AF-738
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RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume Issue : ()

Effect of Soil Compaction due to Organic Matter and 4-Wheel Tractor Traffic on Sugarcane Growth

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10.18805/IJARe.AF-738

ABSTRACT

Background: Soil compaction can occur due to the intensity of tractor traffic in the tillage process. The objective of this study was to determine the changes in physical, mechanical properties of the soil and plant growth that occurred due to tractor traffic and how it would affect if the addition of organic matter (compost) was added to the soil.

Methods: The experimental work was conducted at the Sugarcane Plantation of PTPN II Klumpang at an initial soil moisture content of 24.69% and a bulk density of 1.08 gr/cm^3 with compost and no compost then the land is traversed by the tractor with 2,4 and 6 passes.

Result: The results of indicate that the tractor trajectory and the addition of compost have a significant effect on soil compaction. The highest values for water content, bulk density, particle density and penetration resistance were obtained at 6 times tractor traffic with soil without compost sowing respectively 35.36%, 1.31 gr/cm^3, 1.87 gr/cm^3, 9.61 kgf/cm^2, while in soil with compost, the values obtained were 33.62%, 1.23 gr/cm^3, 1.82 gr/cm^3, 9.04 kgf/cm^2, respectively. These findings indicated that the application of compost can reduce the level of soil density so that plant growth becomes better and more even rate of plant growth is obtained than without compost.

Key words: Compost sowing, Soil compaction, Soil physical properties, Tractor traffic.

INTRODUCTION

Intensive tillage using tractors as the prime mover creates serious problems in soil compaction. Soil compaction has been recognized as a severe problem in agricultural mechanization and can affect many soil properties (Botta *et al*., 2012). Cultivation of sugarcane with intensive use of machinery especially for harvesting indicates soil compaction, affecting plant development. Tractor traffic control is needed to maintain the physical quality of the soil which can increase sugarcane root growth and productivity and technological quality (Gómez-Rodríguez *et al*., 2013).

The spread of pressure due to tractor trajectories on soil with high humidity getting to the deeper layers is getting bigger because of the low soil resistance (Bergamin *et al*., 2015). Soil deformation due to compaction with heavy equipment is one of the biggest threats to soil function (Holthusen *et al*., 2018). Organic matter can affect the structure of the soil to become more crumbly and loose, although the original soil has a high organic matter content which can reduce the susceptibility of the soil to compaction, the large weight of the tractor used for tillage can cause high levels of compaction (Iqbal *et al*., 2006). In addition to increasing soil compaction, tractor traffic can also affect the flow and availability of water (Soracco *et al*., 2015). The average bulk density that occurs at each level of soil depth and the amount of tractor traffic is higher. This is due to a decrease in soil porosity due to the process of soil compaction. So the value of bulk density is significantly different for each amount of traffic (Rizadi *et al*., 2020). Increased soil compaction resulted in a decrease in plant height, stem diameter and leaf area index (Kirnak *et al*., 2016). The objective of this study was to evaluate the effect of soil density level with the addition of organic matter and without the addition of organic matter on the growth of sugarcane plants.

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How to cite this article: Rizaldi, T., Putri, F.N.E and Rifai, M. (2022). Effect of Soil Compaction due to Organic Matter and 4-Wheel Tractor Traffic on Sugarcane Growth. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.AF-738.

Submitted: 03-05-2022 **Accepted:** 30-08-2022 **Online:** 06-09-2022

MATERIALS AND METHODS

The research was carried out in the sugarcane plantation area of PTPN II Medan and in the greenhouse laboratory at the Faculty of Agriculture, Universitas Sumatera Utara, Medan from January 2020 to February 2021. The materials used in this study were soil plots of 8 m × 12 m into 3 plots, soil samples that had been processed and organic materials (compost fertilizer) at a dose of 4 tons/ha, sugar cane, while the tools used were four-wheel tractor type namely; New Holland TM 150 with a weight of 5249 kg, moldboard plow as soil tillage tool, ring to take soil samples, scales to measure soil weight, oven to dry the soil and a penetrometer to determine soil penetration resistance. The method used is an experiment on sugar cane plantations. The treatments designed were the intensity of tractor traffic and the application of compost to the soil at a dose of 4 tons/ha with three replications. The experimental design used was a randomized block design where the first factor was the number of tractor traffic (L):

L0: without tractor track
L2: two tractor passes
L4: four tractor passes
L6: six tractor passes

The second factor is organic materials in the form of compost (K):

K0: no compost
K4: compost dose 4 tons/ha

Parameter measurements were carried out at each soil depth of 5 cm, 10 cm and 15 cm.

Fig 1 show the condition of the experimental field. The soil was cleaned of plant remains and then 3 plots are made with a size of 8 m × 12 m. Before being passed by the tractor, soil samples were taken and the physical properties of the soil were measured in the laboratory. Next, compost is sown on the soil at a dose of 4 tons/ha. Then the soil was plowed so that the compost and soil are mixed perfectly. Leave the soil for one week (incubation period) so that the soil decomposes. After that, soil traffic was carried out with a four-wheel tractor of the New Holland TM 150 type with 2, 4 and 6 times the traffic with 3 replications in each plot. Fig 2 show how to take samples and measure soil penetration resistance. Measurement of soil penetration resistance is carried out after being passed by a tractor with a penetrometer. Then soil samples were taken on each track passed by the tractor to measure the physical properties (soil texture, soil moisture content, bulk density, particle density).

Soil moisture content can be calculated by equation:

$$KA = \frac{W_a - W_b}{W_b} \times 100\% \qquad .....(1)$$

Where:
KA= Moisture content (%).
W_a= Wet soil sample weight (gr).
W_b= Dry soil sample weight (gr).

Bulk density can be calculated by equation:

$$pb = \frac{M_s}{V_t} \qquad .....(2)$$

Where:
pb= Bulk density (gr/cm^3).
M_s= Soil solid mass (gr).
V_t = Total soil volume (cm^3).

While the particle density can be calculated by the equation:

$$ps = \frac{M_s}{V_s} \qquad .....(3)$$

Where:
ps= Particle density (gr/cm^3).
M_s= Soil solid mass (gr).
V_s= Soil solid volume (cm^3).

Furthermore, sugarcane seedlings were planted and their growth was observed every week until the 18th week.

RESULTS AND DISCUSSION

Effect of tractor traffic on soil physical properties

The experimental soil used is land with a flat surface that contains grass and plant remains. Prior to the experiment, the sugarcane plantation area was cleaned first. The soil texture at the experimental site is clay loam with a content of 36.45% sand, 29.89% clay, 33.65% clay which has the characteristics of crumbs and clumps in dry conditions. The average moisture content on the soil surface at a depth of 5 cm is 23.36%, at a depth of 10 cm is 25.91% and a depth of 15 cm is 24.81%. Data in Table 1-4 above informs that the number of tractor tracks has a significant effect on soil moisture content. The deeper into the soil, the more moisture content will increase for for each number of tractor passes. As a result of compression, the gas contained in the pore space will come out while the liquid is trapped in the soil pores. While compost application has a significant effect on increasing soil water content, this is due to the increasing pore space in the soil so that the volume of water entering the pore space becomes more. Based on the experimental design results, it is shown that the intensity of the traffic has a significant effect on soil moisture content, bulk density, particle density and soil penetration resistance value at the level of α= 0.05 and is very significant at the level of α= 0.01. Soils with higher moisture content have greater propagation of stress to deeper layers and consequent compaction (Bergamin *et al*., 2015). This is in accordance with the statement that the dynamic indicator (number of tractor passes) is more sensitive to the effect of compaction (Botta *et al*., 2012). The values of bulk density, particle density and penetration resistance were higher for each into the soil and the increase in the number of passes, but the value was lower with the addition and application of compost. Based on the experimental results, it was shown that the treatment of giving compost to the soil at a dose of 4 tons/ha gave a significant effect on the value of water content, bulk density, particle density and soil penetration resistance at the level of = 0.05 and very significant at the level of = 0.01.

The higher the amount of tractor traffic, the value of bulk density and particle density will be higher, while the value of porosity and water content will be lower. Giving compost to the soil causes the bulk density and particle density to decrease while the porosity and water content values increase for each number of passes. The treatment of the number of tractors causes an increase in the value of soil penetration resistance in soil conditions with no compost. At each soil depth, the value of the penetration resistance decreases with the addition of compost.

Effect of soil density on sugarcane growth

The treatment of tractor traffic intensity has an effect on increasing the density and soil penetration resistance. This

Table 1: Value of moisture content at each soil depth level.

Soil depth (cm)	Moisture content (%)							
	L0K0	L0K4	L2K0	L2K4	L4K0	L4K4	L6K0	L6K4
5	27.71	29.06	28.38	29.57	30.64	30.00	31.25	32.00
10	28.47	29.45	31.80	29.67	32.27	33.35	33.25	33.36
15	30.39	29.68	32.33	31.93	33.48	34.87	35.36	33.62

L0K0: Without tractor track and no compost; L0K4: Without tractor track and compost dose 4 tons/ha; L2K0: Two tractor passes and no compost; L2K4: Two tractor passes and compost dose 4 tons/ha; L4K0: Four tractor passes and no compost; L4K4: Four tractor passes and compost dose 4 tons/ha; L6K0: Six tractor passes and no compost; L6K4: Six tractor passes and compost dose 4 tons/ha.

Table 2: Value of bulk density at each soil depth level.

Soil depth (cm)	Bulk density (gr/cm^3)							
	L0K0	L0K4	L2K0	L2K4	L4K0	L4K4	L6K0	L6K4
5	1.09	1.08	1.16	1.14	1.17	1.16	1.21	1.19
10	1.16	1.13	1.20	1.16	1.21	1.18	1.25	1.20
15	1.23	1.19	1.21	1.24	1.26	1.24	1.31	1.23

L0K0: Without tractor track and no compost; L0K4: Without tractor track and compost dose 4 tons/ha; L2K0: Two tractor passes and no compost; L2K4: Two tractor passes and compost dose 4 tons/ha; L4K0: Four tractor passes and no compost; L4K4: Four tractor passes and compost dose 4 tons/ha; L6K0: Six tractor passes and no compost; L6K4: Six tractor passes and compost dose 4 tons/ha.

Table 3: Value of particle density at each soil depth level.

Soil depth (cm)	Particle density (gr/cm^3)							
	L0K0	L0K4	L2K0	L2K4	L4K0	L4K4	L6K0	L6K4
5	1.72	1.62	1.73	1.65	1.76	1.72	1.77	1.74
10	1.77	1.66	1.78	1.70	1.80	1.75	1.82	1.76
15	1.81	1.75	1.83	1.73	1.85	1.80	1.87	1.82

L0K0: Without tractor track and no compost; L0K4: Without tractor track and compost dose 4 tons/ha; L2K0: Two tractor passes and no compost; L2K4: Two tractor passes and compost dose 4 tons/ha; L4K0: Four tractor passes and no compost; L4K4: Four tractor passes and compost dose 4 tons/ha; L6K0: Six tractor passes and no compost; L6K4: Six tractor passes and compost dose 4 tons/ha.

Table 4: Value of penetration resistance at each soil depth level.

Soil depth (cm)	Penetration resistance (kgf/cm^2)							
	L0K0	L0K4	L2K0	L2K4	L4K0	L4K4	L6K0	L6K4
5	2.59	2.15	3.96	3.78	4.05	3.84	7.02	5.79
10	3.84	2.65	5.85	4.90	5.85	5.07	9.06	7.98
15	6.03	5.47	7.54	6.55	8.01	7.34	9.61	9.04

L0K0: Without tractor track and no compost; L0K4: Without tractor track and compost dose 4 tons/ha; L2K0: Two tractor passes and no compost; L2K4: Two tractor passes and compost dose 4 tons/ha; L4K0: Four tractor passes and no compost; L4K4: Four tractor passes and compost dose 4 tons/ha; L6K0: Six tractor passes and no compost; L6K4: Six tractor passes and compost dose 4 tons/ha.

(a) (b) (c)

Fig 1: (a) Experimental field; (b) Sowing compost and incubation period; (c) Tractor traffic movement.

(a) (b)

Fig 2: (a) Soil sampling; (b) Soil penetration resistance measurement.

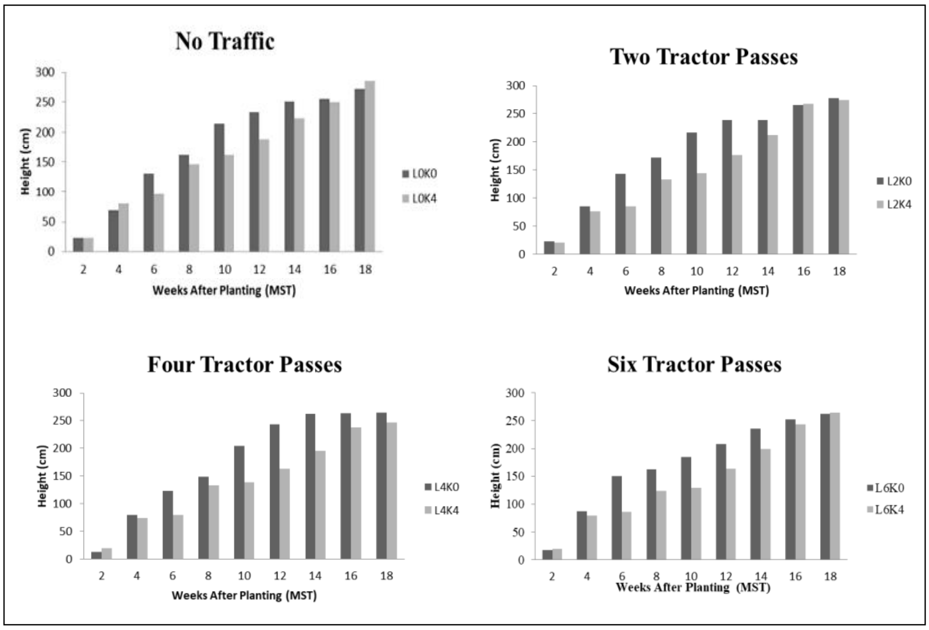

Fig 3: Sugarcane plant growth until 18 weeks after planting.

will certainly affect root propagation and will certainly affect the growth of sugarcane. Soil density testing on sugarcane growth was carried out at the soil density level as shown in Table 2 above with and no compost (K0 and K4).

Fig 3 explains that at the beginning of plant growth without compost sowing is better than compost sowing. However, the addition of compost showed a more stable rate of increase in growth. Until week 18, the height of the sugarcane plant was close to the same height and it was possible to obtain better growth by adding compost if the number of weeks of growth measurement was increased. In the area between the wheels of the tractor used does not cause compaction and can be used for sugarcane cultivation. For this reason, it is necessary to regulate tractor traffic by adjusting the width of the tractor track that allows the development of plant roots to be better (Gómez-Rodríguez *et al*., 2013).

CONCLUSION

The higher the level of soil depth, the higher the strength of the soil, this is due to soil compaction which is the result of repeated tractor operations on a track. The use of compost can reduce soil compaction, especially on sugar cane plantations, seen from the decreasing bulk density of the soil after composting. Meanwhile, for plant growth in the first 14-16 weeks of solid soil conditions, it still had no effect but the effect could be seen starting to enter the 18^{th} week. This was due to the disruption of root distribution because roots were difficult to penetrate the soil in denser soil conditions.

ACKNOWLEDGEMENT

The author would like to thank the Universitas Sumatera Utara for the research funding for the USU TALENTA Basic Research scheme sourced from NON PNBP funds with a contract number No: 353/UN5.2.3.1/PPM/KP-TALENTA USU/2019.

Conflict of interest: None.

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