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Deciphering chemical fertilizers and chicken compost effects on soil chemical properties and mung bean yield under ideal moisture conditions

Nicodemus M. Musyoka and Suphachai Amkha*

Department of Soil Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom, Thailand
*Corresponding author: agrscak@ku.ac.th

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Abstract

The aim of this research was to comprehend the impacts of fertilizers in fostering sustainable agriculture, aiming to enhance crop output while safeguarding the environment. Investigating the effects of chemical fertilizers and chicken compost on mung bean yield and soil chemical properties, six treatments were administered across "KUML4" mung bean. Statistical analysis revealed substantial variations in soil pH, electrical conductivity, and organic matter content among the treatments. Notably, the exclusive use of chemical fertilizers triggered a 9.9% increase in soil electrical conductivity, accompanied by decreases in pH and organic matter content. Conversely, chicken compost stabilized pH levels in slightly acidic soils and significantly boosted soil organic matter. Optimal mung bean yield, experiencing a 31% increase compared to the control treatment, was achieved by combining 75% chemical fertilizers with 25% chicken compost. Crucially, synergizing chicken compost with chemical fertilizers notably improved soil chemical properties, while a combination of 75% chemical fertilizers and 25% chicken compost optimized mung bean yield. These findings highlight the potential of integrating chicken compost with chemical fertilizers as a promising strategy for sustainable agriculture, emphasizing both soil chemical enhancement and yield improvement.

Keywords: Crop yield, Soil electrical conductivity, Soil organic matter, Soil pH

1. Introduction

The sustainable cultivation of crops remains an enduring challenge in modern agriculture, particularly concerning the delicate balance between maximizing yields and preserving the ecological integrity of the soil. Today, claims that the global food system is 'in crisis' or 'broken' are increasingly common [1]. These claims point to a wide variety of issues, including hunger, poverty, obesity, industrial farming, over-dependence on chemical fertilizers and pesticides, poor-quality (if not unsafe) food, environmental degradation, biodiversity loss, exploitative labor relations, and animal welfare, as well as corporate dominance and lack of resilience [2]. It is in this context, where every aspect of food production, distribution, and consumption is being questioned, that the current interest in 'regenerative agriculture' and 'regenerative farming' has taken root [3].

Studies have highlighted the positive impact of chemical fertilizers on crop yield, addressing specific nutrient deficiencies and promoting rapid plant development [4]. However, the environmental impact of excessive fertilizer use, including water pollution and soil degradation, has raised concerns [5]. Conversely, organic substitutes like chicken compost have gradually emerged to fill their own niche. They not only promote soil fertility and structure but also contribute to a more balanced ecosystem [6].

Despite the extensive research on the effects of chemical fertilizers and organic amendments on soil health, there is a notable gap in the literature regarding their synergistic impact on specific crops, such as mung beans [7]. This underscores the need for further investigations that delve into their intricate interactions in the context of mung bean cultivation and soil chemistry, ultimately contributing to more holistic and tailored agricultural practices.

Key soil chemical properties-pH, soil organic matter, and electrical conductivity—were investigated for their potential interactions when applied together and the long-term impacts of their repeated applications on soil chemistry and mung bean (*Vigna radiata)* yield. Mung bean is a leguminous crop with high nutritive value and significant economic importance, adaptable to different environments [8].

By elucidating these facts, the research aimed to shed new light on their impacts, offering useful insights into the discussion about how best to practice sustainable agriculture in accordance with one of the targets under the UN Sustainable Development Goals-ensuring at least 75% healthy soils by 2030 [9].

2. Materials and methods

2.1 Experimental background

Field experiments were conducted at the Kamphaeng Saen Training and Research Farm situated in Nakhon Pathom province, Thailand (Latitude: 14° 1′ 40.111″ N, Longitude: 99° 58′ 16.706″ E, Altitude: 10.26 m). Soil analysis was performed at a laboratory within the Soil Science Department at Kasetsart University. The primary focus of the experimentation centered on soil pH, organic matter content, and electrical conductivity, all integral facets determining soil chemistry, alongside the assessment of mung bean yield. Initial soil analysis revealed a baseline electrical conductivity (EC) of 0.972 mS/cm, an average pH of 7.0, and an organic matter content averaging 1.24%.

These findings underlined the need to preserve particular soil conditions for optimal mung bean cultivation. Research-based recommendations suggested maintaining the pH within a suitable range of 6.2-7.2, elevating organic matter content to an optimized range of 1.9-2.2%, and regulating soil EC between 0.8-1.8 mS/cm to foster ideal conditions for both mung bean yield and overall soil health [10].

2.2 Experimental design and treatments

Mung bean seeds of the KUML4 cultivar were sown in a spacing arrangement of 35 cm by 15 cm within plots measuring 4 m × 1 m. The plots were set with a 30 cm gap between each other and a 1-m separation between rows. The irrigation regime comprised daily watering sessions spanning 90 days, each lasting 24 min at a flow rate of 7.5 L/min, effectively simulating 241 mm of rainfall, a quantity tailored to replicate ideal conditions for irrigated mung bean cultivation [11].

The experimental setup involved the application of varying levels of chemical fertilizer and chicken compost to the designated plots as in Table 1. To ensure consistency, uniform cultural management practices were maintained across all plots. The experimental design followed a randomized complete block design (RCBD) with four replications to minimize biases and enhance the robustness of the study's outcomes.

Table 1 Research treatment details of the experiment.

Treatment	Ratios	Basal Application	Top dressing
T1	CF 100%	32 kg P_2O_5/Acre equivalent to 70 kg/acre of NPK 0:46:0	20 kg of K_2O/acre Equivalent to 33 kg/acre of NPK 0:0:60
T2	CC 100%	2 tons of chicken compost/acre	2 tons of chicken compost/acre
T3	CF 25%+CC 75%	8 kg P_2O_5+1.5 tons chicken compost/acre	5 kg K_2O +1.5 tons chicken compost/acre
T4	CF 50%+CC 50%	16 kg P_2O_5+1 ton chicken compost/acre	10 kg K_2O+1 ton chicken compost/acre
T5	CF 75%+CC 25%	24 kg P_2O_5+0.5-ton chicken compost/acre	15 kg K_2O+0.5-ton chicken compost/acre
T6	CF 0%+CC 0%	0	0

Remarks: CC = Chicken Compost, CF = Chemical Fertilizer

2.3 Data collection

Throughout the study, soil sampling was carried out at specific intervals: initially at the time of planting, followed by samplings at 30 and 60 days after sowing (DAS). These soil samples were analyzed to determine crucial soil chemical properties, including soil EC, soil pH (soil: water; 1:1), and organic matter content using the Walkley and Black method [12].

To measure soil pH, the collected soil samples underwent a process of drying, grinding, and sieving through a 2 mm sieve, followed by dissolution in distilled water at a ratio of 1 g of soil to 1 mL of water (20 g of soil: 20 mL of water). The pH levels were then measured using a Mettler Toledo pH meter calibrated to at least 95% slope. The percentage change in soil pH was calculated as follows:

$$\text{Percentage Change in pH} = \frac{\text{New pH-Initial pH(7.0)}}{\text{Initial pH (7.0)}} \times 100\%$$

Soil electrical conductivity was tested by drying the soil, grinding, sieving through a 2 mm sieve, and dissolving 100 g of the soil sample in distilled water to saturation. The soil paste was covered and left overnight. Electrical conductivity of the solution derived from the suction of the saturated soil paste was tested using a Mettler Toledo EC meter. The percentage change in EC was calculated as follows:

$$\text{Percentage Change in EC} = \frac{\text{New EC-Initial EC(0.972 mS/cm)}}{\text{Initial EC (0.972 mS/cm)}} \times 100\%$$

For testing soil organic matter, the soil sample was dried, ground, and sieved through a 0.5 mm sieve. One gram of soil was weighed, and the total organic carbon calculated using the Walkley-Black titration method [12]. Soil organic matter was then calculated as follows: Organic matter (%) = Total organic carbon (%)×1.72 (conversion factor assuming organic matter contains 58 % organic carbon)[12]. The percentage change was calculated as:

$$\text{Percentage Change in soil organic matter} = \frac{\text{New organic matter-initial organic matter(1.24)}}{\text{Initial organic matter (1.24)}} \times 100\%$$

To ascertain mung bean yield per acre, a calculated formula was used:

$$y = \frac{n \times p \times gp \times gw}{1000}$$

where y represented the crop yield measured in kg/acre, n signified the estimated crop population per acre [calculated as 77,066 crops per acre using the formula $\frac{4046m^2}{0.35m \times 0.15m}$ p denoted the number of pods per plant, gp stood for the count of grains per pod, gw signified the weight of an individual grain in grams, and m stood for meters.

2.4 Data analysis

The collected data underwent thorough statistical analysis based on the respective parameter values for an analysis of variance under a randomized complete block design (RCBD). Differences between the means were determined using a least significant difference (LSD) test with a 5% significance level to verify treatment effects. Correlation analysis to examine relationships between different parameters was conducted using Statistix 10.0 software. This comprehensive analytical approach helped to understand in-depth inter-parameter correlations and clarified some of the relationships within these complex sets.

3. Results

3.1 Effects on the soil pH

Results revealed distinct pH variations among different treatment groups as depicted in Table 2. Notably, the application of a combined mixture of chicken compost and fertilizer at 50%, as well as the control group, demonstrated no significant alterations in soil pH levels. Conversely, the application of chicken compost at 100% and a mixture of 75% chicken compost and 25% chemical fertilizer exhibited an elevation in soil pH, averaging 6.7%. In contrast, the application of chemical fertilizers at 100% and 75% manifested a reduction in soil pH, averaging 7.1%.

Table 2 Effects of chicken compost and chemical fertilizer on soil pH 60 DAS.

Treatments	Ratios	Soil pH	% Change
Initial		7.00	-
T1	CF 100%	6.45±0.13 [c]	-7.9
T2	CC 100%	7.50±0.29 [a]	+7.1
T3	CF 25% + CC 75%	7.44±0.06 [a]	+6.3
T4	CF 50% + CC 50%	6.98±0.14 [b]	-0.29
T5	CF 75% + CC 25%	6.56±0.10 [c]	-6.3
T6	CF 0% + CC 0% (control)	6.93±0.22 [b]	-1.0
F-test		*	
CV. (%)		2.06	
Grand mean		6.97	

CF=chemical fertilizer; CC=chicken compost

*Values (mean± SD) in the same column superscripted with different lowercase letters are significantly ($p < 0.05$) different.

3.2 Effects on the soil electrical conductivity (EC)

The experimental plots were subjected to diverse ratios of chemical fertilizer and chicken compost, and the EC of the solution derived from saturated soil paste samples collected at distinct phases (planting, 30, and 60 DAS) was systematically assessed, with averages recorded across replications. All treatments exhibited varying degrees of EC increment, with the highest observed in the application of chemical fertilizers, particularly in its diverse combinations. Following this, the chicken compost treatments demonstrated a moderate increase, while the control experiment exhibited the least increment as shown in Table 3.

Table 3 Effects of chicken compost and chemical fertilizer on soil EC 60 DAS.

Treatments	Ratios	Soil EC (mS/cm)	% Change
Initial		0.972	
T1	CF 100%	1.07±0.02 [a]	+10.1
T2	CC 100%	1.03±0.02 [ab]	+6.0
T3	CF 25% + CC 75%	1.04±0.02 [ab]	+7.0
T4	CF 50% + CC 50%	1.06±0.02 [a]	+9.1.
T5	CF 75% + CC 25%	1.06±0.01[a]	+9.1
T6	CF 0% + CC 0% (control)	0.99±0.09 [b]	+1.9
F-test		*	
CV. (%)		4.11	
Grand mean		1.04	

CF=chemical fertilizer; CC=chicken compost

* Values (mean± SD) in the same column superscripted with different lowercase letters are significantly ($p < 0.05$) different.

The outcomes elucidate that agricultural practices devoid of fertilizers and chicken compost did not impart a statistically significant influence on soil electrical conductivity. Notably, the application of chemical fertilizers resulted in an average soil EC increment of 10.1%, whereas the application of chicken compost yielded an average increment of 6%.

3.3 Effects on the soil organic matter content

The application of chicken compost demonstrated a discernible capacity to enhance soil organic matter content. In contrast, the independent application of chemical fertilizers exhibited a negative correlation with soil organic matter. Notably, agricultural practices devoid of fertilizers and manure resulted in a slight reduction in soil organic matter content as shown in Table 4.

Table 4 Effects of chicken compost and chemical fertilizer on soil organic matter 60 days after sowing (DAS).

Treatments	Ratios	Soil Organic Matter (%)	% Change
Initial		1.24	-
T1	CF 100%	1.18± 0.03	-4.8
T2	CC 100%	1.35± 0.04[a]	+8.9
T3	CF 25% + CC 75%	1.32± 0.04[a]	+6.5
T4	CF 50% + CC 50%	1.28± 0.02[b]	+3.2
T5	CF 75% + CC 25%	1.25± 0.01[b]	+0.8
T6	CF 0% + CC 0% (control)	1.20± 0.02[c]	-3.2
F-test		*	
CV. (%)		2.08	
Grand Mean		1.26	

CF=chemical fertilizer; CC=chicken compost

*Values (mean± SD) in the same column superscripted with different lowercase letters are significantly ($p < 0.05$) different.

3.4 Effects on the mung bean yield parameters

Globally, mung bean cultivation spans approximately 7 million hectares, yielding around 5 million tons [8]. Despite its potential for yields ranging between 2.5 to 3.0 tons per hectare, the average global productivity stands at a mere 0.5 tons per hectare [8]. This glaring disparity underscores the substantial room for enhancement in productivity, necessitating the broader adoption of improved varieties and agricultural methodologies [13].

The combined application of chemical fertilizers and chicken compost (T5) yielded the highest average number of pods per crop, followed by the sole application of chemical fertilizers (T1), T3, T2, and T4, while the control treatment (T6) exhibited the lowest average number of pods per crop. Further analysis showed no significant difference in the number of grains per pod among the treatments. Upon weighing, grains from T2 and T4 showcased the highest weights, followed by T1, T3, T5, and T6, with insignificantly different weights. The highest overall yield was achieved in T5, closely followed by T1. T2, T3, and T4 exhibited yields that were insignificantly different from each other, while the control (T6) demonstrated the lowest yield as shown in Table 5.

Table 5 Effects of chicken compost and chemical fertilizer on mung bean yield components.

Treatments	Ratios	Pods/plant	Grains/Pod	Grain Weight (g)	Yield (kg/Acre)	% Change
T1	CF 100%	24.6±0.97^{b}	11.00±0.8^{a}	0.0715±0.00	1491.0±51.20^{b}	24.5
T2	CC 100%	22.09±0.87^{cd}	10.75±1^{a}	0.0738±0.00^{a}	1350.6±58.60^{c}	12.8
T3	CF 25% + CC 75%	23.32±1.04^{bc}	10.75±0.5^{a}	0.0715±0.00^{b}	1381.4±31.60^{c}	15.4
T4	CF 50% + CC 50%	22.06±1.39^{cd}	11.00±1.2^{a}	0.0744±0.00^{a}	1391.4±40.60^{c}	16.2
T5	CF 75% + CC 25%	26.13±0.66^{a}	11.00±0.8^{a}	0.0708±0.00^{b}	1568.2±43.70^{a}	31.0
T6	CF 0% + CC 0%	21.5±0.70^{d}	10.25±0.5^{a}	0.0705±0.00^{b}	1197.4±42.40^{d}	-
F-test		*	*	*	*	
CV. (%)		4.31	7.74	1.27	3.27	
Grand mean		23.28	10.79	0.072	1396.7	

CF=chemical fertilizer; CC=chicken compost

*Values (mean± SD) in the same column superscripted with different lowercase letters are significantly *(p* < 0.05) different.

These findings illuminated the differential impacts of distinct treatments on crucial yield parameters, underscoring the potential of combined applications in augmenting mung bean productivity as shown in Figure 1. To conform to the scale of graphical representation, the number of pods per plant was divided by 2, the grain weight in grams was multiplied by 100, and the yield in kg per acre was divided by 100.

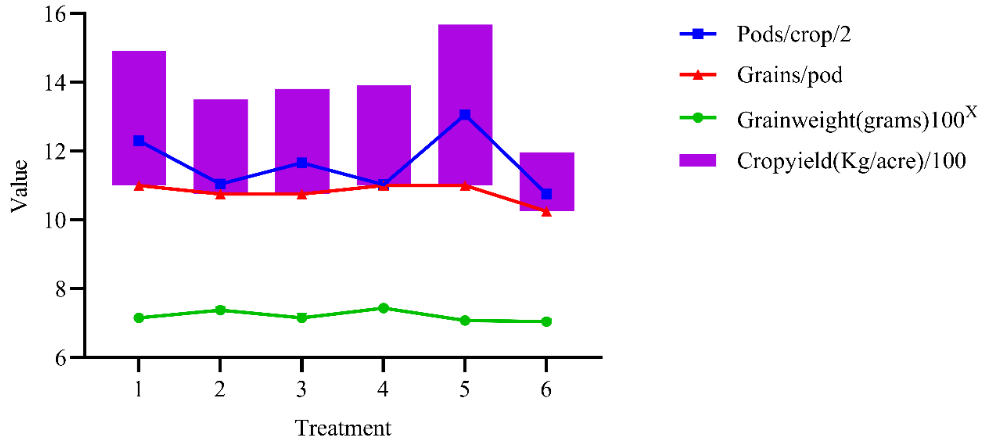

Figure 1 Chicken compost and chemical fertilizer ratios on mung bean yield parameters in ideal moisture.

4. Discussion

The research revealed intricate interactions between soil amendments and chemical properties, emphasizing the necessity of tailored approaches based on specific soil conditions. Chemical fertilizers were found to disrupt pH and organic matter levels, potentially compromising soil chemical properties and posing risks to long-term soil quality, including salinization and acidification, phenomena already affecting 424 million hectares of topsoil globally [14, 15].

Treatment 4, comprising a 50% combination of chemical fertilizer and chicken compost, demonstrated superior resilience in maintaining soil pH within the optimal range of 6.2-7.2 [16, 17] across multiple cropping cycles. Conversely, Treatments 2 and 3, characterized by 100% chicken compost and a mix of 25% chemical fertilizer with 75% chicken compost, respectively, showed a moderate increase in soil electrical conductivity, crucial for long-term soil health preservation [18]. The application of 100% chicken compost in Treatment 2 significantly enriched soil organic matter, with the potential to attain the recommended range of 1.9-2.2% [16, 19], crucial for optimizing yields over subsequent growing seasons. Additionally, Treatment 5, composed of 75% chemical fertilizer and 25% chicken compost, yielded the highest mung bean output, indicating its potential to enhance yield across successive seasons.

Farming practices devoid of manure and fertilizers resulted in diminished soil organic matter, reduced soil pH, and suboptimal yields, posing substantial risks to sustainability and food security as depicted in Figure 2.

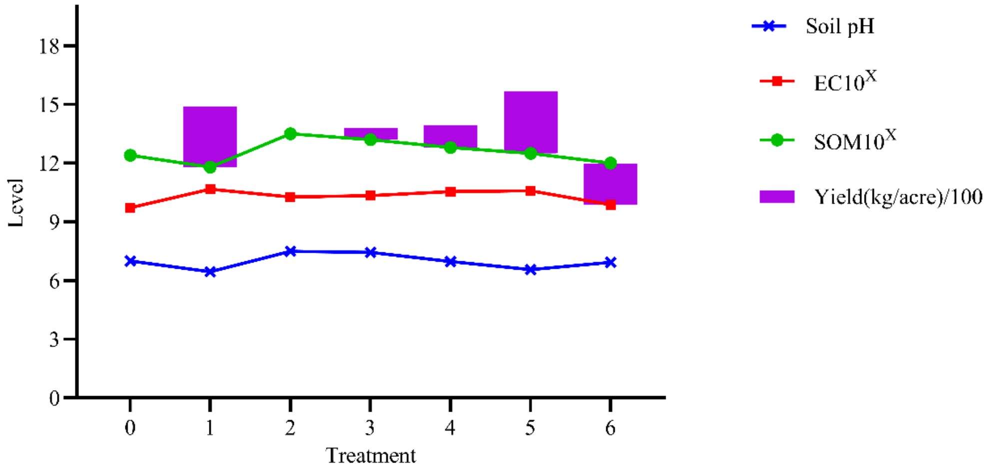

Figure 2 Effects of chemical fertilizers and chicken compost on soil pH, EC, OM, and mung bean yield.

We strongly recommend the adoption of an integrated approach combining chemical fertilizers with chicken compost as shown in Figure 3. This strategy not only enhanced nutrient levels and crop productivity but also improved soil chemical properties, ensuring both short-term gains and long-term sustainability [20].

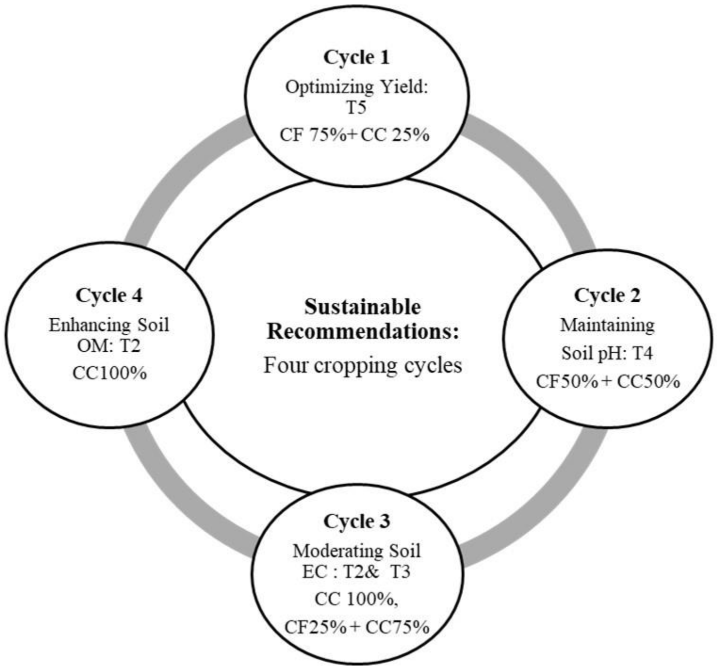

Figure 3 Sustainable soil amendment recommendation. Case study; Kamphaeng Saen Soil.

These findings underscore the critical importance of tailored soil management practices in addressing the multifaceted challenges of modern agriculture [21]. Farmers are encouraged to embrace this integrated approach to optimize soil health and productivity, thereby fortifying the resilience of agricultural systems and enhancing global food security.

5. Conclusion

It is imperative to acknowledge the profound and lasting impact of our soil management decisions. Our findings revealed that while the exclusive use of chemical fertilizers disrupted soil pH and organic matter, combining them with chicken compost in appropriate proportions mitigated these negative effects and maximized crop yield.

The implications of our research transcend mung bean cultivation and the specific conditions studied. Our work lays the foundation for further exploration, urging future research to investigate the synergies between chemical fertilizers and other organic amendments, as well as delving into the microbial communities essential for soil health.

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7. Conflict of Interest

The writers affirm that they are free from any conflicts of interest.

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