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FULL LENGTH ARTICLE

Effect of velocity, wheel load and multipass on soil compaction

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Abstract Vehicle imposed soil compaction is one of the serious concerns in agriculture and environmental problems that requires accurate studies. We were inspired to launch an investigation for soil compaction determination at three levels of wheel load (1, 2 and 3 kN), three levels of velocity (0.5, 0.75 and 1 m/s) and at 1, 2 and 3 passages of wheel with three replications on clay-loam soil. Experiments were conducted utilizing a single wheel-tester inside a soil bin. Penetration resistance and soil sinkage were determined as soil compaction indices. Data were examined by analysis of variance (ANOVA) at.%1 significance level. Results indicated that the highest penetration resistance of 260 kPa occurred at a depth of 210 mm, third pass, wheel load of 3 kN and velocity of 0.5 m/s. The lowest penetration resistance of 121 kPa was at 1 kN wheel load, first pass and at a velocity of 1 m/s. The greatest soil sinkage obtained was 62.91 mm for wheel load of 3 kN, at 0.5 m/s and at the third passage of wheel while the lowest soil sinkage was 18.04 mm for wheel load of 1 kN, at a velocity of 1 m/s and at first pass. Findings disclosed that augmentation of wheel load and multiple pass increased soil compaction while the increase of velocity had a reverse effect. Two models were proposed for penetration resistance and soil sinkage with coefficient of determination of 0.9375 and 0.9731, respectively.

1. Introduction

Heavier agricultural practices by more massive vehicles impose extra loads on the soil that result in soil stress–strain phenomena. Soil tension brings about a volumetric change of soil constituents towards further compacted soil. Soil compaction is an inhibitor of soil respiration through compressing and disconnecting soil porosity. Consequently, plant's budding confronts with serious predicament owing to shortages of mineral material and difficulty of air circulation. Global demand for food production obligates the scientists, researchers, and farmers to pay attention to surpass detrimental outcomes of imposed soil compaction. It is documented that soil compaction brings about excessive problems such as soil erosion, runoffs, wear of

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tillage implements, energy consumption, drainage difficulties, hardpan production and additional severe environmental disasters. Soil compaction is a worldwide problem, especially with the adaption of mechanized agriculture. It has caused crop yielding reductions between 40% and 90% in West African countries (Charreu, 1972; Kayombo and Lal, 1994) and approximately 25–50% in some districts of Europe and North America (Eriksson et al., 1974). As reported, in Ohio for example, reductions in crop yields are 20% in soybeans, 30% in oats, and 25% in maize (Lal, 1996). On-farm losses through land compaction in the USA have been estimated at US$1.2 billion per year (Gill, 1971). These statistics signify the requirement for unanimous endeavour to attain a correct insight into optimized farm management.

The effect of self-propelled wheels and a track of high axle loads (9–24 tons) were studied on soil compaction on the basis of soil displacement, soil density, soil dry bulk density and penetrometer resistance measurements (Ansorge and Godwin, 2007). Ansorge and Godwin (2008) in a later study investigated the effects of various wheel loads, tyre inflation pressures and number of passes on soil physical change in a controlled laboratory condition measuring penetration resistance and dry bulk density. Patel and Mani (2011) carried out a field investigation on sandy loam soil to quantify subsoil compaction at ranged wheel loads and multiple passes in terms of bulk density and penetration resistance. Raper and Reeves (2007) experimentally determined the differences in soil bulk density and cone index (CI) obtained from various interactions of surface tillage, subsoiling, and controlled traffic in a corn- soybean farm in the U.S. and reported that for trafficked row middle, non-trafficked row middle and in-row position, CI almost increased in both topsoil and soil levels (i.e. up to about 20 cm depth) and decreased in the subsoil level (20–55 cm). Smith and Dickson (1990) investigated the effects of vehicle weight and ground pressure on soil compaction through a series of field experiments. They reported that an increase in wheel load, at a given ground pressure, produces a significant increase in compaction only at a greater depth. Çarman (1994) conducted studies for soil compaction determination beneath the tyre track of a two-wheel drive tractor. The dynamic load on each rear tyre varied from 7.27 to 13.50 kN and the forward velocity from 0.78 to 2.5 m/s. Cone index was measured to determine soil compaction. The results indicated that increasing the tyre load at a given forward velocity increased the compaction. Wherein a majority of investigations focused on field experiments, Çarman (2002) investigated compaction characteristics of towed wheels on clay loam soil in a soil bin. It should be noted that a soil bin provides a completely reliable and accurate environment for soil-wheel interaction measurements. Tests were carried out at three tyre loads (3.5, 5.5 and 7.5 kN) and two forward velocities (0.8 and 1.4 m/s) on a clay loam soil. According to the reported experimental results, decreasing contact duration by increased forward velocity decreases soil compaction (Çarman, 2002).

Literature review indicates that further investigations are required involving additional prominent parameters to obtain a better insight into soil compaction and also, experimenting in soil bin facility owing to its controlled condition. The shortage of knowledge in the domain of wheel load, velocity and multipass and their interactions for creating soil compaction inspired the authors to initiate the current study. The hypotheses below are outlined:

1.- At a constant inflation pressure, wheel load does not affect the deformation (compaction) in the uppermost layers and that it affects compaction in the deeper layers.
2.- Increase in the number of passes increases compaction and increase in velocity reduces compaction.
3.- Clay loam texture of soil tends to easily compact (Çarman, 2002).

The objectives of the present study were to (a) evaluate the role of wheel load on soil compaction, (b) impact of various velocities on soil compaction and (c) effect of multipass on imposed soil compaction, by two soil compaction indices of penetration resistance and soil sinkage.

2. Materials and methods

A soil bin featuring 23 m length, 2 m width and 1 m depth was utilized in this study (Mardani et al., 2010). The soil bin consisted of a wheel carriage, a single-wheel tester and bin frame. A vertical Bongshin Model DBBP load cell with the capacity of 2000 kg, sensitivity of 0.1 kg and frequency of 50 Hz was calibrated and then was interfaced to the data acquisition system including Bongshin digital indicator BS7220 model connected to RS232 port of a data logger, enabled monitoring the data on a screen and transmitting to a computer, simultaneously. A three phase electromotor (MOTOGEN Corporation, 30hp) generated the power for movement of the carriage and single wheel-tester along the length of the soil bin. By means of a SV 220 IS5-2NO, 380V Model (LG Corporation) inverter providing various velocities, the carriage could traverse the length of the soil bin in both forward and reverse

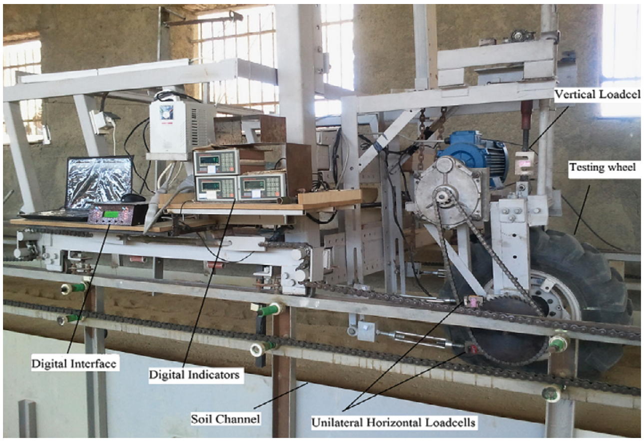

Figure 1 The general system set up of the single-wheel tester in a soil bin.

Table 1 Summary of experiment conducted.

Independent parameters			Dependent parameter
Wheel pass	Wheel load (kN)	Velocity (m/s)	
1	1	0.5	Penetration resistance
2	2	0.75	
3	3	1	Soil sinkage