High-Carbon Organic Fertilizer Effects on Soil Physical Properties of Sandy Loam Soil and Corn Growth

1st Danang Widjajanto
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
danangwidjajanto20@gmail.com

2nd Bunga Elim Somba
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
e_somba@hotmail.com

3rd Rois
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
rois_h@yahoo.co.id

4th Uswah Hasanah
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
uswahmughni@yahoo.co.id

5th Abdul Rahman
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
mankuntad72@gmail.com

6th Rachmat Zainuddin
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
rachmat_zainuddin@yahoo.com

7th Rezi Amelia
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
reziamelia@gmail.com

8th Rully Akbar Pribudi Djalalelmbah
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
rully.akbar2588@gmail.com

9th Rizki Puspitasari
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
rizkypupitas2811@gmail.com

10th Desi Ratnasari
Soil Science Laboratory
Agriculture Faculty of Tadulako University
Palu, Indonesia
dhesiratnasari36@gmail.com

***Abstract*—Organic fertilizer (OF) as an ameliorant is best known for improving soil structure and plant growth. This study aimed to determine the effect of organic fertilizer swallow droppings on soil physical properties and plant growth. It is a pot experiment arranged in a randomized block design with six treatments of various doses of swallow droppings as the organic fertilizer, i.e., No OF added (P0), 5 Mg OF ha^{-1} (P1), 10 Mg OF ha^{-1} (P2), 15 Mg OF ha^{-1} (P3), 20 Mg OF ha^{-1} (P4), and 25 Mg OF ha^{-1} (P5). The swallow droppings were collected from the swallow-caged building in the Sindue sub-district of Donggala. The organic fertilizer significantly affects total organic carbon, bulk density, hydraulic conductivity, penetration resistance, saturated water holding capacity and field capacity, root growth, and biomass dry weight. The organic fertilizer dramatically improves the soil's physical properties and plant growth at doses ranging from 10 – 15 Mg Ha^{-1}. Increasing total organic carbon is not positively correlated with increasing soil water availability.**

Keywords— Available soil water, Root growth, Soil structure

I. INTRODUCTION

The sustainability of agricultural development can be influenced by water availability. The poor management of water resources has resulted in a decline in the community's economic growth [19].

Swallow droppings are rich in organic carbon and plant nutrients. These materials can be used as organic fertilizers [21]. Using organic fertilizer from swallow droppings at a dose of 5 Mg ha^{-1} can improve soil quality and the financial benefits of corn farming by up to 315% [12]. Likewise, adding up to 40 Mg ha^{-1} can improve soil structure and cassava production [25].

Using organic fertilizers in the soil increases organic carbon-nitrogen and soil structure stability [34]. Poor soil structure contributes to the low absorption of soil water and plant nutrients [22, 20].

Root activity also affects the availability of soil organic carbon. The low availability of soil organic carbon causes

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competition for carbon use with soil microorganisms. Adding organic carbon is necessary to stimulate various activities of soil microorganisms beneficial for agriculture [7, 31].

Organic carbon and clay have an essential role in influencing soil structure formation. Application of organic fertilizers containing high C/N can increase macro pore space in clay and massive soils [4, 34, 13].

Coarse textured soils have a lower water-holding capacity than clay soils [9, 35]. Increasing the micro-pore spaces with increased availability of organic carbon benefits the soil water supply during plant growth [15]. Sufficient soil water during vegetative growth will ensure optimal root growth [5, 2].

Experts have widely studied the role of organic carbon and clay on changes in soil structure. However, several studies have shown inconsistent results. Some experts say that organic carbon levels significantly affect water-holding capacity, aggregate stability, and plant root growth [10, 8].

Several different opinions state that applying organic matter can affect changes in soil's physical properties differently. Excessive application of organic fertilizers can even worsen the quality of soil structure [26]. Knowledge of the total organic carbon : clay ratio is considered more important in explaining the ability of organic matter to influence changes in soil structure compared to the total organic carbon [16, 33].

The inconsistency of the research results of several soil scientists is interesting for further research related to the effect of high-carbon organic fertilizer application on changes in soil structure. Observations of several physical properties of the soil and the growth of plant roots are used to support the explanation of changes in soil structure.

The study aimed to determine the effect of applying organic fertilizer swallow droppings on some soil physical properties and corn growth on sandy loam soil.

II. MATERIAL AND METHOD

The pot experiment was carried out in the greenhouse of the Faculty of Agriculture, Tadulako University. Soil samples and swallow droppings (Collocalia vestita) were taken from Sindue District, Donggala Regency, Central Sulawesi, Indonesia

A. *Organic Fertilizer Preparation*

Organic fertilizers are manufactured at the organic house, Faculty of Agriculture, Tadulako University. 10 kg of air-dried swallow droppings is introduced into a plastic bioreactor and added 50 g of sugar and 50 g of urea are. EM4 (Effective Microorganism 4) is added at the recommended dose. Stir daily until smooth, and add enough water to prevent excessive temperature rise in the bioreactor. Making organic fertilizer was stopped after 20 days and did not show an unpleasant odor. The treatment material used in the experimental pot was organic fertilizer that passed a 2 mm sieve. The results of the analysis of the chemical properties of organic fertilizers are presented in Table 1.

TABLE 1. CHEMICAL PROPERTIES OF ORGANIC FERTILIZERS

pH H_2O	**C-org (%)**	**N Total (%)**	**P_2O_5 (%)**	**K_2O (%)**
6.48	*51.82*	*3.11*	*1.04*	*1.93*

B. *Soil Preparation*

Soil samples from Sindue Subdistrict, Donggala Regency, were taken at 0 – 20 cm depth. Air-dried soil that has passed a 2 mm sieve is used as experimental material. The results of the analysis of the Physico-chemical properties of the initial soil are presented in Table 2.

TABLE 2. PHYSICO-CHEMICAL PROPERTIES OF THE SOIL BEFORE TREATMENT

Texture (%)			**Bulk Density ($kg\ dm^{-3}$)**	**C-org (%)**	**pH**	**CEC ($cmol(+)\ kg^{-1}$)**	**Nutrient**		
Sand	**Silt**	**Clay**					**N (%)**	**P_2O_5 ($mg\ 100\ g^{-1}$)**	**K_2O ($mg\ 100\ g^{-1}$)**
64.18	*18.59*	*17.23*	*1.32*	*2.41*	*6.52*	*19.43*	*0.27*	*34.16*	*23.92*

C. *Soil Plant Analysis*

Soil-plant sampling occurs when the corn is 58- 60 days after planting. The soil texture was analyzed using the pipette method [11]. The core method determines the bulk density [18]. Soil organic carbon is established based on the Walkley-black method. A flat-toed pocket penetrometer (Eijkelkamp, Giesbeek, The Netherlands) is used to measure soil penetration resistance [28]. The hydraulic conductivity of saturated soils is measured using the constant head permeameter method [3]. The saturated soil water (0 kPa), field capacity (-33 kPa), and permanent wilting point (-1500 kPa) are determined based on the method of observation of soil water retention in soil science laboratory [23]. The dry weight of biomass and roots was observed by drying at 60 ^oC for 24 hours. The total root length was determined by the method of quantitative [1].

D. *Research Procedure*

Pot experiments were conducted based on a randomized block design. The study consisted of 6 dose treatments of fermented organic fertilizer application. The treatment in the study was successively the dose of organic fertilizer application of 0, 5, 10, 15, 20, and 25 Mg ha^{-1}. Each treatment is repeated three times.

The experimental material used a sample of air-dried soil that had passed a 2 mm sieve. The weight of the soil used in each experimental pot is 8 kg. Hybrid corn is used as an indicator crop. During the experiments not applied fertilizer as an additional nutrient. Pest control of plants is carried out using pesticides according to the recommended dosage.

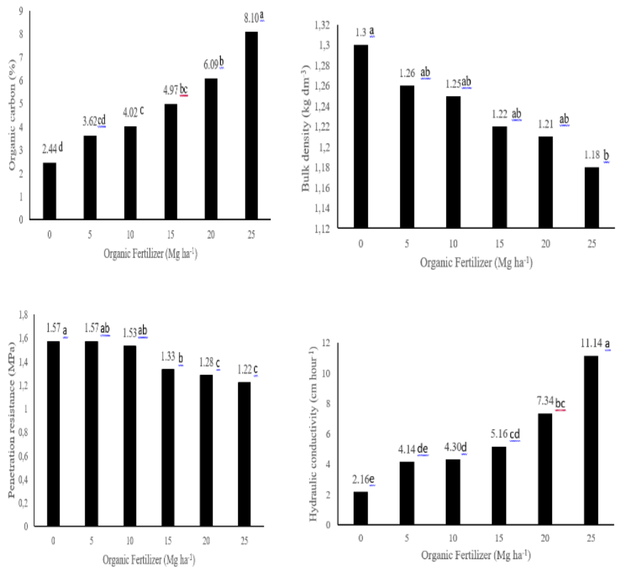
Corn seeds are planted in pots measuring 30 cm high and 24 cm in diameter. The provision of water as much as 2 dm^3/pot is carried out with a frequency of 3 days. The bottom of the pot is given enough holes for drainage.

E. *Statistical Analysis*

One-way variance analysis is performed using SPSS 16.0 software. If there is a fundamental difference between the experimental treatments, a further test is carried out using the honestly significant difference test (HSD $p < 0.05$).

III. RESULT AND DISCUSSION

Water deficit and soil compaction are problems that often occur in sandy loams. Using organic fertilizers is an alternative to overcome the limited soil water supply and inhibition of plant root growth. The effect of applying organic fertilizers on soil organic carbon, bulk density, penetration resistance, and soil hydraulic conductivity is presented in Figure 1.



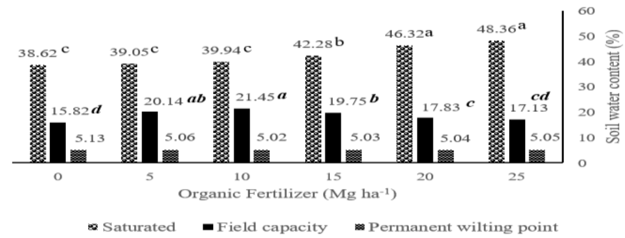
Note: Values followed by the same letter show no significant difference at the 0.05 level

Fig. 1. Effect of organic fertilizer dose on total organic carbon, bulk density, penetration resistance, and soil hydraulic conductivity.

The increase in organic carbon by 231.9% led to a decrease in bulk density and soil penetration resistance by 10.17% and 28.68%, respectively. On the other hand, hydraulic conductivity increases sharply until it reaches 415.74%. Increasing the volume of macro soil pores can increase the rate of movement of soil water. Decreased bulk density and penetration resistance of the soil leads to lose soil.

The availability of soil organic carbon 8% in applying high C/N organic fertilizer treatment can reduce bulk density by 9.25% on soils with high clay. The rate of movement of soil water increases markedly in line with the increasing application of organic fertilizers [32].

The soil water content field capacity received the best treatment at 10 Mg ha^{-1}. The ability to hold water at field capacity increased by 5.63% compared to the treatment without applying organic fertilizers. The water holding capacity in the measurement of the permanent wilting point showed no noticeable difference between treatments (Figure 2).



Note: Values followed by the same letter on the same bar show no significant difference at the 0.05 level

Fig. 2. The effect of organic fertilizers on saturated soil, field capacity, and permanent wilting point.

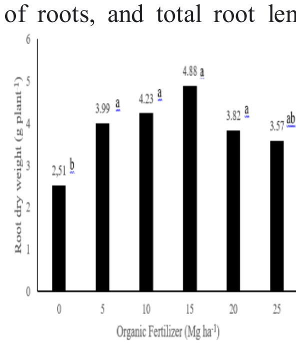
The 1:8 organic carbon : clay ratio effectively improves the structure of degraded soils. A ratio of organic carbon:clay less than 1:10 can reduce soil structure stability [22,29]. Applying organic matter and clay can improve sandy soils' hydraulic conductivity and water-holding capacity [17].

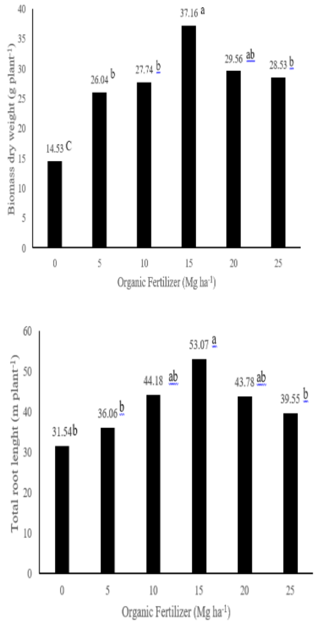
Applying organic fertilizer at 10 Mg ha^{-1} significantly increased field capacity water retention. It is hoped that analyzing the distribution of pore sizes at several levels of organic carbon and clay can explain the inconsistency of the results of previous research by experts.

Applying organic fertilizer significantly affected the water holding capacity up to a dose of 25 Mg ha^{-1}. The increase in total pore volume due to the increase in soil organic carbon can be caused by the dispersion of clay particles by non-complex organic carbon.

The interaction between complex organic carbon – clay affects the formation of micropore spaces. Total organic carbon is not positively correlated with soil structural porosity. Non-complexed clay particles are more easily dispersed in water. Soils containing high levels of non-complex organic carbon tend to form a constant volume of macro pore space at its maximum value [6].

Root growth and corn biomass reached the optimum at 15 Mg ha^{-1}. Increasing the amount up to 25 Mg ha^{-1} caused a decrease in root growth and corn biomass. The effects of organic fertilizer on the dry weight of biomass, dry weight of roots, and total root length are presented in Figure 3.





Note: Values followed by the same letter show no significant difference at the 0.05 level.

Fig. 3. Effect of organic fertilizer on dry biomass weight, root dry weight, and total root length.

The relationship between soil water availability and plant growth is influenced by the interaction between the physical properties of soil, water, and plants. Applying fertilizers containing high organic carbon tends to affect the formation of soil macro pore spaces (> 500 µm). In comparison, micropores (< 50 µm) are influenced by materials that have low organic carbon [24]. Micro pores are vital in controlling the soil moisture content of field capacity [30, 14]. Changing soil bulk density and increasing water availability can affect root growth and the dry weight of biomass [27].

IV. CONCLUSSION

The use of organic fertilizer swallow droppings has significantly affected total soil organic carbon, bulk density, penetration resistance, hydraulic conductivity, root growth, and biomass weight. Applying organic fertilizer up to 10 Mg ha^{-1} increases soil water availability. Increasing the dose fertilization to 25 Mg ha^{-1} can significantly reduce the soil water holding capacity of the field capacity. An increase in soil organic carbon availability is not positively correlated with increasing soil water availability.

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