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Research Article

Effectiveness of compost application in reducing inorganic fertilizer on soybean cultivation

Elfarisna[1]*, Sularsih[1], Ade Sumiahadi[1], Mulono Apriyanto[2], M. Indar Pramudi[3], Lovi Sandra[4], Yetti Elfina S[5], Latarus Fangohoi[6]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Jakarta 15419, Indonesia

[2]Department of Food Science, Faculty of Agriculture, Islamic University of Indragiri, Indonesia

[3]Department of Plant Protection, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru 70714, Indonesia

[4]Department of Fishery Products Technology, Faculty of Science and Technology, University of Ibrahimy, Indonesia

[5]Department of Agrotechnology, Faculty of Agriculture, Riau University, Indonesia

[6]Department of Sustainable Agricultural Extension, Manokwari Agricultural Development Polytechnic, West Papua, Indonesia

*Corresponding Author, Email: elfa.risna@umj.ac.id

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ABSTRACT

One of the efforts to increase edamame's productivity is to increase soil productivity by using organic fertilizers. This study aimed to determine the effectiveness of compost application with the reduction of inorganic fertilizers on the growth and production of edamame soybeans. The study was conducted at the Experimental Garden of the Faculty of Agriculture, University of Muhammadiyah Jakarta, from November 2020 to March 2021. The study used a randomized complete block design (RCBD), with five treatments, namely control (100% Recommendation Dose (RD) of inorganic fertilizer), 50% RD of inorganic fertilizer + compost 25 g plant^{-1}, 50% RD of inorganic fertilizer + compost 37.5 g plant^{-1}, 50% RD of inorganic fertilizer + compost 50 g plant^{-1}, and 50 % RD of inorganic fertilizer + compost 62.5 g plant^{-1}. The results showed that compost reduced the use of inorganic fertilizers by 50% with the recommended amount of compost being 25 g plant^{-1}.

INTRODUCTION

Soybean (*Glycine max* (L.) Merril) is one of the primary food commodities after rice and corn. The use of soybeans as daily food such as tempeh, tofu, soy sauce, and soy milk cause the demand for these commodities to be very high. Soybeans can be used in the form of dry seeds and fresh seeds. The most widely used fresh soybean variety is edamame (vegetable soybean).

In Indonesia, soybean is an essential commodity for the community. Therefore, efforts to increase soybean productivity must be made to meet the needs of soybean commodities in Indonesia. The growth, production, and yield quality of soybeans are affected by two factors, namely genetic factors such as the use of superior varieties, and environmental factors such as soil fertility. Efforts that can increase soil fertility include applying fertilizers, both organic and inorganic fertilizers.

Fertilization aims to increase the availability of nutrients in the soil. Soils experience nutrient loss through leaching, evaporation, harvest-time transportation, and improper nutrient management [1]. Fertilizer has a vital role in improving soil fertility and plant growth. Most people in Indonesia still depend on inorganic fertilizers, even though excessive use of inorganic fertilizers causes environmental pollution [2]. Moreover, continuous use of inorganic fertilizers for a long time can lead to decreased land productivity and reduced soil fertilizing microorganisms [3]. Municipal Solid Waste (MSW) use for compost has become one of the waste management focuses in recent years. Applying MSW compost to agricultural land improves the physico-chemical characteristics of the soil. In addition, it helps to enhance the cultivated land's biological response [4].

Organic waste from household activities continues to be generated every day, and as the population increases, its amount tends to increase. Improper management can lead to several problems, such as water and air pollution, greenhouse gas emissions, and the emergence of various diseases [5,6]. However, if household organic waste is processed suitably and correctly, it can produce organic fertilizer that can improve the soil's physical, chemical, and biological properties [7,8,9].

Household organic waste (food scraps, vegetable wastes, fruit peels, leaves, etc.) is very suitable to be processed into compost. Compost is a fertilizer derived from decomposing organic materials such as leaves, straw, reeds, grass, animal waste, organic waste, and others [10]. According to Adediran et al. [11], several composts from different sources of organic matter (corn waste, municipal domestic waste, leaf litter, weeds, and soybean waste) contained high macro and micro-nutrients. Another study by Choy et al. [12] also showed that compost from organic wastes (leaves and pruning residues, fruit peels, food waste, and soybean waste) had high macronutrient contents.

Compost can be a sustainable, economical, and feasible solution to efficiently utilize the nutrients from leftover food before and after consumption. Compost application is able to support plant growth and production optimally. Food waste compost has the ability to improve soil fertility and increase onion output, according to Bhadwal et al. [13]. Therefore, food waste can be utilized to create compost in sub-tropical climates to increase onion output.

Compost can be used as an alternative to reduce synthetic fertilizer application. Several studies reported the potential to reduce chemical fertilizer uses with optimum plant growth and production. A Study by Rady et al. [14] showed that compost from agricultural wastes at a dose of 20 tons ha^{-1} combined with 50% of NPK-fertilizer improved soil physic and chemical properties and produced the same growth and yield of Phaseolus vulgaris plants compared to the control (100% of NPK fertilizer). Result study by Cahyono et al. [15] also showed that compost significantly improved soil physical and chemical properties compared to the control (100% of chemical fertilizer). The application of compost at a dose of 25 tons ha^{-1} consistently produced a higher yield of pineapple plants than the control and could reduce the use of chemical fertilizer by 40%. A most recent study by Porto et al. [16] also reported that applying organic compost and its mixture with a chemical fertilizer proved to be an alternative for lettuce production, giving better values to the organic residues and promoting the reduction of chemical inputs. This study aims to determine the effectiveness of food waste compost and the reduction of inorganic fertilizers on the growth and production of edamame soybeans.

MATERIALS AND METHODS

The research was carried out from November 2020 to March 2021 at the Experimental Field of Agricultural Faculty, University of Muhammadiyah Jakarta. The research location was at an altitude of ±25 m above sea level with Latosol soil type. The materials used in this research were edamame Ryokkoh 75 (R75) soybean seeds, household waste compost, 100 kg Urea ha^{-1}, 150 kg SP-36 ha^{-1}, and 125 kg KCl ha^{-1} [17].

Table 1. Composition of wastes used for compost.

Waste Type	Amount (kg)	Proportion (%)
Mango peel	2.00	13.33
Kangkong waste	2.00	13.33
Banana leaves	0.50	3.33
Amaranth waste	2.00	13.33
Banana peel	3.00	20.00
Tea waste	1.00	6.67
Mustard waste	2.00	13.33
Carrot waste	1.00	6.67
Papaya peel	1.00	6.67
Egg shell	0.25	1.67
Shallot peel	0.25	1.67
Total	15	100

Compost was made using a composter. Household waste used as vegetable, fruit, eggshells, tea dregs, and others (Table 1, Plate 1) as much as 15 kg. Household waste was cut into small pieces to a size of 1-2 cm and then put into a composter. The organic waste that had been cut into pieces was then sprayed with a bio-activator (EM4 solution 20 ml l^{-1} water). After that, 50 g of wood ash, 100 g of bran, and 200 g of brown sugar were added and stirred until evenly distributed. The composter was tightly closed and opened once every seven days and stirred to remove the gas in the composter. On the 28th day, the compost was removed from the composter and aerated for seven days under the sun until the compost was completely dry. The compost was then sieved until a fine compost was obtained. The results of the compost content analysis are presented in Table 2.

The study was conducted using a Randomized Complete Block Design with five treatments, namely 50% RD of inorganic fertilizer + 25 g plant^{-1} of compost, 50% RD of inorganic fertilizer + 37.5 g plant^{-1} of compost, 50% RD of inorganic fertilizer + 50 g plant^{-1} of compost, 50% RD of inorganic fertilizer + 62.5 g plant^{-1} of compost, and control (100% RD of inorganic fertilizer. Each treatment was repeated five times, resulting in 25 experimental units. Each experimental unit consisted of 3 plants.

Plate 1. Composting. (a) Compost materials, (b) Compost drying.

Table 2. Physical and chemical properties of compost.

Compost Properties	Unit	Value
Texture	-	Fine and moist
Color	-	Soil black
Odor	-	No odor
Water content	%	30.32
pH	-	9.49
C/N ratio	-	12.29
C-organic	%	28.25
N-Total	%	2.30
Phosphor (PO_2)	%	0.59
Kalium (K_2O)	%	0.19

The application of household waste compost on edamame soybean plants was carried out once when the plants were 10 days after planting (DAP) as much as 5 t ha^{-1} (25 g plant^{-1}), 7 t ha^{-1} (37.5 g plant^{-1}), 10 t ha^{-1} (50 g plant^{-1}) and 12.5 t ha^{-1} (62.5 g plant^{-1}). In the control treatment (100% RD of inorganic fertilizer), Urea and KCl were given twice [18] (Plate 2).

The observed variables were growth and production variables, including plant height, number of branches, flowering age, number of pods per plant, pod weight per plant, percentage of filled pods per plant, and yield conversion per hectare. Observational data were analyzed using ANOVA, and the significance between treatments was seen using the Honest Significant Difference (HSD) test with a level of 5%.

Plate 2. (a) Edamame soybean Plants, (b) Soybean plants ready for harvest.

RESULTS AND DISCUSSION

Plant growth

The plant growth variables observed were plant height and the number of branches. These growth variables were observed every week from 2 to 7 week after planting (WAP). The analysis of variance showed that the fertilizer application had no significant effect on the plant height of edamame soybeans at 2 WAP but had a significant effect at 3-7 WAP. Based on the HSD test, the control treatment produced the highest plant height and was significantly different from all other treatments (Fig. 1).

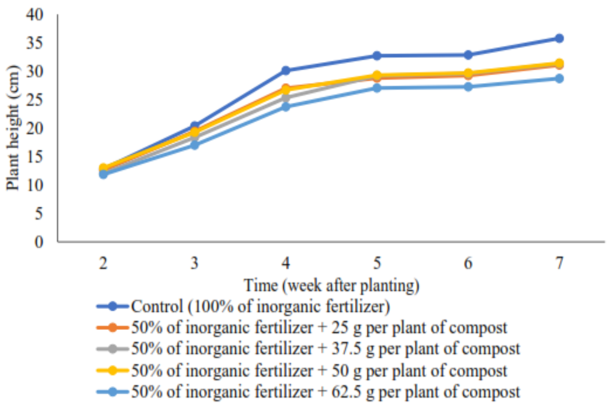

Fig. 1. Effectiveness of compost application with reduction of inorganic fertilizer on edamame soybean plant height at 2-7 WAP.

Assumedly, nutrient availability, especially N, in control (100% RD of inorganic fertilizer) treatment is superior to compost treatment, resulting in greater plant growth. In this study, soybean plant height was lower than the description of edamame soybean variety R75 (65-80 cm). These results can be influenced by the growing environment affecting plant growth, such as temperature, humidity, and water availability needed by edamame soybean plants [19]. In addition to external factors, the increase in plant height is also influenced by genetic factors, where the same plant variety will show high growth that tends to be the same [20].

Branches on edamame soybean plants appeared in the fourth week. According to the analysis of variance, fertilizer application did not significantly affect the number of edamame soybean branches at 4-7 WAP (Fig. 2). It is suspected that the availability of nutrients is sufficient to support branch growth. This result is supported by the statement of Dhani et al. [21] that the element N is needed by plants to synthesize amino acids and proteins, especially at the growing points of plants, to accelerate plant growth.

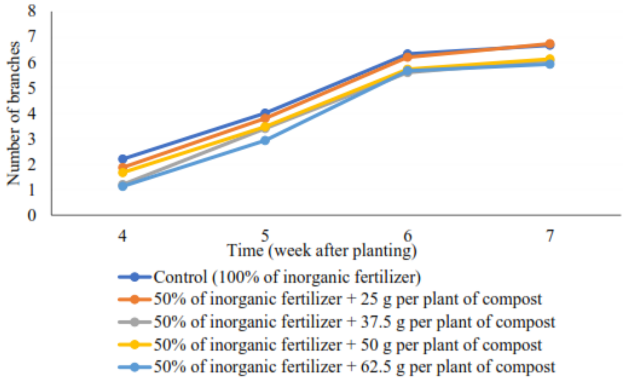

Fig. 2. Effectiveness of compost application with reduction of inorganic fertilizer on the number of branches of edamame soybean at 4-7 WAP.

Several previous studies also reported the effect of compost on soybean plant growth. A reported study by Abd El-Hafez [22] showed that the application of compost with amounts of 1.5 and 2 t ha^{-1} resulted in plant height and the number of branches of two soybean varieties (Giza 111 and Crawford) which were not significantly different from the inorganic N fertilization treatment in the two growing seasons (2005 and 2006). Meanwhile, the application of compost with a lower amount (0-1 t ha^{-1}) resulted in lower plant height and number of branches compared to inorganic N fertilization.

Research by Ruth et al. [23] showed that the application of compost from cassava peel at amounts of 5 t ha^{-1}, 1.25 t ha^{-1} + 75% NPK, 2.5 t ha^{-1} + 50% NPK, 3.75 t ha^{-1} + 25% NPK gave lower soybean stem height compared to 100% NPK treatment at 8-12 WAP. Meanwhile, the treatments had an inconsistent effect on the number of branches variable. These compost treatments yielded more branches than the 100% NPK treatment at 4-8 WAP but produced lower branches at 10-12 WAP.

The results of this study are also in line with the results of research conducted by Yusuf et al. [24] which reported that the use of 100% compost, 25% compost + 75% urea, 50% compost + 50% urea, and 75% compost + 25% urea gave the results of soybean plant growth variables (plant height, number of leaves, root length, dry plant weight, leaf area, and net assimilation rate) was not significantly different from the control treatment (100% urea).

Flowering age

First flowers appeared at the age of 26 DAP as much as 10.67% of edamame soybean plants, then continued the appearance of other flowers at 27 DAP until finished flowering at 31 DAP. Based on the analysis of variance, the fertilization treatment had a significant effect on the flowering age of edamame soybeans. The HSD test showed that the flowering age of edamame soybeans was not significantly different except for the 50% RD of inorganic fertilizer + 37.5 g plant^{-1} of compost treatment, which had a slower flowering time than the other treatments (Table 3).

Table 3. Effectiveness of compost application with reduction of inorganic fertilizer on the flowering time of edamame soybean.

Treatment	Flowering Age (DAP)
Control (100% RD of inorganic fertilizer)	28.73 b
50% RD of inorganic fertilizer + 25 g plant^{-1} of compost	27.53 b
50% RD of inorganic fertilizer + 37.5 g plant^{-1} of compost	29.93 a
50% RD of inorganic fertilizer + 50 g plant^{-1} of compost	27.80 b
50% RD of inorganic fertilizer + 62.5 g plant^{-1} of compost	28.67 b

Note: The numbers followed by the same letter in the same column are not significantly different based on the HSD test at the level of 5%

Edamame soybean R75 varieties used in this study flowered longer than the variety's description (23 DAP). This result is thought to be due to environmental factors in the study, which were not optimal for the flowering process. Table 4 shows that during research, the temperature was quite low, and the humidity was high. Meanwhile, to stimulate flowering, high temperatures, low humidity, and more sunlight are needed [25]. The availability of nutrients also influences the emergence of flowers. Excessive N can prolong vegetative growth and slow the emergence of flowers. This study also indicated that the availability of N in all treatments played a role in slowing the flowering process.

Table 4. Climate data during the study (January-March 2021).

Month	Amount of Rainfall (mm)	Average Daily Temperature (oC)	Average Daily Humidity (%)
January	300.5	26.59	86.58
February	485.7	26.79	86.71
March	113.7	27.59	82.16

Yield components

According to the analysis of variance, fertilizer treatment did not significantly affect the yield components (number of pods, percentage of pithy pods, and pod weight per plant) of edamame soybeans (Table 5; Plate 3). These results indicated that edamame plants using compost and a 50% reduction in inorganic fertilizers could produce the same yields as soybean plants grown with 100% inorganic fertilizers. This result is presumably because the addition of nutrients in compost, especially N and other macro elements, can meet the nutrient needs of plants. In the presence of sufficient nutrients, plant organs will grow at their maximum potential, increasing photosynthesis and supporting plant production [26].

Soybean seeds are wrapped in pods, so the parameter of the number of pods is one of the parameters of the production component. Therefore, the more pods the soybeans produce, the more seed can be produced. The results of this study are in line with Adel et al. [27] that the application of organic fertilizer can increase the number of soybean pods by 3% compared to the application of chemical fertilizers. Slaton et al. [28] also stated that an increase in pods was positively correlated with the number of seeds produced. This is indicated by the percentage of filled pods. The percentage of filled pods that were not significantly different also indicated that the nutrients needed by edamame soybeans for seed formation were well met.

An increasing trend occurred in the compost treatments in the pod weight variable, especially 50% RD of inorganic fertilizer + 25 g plant^{-1} of compost treatment. The increase in pod weight in this treatment was thought to be due to the addition of nutrients in the compost fertilizer, which could increase the yield of pod weight.

The application of organic fertilizers encourages soybean growth and increases soybean yield and quality, equivalent to chemical fertilizers [29]. Abd El-Hafez et al. [22] reported that the application of compost as much as 1.5 and 2 t ha^{-1} resulted in the number of pods and weight of 100 grains per plant for two soybean varieties (Giza 111 and Crawford) were not significantly different from the inorganic N fertilization treatment in two growing seasons (2005 and 2006). Meanwhile, the application of compost with a lower dose (0-1 t ha^{-1}) resulted in lower plant height and number of branches compared to inorganic N fertilization.

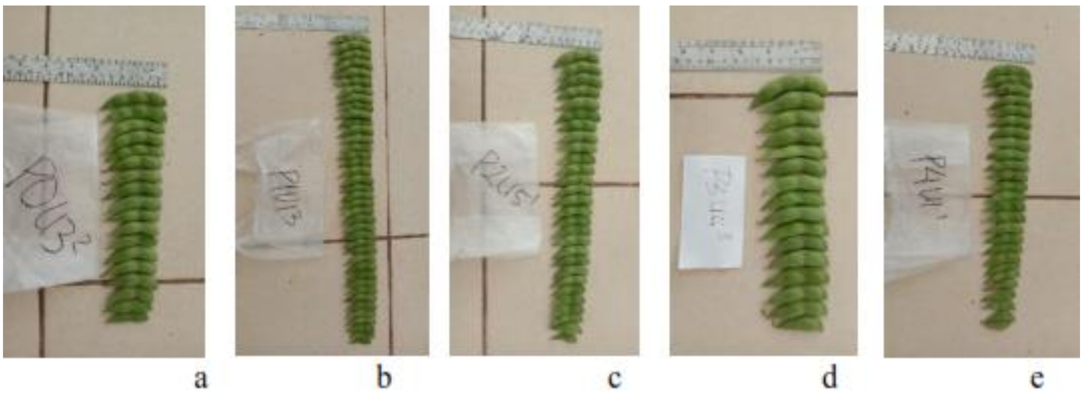

Plate 3. Harvested yield per sample plant: (a) 100% inorganic fertilizer (Control); (b) 50% inorganic fertilizer + 25 g compost; (c) 50% inorganic fertilizer + 37.5 g compost; (d) 50% inorganic fertilizer + 50 g compost; and (e) 50% inorganic fertilizer 50% + 62.5 g compost.

Table 5. Effectiveness of compost application with reduction of inorganic fertilizer on the yield production of edamame soybean.

Treatment	Number of Pods (pod)	Percentage of Filled Pods (%)	Weight of Pods (g)
Control (100% RD of inorganic fertilizer)	41.80	88.08	79.09
50% RD of inorganic fertilizer + 25 g plant^{-1} of compost	46.73	84.36	94.31
50% RD of inorganic fertilizer + 37.5 g plant^{-1} of compost	39.93	85.92	73.78
50% RD of inorganic fertilizer + 50 g plant^{-1} of compost	43.00	86.20	84.91
50% RD of inorganic fertilizer + 62.5 g plant^{-1} of compost	43.07	80.34	80.18

Similar results were also shown by the study of Smiciklas et al. [30], that the application of compost from food waste at doses of 11.2-44.8 t ha^{-1} resulted in soybean yields that were not significantly different from the inorganic fertilizer treatment. Another study conducted by Ruth et al. [23] showed that the use of compost as much as 2.5 t ha^{-1} + 50% of NPK was able to produce higher production per hectare of soybean plants compared to control (100% NPK) and other combination treatments of compost and NPK.

Another study by Yusuf et al. [24] also reported that the use of 100% compost, 25% compost + 75% urea, 50% compost + 50% urea, and 75% compost + 25% urea gave the yield of soybean production variables (number of pods per plant, percentage of filled pods per plant, number of seeds per plant, dry weight of pods per plant, weight of seeds per plant and seed production per hectare) were not significantly different from the control treatment (100% urea). In another plant, similar results were also shown by Wolka and Melaku [5] and reported that the use of compost from food waste was also able to produce the same maize crop production as maize using commercial chemical fertilizers.

The use of organic fertilizers significantly improves soil fertility. Elemental K is important in protein, carbohydrate, fat metabolism, and carbohydrate transport from leaves to roots. The availability of potassium can affect pod formation and seed filling in plants [31]. Research by Lee et al. [32] and Chitravadivu et al. [33] showed that compost from food waste could increase soil nutrient content (Total N, organic matter, C/N, K, Ca, Mg, and Na) better than chemical fertilizers. These studies also add that food waste compost increased the rhizosphere microbial population in the soil significantly compared to chemical fertilizers. In addition, Nunes et al. [34] reported that organic fertilizers could alter soil fertility by enhancing pH, Ca, Mg, K, and P, thereby enhancing soybean growth and yields.

Duong et al. [35] reported that compost increased N and P availability as well as microbial activity in the soil. The study results by Palupi [36] also stated that liquid fertilizer from vegetable and fruit waste qualifies as fertilizer, both as a source of macro-elements and microelements. Furthermore, Yang et al. [37] confirmed that compost application could improve the physical and chemical properties of the soil and increase the population of soil bacteria. These studies support that applying organic fertilizer, in this case, food waste compost can provide nutrients needed by plants to optimize plant growth and production.

The results of this study indicate that in the short term, in general, compost could not produce better plant growth and production than inorganic fertilizers. Despite this, the growth and yield from the compost treatment were equivalent to that of inorganic fertilizers, suggesting that compost could potentially replace or at least reduce the use of inorganic fertilizers. The application of both inorganic and organic manures together can improve the growth, yield, and yield components of Palethwe-1 while potentially reducing the amount of chemical fertilizers used without affecting hybrid rice production [38]. Compost could reduce 40-50% of inorganic fertilizer use and produce the same yield of plants compared to the control (100% of inorganic fertilizer) [14,15].

CONCLUSION

Based on this study's results, household waste compost can reduce the use of inorganic fertilizers by 50%. The recommended dose of household waste compost with a 50% reduction of inorganic fertilizer is 5 t ha^{-1} or equivalent to 25 g $plant^{-1}$.

AUTHORS CONTRIBUTIONS

Elfarisna: concept, writing original draft, final manuscript review, and correction, submission. Sularsih: proposal, field experiments, data collection, and analysis. Ade Sumiahadi: writing English manuscript, revision, finishing manuscript. Mulono Apriyanto: manuscript review and revision; M. Indar Pramudi: manuscript revision; Lovi Sandra: manuscript validation; Yetti Elfina S: manuscript validation; Latarus Pangohoi: layout and visualization.

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