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Effect of Liquid Organic Fertilizer from Chicken, Goat, and Cow Manure on the Content of Nitrogen, Phosphorus, Potassium, and Lead in Soil, and on Stem and Fruit Yield of Tomato

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ABSTRACT
Using manure in the form of liquid organic fertilizer (LOF) influences the heavy metal levels absorbed by plants, which can affect both plant quality and human health. This research aims to assess the impact of LOF on soil pH, total nitrogen, available phosphorus, lead levels, and the fruit yield of tomatoes. A factorial completely randomized design (CRD) was employed, with the first factor being three types of LOF from chicken, goat, and cow manure and the second factor being three doses of LOF: 5, 10, and 15 mL. The study utilized tomato plants grown in latosol soil. Results indicated that the application of LOF from the three manure types affected soil nitrogen, soil lead, and tomato yield. The addition of LOF also influenced lead content and tomato production. However, the use of chicken manure is not recommended due to high lead accumulation in soil and plants. The optimal LOF dose was found to be 5-10 mL, which maintained lead levels within safe limits. The best tomato fruit yield was achieved with 5 mL of goat manure LOF, resulting in low metal accumulation.

Keywords: Chicken manure; Cow manure; Goat manure; Metal accumulation; Nutrient quality

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INTRODUCTION
Liquid organic fertilizer (LOF) is an essential component in modern agriculture (Wijaya et al. 2017). Manure from livestock, including chickens, goats, and cows, can be a source of LOF, with its nutritional content depending on the type of feed used. According to Kalbani et al. (2016), chicken manure significantly enhances both the fresh and dry weight of tomato leaves. Combining organic and inorganic fertilizers in LOF can improve leaf nutrition, growth, yield, and mineral content, ultimately enhancing tomato quality (Ali et al. 2019; Adekiya et al. 2022). Nitrogen (N) promotes leaf development, while phosphorus (P) supports root growth, energy transport, flowering, and shoot development (Meylia and Koesriharti 2018) and is also involved in respiration and photosynthesis (Hapsari and Welasih 2013). Low levels of phosphorus and potassium can lead to reduced fruit formation (Yunita et al. 2016). However, manure can also contain heavy metals that may hinder plant growth and development, with continuous use raising soil concentrations of cadmium (Cd), zinc (Zn), chromium (Cr), and copper (Cu) (Zhen et al. 2020). Thus, manure application can negatively impact plant growth (Sukarjo et al. 2018).

The heavy metal content in chicken, goat, and cow manure ranges from 0.42-1.18 ppm, 1.18 ppm, and 0.96-38.69 ppm, respectively. Oktavia et al. (2016), Trivana and Pradhana (2017) and Li et al. (2021) found that applying manure increases lead (Pb) availability by 14%. Specifically, LOF from chicken and goat manure contains 1.75 ppm and 1.5 ppm of Pb, respectively (Zuhro et al. 2019; Annisa et al. 2022). The maximum permissible lead level in LOF is set at five ppm (MARI 2019). Lead accumulation in plants can alter their morphology, affecting height, root length, leaf area, and dry weight (Pratama et al. 2013). Different plant species exhibit varied responses to metal ions such as Pb(II) and Cu(II) in contaminated environments (Pratama et al. 2013).

Soil metal content greatly impacts the metal levels in plants (Vasilachi et al. 2023). Roots are the first to encounter Pb ions (Vasilachi et al. 2023). Studies show that 93-98% of total Pb absorbed by plants is stored in the roots (Afzal et al. 2023). Pb can then be transported to other plant parts, including leaves and fruit, via the xylem (Collin et al. 2022). For instance, zucchini roots can absorb metals and transfer them to the shoots (Eissa 2019). Pb pollution can diminish the quality of agricultural produce and pose health risks to consumers (Sanra et

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al. 2015). This research aims to assess the impact of LOF derived from cow, goat, and chicken manure on soil pH, electrical conductivity, nutrient levels, and Pb status. This study is crucial, given the rising use of manure as LOF and the public's direct consumption of tomatoes.

MATERIALS AND METHODS

Study site

The research took place from April to August 2020 in Sambirejo Village, Jogorotato District, Jombang Regency. The location of the research is at coordinates 5° 20'02" to 5° 30'01" East Longitude and 7° 45'01" South Latitude. Jogoroto District is part of the Central Jombang area, which is south of the Brantas River, and most of it is agricultural land suitable for rice and secondary crops because the irrigation is quite good. The area of yard land is higher than the rice and dry fields, so developing yard cultivation for vegetables is one alternative to increase production.

Materials and Methods

This study employed a randomized complete block design featuring three types of liquid organic fertilizer (LOF) derived from chicken, goat, and cow manure. Each type of LOF was tested at four different doses: 0 (control), 5 $mL.L^{-1}$ water, 10 $mL.L^{-1}$ water, and 15 $mL.L^{-1}$ water, with three repetitions for each treatment, resulting in a total of 36 experimental pots.

The LOF was created using manure from chickens, goats, and cows sourced from local farms. The livestock were fed differently: goats were given grass, cows were fed grass and tofu dregs, and chickens received commercial chicken feed. The LOF preparation method was adapted from Pancapalaga's (Pancapalaga 2011). For each type of manure, 5 kg was placed into a 25-liter fermentation tank. Additional ingredients included 5 L of coconut water, liquid from rice washing, 1 L of molasses, and EM4. All components were mixed thoroughly and covered with plastic for 14 days to allow for fermentation.

The soil samples used for the study included grayish regosol with sandy clay until it had a silty clay texture. Soil samples were collected from the top 0–20 cm of the yard soil, which was then sifted through a 2 mm sieve. Ten kilograms of the prepared soil was placed into polybags measuring 40 cm x 40 cm. A base fertilizer of NPK was applied at a rate of 400 $kg.ha^{-1}$, equivalent to 2 g per plant, before planting. The LOF treatments were administered weekly according to the specified doses. Bamboo stakes were installed to support the tomato plants. Maintenance included manual pest and disease control and weed management. Tomatoes were harvested when the plants reached 72 days after planting (DAP), with harvesting occurring three times daily.

Soil and LOF analyses

The analysis of the LOF and soil included both chemical and physical parameters. The chemical parameters measured were pH, nitrogen, phosphorus, potassium, heavy metals (Pb and Cu), and soil organic matter. The physical parameters assessed included texture, permeability, bulk density, and particle density. Details of the methods used are summarized in Table 1. Soil and LOF analysis methods use standard methods.

Plant analyses

The levels of phosphorus (P), nitrogen (N), and lead (Pb) in plants are measured using the wet oxidation method, with quantification done via atomic absorption spectrometry (AAS) (Eviati et al. 2023). For Pb analysis, tomato leaves and fruits are dried at approximately 70 ºC until a constant weight is achieved, then ground to a fine powder and sieved through a 0.5 mm mesh. Nutrient content in plant tissue is assessed using wet extraction with a mixture of H_2SO_4 and HNO_3.

Data Analysis

The data obtained from the application of LOF on soil and plants were analyzed using SPSS version 22. This included descriptive statistics and one-way ANOVA for mean comparison, followed by Duncan's post-hoc test at the 5% significance level, along with regression and correlation analyses.

Table 1. Methods used for the measurement of LOF and soil content

Variables	Methods	Variables	Methods
Soil pH	Potentiometric	Texture	Pipet
CEC ($cmol.kg^{-1}$)	NH4Oac 1 N	Permeability ($cm.hour^{-1}$)	*Hydraulic conductivity*
Soil organic-C (%)	Walkey and Black	Volume density ($g.cm^{-3}$)	Gravimetric
Soil total-N (%)	Micro Kjeldahl	Particle density ($g.cm^{-3}$)	Gravimetric
Soil Available-P	Bray-1		
Base saturation (%)	Exch-cation/ CEC		
Heavy metals (Pb and Cu)	mixed extraction method of HNO_3 and $HClO_4$		

RESULTS AND DISCUSSIONS

Soil and LOF characteristic

The soil measurements from this study are detailed in Table 2. The soil sampled from Ngrimbi Village is classified as latosol, characterized by a reddish-brown color and a dusty clay texture. Its fertility is relatively low in both chemical and physical properties. Typically, low soil pH levels are associated with high exchangeable aluminum and iron, which can bind essential plant nutrients like $H_2PO_4^-$ and NO_3^-, resulting in reduced nitrogen and phosphorus availability. Additionally, the soil's relatively low cation exchange capacity (CEC) diminishes its ability to retain cations such as calcium, magnesium, and potassium, making it more susceptible to leaching. This low CEC is further attributed to a low organic carbon content in the soil. Consequently, the low levels of CEC, pH, and organic carbon correlate with insufficient availability of nitrogen, phosphorus, and other nutrients. Therefore, the condition of this soil is unlikely to impact the treatments applied in the study.

Before application to plants, the liquid organic fertilizer (LOF) was analyzed for nitrogen (N), phosphorus (P), potassium (K), and lead (Pb) content, with results presented in Table 3. The LOF derived from different types of livestock manure displayed varying nutrient levels. Notably, the N content was the highest among the macronutrients, with chicken manure LOF exhibiting the greatest N content, while cow manure had the highest P content, and goat manure contained the most K. Pb levels were found to be higher in chicken and cow manure LOF (0.06 ppm) compared to goat manure LOF (0.05 ppm). These variations in nutrient content are likely influenced by the types of feed provided to the animals. Chicken manure has a higher N content due to the high-protein concentrate feed given to chickens, while cow and goat manure are richer in P and K due to their diets consisting mainly of hay, grass, and green leaves.

Effect of LOF on Pb accumulation

The analysis of the effects of liquid organic fertilizer (LOF) on tomato plants revealed significant impacts on several parameters, including nitrogen (N) levels in the soil, lead (Pb) levels in the soil, and Pb accumulation in tomatoes (Table 3). Results for N levels after applying various livestock manures are shown in Figure 1. The optimum dose for chicken manure LOF is 5 mL, with higher doses inversely affecting N content in the soil. For goat and cow manure, the optimal LOF dose is 10 mL, as increasing the dose beyond this does not benefit N levels and can even reduce them, particularly with 15 mL of cow manure. Pb accumulation in the soil increased with higher LOF doses (Figure 2), and a 5-10 mL dose was found to be safe, with 10 mL resulting in the lowest Pb accumulation. The analysis indicated a strong correlation between LOF and soil N and Pb levels in tomatoes, but no correlation was found with pH, electrical conductivity (EC), or available phosphorus (P) (Table 4). Additionally, soil pH correlated with soil N, suggesting that increased N can lead to higher acidity due to H^+ release from NH_4. Careful consideration of LOF dosage is essential to achieve desired outcomes without negatively impacting plants or soil health.

Table 2. Chemical and physical properties of soil

Chemical Properties			Physical Properties		
Kind of Analysis	Value	Criteria	Kind of Analysis	Value	Criteria
Soil pH	5.26	Acid	Texture		
CEC (cmol.kg^{-1})	19.73	Low	% Clay	34.72	Silty Clay
Soil organic-C (%)	0.92	Low	% Silt	51.97	
Soil total-N (%)	0.25	Very low	% Sand	13.31	
Soil Available-P	12.20	Low	Permeability (cm.hour^{-1})	8.23	Rather quickly
Base saturation (%)	29.07	Low	Volume density (g.cm^{-3})	1.21	
			Particle density (g.cm^{-3})	2.57	

Table 3. Content of Nitrogen (N), Phosphorus (P), Potassium (K), and Lead (Pb) in Liquid Organic Fertilizer from Chicken, Goat, and Cow Manures

Type of Manure	Total-N (%)	Total-P (%)	Total-K (%)	Pb (ppm)
Chicken	1.61	0.80	0.35	0.06
Goat	1.31	0.65	0.52	0.05
Cow	1.47	0.96	0.45	0.06

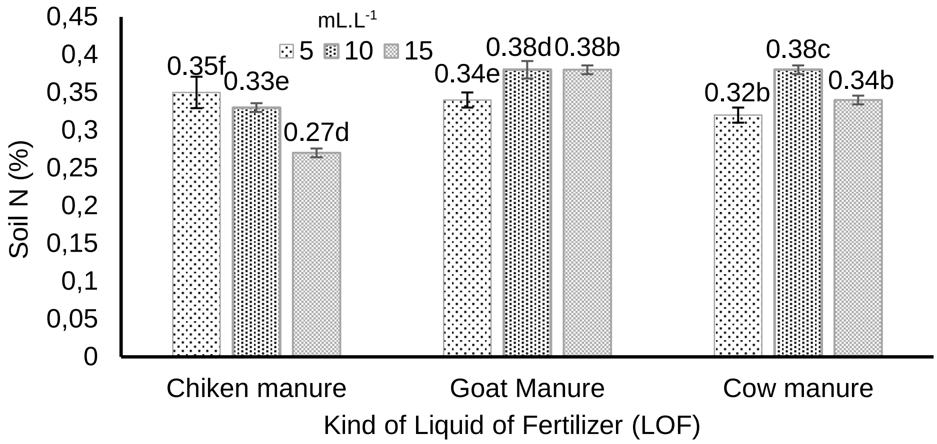
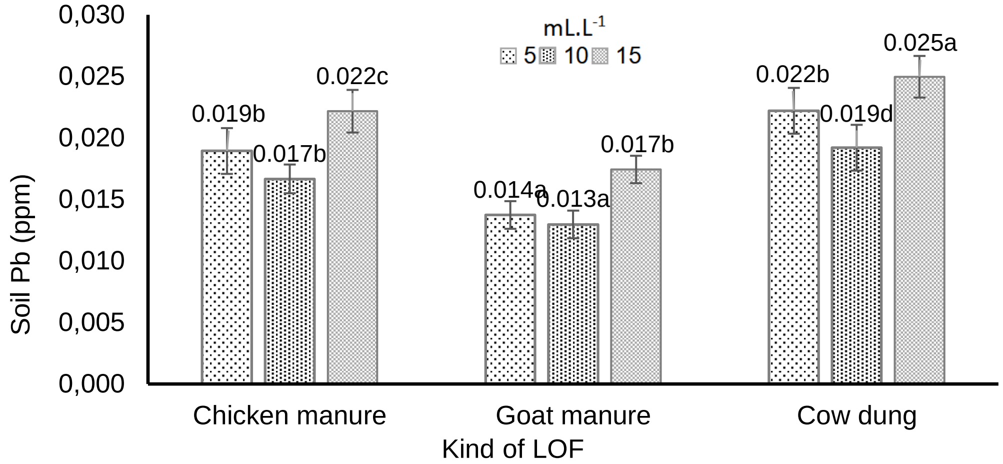


Figure 1. Effect of liquid organic fertilizer dosages from chicken, goat, and cow manure on soil nitrogen (N)



Remarks: the averages accompanied by the same letter are not significantly different at the 5% level

Figure 2. Effect of liquid organic fertilizer dosages from chicken, goat, and cow manure on soil lead (Pb)

Table 4. Analysis of variance (ANOVA) soil properties and plant component

Soil Properties	Sum of Squares	Mean Square	*F*	Sig.
pH in H_2O	0.84	0.094	3.48	0.01
EC ($mS.cm^{-1}$)	69547.30	7727.478	0.29	0.97
Total-N (%)	0.08	.009	**293.44****	0.00
Available P (ppm)	270.14	30.016	0.61	0.78
Soil Pb (ppm)	0.00	.000	**21.89****	0.00
Stem N (%)	29.35	3.261	2.011	0.09
Stem P (%)	0.21	.024	0.76	0.65
Tomato Pb (%)	0.001	.000	**609.84****	0.00
Tomato weight (g per plant)	27775.04	3086.115	0.49	0.87

Remarks: ** = very significant ($p \leq 0.01$)

The accumulation of lead (Pb) in the soil is directly related to the Pb content in the liquid organic fertilizer (LOF), with levels from cow manure, chicken, and goat manure being 0.045, 0.056, and 0.061 ppm, respectively. These levels remain within safe limits for soil health. In tomatoes, Pb content is significantly lower than in the soil, largely influenced by the roots' ability to extract metals and the soil's capacity to release Pb. Tomato roots are less efficient at absorbing heavy metals compared to plants used for phytoremediation, making tomatoes safe for consumers when grown in treated substrates. Sukarjo et al. (2018) noted that using only inorganic fertilizers leads to Pb accumulation in the soil and subsequent uptake by plants.

The use of livestock manure fertilizers affects metal deposition in the soil and, if absorbed by plants, could pose health risks to consumers. Soil pH, nitrogen (N), and Pb levels, along with Pb in fruit, were significantly influenced by LOF. The pH increased by about 0.56 units after LOF application, with chicken manure contributing the most to this increase, likely due to its ingredients and the calcium and phosphorus in chicken feed. Although soil phosphorus (P) levels rose with LOF application, the increase was not significant (Table 5). Pb levels in LOF-treated soil remained below the safe limit of 10 $mg.kg^{-1}$ (Sanra et al. 2015).

Organic fertilizer notably enhanced the levels of N, P, K, calcium (Ca), magnesium (Mg), vitamin C, lycopene, and total soluble solids. A combination of organic and NPK fertilizers yielded better results than organic fertilizers alone (Ali et al. 2019). Soil N content increased with higher doses of organic liquid fertilizer, rising from about 0.07% to 0.019% by the end of planting, indicating plants utilized approximately 0.051%. Soil N content increases in line with increasing doses of organic liquid fertilizer, around 0.07%, and at the end of planting, it becomes 0.019%, which means plants use around 0.051 %. Adekiya et al. (2022) found that LOF from both organic and inorganic sources improved growth, yield, and nutrient concentration in tomatoes and cucumbers, especially in soilless media like coco peat and rice husk. Kalbani et al. (2016) found that the chicken manure had a significant effect on plant height and root length, leaf area of sun cherry, root fresh and dry weight, and Lelord, leaves fresh and dry weight of tomato.

Doses of 5-10 mL were found safe for Pb levels in tomatoes. Mahendra et al. (2016) noted that bioavailable lead (Pb) and cadmium (Cd) levels in soils pose health concerns. The combination of rice straw waste with manure or NPK increased soil Pb^{2+}, Cd^{2+}, and Cu^{2+} levels (Hindarwati et al. 2023). Notably, Pb accumulation in tomatoes was higher following cow manure application (Table 5).

The liquid organic fertilizer (LOF) derived from manure showed a strong correlation with soil nitrogen (N) and lead (Pb) levels in tomatoes, but no correlation was found with soil pH (Table 6). The application of LOF significantly enhances soil nitrogen availability, indicating a notable increase in nitrogen levels. Among the parameters assessed, the strongest correlations were observed between soil nitrogen and tomato Pb, as well as between stem phosphorus (P) and fruit weight. The availability of nitrogen in the soil has a considerable impact on the uptake of other nutrients.

Impact of LOF livestock on plants

The application of liquid organic fertilizer (LOF) from manure did not significantly affect lead (Pb) accumulation in tomato fruit. Pb recovery in fruit is primarily due to its presence in the soil, which is absorbed by the roots—the first organs exposed to Pb ions (Fahr et al. 2013).

Table 5. Effect of liquid organic fertilizer from chicken, goat, and cow manure on soil pH, stem nitrogen, and stem lead content of tomato

LOF per polybag		Soil	Plants	
Manure	**$mL.L^{-1}$**	**pH**	**Stem Pb (ppm)**	**Stem N (%)**
Chicken	**5**	5.63±0.05 c	0.002±0.0001 ab	6.39±1.63 ab
Chicken	**10**	5.23±0.01 ab	0.002±0.0003 ab	6.48±2.28 ab
Chicken	**15**	5.27±0.01 ab	0.003±0.0003 cd	4.31±0.41 a
Goat	**5**	5.44±0.02 bc	0.002±0.0001 ab	5.90±1.07 ab
Goat	**10**	5.11±0.05 a	0.001±0.0002 a	4.99±0.43 ab
Goat	**15**	5.15±0.06 ab	0.002±0.0004 ab	6.03±1.38 ab
Cow	**5**	5.07±0.03 a	0.003±0.0005 d	6.98±1.06 ab
Cow	**10**	5.44±0.06 bc	0.002±0.0003 bcd	7.08±1.69 b
Cow	**15**	5.33±0.00 ab	0.003±0.0002 d	4.43±0.39 a
Control		5.12±0.10 ab	0.019±0.0006 e	4.70±0.90 ab
LSD		0.017	0.001	0.55

Remarks: the averages accompanied by the same letter are not significantly different at the 5% level

Table 6. Correlation matrix of chemical properties of liquid organic fertilizer with soil and stem chemical properties of tomato and fruit yield

	Soil pH	Soil EC (mS.cm-1)	Soil N (%)	Soil P (%)	Soil Pb (ppm)	Steam P (%)	Tomato Pb (%)	Fruit weight per plant (g.)
LOF-Manure	-0.256	-0.036	**-0.908****	-0.261	0.124	0.002	**0.567****	0.079
Soil pH	1	0.025	0.165	-0.017	0.268	0.006	**-0.513****	0.302
Soil EC (mS.cm^{-1})		1	0.050	0.072	0.062	-0.245	-0.253	0.034
Soil N (%)			1	0.291	-0.271	0.000	**-0.461***	-0.118
Soil P (%)				1	0.036	-0.008	-0.184	-0.181
Soil Pb (ppm)					1	0.087	-0.268	0.182
Steam P (%)						1	0.112	**0.390***
Tomato Pb (%)							1	-0.080

In various plant species, including those in the Brassicae and *Zea mays* families, nearly 90% of Pb accumulates in the roots (Bortoloti and Baron 2022). A similar trend is observed in zucchini, where roots absorb more metals and transfer less to the shoots (Eissa 2019), with roots storing. 93-98% of the total Pb is absorbed by intact plants (Afzal et al. 2023).

Measuring Pb content in fruit is crucial since it is the part consumed. Pb accumulation in tomatoes is strongly linked to soil Pb levels, as noted by Vasilachi et al. (2023) who emphasized that soil metal content significantly influences plant metal content. Additionally, several factors, including soil chemistry, metal types, pH, and plant sensitivity, affect Pb accumulation in fruit. Pb uptake in plant cells and tissues can also spread to other organs through the xylem to leaves and fruit (Collin et al. 2022).

Figure 2 indicates that the control treatment resulted in the lowest lead (Pb) accumulation in tomatoes, contrasting with Sukarjo et al. (2018), who found that inorganic fertilizers lead to higher Pb absorption by plants, while organic fertilizers accumulate Pb in the soil. This suggests that the treatment does not significantly affect Pb levels in fruit, as other factors related to soil and cultivation location play a role. After applying cow LOF, Pb accumulation was high due to the greater Pb content in cow manure compared to other livestock. However, the increase in LOF concentration does not directly correlate with higher Pb levels in the fruit, as Pb absorption is influenced by factors beyond just LOF concentration. Hayati (2010), noted that the accumulation of heavy metals also depends on the plant's physiological status, including age, type, and soil conditions.

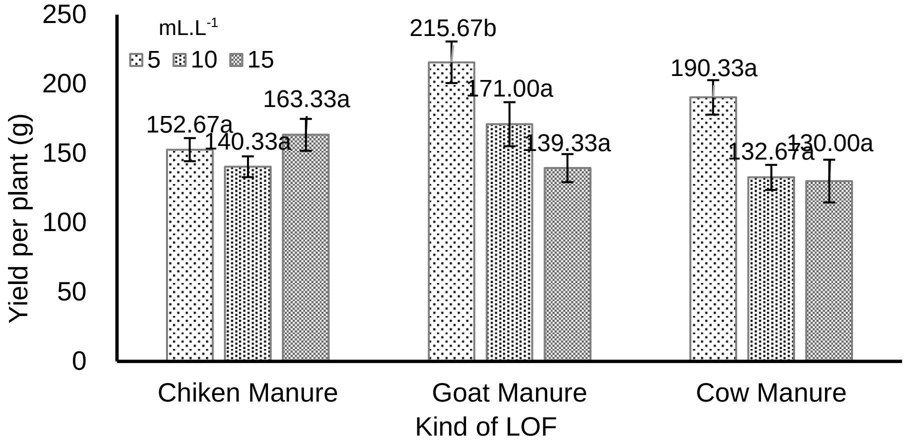
As shown in Table 1, the application of LOF from 5 to 15 mL.L^{-1} still resulted in safe Pb levels, remaining below the Indonesian National Standard limit of 0.5 mg.kg^{-1} for lead contamination in tomatoes. There is a relationship between Pb levels in fertilizer, soil, and plants (Table 2). Interestingly, the highest fruit weight observed in the cow LOF treatment at 15 mL.L^{-1} was inversely related to yield, suggesting that nutrient levels in the soil and plants still support growth. The Pb content in both soil and tomatoes increased with higher LOF doses, indicating a risk of heavy metal accumulation that could endanger human health over time. Strong correlations were found between soil pH, nitrogen (N), Pb, and copper (Cu) content in LOF, while no correlation existed between plant N, P, Cu, and LOF. Additionally, soil pH correlated with soil N. Diverse responses to Pb(II) and Cu(II) among different plant species were highlighted by Vasilachi-Mitoseru et al. (2023). Hindarwati et al. (2023) found that various fertilizers, including NPK and straw, increased heavy metal levels in the soil.

Effect of LOF manure on fruit yield of tomato

The application of different types of liquid organic fertilizer (LOF) did not significantly impact tomato yield (Figure 3), likely because the nutrient content in the three types of LOF is similar. Results indicated that a 5 mL dose was effective for all LOF types, while higher doses (10 and 15 mL) did not yield better results. This may be due to increased Pb accumulation, potentially leading to plasmolysis or toxicity in the plants. Among the LOF types, goat manure produced the highest tomato yield at 5 and 10 mL doses, exceeding 200 g per plant, while chicken and cow manure yields fluctuated.

Although higher doses did not guarantee improved yield, the 5 mL dose of chicken manure failed to meet the nutrient needs for optimal growth. A mount of 15 mL dose resulted in lower yields compared to the control, likely due to excessive Pb accumulation in the soil, despite nutrient delivery. High concentrations of LOF can cause adverse effects like plasmolysis.

Interestingly, the control treatment yielded more tomatoes overall, but their average weight was lower, indicating that while quantity was higher, individual fruit size was reduced. The best results came from applying 5 mL.L^{-1} of cow manure, with the heaviest fruit observed at a 15 mL.L^{-1} concentration. Cow manure is believed to provide adequate nutrients for optimal plant growth, benefiting from the addition of tofu waste, which enriches its nutrient profile.



Remarks: The numbers accompanied by the same letter are not significantly different at the 95% level

Figure 3. Effect of liquid organic fertilizer from chicken, goat, and cow manure on tomato yield

Tofu waste contributes organic nitrogen, phosphorus, potassium, calcium, magnesium, and carbon, enhancing soil fertility. Cow manure's superior nutrient profile—especially in phosphorus—compared to chicken and goat manure supports better growth. While chicken manure LOF can enhance growth and yield, its nutrient content, particularly NPK, is critical for overall production.

Research by Adekiya et al. (2022) supports that both organic and inorganic fertilizers improve growth and nutrient content in tomatoes compared to controls. Inorganic fertilizers may outperform organic ones in terms of performance and mineral content. The optimal yield was achieved with a 35 mL dose in other studies, demonstrating a substantial increase in fruit weight. Insufficient phosphorus and potassium can hinder fruit formation (Yunita et al. 2016), with phosphorus playing a vital role in respiration, photosynthesis, and root development (Hapsari and Welasih 2013). Furthermore, increasing LOF doses inversely affected tomato fruit weight, while the Pb content in stems was directly proportional to yield. Soil nitrogen correlated with Pb levels in tomatoes, indicating that higher soil pH could reduce Pb accumulation in fruit.

Nutrients, particularly phosphorus (P) and potassium (K), play a crucial role in determining production outcomes and fruit weight. Phosphorus is vital for protein synthesis and seed ripening, absorbed as $H2PO4^{-}$ and $HPO4^{2-}$ ions. Research indicates P content in liquid organic fertilizers (LOF) from chicken, goat, and cow manure at 541.44 ppm, 197.98 ppm, and 379.80 ppm, respectively (Lussy et al. 2017). Adequate P is essential for energy transfer, flowering, fruiting, and cell growth (Asngad 2013). Low levels of P and K can hinder fruit formation (Yunita et al. 2016), while organic fertilizers also support root development, enhancing drought resistance and accelerating harvests (Hapsari and Welasih 2011).

Excess lead (Pb) can reduce root growth by up to 42%. Current reviews highlight the global lead contamination status in soils, potential sources, and plant uptake mechanisms. Figure 1 shows Pb content in LOF from different manures, all below the regulatory limit of 5 ppm. Variations in Pb levels can be attributed to animal feed differences; goats typically eat grass, chickens consume pellets, and cows are fed grass and tofu dregs. Notably, cow manure LOF shows higher Pb levels, likely due to the tofu dregs, which may contain Pb from cooking utensils.

In comparison, other studies report higher Pb levels, such as 1.5–1.75 by Korish and Attia (2020), this is likely due to the different materials and processes used. The lower Pb content in the LOF produced through a semi-anaerobic method in covered vats may explain these discrepancies (Chalimah et al. 2011). While some heavy metals like zinc and copper are essential for plant growth, others like cadmium, lead, and mercury lack biological functions (Tangahu et al. 2011), and can adversely affect plant health, soil, and microbial communities (Chu 2018).

The study found that the highest Pb levels in soil and tomatoes coincided with the lowest yields in the cow manure LOF at a 15 $mL.L^{-1}$ treatment. Heavy metal accumulation in crops is influenced by several factors, including total metal concentration, absorption mechanisms, soil properties, chemical speciation, and environmental conditions (Wei et al. 2020). Soil pH significantly affects metal availability, with lower pH promoting greater mobility and availability of heavy metals (Shahid et al. 2016). Long-term chemical fertilizer use can lower soil pH, further impacting heavy metal dynamics.

CONCLUSIONS AND SUGGESTIONS

Liquid organic fertilizer from various manures contains lead (Pb) but at concentrations below the permissible limit. Cow manure LOF had the lowest Pb content at 0.05 ppm, with the least Pb accumulation in soil at 0.0130 ppm and in fruit at 0.0013 ppm. Applying 5 $mL.L^{-1}$ of cow manure, LOF resulted in the highest fruit weight. It is crucial to adhere to recommended dosages to limit impacts on plant or soil accumulation. This research highlights the safety of using livestock manure-based organic fertilizers, with 5 $mL.L^{-1}$ being optimal for both yield and food safety. Increasing the LOF doses for chicken and goat manure to 15 mL.L^{-1} negatively affected yields due to elevated tomato Pb levels, addressing concerns about waste-based organic fertilizers.

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REFERENCES

Adekiya AO, Dahunsi SO, Ayeni JF, Aremu C, Aboyeji CM, Okunlola F, Oyelami AE. 2022. Organic and in-organic fertilizers effects on the performance of tomato (*Solanum lycopersicum*) and cucumber (*Cucumis sativus*) grown on soilless medium. Sci Rep. 12(1):1–8. https://doi.org/10.1038/s41598-022-16497-5.

Afzal MR, Naz M, Wan J, Dai Z, Ullah R, Rehman S ur, Du D. 2023. Insights into the mechanisms involved in lead (Pb) tolerance in invasive plants—The current status of understanding. Plants. 12(11):12112084. https://doi.org/10.3390/plants12112084.

Ali M, El-Tokhy A, El-Sherbini M, Abdel-dayem S, Khpalwak W. 2019. Response Of growth, yield and fruit quality Of tomato (*Solanum lycopersicum* L.) to different organic fertilizer treatments under two pest control programs against Tuta absoluta in a New Valley-Egypt. J Sustain Agric Sci. 45(2):37–57. https://doi.org/10.21608/jsas.2019.9777.1131.

Annisa WA, Santoso SB, Midarti W. 2022. Dampak pemberian pupuk organik cair kotoran ternak terhadap ketersediaan P dan Zn dan serapannya oleh tanaman tomat (*Solanum lycopersicon* L.). Folium J Ilmu Pertan. 6(2):58–70. https://doi.org/10.33474/folium.v6i2.15698.

Asngad A. 2013. Inovasi pupuk organik kotoran ayam dan eceng gondok dikombinasi dengan bioteknologi mikoriza bentuk granul. J MIPA. 36(1):1–7.

Bortoloti GA, Baron D. 2022. Phytoremediation of toxic heavy metals by *Brassica* plants: A biochemical and physiological approach. Environ Adv. 8(December 2021):100204. https://doi.org/10.1016/j.envadv.2022.100204.

Chalimah S, Anif S, Tuti R. 2011. Pemanfaatan pupuk organik kotoran hewan dan bioteknologi cendawan mikoriza arbuskula (CMA) dalam upaya pelestarian lingkungan dan pengembangan bibit tanaman pangan dan buah. Surakarta (ID): LPPM Universitas Muhammadiyah Surakarta.

Chu D. 2018. Effects of heavy metals on soil microbial community. IOP Conf Ser Earth Environ Sci. 113:012009. https://doi.org/10.1088/1755-1315/113/1/012009.

Collin S, Baskar A, Geevarghese DM, Ali MNVS, Bahubali P, Choudhary R, Lvov V, Tovar GI, Senatov F, Koppala S, et al. 2022. Bioaccumulation of lead (Pb) and its effects in plants: A review. J Hazard Mater Lett. 3:100064. https://doi.org/10.1016/j.hazl.2022.100064.

Eissa MA. 2019. Effect of cow manure biochar on heavy metals uptake and translocation by zucchini (*Cucurbita pepo* L). Arab J Geosci. 12(2):48. https://doi.org/10.1007/s12517-018-4191-1.

Eviati, Sulaeman, Herawaty L, Anggria L, Usman, Tantika HE, Prihatini R, Wuningrum P. 2023. Petunjuk teknis: Analisis kimia tanah, tanaman, air, dan pupuk. Ketiga. Sipahutar brahim A, Wibowo H, Siregar AF, Widowati LR, Rostaman T, editors. Bogor (ID): Balai Pengujian Standar Instrumen Tanah dan Pupuk, Kementerian Pertanian RI.

Fahr M, Laplaze L, Bendaou N, Hocher V, Mzibri M El, Bogusz D, Smouni A. 2013. Effect of lead on root growth. Front Plant Sci. 4:00175. https://doi.org/10.3389/fpls.2013.00175.

Hapsari N, Welasih T. 2013. Pemanfaatan limbah ikan menjadi pupuk organik. J Tek Lingkung. 2(1):1–6.

Hayati E. 2010. Effect of organic and inorganic fertilizer on heavy metal in tissue of lettuce. J Floratek. 5(2):113–123.

Hindarwati Y, Soeprobowati TR, Izzati M, Hadiyanto H. 2023. Kontaminan logam berat (Pb, Cd, dan Cu) pada tanah dari pemupukan berbasis jerami padi. J Ilmu Lingkung. 21(1):8–14. https://doi.org/10.14710/jil.21.1.8-14.

Kalbani FOSA, Salem MA, Cheruth AJ, Kurup SS, Senthilkumar A. 2016. Effect of some organic fertilizers on growth, yield and quality of tomato (*Solanum lycopersicum*). Int Lett Nat Sci. 53:1–9. https://doi.org/10.18052/www.scipress.com/ILNS.53.1.

Korish MA, Attia YA. 2020. Evaluation of heavy metal content in feed, litter, meat, meat products, liver, and table eggs of chickens. Animals. 10(4):10040727. https://doi.org/10.3390/ani10040727.

Li J, Chang Y, AL-Huqail AA, Ding Z, Al-Harbi MS, Ali EF, Abeed AHA, Rekaby SA, Eissa MA, Ghoneim AM, et al. 2021. Effect of manure and compost on the phytostabilization potential of heavy metals by the halophytic plant wavy-leaved saltbush. Plants. 10(10):2176. https://doi.org/10.3390/plants10102176.

Lussy ND, Walunguru L, Hambamarak KH. 2017. Karakteristik kimia pupuk organik cair dari tiga jenis kotoran hewan dan kombinasinya. Partner. 22(1):452–463. https://doi.org/10.35726/jp.v22i1.239.

Mahendra R, Made S, Iryanti ES. 2016. Bioavailability of heavy metals Pb and Cd in land for cultivating cabbage in Kintamani area Bangli. Ecotrophic. 12(1):42–49.

[MARI] Ministry of Agriculture of the Republic of Indonesia. 2019. Keputusan Menteri Pertanian No. 261/KPTS/SR.310//M/4/2019. Jakarta (ID): Ministry of Agriculture of the Republic of Indonesia.

Meylia RD, Koesriharti. 2018. Effect of phosphorus fertilizer and potassium different source on the growth and yield of tomato plants (*Lycopersicon esculentum* Mill.). J Produksi Tanam. 6(8):1934–1941.

Oktavia EM, Darjati, Mamik. 2016. Fermentasi jerami padi untuk kompos dengan beberapa aktivator kotoran ternak di Dusun Sugihan Tuban Tahun 2016. Gema Lingkung Kesehat. 14(2):114–118. https://doi.org/10.36568/kesling.v14i2.251.

Pancapalaga W. 2011. Pengaruh rasio penggunaan limbah ternak dan hijauan terhadap kualitas pupuk cair. Gamma. 7(1):61–68.

Pratama DS, Hidayat D, Wijianto E, Yuniar H. 2013. Validasi metode analisis Pb dengan menggunakan flame spektrofotometer serapan atom (SSA) untuk studi biogeokimia dan toksisitas logam timbal pada tanaman tomat (*Lycopersicum esculentum*). Anal Anal Environ Chem. 1(1):26–35.

Sanra Y, Hanifah TA, Bali S. 2015. Analisa kandungan logam timbal pada tanaman tomat (*Solanum lycopersicium* L.) yang ditanam di pinggir jalan raya Kecamatan Aur Bitugo Tigo Baleh Bukittinggi. J Online Mhs Fak Pertan Univ Riau. 2(1):136–144.

Shahid M, Dumat C, Khalid S, Niazi NK, Antunes PMC. 2016. Cadmium bioavailability, uptake, toxicity and detoxification in soil-plant system. In: Reviews of Environmental Contamination and Toxicology. Vol. 241. p. 73–137.

Sukarjo, Hidayah A, Zulaehah I. 2018. Pengaruh pupuk terhadap akumulasi dan translokasi kadmium dan timbal di tanah dan tanaman. In: Kusumadani AI, Nurcahyanto, editors. Isu-isu strategis sains, lingkungan, dan inovasi pembelajarannya; Prosiding Seminar Nasional Pendidikan Biologi dan Saintek (SNPBS) III; Surakarta (ID): Program Studi Pendidikan Biologi Fakultas Keguruan dan Ilmu Pendidikan Universitas Muhammadiyah Surakarta. p. 205–211.

Tangahu BV, Sheikh Abdullah SR, Basri H, Idris M, Anuar N, Mukhlisin M. 2011. A Review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. Bart H-J, editor. Int J Chem Eng. 2011(1):939161. https://doi.org/10.1155/2011/939161.

Trivana L, Pradhana AY. 2017. Time optimization of the composting and quality of organic fertilizer based on goat manure and coconut coir dust using PROMI and Orgadec bio-activator. J Sain Vet. 35(1):136–144. https://doi.org/10.22146/jsv.29301.

Vasilachi-Mitoseru I-C, Stoleru V, Gavrilescu M. 2023. Integrated assessment of Pb(II) and Cu(II) metal ion phytotoxicity on *Medicago sativa* L., *Triticum aestivum* L., and *Zea mays* L. plants: Insights into germination inhibition, seedling development, and ecosystem health. Plants. 12(21):3754. https://doi.org/10.3390/plants12213754.

Vasilachi IC, Stoleru V, Gavrilescu M. 2023. Analysis of heavy metal impacts on cereal crop growth and development in contaminated soils. Agriculture. 13(10):1983. https://doi.org/10.3390/agriculture13101983.

Wei B, Yu J, Cao Z, Meng M, Yang L, Chen Q. 2020. The availability and accumulation of heavy metals in greenhouse soils associated with intensive fertilizer application. Int J Environ Res Public Health. 17(15):1–13. https://doi.org/10.3390/ijerph17155359.

Wijaya AS, Sangadji MN, Muhardi. 2017. Quality of tomato and plant yield added with different concentrationsof liquid organik fertilizer. E-Journal Agrotekbis. 5(1):1–8.

Yunita F, Damhuri, Sudrajat HW. 2016. Pengaruh pemberian pupuk organik cair (POC) limbah sayuran terhadap pertumbuhan dan produksi cabai merah (*Capsicum annuum* L.). AMPIBI J Alumni Pendidik Biol. 1(3):47–55.

Zhen H, Jia L, Huang C, Qiao Y, Li J, Li H, Chen Q, Wan Y. 2020. Long-term effects of intensive application of manure on heavy metal pollution risk in protected-field vegetable production. Environ Pollut. 263:114552. https://doi.org/10.1016/j.envpol.2020.114552.

Zuhro F, Hasanah HU, Winarso S, Hoesain M, Arifandi D. 2019. The characterization of organic fertilizer from manure. Agritrop J Ilmu-Ilmu Pertan. 17(1):103–112. https://doi.org/10.32528/agritrop.v17i1.2192.