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EFFECT OF WHEELING ON PHYSICAL CHARACTERISTICS OF SOILS AND ROOTING OF SOME CEREALS

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S y n o p s i s. Compaction of loamy sand and loamy textured soils induced by wheeling caused a marked increase of mechanical impedance at higher soil moisture tensions and decrease of root length density. Crop yields were highest on moderately compacted plots.

1. INTRODUCTION

The increased use of agricultural machinery is one of the main factor causing compaction of soil, which is marked by higher mechanical impedance, lower infiltration and insufficient aeration [1,4-8,11].

The changes of physical properties of soils may reduce root growth from one side and on the other side may increase the availability of water in the root zone due to soil permeability and higher unsaturated hydraulic conductivity. These effects depend on soil texture and soil moisture content during wheeling.

The objective of the present study was to characterize the effect of wheeling on some physical properties of loamy sand and loamy textured soils and rooting of some cereals.

2. METHODS

In 1983-1985 field experiments were carried out on two soils (loamy sand and loam) of a granulometric composition and some properties as specified in Table 1. The soils were situated not far-away from one another and thus were within the same atmospheric conditions. In 1985 the test crops on loamy sand and loam were spring oat and spring barley respectively and in two consecutive years winter rye on both soils.

T a b l e 1. Texture and some properties of the soils investigated

T a b l e a u 1. Texture et les propriétés choisies des sols etudiés

Soils	Percentual content of granulometric fractions (mm)				Organic matter %	Specific surface area m^2g^{-1}	Moisture (% by weight) at suction pressure hPa	
	1-0.1	0.1-0.02	<0.02	< 0.002			155	15 500
Loamy sand	66	22	12	7	1.21	34.6	16.2	4.3
Loam	29	19	52	18	2.20	112.8	19.8	7.6

Wheel traffic was imposed with a 2700 kg tractor (0, 1, 2 and 4 passes). Various number of passes were made over the entire plot area at soil water content corresponding in 1983, 1984 and 1985 to 60; 59 and 75% of field water capacity for loamy sand and to 78; 80 and 98% for loamy soil.

The following soil measurements were performed: bulk density, penetration resistance and hydraulic conductivity. The bulk density was determined in soil cores of volume 200 cm^3 in 6 replicates in two layers: 5-20 cm and 20-40 cm deep. The penetration resistance was measured in the laboratory (penetrometer with a 30^o cone, 3.8 mm in diameter), at various moisture tensions. Saturated and unsaturated hydraulic conductivity k (to soil moisture tension of 60 hPa) was determined in the plough layer using infiltrometer of diameter 28 cm and gypsum-sand crusts [2]. The unsaturated hydraulic conductivity in a higher range of tension was calculated according to Green and Corey's method as modified by Luxmoore [9] Root length was determined by the line-intersect method [10]. Root length density defined as total root length per unit volume of soil sample was obtained by dividing the total root length per sample by the sample volume.

3. RESULTS AND DISCUSSION

3.1. Soil physical properties

a. Bulk density and penetration resistance

The bulk density increased significantly with the increase of tractor passes and the highest increase was after 1 tractor pass (Tables 2, 3). The increase of bulk density in both soils was highest in 1985 when wheeling was performed at higher soil mositure content. The changes were relatively greater in loamy sand than in loam textured soil.

T a b l e 2. Bulk density of loamy sand soil with respect to wheel traffic

T a b l e a u 2. Densité du sol du sable léger sous l'effet des passages des roues

Years	Depth cm	Tractor passes				LSD 0.05
		0	1	2	4	
			kg·dcm^{-3}			
1983	5-20	1,47	1,58	1,62	1,67	0,026
	20-40	1,55	1,63	1,68	1,71	
1984	5-20	1,50	1,59	1,64	1,67	0,030
	20-40	1,57	1,65	1,68	1,71	
1985	5-20	1,53	1,66	1,70	1,76	0,029
	20-40	1,55	1,68	1,72	1,76	

T a b l e 3. Bulk density of loamy soil with respect to wheel traffic

T a b l e a u 3. Densité du sol limoneux sous l'effet des passages des roues

Years	Depth cm	Tractor passes				LSD 0.05
		0	1	2	4	
			kg·dcm^{-3}			
1983	5-20	1,40	1,48	1,54	1,56	0,026
	20-40	1,42	1,50	1,56	1,59	
1984	5-20	1,42	1,52	1,56	1,59	0,027
	20-40	1,44	1,53	1,57	1,62	
1985	5-20	1,41	1,55	1,60	1,64	0,028
	20-40	1,45	1,57	1,62	1,66	

The increase of bulk density in trafficked plots was reflected in higher soil penetration resistance (Fig. 1, 2). In both soils this relationship was stronger at higher soil moisture tensions.

Lower values of bulk density and higher penetration resistance in loamy soil than in loamy sand soil at similar moisture tensions were primarily associated with the difference in texture and cohesion of the soils. The high cohesion of this loamy soil affected also the crushing strength of its aggregates [7].

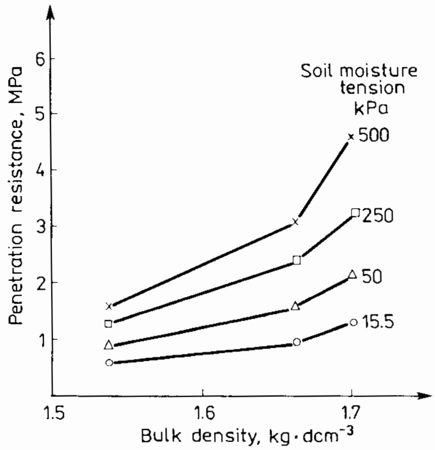

Fig. 1. Relationship between bulk density and penetration resistance of loamy sand soil as a function of different soil moisture tensions

Fig. 1. Relation entre densité apparente et résistance à la pénétration du sable léger en fonction de tension d'humidité du sol differente

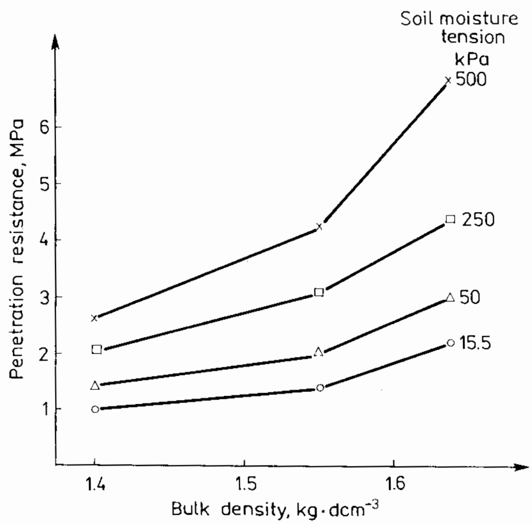

Fig. 2. Relationship between bulk density and penetration resistance of loamy soil as a function of different soil moisture tensions

Fig. 2. Relation entre densité apparente et résistance à la pénétration du sol limoneux en fonction de tension d'humidité du sol differente

b. Hydraulic conductivity

Saturated hydraulic conductivity sharply decreased with increasing bulk density in both soils (Table 4). However, the response of unsaturated hydraulic conductivity was different at various soil moisture tensions. In loamy sand textured soil the hydraulic conductivity at soil moisture tensions of 50 and 100 kPa decreased in all compacted treatments but at higher soil moisture tensions (500 and 1000 kPa) it increased with increasing bulk density. This increase arising mostly from higher contribution of pores of smaller diamater may be favourable in water supply of roots [1, 2].

T a b l e 4. Hydraulic conductivity of soils at various bulk densities and soil moisture tensions

T a b l e a u 4. Conductivité hydraulique des sols a densités et tensions d'humidité du sol variées

Soils	Bulk density $kg \cdot dcm^{-3}$	Soil moisture tension - kPa				
		0	50	100	500	1000
		$cm \cdot day^{-1}$				
Loamy sand	1.50	$365.0 \cdot 10^{0}$	$4.16 \cdot 10^{-3}$	$8.94 \cdot 10^{-4}$	$8.12 \cdot 10^{-6}$	$1.15 \cdot 10^{-6}$
	1.59	$81.4 \cdot 10^{0}$	$3.21 \cdot 10^{-3}$	$6.74 \cdot 10^{-4}$	$9.07 \cdot 10^{-6}$	$1.30 \cdot 10^{-6}$
	1.64	$30.6 \cdot 10^{0}$	$3.54 \cdot 10^{-3}$	$6.82 \cdot 10^{-4}$	$1.08 \cdot 10^{-5}$	$2.07 \cdot 10^{-6}$
	1.67	$10.4 \cdot 10^{0}$	$3.75 \cdot 10^{-3}$	$6.94 \cdot 10^{-4}$	$2.08 \cdot 10^{-5}$	$4.01 \cdot 10^{-6}$
Loam	1.42	$91.1 \cdot 10^{0}$	$9.90 \cdot 10^{-3}$	$1.05 \cdot 10^{-3}$	$1.10 \cdot 10^{-4}$	$2.15 \cdot 10^{-5}$
	1.52	$42.4 \cdot 10^{0}$	$2.85 \cdot 10^{-3}$	$1.80 \cdot 10^{-3}$	$1.20 \cdot 10^{-4}$	$2.00 \cdot 10^{-5}$
	1.57	$8.1 \cdot 10^{0}$	$1.60 \cdot 10^{-3}$	$1.50 \cdot 10^{-3}$	$1.90 \cdot 10^{-4}$	$2.05 \cdot 10^{-5}$
	1.61	$1.1 \cdot 10^{0}$	$5.70 \cdot 10^{-3}$	$5.30 \cdot 10^{-3}$	$2.80 \cdot 10^{-4}$	$4.80 \cdot 10^{-5}$

In loamy soil the increase of bulk density was accompanied by lower hydraulic conductivity at low soil moisture tension (50 kPa) and by higher conductivity at greater soil moisture tensions (100, 500 and 1000 kPa). The differences in k values at high soil moisture tensions between control and moderately compacted soil (to bulk density 1.52 and 1.57 $kg \cdot dcm^{-3}$) were relatively small, however further increase of bulk density resulted in sharp increase of the k values (Table 4).

3.2. Roots

In the layer 0-10 cm the root length density in most cases decreased as intensity of wheeling increased (Tables 5, 6). Only once the root length in this layer increased in each soil after 4 tractor passes. Visual observation showed that it can be attributed to the more horizontal root growth in compacted plots.

T a b l e 5. Root length density in respect to wheel traffic on loamy sand soil

T a b l e a u 5. Longueur de racines par unité de volume du sol sous l'effet des passages des roues dans le sable léger

Years	Crop	Depth cm	Tractor passes				LSD 0.05
			0	1	2	4	
			$cm \cdot cm^{-3}$ of soil				
1983	spring oat	0-10	2.94	2.47	2.36	1.96	0.251
		10-20	0.95	0.55	0.54	0.32	
		20-30	0.73	0.40	0.36	0.26	
		30-40	0,43	0.34	0.22	0.09	
1984	winter rye	0-10	3.21	2.91	2.72	1.81	0.259
		10-20	2.42	2,23	1.80	1.60	
		20-30	1.21	1.14	0.75	0.54	
		20-40	0.90	0.70	0,44	0.25	
1985	winter rye	0-10	4.19	2.60	1.80	1,03	0.170
		10-20	2.20	1.82	1.19	0.40	
		20-30	1.15	0.95	0.50	0.25	
		30-40	0.69	0,45	0.30	0.15	

T a b l e 6. Root length density in respect to wheel traffic on loamy soil

T a b l e a u 6. Longueur de racines par unité de volume du sol sous l'effet des passages des roues dans le sol limoneux

Years	Crop	Depth cm	Tractor passes				LSD 0.05
			0	1	2	4	
			$cm \cdot cm^{-3}$ of soil				
1983	spring barley	0-10	2.72	2.80	2.74	1.82	0.162
		10-20	1.16	0.96	0.53	0.41	
		20-30	0.45	0.43	0.37	0.10	
		30-40	0.32	0.25	0.21	0.05	
1984	winter rye	0-20	2,58	1.80	1.64	1.53	0.152
		10-20	1,79	1.25	1.09	0.80	
		20-30	1,08	1,03	0.47	0.28	
		30-40	0.40	0.35	0.28	0.18	
1985	winter rye	0-10	2.21	2.11	2.36	3.84	0.196
		10-20	1.69	1.04	0.94	0.41	
		20-30	0.74	0.80	0.35	0.14	
		30-40	0.29	0.20	0.10	0.05	

In deeper layer, within the depth of 10-40 cm the quantity of roots decreased with increasing number of tractor passes. This pattern's intensity varied from year to year. For example in 1984 the root length density of rye in the layer 30-40 cm of loamy soil was about 100% higher on unwheeled plots compared to four-fold trafficked plots, while in 1985 the difference was about 600%. This decreases can be largely attributed to significant increase of soil penetration resistance in the compacted soil.

3.3. Crop yields

Generally the highest crop yields were obtained from the plots with one tractor pass and lowest on the most trafficked plots (Tables 7, 8). The highest drop of yield in compacted plots was obrained in 1985 season whealing was performed at higher soil moisture content as compared to remaining seasons. This corresponds to higher mechanical impedance as measured by bulk density and penetration resistance and smaller rootability in most compacted plots obtained in the above-mentioned year.

T a b l e 7. Grain yield ($t \cdot ha^{-1}$) in respect to wheal traffic on loamy sand soil

T a b l e a u 7. Rendements de grains sous l'effet des passages des roues sur le sol du sable léger

Years	Crop	Tractor passes				LSD 0.05
		0	1	2	4	
1983	spring oat	2.99	3.22	3.18	2.45	0.354
1984	winter rye	`3.75	3.87	3.80	3.58	NS
1985	winter rye	3.65	4.05	3.42	3.10	0.308

T a b l e 8. Grain yield ($t \cdot ha^{-1}$) in respect to wheel traffic on loamy soil

T a b l e a u 8. Rendements de grains sous l'effet des passages des roues sur le sol limoneux

Years	Crop	Tractor passes				LSD 0.05
		0	1	2	4	
1983	spring barley	3.23	3.34	3.30	3.02	NS
1984	winter rye	4.01	4.12	3.86	3.72	NS
1985	winter rye	4.15	3.95	3.64	3.16	2.51

4. CONCLUSIONS

Increase of bulk density in loamy sand and loam due to wheeling (0, 1, 2 and 4 tractor passes) was relatively higher when wheeling was applied at higher soil moisture content. Increase of bulk density was reflected in higher penetration resistance especially at high soil moisture tensions and significantly lower saturated hydraulic conductivity. Unsaturated hydraulic conductivity at soil moisture tensions 500 and 1000 kPa was higher in the compacted than in the uncompacted soil.

Root length density generally decreased as bulk density increased. Less penetration of roots in compacted soils is mostly attributed to excessive mechanical impedance. The highest crop yields were obtained on once trafficked plots and the lowest from trafficked plots. The results obtained indicate the importance of soil water content during field operation and its effect on soil compactibility and consequently on root growth and crop yields.

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INFLUENCE DU TASSEMENT DES SOLS PAR LES PASSAGES DES ROUES SUR LEURS PROPRIÉTÉS PHYSIQUES ET L'ENRACINEMENT DES CÉRÉALES CHOISIES

R é s u m é

On a étudié l'influence du tassement de deux sols (sable léger, limon) à differentes valeurs d'humidité, entraîné par les passages d'un tracteur (0, 1, 2, 4) sur leur propriétés physiques choisies et sur le developpement du système racinaire des plantes.

L'augmentation de la densité des sols après les passages d'un tracteur a été plus grande quand l'humidité des sols était plus élevée. Les changements de densité ont été relativement plus grands dans le sol dont la granulometrie était elle du sable limoneux. Les changements de densité ont eu pour effet le coefficient de filtration considérablement plus petit et une plus grande resistance à la pénétration, surtout dans le cas où la tension d'humidité des sols était grande. Le coefficient de conductivité hydraulique, à la tension 500 et 1000 kPa a été plus grand dans le sol tassé que dans le sol non tasse.

La croissance des racines par unité de volume de sol diminuait avec la croissance de la densité des sols. La pénétration plus faible des racines dans le sol tassé est due surtout a l'augmentation de la densité des sols et à la résistance mecanique plus grande. Le plus rendement de grains de cereals a été obtenu sur des parcelles tassées par un passage d'un tracteur, et le plus bas - sur das parcelles les plus tassées.

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WPŁYW PRZEJAZDÓW CIĄGNIKA NA WŁAŚCIWOŚCI FIZYCZNE GLEB I UKORZENIENIE WYBRANYCH ZBÓŻ

S t r e s z c z e n i e

Badano wpływ zagęszczenia gleb wywołanego przejazdami cięgnika (0, 1, 2 i 4 razy) przy różnych wilgotnościach na ich właściwości fizyczne i rozwój systemu korzeniowego roślin. Badania przeprowadzono na glebie piaszczystej i gliniastej.

Wzrost gęstości gleb był większy po przejazdach wykonanych przy większej wilgotności gleb. Zmiany gęstości były większe w glebie piaszczystej. Znalazły one odbicie w większym oporze penetracji, zwłaszcza przy większych ciśnieniach ssących gleb oraz w znacznie mniejszym współczynniku filtracji. Współczynnik przewodnictwa wodnego przy ciśnieniach ssącach 500 i 1000 kPa był większy w glebie ugniatanej niż nie ugniatanej.

Długość korzeni na jednostkę objętości gleby zmniejszała się wraz ze wzrostem gęstości gleb. Słabsza penetracja korzeni w glebie ugniatanej jest głównie wynikiem wzrostu gęstości gleb i nadmiernego oporu mechanicznego. Najwyższy plon ziarna zbóż uzyskano z poletek po jednym przejeździe ciągnika zaś najniższy z poletek najbardziej ugniatanych.