African Journal of Biotechnology Vol. 10(73), pp. 16536-16540, 21 November, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.2237
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

A simulation test of the impact on soil moisture by agricultural machinery

Wenting Han[1, 2], Shuaibin Shi[3], Zhaolong Zhu[1,3]*, Xue Liu and Zhang Juanli[4]

[1]Institute of Efficient Water Use for Arid Agriculture of China, Northwest A&F University, Yangling, China.
[2]Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, China.
[3]College of Mechanical and Electronic Engineering, Northwest A&F University, Yangling, China.
[4]Xingyi Normal University for Nationalities, Xingyi, Guizhou 562400, China.

Accepted 30 September, 2011

To study the impact by agricultural machinery on changes in soil moisture, we used a simulated test method employing round iron plate based on the ground pressure ratio between the front and rear wheels of wheeled tractors and crawler tractors. We conducted soil compactions with five pressure loads (35, 98, 118, 196 and 345 kg), and measured soil moistures at different depths and under different compaction times, as well as compared those before the loads was applied. The results indicate that soil moisture was generally lost after compaction by agricultural machinery and its loss was related to pressure load, soil depth and compaction times. Generally, moisture loss increased with the increase of pressure load and mostly occurred at the soil surface (0 to 5 cm) for light loads (<110 kg), but at deeper soil for heavy loads (>110 kg). Moreover, the moisture loss decreased gradually with the increases in soil depth for light loads (37 and 98 kg), although it was first increased and then quickly decreased for heavy loads (>= 118 kg). The loss of soil moisture by 5 compactions was in similar pattern with 1 compaction, but was much larger with the gap by 0.5 to 1.5% between them.

Key words: Simulated test, soil moisture, pressure load, soil compaction.

INTRODUCTION

As agricultural machines become larger and heavier, there is a growing concern about soil compaction owing to their intensive use which is a serious issue for soil management throughout the world (Batey, 2009; Zhang and Sui, 2005). Wang et al. (2000) researched the effect of tractor wheel compaction on runoff and infiltration. Li et al. (2001) promoted a prediction model for soil compaction by small tractor using finite element method. Zhang and Sui (2005) also investigated the causes of soil compaction, the measurement and harmfulness of soil compaction, and the management strategies of alleviating soil compaction induced by tractors while Van den Akker and Hoogland (2011) established a risk assessment model for soil sensitivity to agricultural machinery compaction using soil density and mechanical strength as the major parameters.

Soil compaction is an important component of the land degradation syndrome, which could influence soil properties such as pore size distribution, soil moisture and density. Jung et al. (2010) studied the impact of agricultural machinery compaction on soil water content, density and other parameters of clay-pan soil under tillage corn, no-tillage corn and other cropping systems. More also, Saffih-Hdadi et al. (2009) studied agricultural machinery compaction models under different soil water contents and density conditions. Hamza et al. (2011) investigated the influence of combinations of external

*Corresponding author. E-mail: longmega@gmail.com. Tel: +86-29-87091325. Fax: +86-29-87091269.

Table 1. The configuration for setting pressure loads with weights.

Weight type (kg)	Quantity of weight required for setting pressure load				
	37 kg	98 kg	118 kg	196 kg	314 kg
30	0	3	2	6	8
25	1	0	2	0	2
4	2	1	1	3	5

load and soil water on soil compaction.

However, how soil compaction by agricultural machinery reduces soil moisture is complex and ambiguous. Hence, in this study, we investigated the influence of compaction on soil moisture by a simulated test method employing round iron plate based on the ground pressure ratio between the front and rear wheels of wheeled tractors and crawler tractors.

MATERIALS AND METHODS

Simulated pressure loads for the tractors

Two commonly used tractors were introduced in this study: Dong Fang Hong-75 crawler tractor with a weight of 5460 kg and Shanghai 50-wheeled tractor with a weight of 2020 kg. For the former, its local pressure ratio is about 38.3 kPa, and the average pressure ratio can be calculated as 101 kPa with its contact area on ground by 5304 cm^2 while for the latter, the contact area on ground of the front wheel and rear wheels were fingered out to 190.7 and 500 cm^2 separately by calculating the length and width of its tires in case of tires' variant for pressure (Chen 1981), and thus their respective ground pressure ratios are 201.9 kPa and 121.5 kPa.

To simulate the pressure impacted on soil by the tractors, a round iron plate with the diameter, height and weight by 11 cm * 5 cm * 4 kg and several weights with three different masses of 30, 25 and 4 kg were used. The contact area of round iron plate was 95 cm^2, and thus the loads needed were approximately 37, 98, 118 and 196 kg for simulating the local and average pressure ratio of Dong Fang Hong-75 crawler tractor and the ground pressure ratios of the rear and front wheels of Shanghai 50-wheeled tractor. In consideration of the possible loads on tractors, we took the combined soil compaction by both front and rear wheel of Shanghai 50-wheeled tractor and set 314 kg as the extreme load compacted on soil for our experiments. Considering the mass of round plate (4 kg), the configuration of weights for pressure loads was set up as shown in Table 1. The compaction simulation was conducted by adding the weights for a specific load on the round iron plate.

Test field and treatments

On the experimental farm of Northwest A&F University (108°4'15"E, 34°17'18"N), a flat fallow field with 2 m long and 1.5 m wide was chosen as the test field for this study. Before the experiment, the field soil characterized as sandy loam was loosened and watered artificially until the compaction was about 200 N cm^{-3} and the soil moisture at 0 to 5 cm depth was approximately 15%, and then naturally dried under the sun for two days. The experiment was conducted in May with temperatures ranging from 25 to 33°C.

The field characterized was divided into five zones for tests with five pressure loads accordingly. Before compaction, the soil moistures in each zone were measured first at a selected point with 0 to 5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30 and 30 to 35 cm depths. Then, the compaction simulation was conducted by adding weights for a pressure load on the round iron plate at a place close to the point, and last for 5 to 10 s before the weights and round iron plate were removed. After that, the soil moistures at same depths were measured. By comparing it to the soil moisture before compaction, the loss of soil moisture was calculated. In order to simulate the effect of multi-compactions by tractor, we also pressed soil five times consecutively by the pressure load of 314 kg and did experiments in the same way.

The compaction was measured by TE-3 compaction meter (Nanjing Soil Instrument Factory, NanJing, China), and the soil moisture was measured by conventional oven-dry method, in which the soil samples were baked in an electric oven HXGZ-9 at 105 to 110°C for 7 to 8 h and then quickly weighed by MP4000B electronic balance with an accuracy of 0.05 g. To lessen the effect by the uneven nature of the soil and the influence of both measurement error and random error, we measured them at three different points and then calculated the average.

RESULTS AND DISCUSSION

Soil moisture and its loss after compaction by pressure loads

Soil moistures that resulted by the pressure loads varied from 12 to 17% (Table 2), which was caused mainly by the uneven nature of the soil and the pre-treatment of loosing and watering soil. The loss of soil moisture is calculated in Table 3. The value of moisture loss was -0.017% for 15 to 20 cm depth, and -0.002% for 20 to 25 cm depth, which is for the measure error and the low impaction by load on soil moisture.

The loss of soil moisture impacted by compaction with pressure load

Generally, soil moisture lost after compaction, shown as the positive moisture loss at the 0 to 5, 5 to 10, 10 to 15 and 15 to 20 cm depth after compaction is depicted in Figure 1. The moisture losses at different depths increased first sharply and then gradually as the increases of pressure load. Some of them went flat and

Table 2. Soil moisture at different depths after compaction by pressure load.

Depth (cm)	Soil moisture after compaction by pressure load (%)				
	37 kg	98 kg	118 kg	196 kg	314 kg
0 - 5	12.490	11.768	13.880	12.142	12.083
5 - 10	13.305	12.710	14.195	12.431	12.088
10 - 15	14.042	13.543	14.963	13.887	13.339
15 - 20	15.100	14.707	15.921	15.431	15.220
20 - 25	16.030	15.981	16.881	16.353	16.332
30 - 35	16.886	16.891	17.113	16.784	16.771

Table 3. Moisture loss of soil at different depths after compaction by pressure load.

Depth (cm)	Moisture loss after compaction by pressure load (%)				
	37 kg	98 kg	118 kg	196 kg	314 kg
0 - 5	0.208	0.930	1.023	1.885	1.944
5 - 10	0.138	0.733	1.116	2.097	2.440
10 - 15	0.042	0.541	0.820	1.209	1.757
15 - 20	-0.017	0.376	0.295	0.576	0.787
20 - 25	-0.002	0.047	0.016	0.050	0.071
30 - 35	0.013	0.008	0.003	0.007	0.020

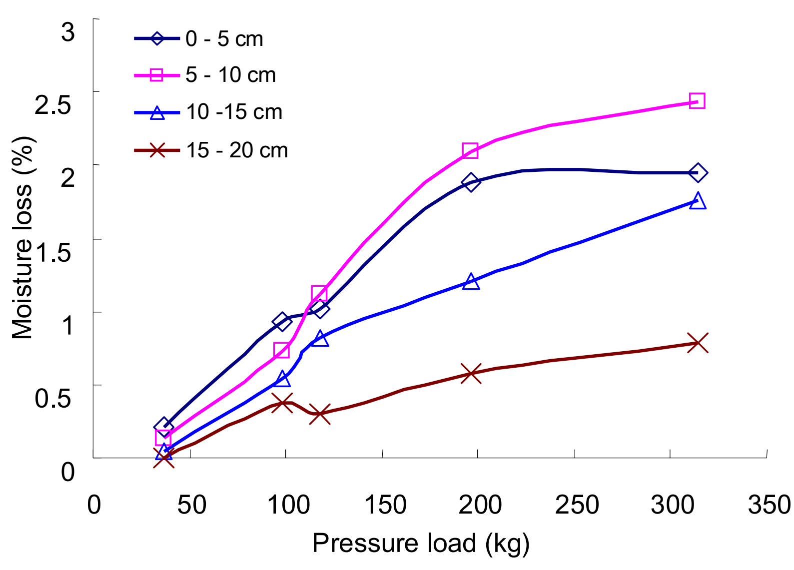

Figure 1. Changes in moisture loss of soil at the same depth with pressure loads.

reached a maximum value, for example, the curve of moisture loss at 0 to 5 cm depth had maximum value of 1.95% by the pressure load of 230 kg (Figure 1). The maximum value of moisture loss was also limited by moisture soil content, which affects soil bulk density well. The soil moisture at 0 to 5 cm depth after compaction was between 12 and 14% (Table 2).

Moreover, the loss of soil moisture at soil surface is commonly larger than the one in deeper soil by compaction, as the order of curves of moisture loss in Figure 1 when the load was <110 kg. However, the curve for 5 to 10 cm surpassed that of 0 to 5 cm when the pressure load was >110 kg. Therefore the maximum of moisture loss could happen in deep soil after compaction

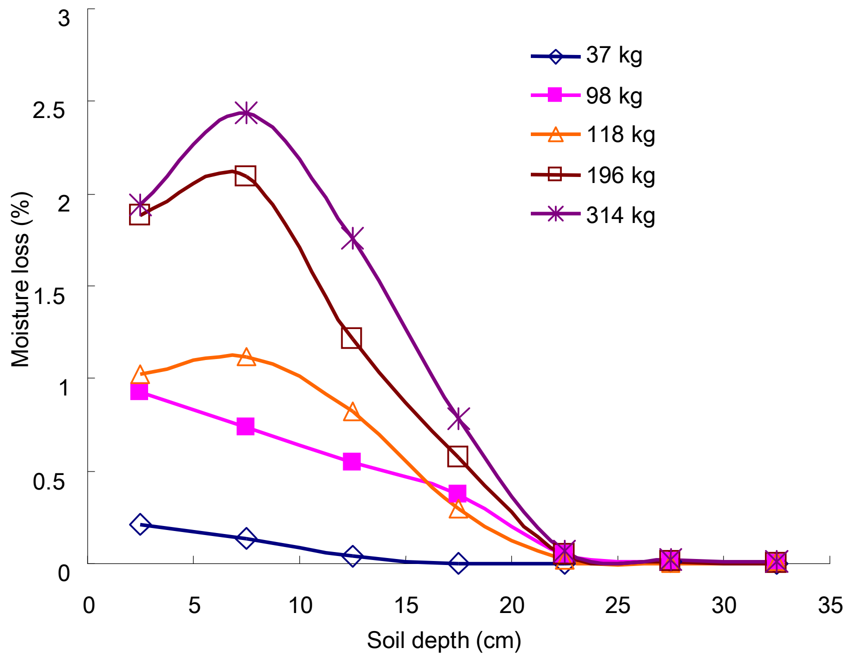

Figure 2. Changes in moisture loss of soil with depths by pressure loads.

by heavy loads, and it also indicates that more than pressure load affects moisture loss well. This phenomenon requires further investigation.

Changes in the loss of soil moisture with depths by compaction

Figure 2 shows the curves of moisture loss changed with soil depths by pressure loads. For light loads (37 and 98 kg), the moisture loss decreased gradually and went to zero with the increases in soil depth. For example, the curve of moisture loss for pressure load of 37 kg reached zero at the depth of 15 cm, while for heavy load (>= 118 kg), the moisture loss first increased with the increases in soil depth but then quickly decreased to zero. The curve inflection point occurred closely at the depth of 7.5 cm when the moisture loss was largest (1.12% for the load of 118 kg, 2.12% for 196 kg, and 2.45% for 314 kg). Moreover, when soil depth was larger than 25 cm, none of the pressure load could take away soil moisture by compaction, indicating that the loads had almost no effect on moisture loss at the depth.

Changes in the loss of soil moisture with times of compaction

The result of moisture loss by different compactions is shown in Figure 3. The pattern of moisture loss by 5 compactions was close to that by 1 compaction, in which the moisture loss first increased to a maximum value (2.45% for one compaction and 3.48% for 5 compactions at the depth close to 7.5 cm) and then quickly decreased with the increase of soil depth. However, the moisture loss by 5 compactions was much larger than 1 compaction, indicating that the compaction and moisture loss could be cumulative. Their gap was between 0.5 and 1.5% for all the observed depth. Moreover, the moisture losses by 5 compactions at all observed depth were higher than 0.68%, but the moisture loss by 1 compaction decreased to 0 at the depth over 25 cm.

Conclusion

The simulated test results demonstrate that in general, after soil compaction by agricultural machinery, soil moisture was partially lost from the soil. The moisture loss increased with the increases of the pressure load, and the highest moisture loss occurred at the soil surface (0 to 5 cm) for light loads (< 110 kg), but at the depth of 5 to 10 cm for heavy loads (>110 kg), thus indicating that the loss of soil moisture is not only related to pressure load. It was also observed that not in one way does the moisture loss change with soil depth. For light loads (37 and 98 kg), the moisture loss decreased gradually and approached zero with the increases in soil depth while for heavy loads (>= 118 kg), the moisture loss first increased with the increases in soil depth, but then quickly

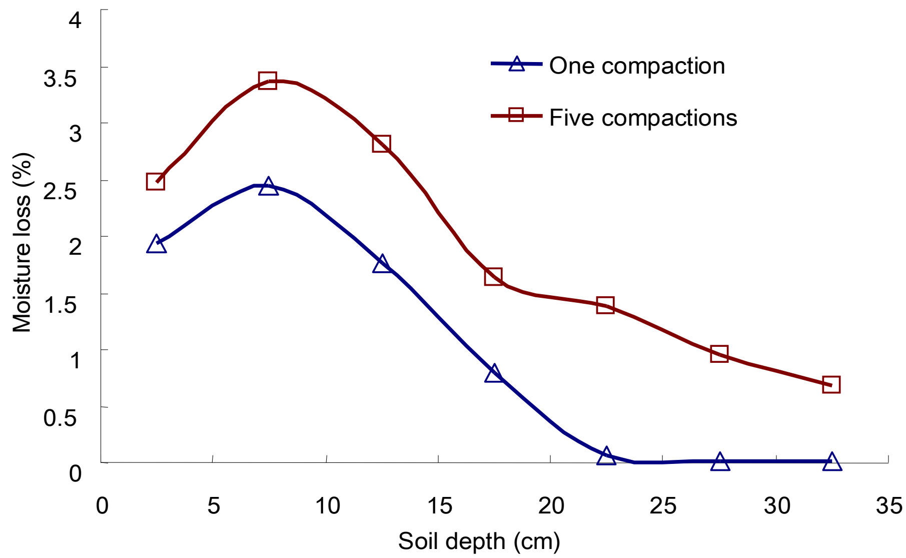

Figure 3. Changes in moisture loss of soil with compaction times by 314 kg load.

decreased to zero. Generally, more compaction resulted in more moisture loss. Also, the loss of soil moisture by 5compactions was in similar pattern with 1 compaction, although much larger with the gap by 0.5 to 1.5% between them for all the observed depth. This therefore implies that the compaction and moisture loss could be cumulative.

ACKNOWLEDGEMENTS

This paper was funded by National Science & Technology Supporting Plan (2011BAD29B08), '111' Project of Chinese Education Ministry (111-2-16) and the Basic Research Supporting Plan of Northwest A & F University.

REFERENCES

Batey T (2009). Soil compaction and soil management-a review. Soil Use Manage. 25: 335-345.

Chen BC (1981). Mechanics of soil-vehicle system. China Agricultural Machinery Press, Beijing, China.

Li RX, Song HB, Gao HW (2001). Prediction of soil compaction by small tractor using finite element method. Trans. CSAE. 17(4): 66-69.

Hamza MA, Al-Adawi SS and Al-Hinai KA (2011). Effect of combined soil water and external load on soil compaction. Soil Res. 49(2): 135-142.

Jung KY, Newell RK, Kenneth AS, Lee KS, Chung SO (2010). Soil compaction varies by crop management system over a clay-pan soil landscape. Soil Tillage Res. 107(1): 1-10.

Saffih-Hdadi K, Défossez P, Richard G, Cui YJ, Tang AM, Chaplain V (2009). A method for predicting soil susceptibility to the compaction of surface layers as a function of water content and bulk density. Soil Tillage Res. 105(1): 96-103.

Van den Akker JJH, Hoogland T (2011). Comparison of risk assessment methods to determine the subsoil compaction risk of agricultural soils in The Netherlands. Soil Tillage Res. 114(2): 146-154.

Wang XY, Gao HW, Li YX, Zhang XF (2000). Effect of tractor wheel compaction on runoff and infiltration. Agric. Res. Arid Areas, 18(4): 57-60.

Zhang XY, Sui YY (2005). International research trends of soil compaction induced by moving machine during field operations. Trans. CSAM, 36(6): 122-125.