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Response of result component and edamame yield to the harvest waste and livestock manure in a wasteless edamame cultivation system

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Abstract

South Kalimantan has good potential for developing edamame soybean cultivation due to its high demand and limited availability. Furthermore, the harvest waste can be reused as an alternative to fertilizer in the following season. Hence, no cultivation waste is lost. The addition of manure is believed to increase the nutrient availability for plants in acid dry land, thereby affecting soybean production. Therefore, this study aims to determine the potential effect of edamame harvest waste (LPE) and livestock manure on its cultivation. LPE was nested in livestock manure using a Nested Factorial Randomized Block Design. The treatment level of the first factor was chicken, cow, and goat manure, while the second factor was 0%, 25%, 50%, and 75% LPE. The results showed that LPE combined with livestock manure affected plant development; 50% LPE treatment combined with 50% goat manure yielded a better developmental response compared to other treatments. Based on the results, LPE and livestock manure have the potential to increase plant production.

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Introduction

Edamame (*Glycine max* (L.) Merill) is a special type of vegetable soybean from Japan that is consumed freshly and has a higher selling value than ordinary soybeans with a wide market trade, specifically in Japan, Korea, Taiwan, China, America, and Australia (Jian, 1984; Shurtleff and Lumpkin, 2001; Nurman, 2013; Sing, 2017; Yu, 2021). The Japanese market demand is approximately 100,000 t per year^{-1}, the United States is at 7,000 t per year^{-1}, while Indonesia only meets the needs of the Japanese market, which is 3% and the remaining 97% is fulfilled by China and Taiwan (Nurman, 2013). Currently, edamame cultivation is still centered on Java Island, specifically Jember Regency, while the region outside Java is still limited to fulfilling local needs. The average production in Jember Regency between 2013-2017 was 8,139.45 t with a productivity of 9.49 t ha^{-1} and a land area of 858.07 ha (Fajrin, 2017; Central Statistics Agency in Jember Regency, 2018).

Edamame soybean is considered to have several advantages, including high productivity capable of reaching 10 t ha^{-1}. This is certainly well above the average productivity of other soybean types, which is only between 1.5–3 t. Furthermore, it is sweeter and has a larger seed size, savory taste, softer texture, as well as a high and complete protein content compared to other soybeans (Esler, 2011; Yu, 2021). It also contains nine essential amino acids needed by the body, is low in saturated fat, rich in fiber, cholesterol-free has vitamins C and B, as well as calcium, iron, magnesium, and folic acid (Marwoto and Suharsono, 2008; Shanmugasundaram and Yan, 2010; Takahashi and Ohyama, 2011; Djanta *et al.*, 2020;). Meanwhile, the cultivation time is relatively short, ranging from 65 to 68 days with large market demand, and the development is majorly centered in Jember Regency and several other areas on Java Island with competitive prices. The price in the export market is quite high, namely USD 1.9 or IDR 20,000 - IDR 22,000 per kg and IDR 25,000 - IDR 45,000 per kg in Banjarbaru City. This implies that the cultivation has great potential to generate large foreign exchange, thereby improving farmers' welfare and narrowing the difference in the price of edamame soybeans in the production and development areas outside the major centers (Firmansyah, 2007).

Currently, edamame cultivation in South Kalimantan Province is starting to grow, several regions including Tabalong Regency has an area of ± 6 ha, Banjar of ± 0.5 ha, Tanah Laut ± 2.5 ha, Tanah Bumbu 1.75 ha, and Banjarbaru City with an area of 4.5 ha (Central Statistics Agency in South Kalimantan, 2020). Although the number of cultivators is still very limited and the land area is relatively narrow, they continuously increase in line with the rising market demand for fresh edamame.

The problem of edamame cultivation activities in the province is majorly the aspect of land fertility as most areas are classified as having acidic soil with low organic matter content (Ritung *et al.*, 2015). A previous study that examined the fertility in an area reported Total N content of 0.10% (low), C-organic of 0.99% (very low), P_2O_5 of 4.72 mg 100g^{-1} (very low), K_2O of 7.34 mg 100g^{-1} (very low), CEC of 18.05 me 100g^{-1} (moderate) and pH value of 5.49 (sour). Currently, efforts made by farmers to overcome the problem of soil fertility include the use of chemical fertilizers accompanied by liming.

However, excessive and continuous use of chemical fertilizers without the addition of organic matter reduces soil quality. Lack of organic matter in the soil can cause several problems, including low-water retaining capacity, the poor absorption efficiency of fertilizer/nutrients, and disruption of soil structure; consequently, soil productivity tends to decrease, while the need for fertilizer continues to increase (Jones and Benton, 2003; Las *et al.*, 2006; Yuliar, 2006). The use of chemical fertilizers also creates dependence on farmers, which leads to new problems such as rising production prices due to high fertilizer prices, scarcity and imbalance of nutrients in the soil, as well as increasing soil acidity (Jones and Benton, 2003). Therefore, the addition of organic matter is needed to improve soil properties by making the soil looser for better aeration and less compaction compared to soils containing low organic matter. Organic matter in the soil is also beneficial in accelerating the activity of microorganisms, thereby increasing the decomposition speed and accelerating the nutrient release (Sutanto, 2002; ; Setyorini *et al.*, 2006; Purnomo *et al.*, 2017).

The role of organic matter in the soil is the key to the success of farming, but recycling plant residue alone is not enough to maintain soil organic-C levels at an initial condition of 2-2.5% (Hakim and Mursidi, 1984; Juarsah, 2014). Therefore, there is a need to add other organic materials in the form of livestock manure, from chicken, cow, or goat. The utilization of edamame harvest waste (LPE) and livestock manure as organic material is one alternative that can improve soil properties, as well as overcome scarcity and the rising prices of commercial fertilizers in the market. For a long time, farmers have not optimally utilized LPE and livestock manure as soil organic matter, although it is estimated that the production rate of LPE can reach 3.3 t ha^{-1}. Certainly, this abundant availability has the potential to be used optimally in further edamame farming activities. Livestock manure, specifically from chicken, goat, and cow, is generally used by farmers in agricultural cultivation activities due to its several benefits. They reportedly contain various important nutrients for plants with a great potential; for example, cows are capable of producing manure of 15-25 kg day^{-1}, goats by 1-2 kg day^{-1}, and chickens by 0.05 to 0.15 kg day^{-1} (Setiawan, 2002).

The commercial use of LPE and livestock manure is one of the efforts to support its cultivation sustainability. The potential use of LPE and large livestock manure can reduce production expenses, including the cost of purchasing commercial fertilizers. Generally, commercial fertilizers are more expensive than livestock manure as a stimulant in edamame cultivation. Furthermore, given that LPE does not need to be transported out of the agricultural land area, this is expected to reduce the cost of land clearing and transportation. LPE and livestock manure can also be used to overcome the problem of land fertility as an effort to increase production in a zero-waste edamame cultivation system. It also has a feasible economic value that can be used to optimally increase production. Moreover, the agricultural environmental ecosystem is maintained and farmers' income is increased; hence, this study was carried out to determine the potential of these two wastes.

Materials and methods

This study was carried out from June to October 2020 at Trans Gunung Kupang Street, and the Integrated Laboratory, Department of Agroecotechnology, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru City, South Kalimantan. A Nested Classification Group Random Design was used in which LPE was nested in livestock manure. The first factor (A) was the three types of manure, namely from chicken (a_1), cow (a_2), and goat (a_3), while the second factor (B) was the percentage of LPE with four levels, namely 0% LPE (b_1), 25% LPE (b_2), 50% LPE (b_3), and 75% LPE (b_4). There were 12 treatment combinations and one control, namely 100% LPE, which was repeated three times. Therefore, a total of 39 experimental units were obtained.

The land used for the study is located at Trans Gunung Kupang Street, Banjarbaru City, South Kalimantan (3°48'47" S and 114°86'34" E). Chicken, cow, and goat manure, as well as LPE, was analyzed for its nutrient content. The total manure used was 49.5 kg each, while LPE was 148.5 kg. The organic matter dose of 10 t ha^{-1} was used as a reference in determining the dose of the treatment combinations (Melati and Andriyani, 2005; Falodun, 2015; Darini *et al.*, 2020).

Soil cultivation activities include land clearing, making beds, and giving agricultural lime. The land was cleared of weeds using machetes and sickles, while the beds were processed using a hoe with a height of 20-25 cm and a size of 3 m x 3 m, with a distance between beds of 50 cm. Afterward, lime was applied two weeks before planting at a dose of 600 kg ha^{-1} (Lembang Agricultural Training Center, 2015).

The application was carried out by chopping up LPE and then mixing it with livestock manure according to the treatment until evenly distributed. Subsequently, the mixture of ingredients was sprinkled on the beds evenly, and the land was incubated for 14 days before planting edamame soybean seeds.

Ryokoh variety edamame soybean was prepared by selecting good seeds without defects; then the seeds were mixed with Rhizobium brand Rhizoka inoculant. The planting began by making a hole with small bamboo arranged according to the size of the spacing, namely 30 x 30 cm with a depth of 1.5 - 2 cm. The bamboo series was placed on the bed to ease the planting according to the spacing. Subsequently, the seeds were planted with one seed per planting hole and covered evenly with soil; however, given that the topsoil is not compacted, the plants easily grew to the surface. Plant embroidery was carried out with a maximum of less than one week after planting (mst).

Maintenance includes watering, weeding, and controlling plant pests and diseases. Watering was carried out once a day, namely in the afternoon; however, when the soil is moist, or it rained, then watering is not carried out. Weeding was performed once a week after planting until the plants were ready to harvest. The goal is to prevent nutrient competition between cultivated plants and weeds. Pest and plant disease control was carried out by spraying plants using vegetable pesticides such as cow urine and *empon-empon* or herbs (POC+).

The spraying of botanical pesticides began one week after planting (mst) until the plants were ready to be harvested. The optimum time for harvesting is determined by observing the physical pod signs, which are still freshly green, immature, and solid with fully developed green seeds. Physical characteristics at the harvest time include 68 days of age with bright green pods, approximately 5 cm long and 1.4 cm wide with two or more seeds (Shanmugasundaram and Yan, 2010; Yu, 2010).

Observations carried out at the harvest time, which is 68 days after planting (HST) include. The number of pods was calculated from the yield of the sample plants, and expressed in pods per plant.

The number of seed contents was calculated from each pod of the sample plant, it was expressed in seeds per pod. Wet weight (BS) of fresh pods was calculated by weighing the yield per sample plant using an analytical balance after the pods had been cleaned of adhering soil residue and expressed in grams (g).

The pods' dry weight (BP) was calculated by weighing the yield per sample plant using an analytical balance after cleaning of adhering soil residue, followed by heating in an oven at 70°C for 48 hours until absolute dryness. The sample was weighed using an analytical balance and the unit of calculation was expressed in grams (g).

The data were analyzed using GenStat 12th edition to determine the effect of LPE and livestock manure on the Result Component and Edamame Yield in an acid dry land.

The data were tested for homogeneity before being analyzed for variance with the F-test at 1% and 5% significance levels. When the analysis results show an effect on the treatment given, it is continued with Duncan's Multiple Range Test at a 5% significance level (Duncan, 1995).

Results and discussion

The results showed that the data were homogeneous, then the analysis of variance was used and the F-count values obtained are presented in Table 1.

Based on the available data, the type of manure had a significant effect on the number of pods, wet weight, and dry weight per plant, as well as productivity. The percentage factor of LPE that is nested into the livestock manure also had a significant effect on the number of pods, wet and dry weight per plant, as well as productivity.

Table 1. The calculated F-value was obtained from the analysis of variance at the 1% and 5% significant levels.

Source of Diversity	Number of Pods Per Plant	Number of Filled Seeds Per Pod	Fresh Pods Wet Weight Per Plant	Dry Weight of Pods Per Plant	Productivity
Group	2,372	3,085	11,120**	11,818**	11,137**
Control vs Treatment	0,281	0,168	0,903	1,259	0,908
A	12,281**	0,963	11,385**	18,339**	11,372**
BIA	3,772**	1,047	3,196*	3,088*	3,194*

Description: A = type of manure, B = LPE percentage, BIA = LPE is lodged in livestock manure.

Number of pods per plant and number of seeds per pod

The analysis of variance results showed that there was a difference between the treatments and the percentage factor of LPE nested into the livestock manure; hence, further tests were carried out to determine the best treatment. However, this factor did not affect the number of seeds per edamame pod (Table 2).

The average number of pods per plant applied to several types of manure is presented in table 3.Based on the results, the minimum number of pods produced by plants that were not treated with LPE but added with chicken manure ranged from 18 – 39 pods plant^{-1}. However, this result was not significantly different from other plants treated using 25% LPE and added with chicken manure. Furthermore, the plants applied with chicken manure and 50% of LPE produced the largest number of pods per plant, namely 30 pods of plant^{-1}, but it was not significantly different from the treatment with chicken manure and 75% of LPE. The minimum number of 18 pods of plant^{-1} was produced by the edamame plant applied with 25% of LPE and cow manure. However, this result was not statistically different from others treated with 50% LPE and cow manure, as well as plants without LPE and those treated using 75% LPE along with cow manure. The maximum number of 39 pods of plant^{-1}, was produced by the edamame plant applied with 50% of LPE and goat manure, but it was significantly different from those treated with goat manure and added with 0%, 25%, and 50% LPE

Table 2. The average number of pods per plant and number of seeds per pod.

Treatment	Number of Pods Per Plant (pods of plant^{-1})			Number of Seeds Per Pod (pods seed^{-1})		
	BIa_1	BIa_2	BIa_3	BIa_1	BIa_2	BIa_3
b_1	18,00^{a}	22,42^{a}	23,42^{a}	2,31	2,31	2,19
b_2	23,42^{ab}	17,58^{a}	27,17^{a}	2,42	2,48	2,33
b_3	30,25^{b}	18,67^{a}	39,08^{b}	2,38	2,25	2,38
b_4	27,42^{b}	23,00^{a}	27,75^{a}	2,29	2,42	2,29

Description: The same letter in a similar column indicates that the treatment has no significant effect based on Duncan's Multiple Range Test (DMRT) at α 5%. B = LPE percentage, a_1 = chicken manure, a_2 = cow manure, a_3 = goat manure, b_1 = 0% LPE, b_2 = 25% LPE, b_3 = 50% LPE, b_4 = 75% LPE, BIa_1 = LPE nested in chicken manure, BIa_2 = LPE nested in cow manure, BIa_3 = LPE nested in goat manure.

There was a difference in the number of pods per edamame plant and the several types of manure applied with the highest number found in the treatment of goat manure (a_3), followed by chicken (a_1), and cow (a_2) of 29, 25, and 20, respectively. The treatment with the goat manure produced the best response; this is consistent with Muliandari *et al.*, (2018), which stated that the administration of goat manure affected the plant reproductive growth. Furthermore, the maximum number of pods per plant obtained in this study indicates that the results are not optimal because the range of pods per plant for edamame can reach 50 pods (Pambudi, 2013). However, the result is greater than the number of pods per plant produced by the application of artificial N and P fertilizers (Saifudin *et al.*, 2018). This shows that the combination of LPE and livestock manure has great potential in this plant cultivation.

Pod formation requires the presence of N, P, and K nutrients by plants. Hence, sufficient and not excessive N nutrients are needed to increase the number of pods in edamame plantations (Mugnisyah and Setiwan, 2004; Puspasari *et al.*, 2018). According to Ohyama *et al.*, (2013), excessive N application causes dense plant growth but reduces the supply and formation of pods. The application of N fertilizer in soybean cultivation as "Starter N" is used to stimulate early growth. Meanwhile, the natural presence of N can be met through root nodules when the environmental conditions are favorable and Rhizobium inoculants have been administered to the plants. Soybean plants are able to fix N equivalent to 46 kg N ha^{-1}, while the uptake can reach 280.9 kg N ha^{-1} of which 141 kg N ha^{-1} comes from the anchorage of N. Salvagiotti *et al.*, (2008) analyzed data from 480 studies conducted at subtropical and tropical regions, including Indonesia and showed that the total N uptake in soybean was 44–485 kg N ha^{-1} with a mean of 219 kg N ha^{-1} of which 52% comes from fixation. In general, approximately 50% of the N required by plants comes from fixation by rhizobia. This is because land planted with soybeans generally has a high natural population of Rhizobium. However, in nutrient-poor or damaged soils, it is necessary to add 20 kg N ha^{-1} of N fertilizer at the time of planting to meet the N needs (Samsu, 2001; Taufik and Titik, 2012). Additional sources of fertilizer are needed in the form of chicken, cow, and goat manure along with LPE where the N content is 1.95%, 1.53%, 1.17%, and 1.95%, respectively (Santoso *et al.*, 2021).

Table 3. Average number of pods per plant applied to various types of manure.

Treatment	Number of Pods Per Plant (pods of plant^{-1})
a_1	24,77^b
a_2	20,42^a
a_3	29,35^c

Description: The same letter in a similar column indicates that the treatment has no significant effect based on LSD at α 5%. a_1 = chicken manure, a_2 = cow manure, a_3 = goat manure.

Phosphorus (P) is an essential nutrient for plants that functions as an energy carrier and can not be replaced with other nutrients. Its main role is to stimulate root growth, specifically the roots of seeds and young plants. According to Novizan (2003), the greatest use of P begins during the formation of soybean pods to accelerate the formation and ripening, as well as increase the nutritional content of soybeans. The presence of phosphorus is fulfilled by the provision of chicken, cow, and goat manure together with LPE at 4.88%, 1.65%, 2.08%, and 0.34%, respectively (Santoso *et al.*, 2021).

The number of pods is also strongly influenced by potassium (K) which is a primary essential nutrient for plants that are absorbed in more quantities than other elements. Potassium plays a role in the formation of protein and carbohydrates, serves as a source of strength in the face of drought and disease, as well as strengthens the plant body to prevent the leaves, flowers, and fruit from falling easily (Lingga, 2013). In this study, potassium was provided by using organic material in the form of chicken, cow, and goat manure along with LPE of 2.19%, 1.16%, 0.73%, and 2.41%, respectively (Santoso *et al.*, 2021). This is in line with Hapsoh *et al.*, (2019), who reported that the application of organic material in the form of compost could increase N and K leaf levels, as well as soybean production components such as the number and percentage of pithy pods, number of seeds per plant, seed weight per plant, and weight of 100 seeds.

Based on the results, the number of seeds per pod for the plant ranged from 2-3 seeds pod^{-1}. All plants treated with LPE and livestock manure had 2 seeds per pod, except for the treatment with 25% LPE and cow manure which produced 3 seed pods^{-1}. The number of seeds per pod produced in this study is consistent with previous studies which reported that the edamame plant could produce 2-3 seeds per pod due to its inherent genetic factors (Mentreddy *et al.*, 2002; Shanmugasundaram and Yan, 2004;

Shanmugasundaram and Yan, 2010; Pambudi, 2013; Nuroso, 2015). Moreover, Hidayat (1985) stated that the maximum number of pods per plant is genetically determined, while the number of pods formed is influenced by environmental factors during the seed filling process. The formation and filling of pods can affect the production of soybean plants due to the influence of nutrients, water, and sunlight.

Table 4. Average wet and dry weight of fresh pods per plant.

Code	Wet Weight of Fresh Pods Per Plant (g plant^{-1})			Pods Dry Weight Per Plant (g plant^{-1})		
	BIa_1	BIa_2	BIa_3	BIa_1	BIa_2	BIa_3
b_1	$41{,}25^a$	$50{,}92^a$	$58{,}58^a$	$20{,}44^a$	$16{,}50^a$	$19{,}00^a$
b_2	$54{,}67^{ab}$	$44{,}67^a$	$63{,}67^a$	$26{,}00^a$	$15{,}67^a$	$23{,}25^a$
b_3	$77{,}50^c$	$45{,}92^a$	$83{,}83^b$	$43{,}25^b$	$15{,}00^a$	$23{,}00^a$
b_4	$63{,}25^{bc}$	$54{,}08^a$	$67{,}75^{ab}$	$29{,}42^a$	$17{,}25^a$	$22{,}25^a$

Description: A similar letter in the same column indicates that the treatment has no different effect based on Duncan's Multiple Range Test (DMRT) at α 5%. B = LPE percentage, a_1 = chicken manure, a_2 = cow manure, a_3 =goat manure, b_1 = 0% LPE, b_2 = 25% LPE, b_3 = 50% LPE, b_4 = 75% LPE, BIa_1 = LPE nested in chicken manure, BIa_2 = LPE nested in cow manure, BIa_3 = LPE nested in goat manure.

The wet and dry weight of pods per plant

The analysis of variance results showed that there was a difference in the wet and dry weight of pods per plant between the treatments and the percentage factor of LPE nested in the livestock manure, as shown in Table 4. The average wet weight of fresh pods per plant and dry weight of pods per plant applied to several types of manure are presented in Table 5. Based on the results, the wet weight of pods per plant ranged from 41.25 – 83.83 g plant^{-1}. The minimum wet weight of 41.25 g plant^{-1} was produced by the plants treated without LPE but added with chicken manure. This result was not significantly different from the plant applied with 25% LPE and chicken manure.

The highest wet weight, namely 77.50 g plant^{-1} was produced with the application of chicken manure and 50% LPE but was not significantly different from the treatment with chicken manure and 75% LPE.

Table 5. The average wet and dry weight of pods per plant applied to several types of manure.

Treatment	Wet Weight of Fresh Pods Per Plant (g plant^{-1})	Dry Weight of Pods Per Plant (g plant^{-1})
a_1	$59{,}17^b$	$29{,}78^c$
a_2	$48{,}90^a$	$16{,}10^a$
a_3	$68{,}46^c$	$21{,}88^b$

Description: Similar letters in the same column indicate that the treatment has no significant different effect based on LSD at α 5%. a_1 = chicken manure, a_2 = cow manure, a_3 = goat manure.

The lowest wet weight of pods, namely 44.67 g plant^{-1} was found in edamame plants applied with 25% LPE and cow manure. However, the result was not significantly different from the application of cow manure with the addition of 0%, 50%, and 75% LPE. The maximum wet weight, namely 83.83 g plant^{-1} was found in edamame plants treated with 50% LPE and goat manure, but the result was not significantly different from the treatment with 75% LPE and goat manure with a value of 67.75 g plant^{-1}.

The maximum wet weight of the pods was 77.50 g plant^{-1} in the treatment with 50% LPE and goat manure. This indicates that the treatment is very supportive in increasing the pods' wet weight. Meanwhile, the wet weight is also influenced by the generative phase, which is related to the number of pods per plant, indicating the higher the number of pods produced, the greater the wet weight. This is consistent with the results where the treatment of 50% LPE applied with goat manure produced 39 pods. The wet weight in this treatment was significantly different from others treated using chicken manure with the addition of 0%, 25%, and 75% LPE. This result is in line with Muliandari *et al.*, (2018), who reported that goat manure supports the vegetative and generative phases of edamame plants. The number and wet weight of the pods are largely determined by the vegetative phase. Hence, the better the vegetative phase, the higher the photosynthate produced, and the better the ability of plants to form regenerative organs (Shanmugasundaram and Yan, 2010; Sofiana and Syaban, 2017). Plants with a large number of pods will produce a higher wet weight. Among the several types of manure used, there was a difference in the wet weight of pods per plant with the highest wet weight found in the treatment using goat manure (a3), followed by chicken (a1), and cow manure (a2) with values of 68.46 g plant^{-1}, 59.17 g plant^{-1}, and 48.90 g plant^{-1}, respectively.

Table 6. Edamame plant productivity.

Treatment	Productivity (t ha^{-1})		
	BIa_1	BIa_2	BIa_3
b_1	4,58^{a}	5,66^{a}	6,51^{a}
b_2	6,07^{ab}	4,96^{a}	7,07^{a}
b_3	8,61^{c}	5,10^{a}	9,31^{b}
b_4	7,03^{bc}	6,01^{a}	7,52^{ab}

Description: The same letter in a similar column indicates that the treatment has no significant different effect based on Duncan's Multiple Range Test (DMRT) at α 5%. B = LPE percentage, a_1 = chicken manure, a_2 = cow manure, a_3 = goat manure, b_1 = 0% LPE, b_2 = 25 LPE, b_3 = 50% LPE, b_4 = 75% LPE, BIa_1 = LPE nested in chicken manure, BIa_2 = LPE nested in cow manure, BIa3 = LPE nested in goat manure.

Based on the results, the dry weight of the pods ranged from 15.00 to 43.25 g per plant^{-1}. The minimum dry weight, namely 15.00 g plant^{-1} was found in the plant treated with 50% LPE and cow manure; however, it was not significantly different from the treatment with cow manure along with all levels of LPE. The smallest dry weight was found in the plant treated with goat manure and 0% addition of LPE, but the result was not significantly different from the plant administered with goat manure as well as 25%, 50%, and 75% of LPE.

The maximum dry weight, namely 43.25 g plant^{-1} was found in the treatment with 50% LPE and chicken manure. This indicates that the weight loss in this treatment was not significant. Furthermore, the dry weight of pods in this treatment was significantly different from plants treated using chicken manure with 0%, 25%, and 75% LPE. The results suggest that the treatment with 50% LPE and chicken manure provided sufficient organic matter to the soil. The organic matter provided functions to maintain the availability of groundwater, thereby increasing the availability of soil nutrients for plants.

According to Sarief (1985), nutrients are needed to form plant tissue; hence, the presence of balanced nutrients can increase the dry weight of plants, including pods. Sumarsono (2000) also stated that the accumulation of dry matter reflects the ability of plants to bind solar energy through the photosynthesis process as well as interactions between other environmental factors. The photosynthesis process produces energy for the formation of carbohydrates which act as compounds that make up the plant body, also referred to as the dry weight. Among the several types of manure used, there was a difference in dry weight of pods per plant, with the highest dry weight found in the treatment using chicken manure (a1), followed by goat (a3) and cow (a2) with values of 29 .78 g plant^{-1}, 21.88 g plant^{-1}, and 16.10 g plant^{-1}, respectively.

Table 7. Productivity of edamame plants applied to several types of livestock manure.

Treatment	Productivity (t ha^{-1})
a_1	6,57^b
a_2	5,43^a
a_3	7,61^c

Description: The same letter in a similar column indicates that the treatment has no significantly different effect based on LSD at 5%. a_1 = chicken manure, a_2 = cow manure, a_3 = goat manure.

Organic matter contains carbon which functions as a source of food and energy for the growth and development of various types of soil microbes. Meanwhile, microbes facilitate the decomposition of organic matter, which also helps to maintain soil structure or act as a binder of primary grains into the secondary with a strong or stable aggregate. These activities affect the conditions of porosity, water storage, aeration, and soil temperature (Nurhayati *et al.*, 2011; Jankauskienė, 2021). Good soil conditions increase the availability of nutrients needed by plants for their growth. Wibisono and Basri (1993) stated that the improvement of soil physical properties through the addition of organic matter could increase water holding capacity, as well as soil content, aggregates, and permeability. Meanwhile, the improvement of soil chemical properties through the addition of organic matter can provide nutrients, improve cation exchange capacity, and increase the solubility of elements in the soil. This leads to good soil conditions, which affect plant metabolic reactions and, ultimately, the seed weight. This is in line with Saputra *et al.*, (2021), who reported that the application of organic guano fertilizer increased the growth and production of edamame soybeans in the mound soil due to improvements in the physical and chemical properties.

Edamame plant productivity

The analysis for variance results showed that there was a difference between the treatments and the percentage factor of LPE nested in the livestock manure. Therefore, further tests were carried out to determine the best treatment (Table 6). Productivity of edamame plants applied to several types of livestock manure are presented in Table 7.

Edamame plant productivity in this study ranged from 4.58 to 9.31 t ha,$^{-1}$ the minimum productivity was found in the treatment without LPE and chicken manure. However, the result was not significantly different from the productivity of the plant treated using 25% LPE with the addition of chicken manure. The highest productivity was found in the treatment with chicken manure and 50% LPE, but it was not significantly different from others treated with 75% LPE and chicken manure. Furthermore, the productivity with the addition of cow manure and various levels of LPE showed no difference; the results obtained ranged between 4.96 – 6.01 t ha^{-1}.

The maximum plant productivity, namely 9.31 t ha^{-1} was produced by edamame plants treated using the 50% LPE and goat manure. However, the result produced was not significantly different from the productivity obtained with the application of 75% LPE with goat manure, namely 7.53 t ha^{-1}. This is above the average description of edamame plant productivity ranging from 6-7 t ha^{-1}. Among the several types of manure used, there was a difference in the productivity of edamame plants, with the highest productivity found in the treatment of goat manure (a3), followed by chicken (a1) and cow (a2) with values of 7.61 t ha^{-1}, 6.57 t ha^{-1}, and 5.43 t ha^{-1}, respectively.

LPE used in this study was derived from leaf and stem tissues that are not used for any purpose or were considered useless by some farmers hence it was simply thrown away into the agricultural environment. However, based on the analysis results, the total N in the leaves and stems of the edamame plant was 2.27% and 1.63%, the organic C was 29.67%, and 28.73%, while the C/N ratio was 13.06 and 17.67, respectively (Santoso *et al.*, 2021). The essential element in the form of phosphorus (P) needed by plants for growth was obtained by giving chicken, cow, and goat manure as well as LPE of 4.88%, 1.65%, 2.08%, and 0.34%, respectively

(Santoso *et al.*, 2021). Similarly, potassium was provided using organic materials in the form of chicken, cow, and goat manure as well as LPE by 2.19%, 1.16%, 0.73%, and 2.41%, respectively (Santoso *et al.*, 2021). All organic materials used contain nutrients that have the potential to enhance the development of the edamame plant. However, the number of nutrients contained and the characteristics of the material also affect the responses obtained.

Melati *et al.* (2008) stated that organic fertilizer combinations and their residues could be used to fulfill soil nutrient requirements for soybean production. In general, soybean cultivated organically produces better results compared to the cultivation carried out conventionally (Melati and Andriyani, 2005). This is mainly due to the presence of organic matter which improves the physical, chemical, and biological properties of the soil. According to Tufaila *et al.*, (2014), increasing the dose of organic fertilizer on plants will improve the amount of N, P, K, and organic matter in the soil, allowing for an increase in soil pH, total N content, and available P. High levels of organic matter from livestock manure and LPE can improve the physical, chemical, and biological properties of the soil. This manure is very suitable for soils with high acidity levels because it can reduce acid levels, thereby facilitating the planting of various horticultural crops. High levels of K_2O also increase the productivity of fruit plants because potassium is needed in the generative growth process, such as the growth of fruit, flowers, and seeds. The nutrient K found in goat manure is basically higher than in cow. Meanwhile, cow manure contains more cellulose and high carbon content; hence, it has the potential to inhibit plant growth (Sudarsono *et al.*, 2013).

Conclusion

The use of LPE and livestock manure affected edamame yield as demonstrated in the parameters such as the number of pods per plant, wet and dry weight of pods per plant, as well as plant productivity. Based on the results, the use of 50% LPE combined with 50% goat manure is recommended because this combination improves developmental performance with higher productivity.

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