roots of the white mustard had to grow in the root bed left after the various ground pressure treatments.

Figure 1. Application of ground pressure treatments.

Figure 2. Seedbed preparation and sowing of white mustard using CTF.

The soil moisture status during compression of the soil was characterized by the average soil moisture content in the 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm depth layers and the gravimetric moisture content at -10 kPa soil water matric pressure for this soil. The soil moisture samples were taken on the zero ground pressure plots just after conducting the compression treatments. On each plot 4 cores, 30 cm long, were taken per plot, using a gouge auger, 30 mm in diameter. The soil moisture samples for the various depth layers were obtained by cutting the corresponding section from the core. For each depth layer, all samples were combined into one sample for analysis. Soil structure before and after the ground pressure treatments was characterized by total porosity and air-filled porosity at -10 kPa soil water matric pressure according to Kuipers (1961). Each plot was sampled in the 10-15 cm depth layer before and after the ground pressure treatments. Ten cores of 100 cm^3 were taken per plot in a line across the controlled traffic bed.
Crop growth after ground pressure treatments was characterized by the number of established plants per 3 m row and by the dry matter yield, 54 days after sowing. Per plot, the numbers of plants were counted 3 times on 3 m row length. The dry matter yield was determined by hand harvesting an area of 1.5 m^2 per plot.

Results and Discussion

During the compression treatments the moisture content was 25.2, 22.4, 23.0, 23.6, 23.9 and 23.6 respectively for the soil layers 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm, being near field capacity (-10 kPa, 23.3 % w/w; d.b.) decreased with increasing ground pressure (Table 2). Before compression treatment, no significant differences in total porosity and air-filled porosity were present, as expected.

Table 2. Total porosity (ϕ) and air-filled porosity (ϕ_{a1}) at field capacity (in % v/v) before and after the compression treatments.

Treatment	Before treatment		After treatment	
	ϕ	ϕ_{a1}	ϕ	ϕ_{a1}
0 kPa	44.3	10.1	42.5	8.2
40 kPa	44.1	10.0	41.7	7.2
60 kPa	44.6	10.7	41.5	6.9
80 kPa	43.6	8.9	40.2	5.1
lsd ($p<0.05$)	1.3	1.9	1.0	1.4

After treatment, total porosity and air-filled porosity decreased significantly with increasing inflation pressure. Compared with the porosities before treatment, the porosities after the zero pressure treatment were lower than those before treatment. This cannot be correct as these plots were not compressed at all. It is suggested that the difference was caused by measurement errors due the difference in moisture content at sampling (before treatment 16.2 % w/w, dry base and after treatment 21.7 % w/w, dry base). Nevertheless, the figures indicate that the soil responded to all low ground pressure treatments.
Establishment of the white mustard was best for the 40 kPa treatment and this may have contributed to the relatively high yield for this treatment (Table 3). The dry matter yield after treatments was significantly higher for the zero and 40 kPa treatments, compared with the 60 kPa and 80 kPa treatments.

Table 3. Number of plants per 3 meter row and dry matter yield 54 day after sowing.

Tyre inflation pressure (kPa)	Number of plants per 3 m row length.	Dry matter yield (kg/ha)
0	87	962
40	104	1005
60	96	786
80	89	702
lsd ($p<0.05$)	11	134

Conclusions

Under dry or moist (field capacity) soil conditions in a controlled traffic farming system, support of harvesting machinery on the planting bed with tyres inflated to 0.4 bar or comparable low ground pressure running gear did not lead to yield reductions due to soil compaction.

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