Accepted manuscript (author version)

To appear in: International Journal of Recycling of Organic Waste in Agriculture (IJROWA)

Online ISSN: 2251-7715 Print ISSN: 2195-3228

Received: 11 Dec 2023 Revised: 16 Apr 2024

Accepted: 12 Jul 2024

DOI: 10.57647/ijrowa-4wdr-v824

ORIGINAL RESEARCH

Application of chicken manure compost and the amount of water on Sorghum yield and improvement of sub-optimal soil properties

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Abstract

Purpose: Sorghum is relatively tolerant of being planted on suboptimal and relatively dry soil. Still, it requires sufficient water and effort to improve soil properties for optimal growth and yield. Therefore, we studied the effect of providing several doses of chicken manure (CM) combined with the amount and frequency of water application on the growth and yield of sorghum and on improving soil fertility.

Method: Four levels of CM (0, 2.5, 5.0, and 10 t ha^{-1}), three levels amount of water (160, 210, and 260 mm per phase), and watering frequency (3, 5, and 7 times) arranged in a factorial randomized block design with three replications. Observations were made on sorghum growth and yield, as well as soil properties.

Results: The combination of 2.5 t ha^{-1} of chicken manure and 210 mm of water is sufficient to increase sorghum growth (plant height, leaf number, stem diameter, and chlorophyll count), increase straw dry weight by 30% and grain yield by 33% compared to control. However, the application of chicken manure up to 10 t ha^{-1} increases pH, soil organic carbon (SOC), P-available, and the total number of microbes P solvents in the soil.

Conclusion: Providing 2.5 t ha^{-1} of chicken manure and a total of 210 mm of water with a frequency of 5-7 times increased sorghum growth and yield compared to the control. Providing chicken manure up to a dose of 10 t ha^{-1} had a positive effect on improving the observed soil properties.

Keywords: Chicken manure, Sorghum, Soil properties, Watering

Introduction

The largest sorghum plantations in Indonesia are located on sub-optimal land that has limiting factors consisting of poor nutrients and organic matter, low moisture content, and drought. Sorghum with stages and a total life period of 130 days (vegetative, reproductive, maturity, and harvesting stage) requires less water during growth than corn (Widiyono et al., 2021). Although the water requirement of sorghum is lower than that of corn, water stress promotes a reduction in the number of leaves (Ndlovu et al., 2021) and stem diameter of sorghum (Fathi 2022), decreases photosynthetic rate, cell development, yield productivity (Abreha et al., 2022), and on water use efficiency (Jabereldal et al., 2017).

The addition of soil organic carbon (SOC) by including plant residues, compost, or biochar is expected to increase the soil's capacity to hold more water when it rains and then release it again in dry conditions. The positive effect of SOC on available water capacity has been widely reported, especially in coarse-textured soils (Minasny and McBratney., 2017). The accuracy of water availability at the growth stage affects sorghum yield. Therefore, optimal results will be achieved if the plant's water needs are met in the early vegetative phase, flowering, and panicle filling (Osakabe et al., 2014).

Apart from sufficient water, adequate nutrient elements are also important, especially on suboptimal soil. Providing organic matter contributes macro and micro-nutrients to plants, increases the binding capacity of soil water, and increases the amount of water available for plant needs (Sardiana et al., 2017).

Chicken manure is one of the wastes produced by both laying hens and broiler chickens, and it has great potential as organic fertilizer through composting techniques. The composition of poultry manure varies depending on several factors such as source of manure, feed and condition of animals, storage, and handling of manure. Composting, or the controlled biological breakdown of organic materials, has been investigated as a method of stabilizing poultry manure before use on land. This process produces a material with several advantages in handling by reducing volume, dry material mass, and odor. Chicken manure contains relatively high total N, P, and K, as well as microelements that can be absorbed by plants (Ashworth et al., 2020). Manure contains about 3-5% nitrogen, 1.5-3.5% phosphorus, 1.5-3.0% potassium, and micro-nutrients in considerable amounts (Jerdrczak et al., 2014; Kacprzak et al., 2023).

The beneficial effects of animal manure on plant growth have been widely reported (Adebayo et al., 2017; Naishima et al., 2019; Majolagbe et al., 2020; Unagwu et al., 2019; Ibode et al., 2022, Wakawa et al., 2023). However, a lack of information was collected related to its interaction with water application to sorghum in acidic and nutrient-poor soils. The research aimed to study the effect of applying chicken manure and its interaction with the amount of water (total amount and frequency of water application) according to the growth phase on sorghum growth and its effect on soil properties.

Materials and methods

Experimental site

The study was conducted in the Agriculture Faculty experimental station, The University of North Sumatra (30 33' 29,772" N and 980 39' 13.5" E) about 19.4 m above sea level. The soil was taken from Tuntungan II Village, Pancurbatu District, Deli Serdang Regency, North Sumatra, Indonesia. The following are the physical and chemical properties of the soil (Table 1).

Table 1. Soil physicochemical properties of the soil before the implementation of the experiment

Parameters	Soil texture (%)			Soil moist. (%)	pH H2O	SOC (%)	Total-N (%)	P-Bray ($mgkg^{-1}$)	K_2O ($mgkg^{-1}$)	CEC (cmol/kg)
	Sand	Silt	Clay							
Value	59	26	15	21.24	5.4	1.75	0.26	8.27	180	15.94

Soil moist. (Soil moisture), SOC (soil organic carbon), total-N (total Nitrogen), K_2O (Flame photometry), CEC (Cation Exchange Capacity)

Experimental design and management

The study used a randomized completed block design with three factors and three replications. The first factors were chicken manure compost at 4 levels (0; 2.5; 5.0; and 10 t ha^{-1}), the total amount of water as the second factor at 3 levels were 160, 210, and 260 mm for the growing season, and watering frequency with 3 levels (3, 5, and 7 times per phase). The chicken manure fine compost contains organic C > 15%; total N ± 0.77%; P2O5 ±3.55%; K2O ± 2.01%; CaO ± 2.96%; MgO ± 3.18%; and C/N max 20; and pH 7-9. Application of water according to the plant growth phase includes initial growth aged 0-16 DAP (10%), vegetative 17-37 DAP (20%), generative 38-52 DAP (25%), seed filling 53-83 DAP (35%), and harvest 84-95 (10%). The amount of water applied is based on the treatment in Table 2.

Table 2. Amount and timing of water for the period September 2022-December 2023

Total Water (mm)	Time application (W)	Early growth (0-16 DAP)	Vegetative (17-37 DAP)	Generative (38-52 DAP)	Seed filling (53-83 DAP)	Physiologist maturity (84-95 DAP)
		mm				
T1 (160)		**16.0**	**32.0**	**40.0**	**48.00**	**24.00**
	W1	5.3	10.7	13.3	16.0	8.0
	W2	3.20	6.40	8.00	9.60	4.80
	W3	2.29	4.57	5.71	6.86	3.43
T2 (210)		**21.0**	**42.0**	**52.5**	**63.00**	**31.50**
	W1	7.0	14.0	17.5	21.0	10.5
	W2	4.20	8.40	10.50	12.60	6.30
	W3	3.00	6.00	7.50	9.00	4.50
T3 (260)		**26.0**	**52.0**	**65.0**	**78.00**	**39.00**
	W1	8.7	17.3	21.7	26.0	13.0
	W2	5.20	10.40	13.00	15.60	7.80
	W3	3.71	7.43	9.29	11.14	5.57

Note: Total water T1 = 160 mm; T2 = 210 mm; T3 = 260 mm; Time application W1 =3 times; W2 = 5 times; W3 = 7 times.

The top layer of soil with a thickness of 0.2 m was collected, air-dried, and sieved using a 2 mm sieve. A total of 10 kg of dry field soil is put into a polybag with a size 0.35 x 0.40 m, put into a bucket, and then arranged neatly on a bed with a height of 0.5 m which has a transparent plastic shade and a drainage channel which functions as rainwater management so that it does not affect the treatment during plant growth. The initial soil analysis involved texture (hydrometer), soil moisture content with a pressure plate (pF 2.54), pH (H_2O), soil organic carbon (SOC), total-N, P-available (Bray I), K-available (K-av), Cation Exchange Capacity (CEC), and Base Saturation (BS) (Table 1).

The Suri 3 Agritan variety is used with an age of 95 DAP and a potential yield of 6.0 t ha^{-1}. The dosage of N, P, and K fertilizer is the optimum dosage based on Kansas State University (2013) with a dose of N 122 kg ha^{-1}, P 51 kg ha^{-1}, and K 74 kg ha^{-1}. N fertilizer was applied 3 times, 7 days after planting (DAP), 21 DAP, and 35 DAP. P fertilizer was applied at the beginning of planting at 7 DAP, while K was applied twice, i.e., simultaneously with the first and second N fertilization. Pre-emergence herbicide application at 30 DAP. The pesticide application at 0 DAP is a fungicide with an active content of prominent 70% at a dose of 2 g kg^{-1} of seed as a seed treatment. As a result of a 20% anthracnose attack when grain filling, a fungicide of 1% acibenzolar-s-methyl + 48% mancozeb was implemented from the age of 60, 67, 74, and 81 DAP at a dose of 2.5 g per liter of water.

Parameters observed

Soil parameters observed: soil moisture content measurement four times at 3; 18; 44; 59 DAP; pH (pH meter; 1:2.5), SOC (Walkley and black), and P-available (Bray I) at harvest time. Soil biology analyzed was the number of microbes Solvent P (plate count method) at harvest. The total phosphate solubilizing microbes (Goldman and Green, 2015) present in the planting media is calculated using the formula:

The total number of microbes (CFU g^{-1}) = Number of colonies per plate x 1/dilution factor

Observation of growth parameters and yield component was covered on plant height (cm), stem diameter (cm), leaves number, chlorophyll using Minolta 181 502 SPAD meter, flowering time (%), number of plants that have panicles, percent filled spikelet's (%), grain thousand weight (g), straw oven dry weight (kg ha^{-1}), grain straw ratio, panicle length (cm), and total dry matter (t ha^{-1}).

Data analysis

All data were analyzed using the software for agricultural statistics (SAS) version 9.4 (SAS Institute, Cary, NC, USA). The data variations were inspected visually by plotting the residuals to confirm normality and non-normal data and then log-transformed before carrying out the ANOVA test. Significant Difference uses the DMRT to compare treatment means based on a probability level of 5% or lower. The relationship between observed parameters was analyzed using the Pearson correlation coefficient.

Result and discussion

Sorghum plant growth

The application of chicken manure at a dose of 2.5 to 10 t ha^{-1} increased plant growth (plant height, chlorophyll, and leaf number) in the vegetative phase compared to the control (Table 3). The highest plant height was obtained in the treatment combination of 2.5 to 10 t of chicken manure ha^{-1}, 210 mm of the total amount of water, and 4- or 6-times watering frequency. This indicates that there was a positive interaction between the three treatments on sorghum plant height.

The application of chicken manure increases the amount of sorghum chlorophyll in the vegetative phase. Chlorophyll is vital for photosynthesis which allows plants to absorb energy from light. Chlorophyll and N content in plants are closely related. Leaf N content increases when N fertilizer is applied. Higher N contents in leaves are associated with higher chlorophyll and increased chloroplast activity and thus increased photosynthetic productivity (Fathi 2022). Organic matter granules play a role in the formation of soil aggregates (soil structure-forming granulators) which cause the soil structure to be stable, loose, easy to cultivate, and have sufficient pores for soil water and air content. Loose soil structure encourages good root growth, so it also has a positive effect on the growth of plant shoots. In addition, organic matter is a source of nutrition for plants, providing straw decayed product markedly increased pH, available-P, CEC, and decreased Al-exc in Ultisols (Pan et al., 2021).

The combination of the organic fertilizer with the frequency of the water application influences the diameter of sorghum stems. The application of organic fertilizer 5.0 t ha^{-1} combined with the frequency of watering 5 times obtained the highest stem diameter at the plant growth phase (Fig. 1). Stem diameter is related to the enlargement of cells that require carbohydrates and other nutrients. One of the advantages of a larger stem diameter is that it can support the plant more strongly, upright, and does not break or collapse easily. Sorghum treated with manure+ fertilizer had an average of 21%-24% respectively wider stems compared to the control and increased other growth parameters (Kazungu et al. 2023). Stem diameter increases over time during the vegetative growth period of sorghum. When entering the generative growth phase, the soil moisture content almost reaches the permanent wilting point, so it decreases the diameter of the stem (Fig. 1).

Table 3. The effect of chicken manure, the total amount of water, and watering frequency to plant growth at vegetative phase (38 DAP)

Treatments	Plant height (cm)	Chlorophyll Amount	Total leaves
Chicken manure Dosage (t ha^{-1})			
0	120.57b	35.68b	8.3b
2.5	138.98a	38.32a	8.9a
5	137.51a	39.42a	9.0a
10	137.93a	38.87a	9.0a
Total of water (mm)			
160	133.65a	37.68a	8.9a
210	134.81a	38.40a	8.8a
260	132.78a	38.14a	8.7a
Watering frequency (times)			
3	131.17b	36.96b	8.7a
5	136.22a	39.28a	9.0a
7	133.84ab	37.98ab	8.7a

Different letters in the same column indicate significant differences according to the DMRT test ($P \leq 0.05$)

Sorghum yield and straw weight

Based on the result of variance analysis showed that the application of organic fertilizer and total amount of water significantly affected the percentage of flowering sorghum plants (Table 7). Application of 2.5-10 t of chicken manure ha^{-1} tends to increase the percentage of flowering at the age of 68 DAP compared to the control (Table 4). Soil moisture conditions affect the flowering time of sorghum, where at age <44 DAP generally was >25% and at > 44 DAP was < 25 % (Fig. 1). Applying water up to 210 mm increased the flowering percentage but water at 260 mm reduced the flowering percentage of sorghum at 66 DAP compared to the control (Table 4). Excess water can cause an extension of the vegetative period, thereby delaying flowering.

The total amount of water given during the sorghum growing season, and the frequency of water application tended to increase the panicle length of sorghum (Table 4). Likewise, applying 2.5 t ha^{-1} manure gave the highest panicle length of 17.16 cm, however, 5 t ha^{-1} reduced the panicle length to almost the same as the control. Furthermore, based on the result of variance analysis showed that providing chicken manure increased the weight of thousands of grains, the percentage of filled grains, the dry weight of straw, and the grain straw ratio (Table 7), but the amount of water only affected the dry weight of the straw (Table 4). The amount of water absorbed by plants affects the weight of the stover because the water absorbed by plants is a medium for the entry of nutrients into plants which are used for their growth.

Samanhudi et al. (2021) reported that applying 20 t ha^{-1} chicken manure increased the stem diameter and dry weight of sweet sorghum stover. This reflects the capture of energy by plants in the process of photosynthesis, where the higher dry stover weight indicates that the photosynthesis process is running well. Based on the results of this study, applying chicken manure 2.5 t ha^{-1} increased straw dry weight by 30% compared to the control, and 10 t ha^{-1} was the highest straw weight (7.42 t ha^{-1}) (Table 4).

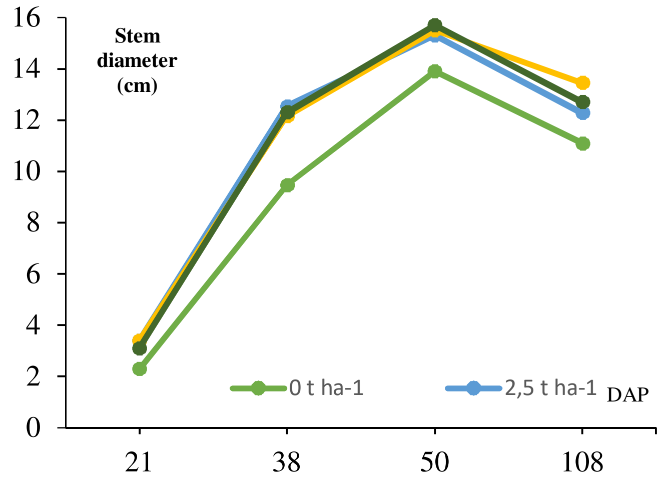

Fig. 1 The effect of chicken manure application to stem diameter of sorghum at several phases of sorghum growth.

Table 4. The effect of chicken manure, total amount of water, and watering frequency on the percentage of flowering and yield components of sorghum

Treatments	Flowering 68 DAP (%)	PPP (%)	PL (cm)	TGW (g)	PFS (%)	SDW (t ha^{-1})	GSR
0	20.4c	61.1a	14.38b	18.11b	96.57a	5.06c	0.23ab
2,5	66.3a	65.2a	17.16a	22.12a	96.12a	6.68b	0.27a
5	24.4bc	48.9b	14.93b	17.49b	97.58a	6.07b	0.21ab
10	30.7b	47.4b	16.76a	17.90b	97.83a	7.42a	0.19b
Total of water (mm)							
160	35.8ab	50.6a	15.54b	18.83a	96.96a	5.61b	0.20a
210	48.1a	56.7a	16.38ab	19.00a	97.10a	6.75a	0.23a
260	29.4b	52.2a	17.00a	18.89a	97.01a	6.56a	0.21a
Watering frequency (times)							
3	34.2a	46.7a	15.27b	21.58a	97.08a	4.86b	0.23a
5	35.8a	55.0a	16.47a	17.88b	97.21a	6.71a	0.20a
7	33.3a	57.8a	17.19a	17.26b	96.78a	7.36a	0.22a

DAP=Day after planting; PPP= Percent of plant that have panicle; PL= Panicle length; TGW= Thousand grain weight; PFS= Percent of filled spikelet's; SDW= Straw dry weight; GSR= Grain straw ratio

Different letters in the same column indicate significant differences according to the DMRT test ($P \leq 0.05$)

The treatment combination of 2.5 t of chicken manure ha^{-1}, with the addition of 210 mm per phase and 5 times watering frequency was the highest grain-straw ratio (Table 4). Similar result, we found that the highest sorghum grain yield was also obtained from the combination of 2.5 t/ha of chicken manure and 260 mm of water (2.21 t/ha) which was not significantly different from the combination of 2.5 t ha and 210 mm of water (2.03 t/ha) (Fig. 2). Sekou et al. (2020) reported that sorghum yield was influenced by plant density and nitrogen application with average grain-straw ratios in 2018 and 2019, 0.32 and 0.21 respectively. The average sorghum yield from 2016-2018 was 5.24 t/ha with an average grain straw ratio of 0.25 (Baranovskiy et al., 2020). The provision of chicken manure contributes to nutrient elements that encourage an increase in grain weight. Meanwhile, providing 160 mm of water per phase proved to be insufficient to meet sorghum needs. Lack of water causes photosynthetic activities to be disrupted and causes low assimilation produced (Yang and Luo, 2021). Assimilation is the energy used by plants for the process of cell division, multiplication, and elongation which is manifested in the form of an increase in the size, weight, and volume of the plant.

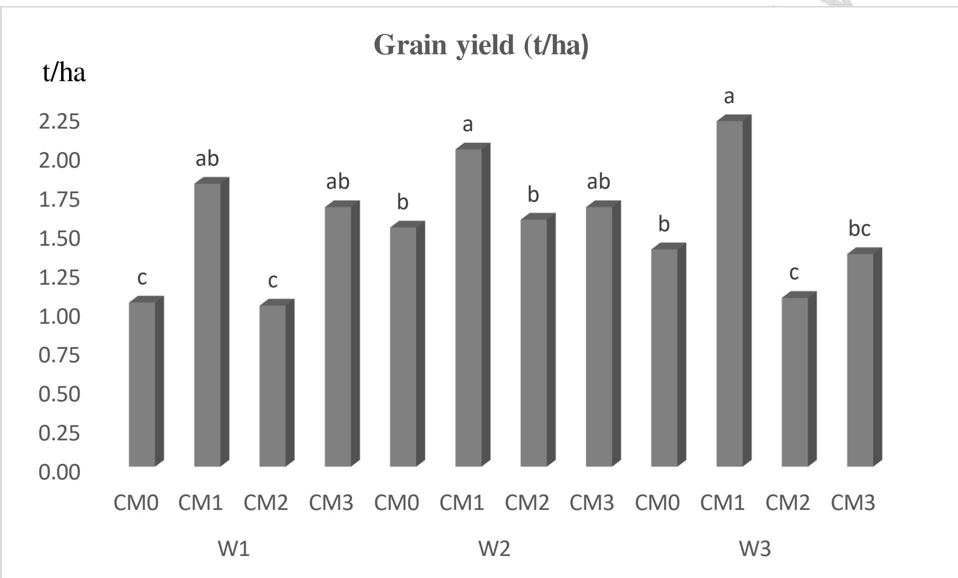

Fig. 2 The effect of several doses of chicken manure and the amount of water on the grain yield of sorghum (CM: chicken manure 0: 0 t ha^{-1}; 1: 2.5 t ha^{-1}; 2: 5 t ha^{-1}; 3: 10 t ha^{-1}; W: Amount of water 1: 160 mm, 2: 210 mm, 3: 260 mm). Different letters in the above bar indicate significant differences according to the DMRT test (P≤0.05)

Biophysiochemical of soil

The soil moisture content at the initial growth stage is >25% but entering the final vegetative or early generative stage (59 DAP), the soil water content decreases to <25% (Fig. 3). The soil moisture continued to decrease as the sorghum plants grew to harvest, even reaching a permanent wilting point because plants absorb more water. During the active vegetative process up to seed filling, plants need sufficient water, because of the vital role of water in the process of opening and closing the stomata on the leaves during photosynthesis. So, the lack of water in this phase causes turgidity to narrow and photosynthesis to be disrupted.

The results showed that the providing chicken manure significantly increased soil moisture in the early growth phase (at 18, 44, and 59 DAP) (Table 8 and Fig. 3). Organic matter granules play a role in the formation of soil aggregates (soil structure-forming granulators), which cause the soil structure to be stable, loose, easy to cultivate, and have sufficient pores for soil water and air content. The application of organic matter to the soil plays a role in maintaining soil water levels, especially during dry periods and during critical phases of water requirements for plants (Barus et al., 2023).

The amount of water treatment significantly increased soil moisture at control (without chicken manure) and applying chicken manure 2.5 t ha^{-1} (Table 5). However, increasing the amount of water and the dose of manure did not increase soil moisture and water content. Soil treated with chicken manure is better given the least amount of water (160 mm). Physically, the function of organic matter is to bind soil particles so that they are better able to bind water to make it available to plants. Based on soil moisture content, the amount of water >160 mm per phase should be given more frequently (5-7 times) (Fig. 3). This is related to the high percentage of sand (59%) in soil texture as shown in Table 1. Soil has different characteristics in holding water and nutrients as well as resistance to root penetration. Sandy soil texture will quickly through water so that much of the water will not be bound by soil grains. Besides that, daily water requirements for sorghum growth vary at each growth stage, depending on the growing period, mainly due to variations in crop canopy and climatic conditions. Early in the growing season, average daily water use is low; then the water requirement is low until the boot stage and maximum daily water use occur from the boot stage until after anthesis (Assefa et al., 2010). For sorghum, the water requirement at mid-season (> 30 days) was 180 mm, while for the seasonal total (110 days) was 428.4 mm (Kokilavani et al., 2018).

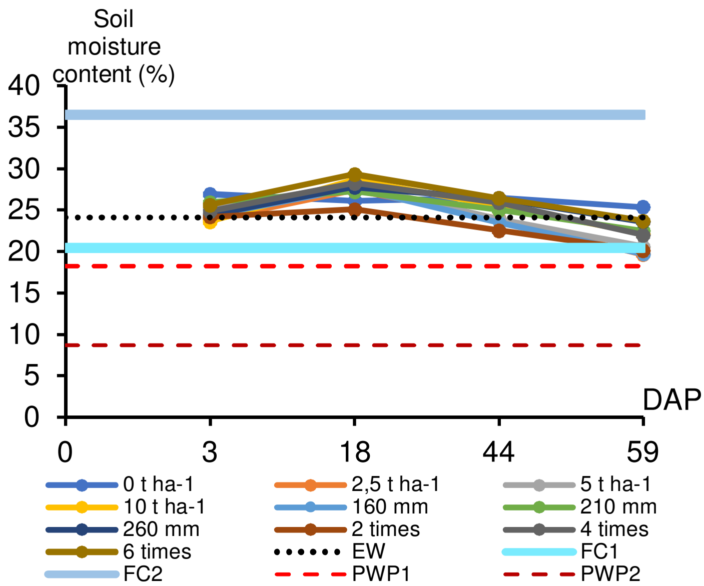

Fig. 3 The effect of chicken manure, the total amount of water and watering frequency to soil moisture content at several phase of sorghum

Tabel 5. Soil water content after organic matter and water application at 44 DAP.

Amount of water (mm)	Manure (t ha^{-1}) 0	2.5	5	10
160	25.04b	26.78b	27.47ab	25.24b
210	25.29b	26.38b	29.41 a	27.91a
260	28.00a	29.07a	27.26ab	26.77ab

Different letters in the same column indicate significant differences according to the DMRT test (P ≤ 0.05)

Soil pH increased to slightly acidic (5.4-5.8) by adding 2.5-10 t of chicken manure ha^{-1} (Table 6). However, total water and watering frequency insignificantly affect soil pH (Table 8). Based on the soil pH values in Table 5, they are generally above 5.5, so they are not an obstacle to sorghum growth. As reported by Elaalem (2012) sorghum grows well in soils with pH between 5.5 and 6.5.

The application of chicken manure significantly increases soil organic carbon (SOC), available P, and the total of microbes' P solvents (Table 8). Providing 10 t ha^{-1} manure increased SOC from 1.74 to 5.59 % and increased P-available from 8.08 to 19.37 mg kg^{-1}. Increasing soil C-organic levels correlates with the chicken manure used in this study containing high organic-C (> 15%). Similarly, it was reported that soil organic carbon has a positive correlation with fertilizer applied as manure (Ku'smiers et al., 2023; Traore et al., 2016).

An increase in P-availability also occurred before the research, 8.27 (Table 1) to the highest P availability is 19.37 mg kg^{-1} (Table 6). This increase was due to the chicken manure applied in this study containing high levels of P (2.55% P_2O_5). While using chicken manure containing 0.46% P and its application to the soil at 5 t ha^{-1} increased P-available from 7.45 to 8.02 mg kg^{-1} (Verde et al., 2013). Besides that, compost as an organic soil amendment can increase soil pH, which is beneficial for acidic soil. This is because, in acidic soils, Fe and Al can reduce the availability of P in the soil either as free cations in the soil solution, or as exchangeable cations that occupy the location of soil colloids, or as colloids the size of clay mineral oxides that absorb P (Antoniadis et al., 2015; Ifansyah 2013). Furthermore, a significant correlation was found between the P availability and soil properties related to Fe and Al content, organic matter, and microbial biomass (Bueis et al., 2019). Providing several sources of organic matter markedly increased nitrogen availability and sorghum production (Soma et al., 2018).

The application of chicken manure also significantly increases the number of microbial P solvents. Providing 10 t/ha increased the number of P-solvent microbes more than four times compared to the control (Table 6). Several studies reported that the structure of the soil microbial community (composition, diversity, and relative abundance of specific taxa) changes after adding organic fertilizer to soil (Ashworth et al., 2017). Many studies conclude that organic fertilizer increases the content of organic matter and micronutrients in the soil, improves soil structure, and promotes a higher number and diversity of microbes in the soil.

Statistically, the interaction effect of the three factors (chicken manure, amount of water, and watering frequency) have insignificant influence on the development and yield of sorghum, however, individually, the factors of chicken manure and the amount of water have an effect, especially at the beginning of growth, and on the characteristics of soil properties observed (Table 7 and 8).

The results also show that sorghum is efficient in using water and does not require large amounts of water. It is suitable for planting in dry areas (low rainfall). Chicken manure, apart from being a source of nutrients for plants, increases soil organic matter, and soil moisture, and acts as a binder for soil particles, especially in soil that has a lot of sand.

Table 6. The effect of chicken manure, the total amount of water, and watering frequency to pH, soil organic carbon (SOC), Available-P, and a total of microbes of P solvent

Treatments	pH	SOC (%)	Available-P (mg kg^{-1})	Total of microbes P solvent (cfu g^{-1})
Chicken manure Dosage (t ha^{-1})				
0	5.1b	1.74c	8.08d	6.48 x10^{3}c
2.5	5.4ab	3.99b	13.49c	18.85 x10^{3}abc
5	5.6a	4.91b	15.84b	21.96 x10^{3}ab
10	5.8a	5.59a	19.37a	28.78 x10^{3}a
Total of water (mm)				
160	5.4a	4.00a	12.33b	13.67 x10^{3}b
210	5.4a	4.13a	13.08a	20.26 x10^{3}a
260	5.6a	4.04a	13.21a	13.37 x10^{3}b
Watering frequency (times)				
3	5.5a	3.88a	11.88c	10.64 x10^{3}c
5	5.4a	4.28a	15.26a	24.83 x10^{3}a
7	5.6a	4.01a	15.39a	21.58 x10^{3}b

Different letters in the same column indicate significant differences according to the DMRT test ($P \leq 0.05$)

Table 7. The ANOVA table for flowering time, thousand-grain weight (TGW), straw dry weight (SDW), and grain straw ratio (GSR) were influenced by chicken manure and the total amount of water application.

Dependent variables	Flowering		TGW		SDW		GSR	
	F value	MS	F value	MS	F value	MS	F value	MS
Chicken manure (CM)	8.14**	0.9	2.00^{ns}	0.9	6.38**	98.0	5.52**	0.02
Total amount of water (T)	1.36^{ns}	0.0	0.05^{ns}	0.0	3.64*	55.9	1.24^{ns}	0.00
CM x T	0.91^{ns}	0.5	1.12^{ns}	0.5	0.37^{ns}	5.7	1.28^{ns}	0.00
Watering frequency (W)	0.63^{ns}	1.5	3.28*	1.5	17.16**	263.5	0.78^{ns}	0.00
CM x W	0.59^{ns}	0.6	1.27^{ns}	0.6	2.19^{ns}	33.7	1.27^{ns}	0.00
T x W	1.01^{ns}	0.4	0.98^{ns}	0.4	2.00^{ns}	30.7	0.74^{ns}	0.00
CM x T x W	0.98^{ns}	0.2	0.41^{ns}	0.2	0.80^{ns}	12.3	1.61^{ns}	0.00

*Significant difference at 0.05, ** Significant difference at 0.01 probability levels, ns: not significant

Conclusion

Providing chicken manure has a positive effect on plant growth and yield components of sorghum. However, the interaction of chicken manure, total water, and watering frequency, in general, was not significant in sorghum growth. The interaction of chicken manure and total water significantly increased soil moisture at 18 and 44 DAP (Day after planting).

The application of chicken manure increases pH, soil organic carbon (SOC), P-available, and the total number of microbes P solvents in the soil.

Based on the results of this research, a combination of 2.5 t ha^{-1} of chicken manure and 210 mm of water is sufficient to increase sorghum growth and yield (increased grain weight by about 33% compared to the control). However, for soil chemical properties (pH, soil organic carbon, available-P, and total of microbes), the highest dose of chicken manure (10 t ha^{-1}) is better than the lower dose.

Table 8. ANOVA table for soil moisture content, pH, soil organic carbon (SOC), and P-available of soil as influenced by chicken manure and the total amount of water.

Dependent variables	Soil moisture content								pH		SOC		P-Available	
	3 DAP		18 DAP		44 DAP		59 DAP							
	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value
CM	0.5	1.00^{ns}	31.7	2.81*	42.7	3.39*	2.2	9.54**	2.3	26.24**	5.1	97.06**	61391	86.13**
T	0.2	0.42^{ns}	2.7	0.24^{ns}	72.4	5.75**	1.7	7.34**	0.3	2.91^{ns}	0.01	0.12^{ns}	1090	1.53^{ns}
CM x T	0.2	0.39^{ns}	34.0	3.01*	5.4	3.43*	0.2	0.83^{ns}	0.1	1.32^{ns}	0.05	0.94^{ns}	286	0.40^{ns}
W	0.1	0.24^{ns}	174.8	15.46**	159.4	12.65**	1.3	5.63**	0.2	2.68^{ns}	0.08	1.48^{ns}	14252	19.99**
CM x W	0.4	0.85^{ns}	11.8	1.04^{ns}	2.8	0.22^{ns}	0.1	0.44^{ns}	0.1	1.18^{ns}	0.01	0.28^{ns}	7139	10.02**
T x W	0.2	0.33^{ns}	11.9	1.05^{ns}	19.7	1.57^{ns}	0.2	1.05^{ns}	0.1	1.60^{ns}	0.07	1.39^{ns}	469.7	0.66^{ns}
CMxTxW	0.8	1.57^{ns}	8.8	0.78^{ns}	5.1	0.41^{ns}	0.1	0.54^{ns}	0.1	1.1^{ns}	0.02	0.49^{ns}	894.1	1.25^{ns}

*Significant difference at 0.05, ** Significant difference at 0.01 probability levels, ns: not significant

CM: chicken manure; T: Total amount of water; W: Watering frequency

Author contributions: Conceptualization: S.S.G, J.B.; Methodology: S.S.G., J.B., A.Sp., A.St, D.R.S., J.M.L.T.; Data collection: S.S.G., A.Sb., A.St., E.S.U., D.R.S., V.A., T.I., J., S., J.M.L.T., D.S.L.; Formal analysis: J.B., A.Sp., A.Sb., S.S.G.; Validation and Writing-original draft: S.S.G., J.B., A.Sp., A.Sb.; Writing-review & editing: S.S.G., J.B., A.Sp., A.Sb., E.S.U., D.R.S., V.A., Ms., Jh.; Supervision: S.S.G; Funding acquisition: S.S.G., J.B., A.Sp., A.Sb., A.St., E.S.U., D.R.S., V.A., Ms., J.M.L.T., D.S.L., Jh. All co-authors reviewed the final version and approved the manuscript before submission.

Acknowledgments: The research was supported by the National Research and Innovation Agency in 2022 Number B-3973/III.11/HK.01.00/10/2022. The authors thank the Faculty of Agriculture, University of North Sumatra for the land and laboratory facilities.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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