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THE EFFECT OF SUGAR BEET CULTIVATION SYSTEM ON SOIL COMPACTION

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A b s t r a c t. The state of compaction of a soil largely establishes the air, water, and temperature relationships and largely influences the plant growth. In order to investigate the effect of different cultivation systems on soil compaction a penetration test with cone penetrometer and the measurement of the dry bulk density of the soil with aeropycnometer in a sandy loam soil were conducted by standard tillage and mulching systems. The results have showed that in comparison with standard tillage system the dry bulk density of the soil by mulching system is higher down to 10 cm depth, but there are no significant differences in penetration resistance in the 10 to 20 cm depth between the two systems. The traffic causes soil compaction in wheel tracks in the soil surface down to 10 cm depth, but in the 10 cm to 20 cm soil depth the traffic has no significant influence on the soil compaction for the two cultivation systems in comparison with the soil density in rows of sugar beet under usual cultivation condition in the Rheinland area.

K e y w o r d s: sugar beet, soil compaction

INTRODUCTION

The soil compaction can be measured as cone penetration resistance and as bulk density. The soil bulk density that is recognized as dry mass by unit volume of soil in g/cm^3 represents one of the important physical properties of the soil, which describes the porosity of the soil. The bulk density is affected by two sorts of factors: (a) natural factors, i.e., soil type, climate and weather; (b) crop cultivation, i.e., technique of tillage and crop use [2,5,6].

Because of the use of heavy agricultural machines by limited tire dimension a steady compaction is the result. The state of compaction of a soil affects the air, water, and temperature relationships and largely influences seed germination, seedling emergence, root growth, and in fact all phases of crop growth and production [1,3].

To avoid the undesired soil compaction and to keep the bulk density of a soil at optimal range for the crop growth different systems of crop cultivation were developed, i.e., 'no tillage system' and 'minimal tillage system' [6-8]. At the Agricultural Engineering Department of the University of Bonn different cultivation systems for sugar beet are steady tested, along with controlled traffic system like 'bed system' and 'mulch system' in comparison with 'standard cultivation system'.

In order to investigate the effect of different cultivation systems on soil compaction a field research including a penetration test with cone penetrometer was conducted to be compared with the soil bulk density [1]. The measurement was concerned to investigate the influence of cultivation system on the dry bulk density of the soil and the relationship among the penetration resistance, bulk density and moisture content of the soil.

VARIANTS OF EXPERIMENT

The experiment was carried out with two systems, namely standard system and mulch system on the sandy loam soil. The measurement was conducted within the row of sugar beet and the track, so that there are four variants by the experiment as follow:

1. standard system:
   a) row of sugar beet (stand. row)
   b) track of traffic (stand. track)
2. mulch system:
   a) row of sugar beet (mulch. row)
   b) track of traffic (mulch. track).

EQUIPMENT AND MEASUREMENT

A cone penetrometer (Fig. 1) was used to measure the penetration resistance of the soil. The penetrating element has a cone-shaped tip with 30° angle and 20 mm^2 basis (ASAE Standard: ASAE S 313.1, 1984). The cone was advanced into the soil at a steady rate 6.67 mm/s by an electronic motor to a depth of 20 cm. The inductive force transducer measures the penetration and the depth of penetration was recorded by a distance transducer. The outputs were written on a floppy disk through a computer. The measurement was 10 times repeated for each variant.

In comparison with the penetration resistance an aeropycnometer was used to measure the bulk density of the soil. The measurement was conducted on the same point as penetration test and the soil samples were taken out with a volume of 100 cm^3 at 4 steps of depth, each step has a depth of 5 cm until 20 cm soil depth was reached. After drying of samples the dry bulk density and the moisture content of the soil were determined.

The value of penetration forces was calculated into penetration resistance cone index in kPa which represents the degree of soil compaction. The results show the change of the bulk density versus the depth of the soil.

RESULTS

The dry bulk density and the moisture content of the soil at 4 steps of depth for 4 variants of the experiment is shown in Fig. 2. The cone index versus the depth of the soil by 4 variants and their comparisons are illustrated in Fig. 3 .

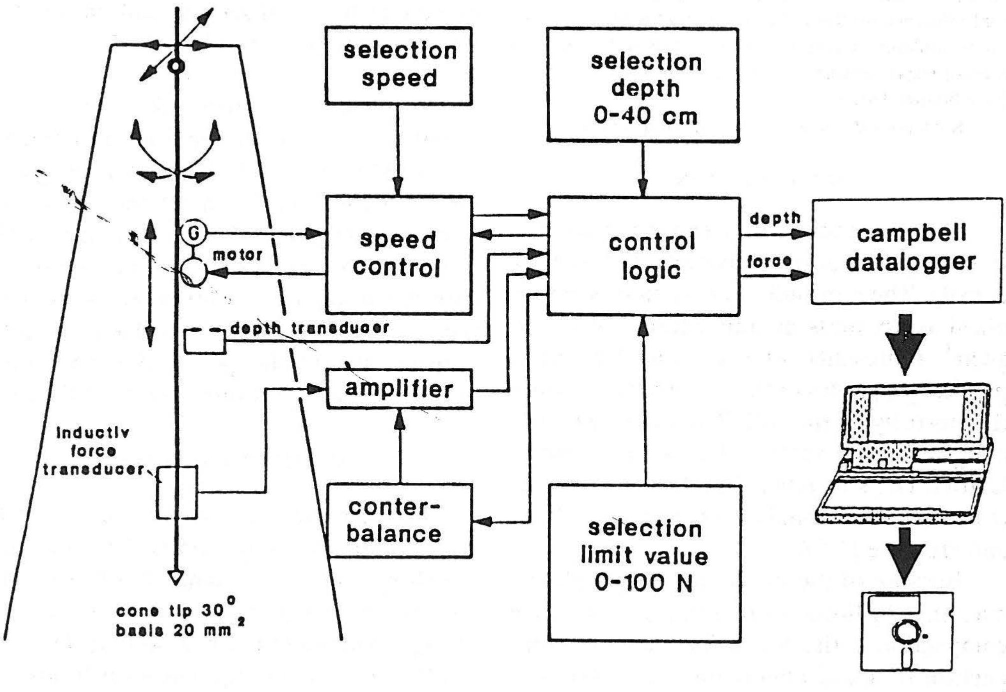

Fig. 1. Experimental setup of penetrometer for the measurement of soil resistance.

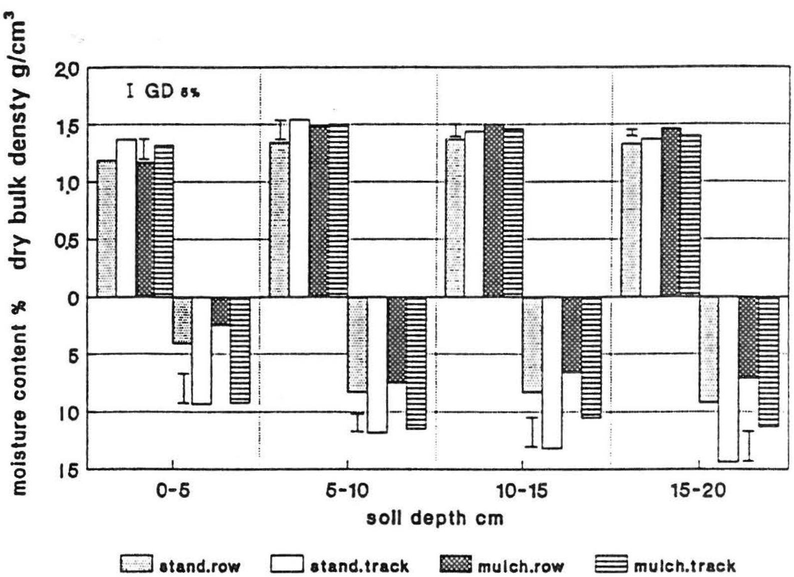

Fig. 2. Dry bulk density and moisture content of the soil for 4 variants in different soil depth.

STATISTICAL ANALYSIS OF RELATION AMONG PARAMETERS

The relationship among the penetration resistance, moisture content and dry bulk density of a soil cannot be expressed directly with a pure mathematical model, because the state of the soil was determined by soil type and soil properties, each soil type has themselves relation among the parameters. In most cases the penetration resistance was used to describe the compaction and furthermore to present the dry bulk density of the soil. From the results of the experiment here the relationship among the penetration resistance cone index *CI* in kPa, dry bulk density ρ in g/cm^3 and moisture content, *m.c.* in %, was analysed statistically with multiple regression [4].

Because the measurement of moisture content and bulk density of the soil was conducted step by step in 4 depths, the values were considered as average by middle depth each steps. Combining these values with penetration resistance at 4 soil depth the multiple regression was carried out for 4 variants together. For examination of the results the coefficient of multiple correlation r, square of regression R, standard error S, F-value of variant analysis of the equation F and significant level F_{sig} were calculated. The results are as follow:

$$CI = 8.255\, m.c. - 11.756\ \rho\ (m.c.)^2 + 89.999\, m.c.\, \rho^2 \qquad (1)$$

with: r=0.9061; R=0.8211; S=409.7979; F=240.1541; F_{sig}=0.0000.

$$\rho = 1.0739 + 0.0469\, m.c. + 1.7313 \cdot 10^{-4}\, CI - 2.2019 \cdot 10^{-3} (m.c.)^2 - 4.6413 \cdot 10^{-9}\, m.c.\, CI \qquad (2)$$

with: r=0.6347; R=0.4028; S=0.0978; F=26.1342; F_{sig}=0.0000.

DISCUSSION AND CONCLUSIONS

Because of unhomogeneous properties of the soil the penetration resistance by each variant of the experiment changes greatly. For the representation of soil compaction

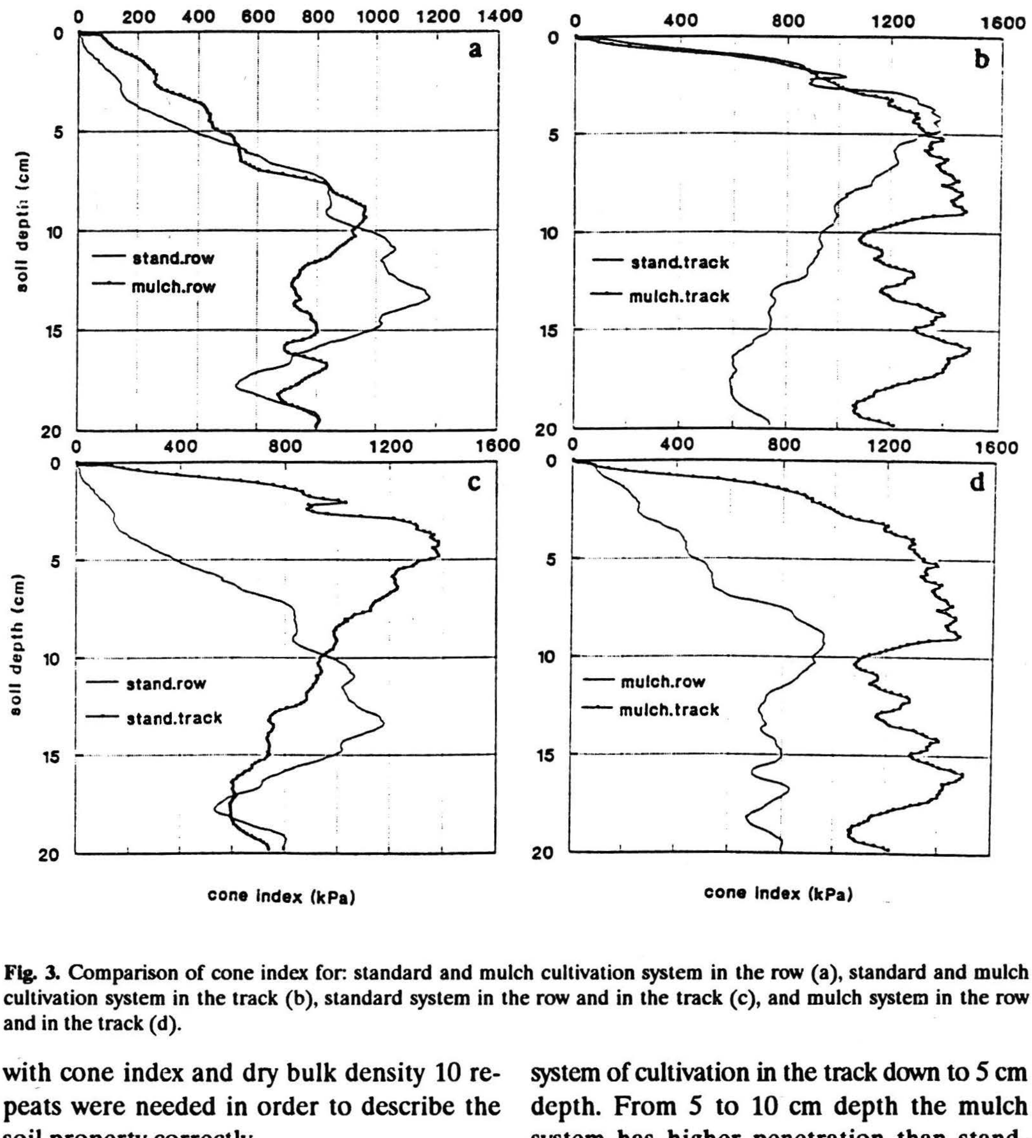

Fig. 3. Comparison of cone index for: standard and mulch cultivation system in the row (a), standard and mulch cultivation system in the track (b), standard system in the row and in the track (c), and mulch system in the row and in the track (d).

with cone index and dry bulk density 10 repeats were needed in order to describe the soil property correctly.

The cone index is highly significant correlated with moisture content, therefore the cone index only describes the compaction on the same moisture level.

In comparison with standard system the dry bulk density of the soil is higher by mulch system in the soil surface to 10 cm depth. There are no significant differences by penetration resistance in the 10 to 20 cm depth between two systems.

There are no significant differences in penetration resistance by standard and mulch system of cultivation in the track down to 5 cm depth. From 5 to 10 cm depth the mulch system has higher penetration than standard system.

The comparison of penetration resistance in the row and in the track has shown that the traffic by cultivation of soil and by the sowing of the seeds caused a great compaction of soil surface down to 10 cm soil depth. For the soil layer below 10 cm depth the passage of machine has not significant influence on the soil compaction.

The result of regression analysis with dry bulk density and moisture content of soil as independent, and penetration resistance cone index as dependent variant (Eq. (1)), has demonstrated that the relation among three parameters is good to describe with the equation developed, which has a higher significant level and fits perfectly with empiric value of the experiment.

The regression equation with penetration resistance cone index and moisture content as independent and dry bulk density as dependent variant (Eq. (2)) has shown that the equation is higher significant. With the use of this equation the dry bulk density can be estimated with the penetration resistance and moisture content of the soil, which are measured in common practice.

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