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Growth and Development Responses of Soybean (*Glycine max* L.) Under Several Combinations of Inorganic and Organic Fertilizer

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ABSTRACT

One of familiar green soybean, edamame is a vegetable that popularly chosen by the richest consumer. The reducing inorganic fertilizers can be realized gradually by transforming the farming from conventional to organic. Related to transformation, we observed the suitable combination of inorganic and organic fertilizers for the edamame growth and production. By a randomized block design, seven combinations of inorganic fertilizers (150 kg/ha Urea, 150 kg/ha SP-36, 100 kg/ha KCl) and organic fertilizers (compost) were applied. Three repeatations was adopted for each treatment and 30 plants per plot was used. The analysis of variance and Tukey HSD at 5% error were chosen. Based on the result, the combination of inorganic fertilizers and compost effect four plant growth and development variables such as the plant height, the number of leaves, the number of productive branches, and the time to produce 50% of a flower. The application of inorganic fertilizers at 50% and 75% combined with compost 10 t/ha increased the plant height, the number of productive branches, and the number of leaves. The number of seeded pods and the pod weight are not affected by all combinations of treatments.

INTRODUCTION

Edamame (*Glycine max* (L.) Merril.) is a plant species that belongs to the vegetable crop (green soybean vegetable) (Williams II, Zhang, Fu, & Ross, 2022) and is commonly consumed as a vegetable and healthy snack in Japan (Guo et al., 2020). Edamame contains a high nutritional value, rich in isoflavones which are organic compounds that are antioxidants and are efficacious in preventing cancer (Kim, 2021; Williams II, Zhang, Fu, & Ross, 2022; Yu et al., 2021). The market opportunity for edamame soybeans is relatively more significant in exports and locally (Wibowo, Mahardika, Afrizal, & Udayana, 2020). This soybean can potentially reduce the volume of imports of raw materials for animal feed and the food industry in the country. The productivity of edamame soybeans can reach 3.5 t/ha, which is higher than ordinary soybeans (Marwoto, 2007). Innovating cultivation technology, such as providing nutrients or fertilizing, is necessary to achieve the expected productivity.

The type of fertilizer that is often used in planting edamame soybeans is inorganic fertilizer. Edamame soybean farmers mostly use inorganic fertilizers at high doses of 600 kg/ha (Sudiarti, Hasbiyati, & Hikamah, 2019). It has exceeded the threshold recommended by Indonesian National Standard (SNI), which is 300 kg/ha. The utilization of inorganic substances in the form of fertilizers or pesticides surpassing the dose poses a severe problem. The use of inorganic fertilizers is not only harmful to agricultural land but also endangers human health. Most farmers prefer to provide a high dose of inorganic fertilizer for their crops, and organic fertilizers are applied to reduce the dosage

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of inorganic fertilizers that are too high (Maswar & Soelaeman, 2016).

Developing environmentally friendly agriculture by employing an alternative organic fertilizer is essential. Organic fertilizers known by farmers are organic fertilizers in the form of bokashi, decomposed by microorganisms. Bokashi increases the binding capacity of sandy soil (light soil), improves the structure of loamy soil (heavy soil), increases water holding capacity, drainage and soil air conditioning, fertilization from artificial fertilizers, the availability of nutrients, and the binding capacity of the soil to nutrients (Tong, Whitehead, & Fawole, 2021). According to other researchers, giving compost in the form of bokashi increases plant development and growth, including the sum of productive branches, the sum of pods, the number of empty pods, and the weight of seeds (Faozi, Yudono, Indradewa, & Ma'as, 2018).

Compost or bokashi is expected to be able to substitute the inorganic fertilizers. *Chromolaena odorata* and *Lannea coromandaleca* are common materials used to produce bokashi. *Chromolaena odorata* contain nitrogen nutrients which are pretty high (2.65%) and can produce high biomass, so they can potentially be used as a source of organic matter (Peniwiratri & Arbiwati, 2022). *Lannea coromandaleca* leaves include dry matter 24.492%, crude protein 18.459%, natural fat 1.338%, and crude fiber 23.53%. Javanese wood, *Lannea coromandaleca* cortex contains flavonoids, tannins, and terpenoids (Lubis & Zulfa, 2021). The study's objectives are (1) to analyze the effect of inorganic and organic fertilizers on the growth and production of edamame soybeans; (2) to obtain a dose of organic fertilizer that can substitute for inorganic fertilizers on the development and harvest of edamame soybeans.

MATERIALS AND METHODS

The research was conducted in Sanrobone Village, Sanrobone District, Takalar Regency. The implementation of this research was carried out from May to August 2020. The materials used were Edamame Ryokkoh Soybean seeds, Urea fertilizer, SP-36 fertilizer, and KCl fertilizer, materials for making bokashi fertilizer (which were made from *Chromolaena odorata* and *Lannea coromandelica*), a mixture of making bokashi (EM4, husk, bran, sugar) and water. While the tools used are water reservoirs, scales, tarpaulins, sacks, Japanese ropes, machetes, buckets, labels, cutters, flush tools (spray), hoes, hand tractors, chopping machines, thermometers, cameras, meters, stationery, ruler.

This research was carried out using the Randomized Block Design, consisting of seven combination treatments: compost or bokashi and inorganic fertilizer (Urea: 150 kg/ha, SP–36: 150 kg/ha, and KCl: 100 kg/ha). Each treatment was replicated three times; therefore, there were 21 experimental units, and every experimental unit included 30 plants per plot, so there were 630 plants. The treatment combinations were: (A) 100% inorganic fertilizer (control) per plot; (B) 75% inorganic fertilizer + compost 10 t/ha (2.2 kg) per plot; (C) 50% inorganic fertilizer + compost 10 t/ha (2.2 kg) per plot; (D) 25% inorganic fertilizer + compost 10 t/ha (2.2 kg) per plot; (E) 75% inorganic fertilizer + compost 20 t/ha (4.4 kg) per plot; (F) 50% inorganic fertilizer + compost 20 t/ha (4.4 kg) per plot; (G) 25% inorganic fertilizer + compost 20 t/ha (4.4 kg) per plot.

The bokashi or compost was made from two main organic materials: *Chromolaena odorata* and *Lannea coromandelica*. Additional ingredients include husks, bran, EM4, and granulated sugar. The EM4 solution was made by mixing one liter of EM4 solution, 40 liters of clean water, and 1 kg of granulated sugar and pouring it on the chopped organic matter until it reached about 30-40%. The organic material is then fermented for approximately three weeks. Plots were made after the land had been processed. The plots used were 21 plots of 1 m x 2.2 m. The application of compost was carried out according to the treatment, and after that, one Edamame seed per planting hole was planted individually with a spacing of 20 cm x 25 cm. Inorganic fertilizers were applied to soybean plants twice, namely at the age of 14 days following planting and thirty days after planting. Inorganic fertilizers given for a 100% dose are Urea fertilizer: 150 kg/ha, SP-36 fertilizer: 150 kg/ha, and KCl fertilizer: 100 kg/ha. The harvest time for edamame soybeans was 63-68 days after planting. Plant growth and development variables that were observed were plant height (cm), leaf count, the sum of productive branches, time of flower emergence 50% (days), the sum of pods, weight of planted pods (g), the weight of pods per plot (g), pod production per hectare (t/ha), fresh weight of plant parts (g) and the sum of empty pods (%).

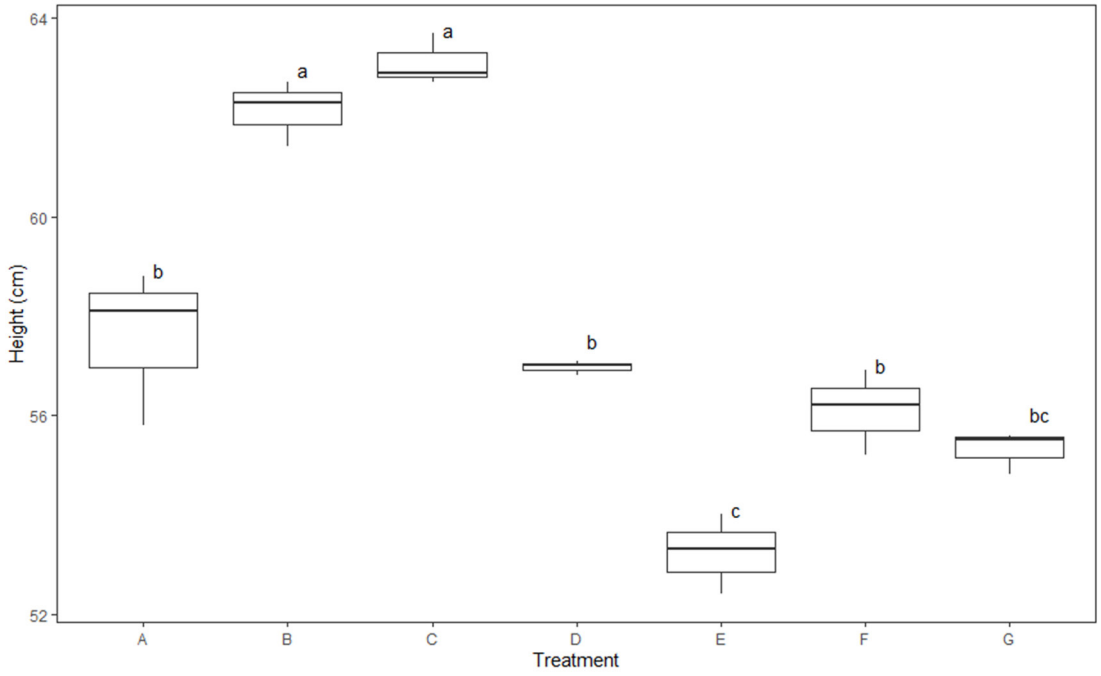
Data were analyzed by variance (ANOVA) analysis of RM and Tukey HSD at a 5% error. Boxplot was chosen to visualize the result of the analysis. R studio was used as statistical software to run each analysis.

RESULTS AND DISCUSSION

Based on plant height, the application of 10 t/ha compost combined with 50% and 75% inorganic fertilizers showed differences compared to the control and other treatments at 42 days after planting (dap). Both applications produced the highest values based on the plant height variable. On the other hand, the application of 20 t/ha of compost combined with 75% inorganic resulted significantly in the lowest value of plant height (Fig. 1).

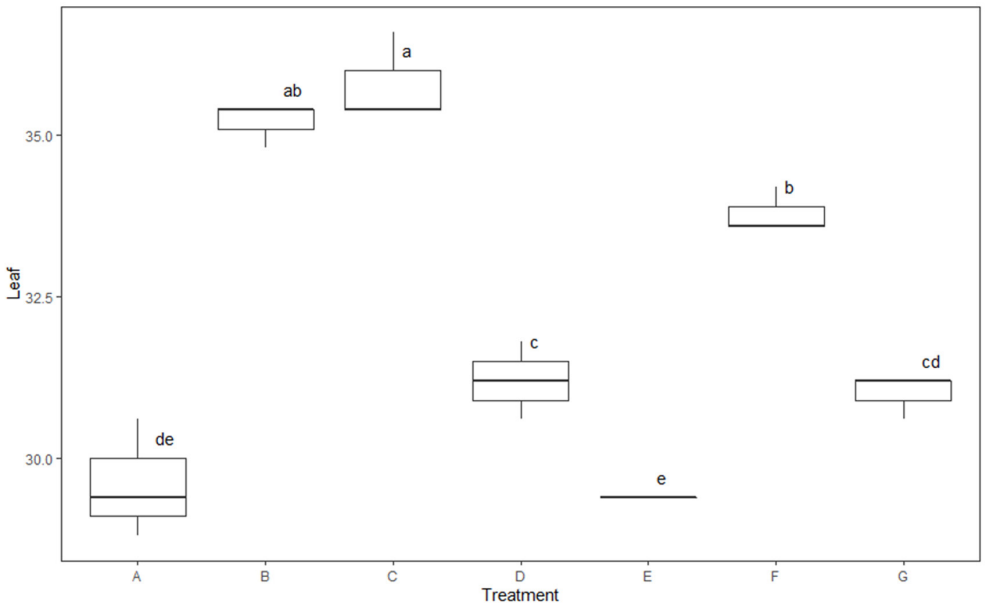
As one of the variables related to biomass production, plant height is affected by the combined application of organic and inorganic fertilizers (Maswar & Soelaeman, 2016). The NPK fertilizer at 50%, mixed with organic fertilizer, increases biomass production. In addition, combining organic and inorganic fertilizers also increases the organic carbon fixation and grain yield of maize and rice (Ghosh et al., 2022; Maswar & Soelaeman, 2016; Moe, Moh, Htwe, Kajihara, & Yamakawa, 2019; Roba, 2018). The combination of organic with inorganic fertilizers as nutrient supply and weed management significantly improved the rice crop's 9% biomass growth, 10% yield, and 7% higher nutrient uptake (Ghosh et al., 2022). The utilization of organic and inorganic fertilizers advances productivity without negative influence on yield quality and remedies soil fertility than the values achieved by organic or inorganic fertilizers individually (Roba, 2018).

At 42 days after planting, applying 10 t/ha of compost combined with 75% and 50%, inorganic fertilizers provided the highest leaf count. The utilization of 20 t/ha of compost mixed with 50% inorganic and 10 t/ha of compost with 25% inorganic fertilizer is also significantly higher than the control. The application of 20 t/ha of compost with 75% inorganic fertilizer is substantially lower than the control based on the leaf count (Fig. 2). Applying 10 t/ha of compost combined with 50% and 75% of inorganic fertilizers produced higher productive branches than the control. Other treatments show no differences compared to the control (Fig. 3).



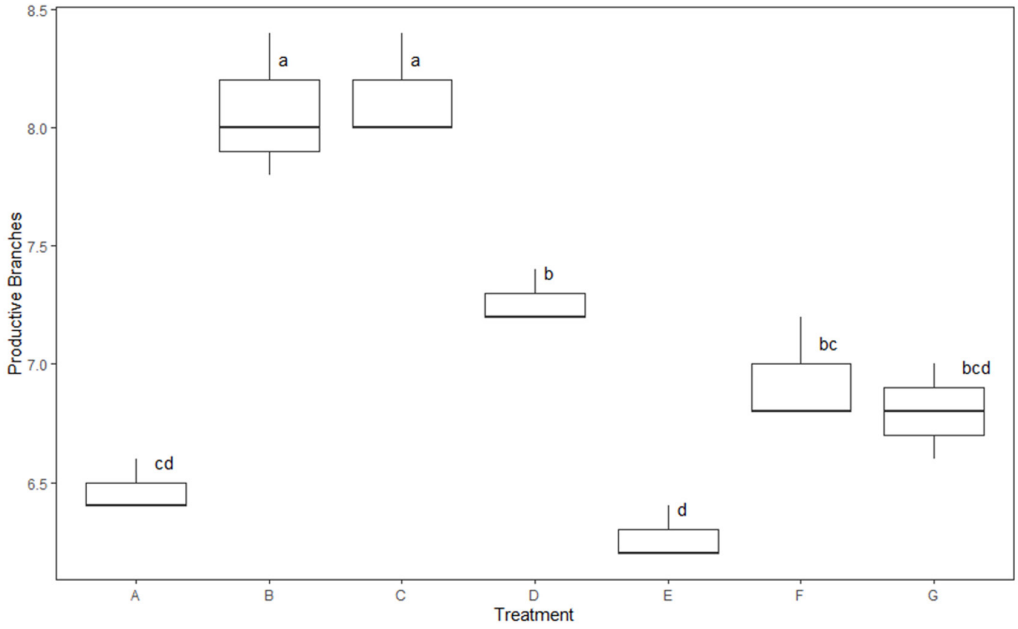
Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

Fig. 1. Comparison of the average height of the edamame plant (42 days after planting) for each treatment based on one-way Analysis of variance RM and Tukey HSD 5%



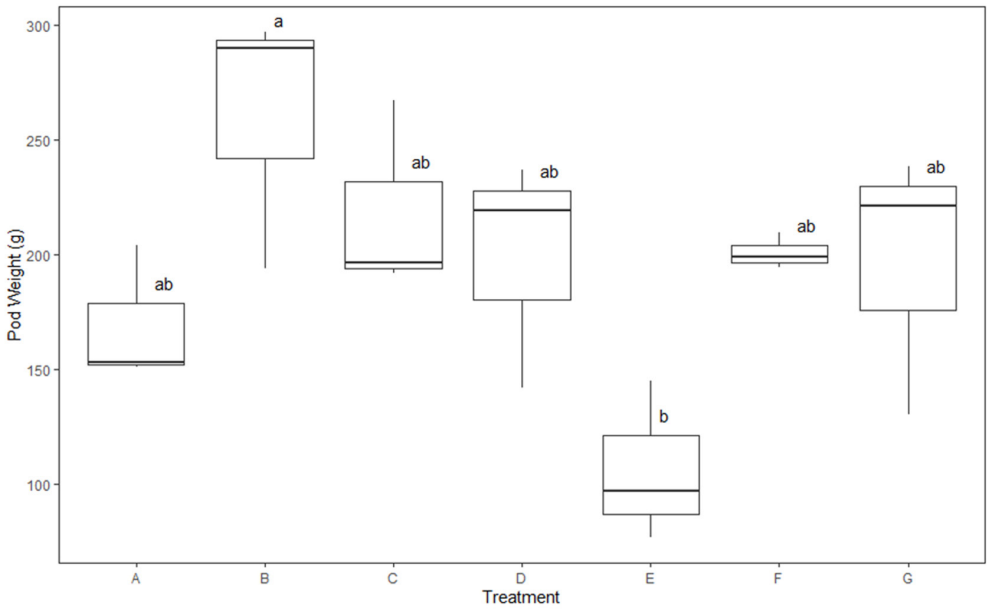
Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

Fig. 2. Comparison of the average leaves of edamame plant for each treatment based on one-way Analysis of variance RM and Tukey HSD 5% (42 days after planting)



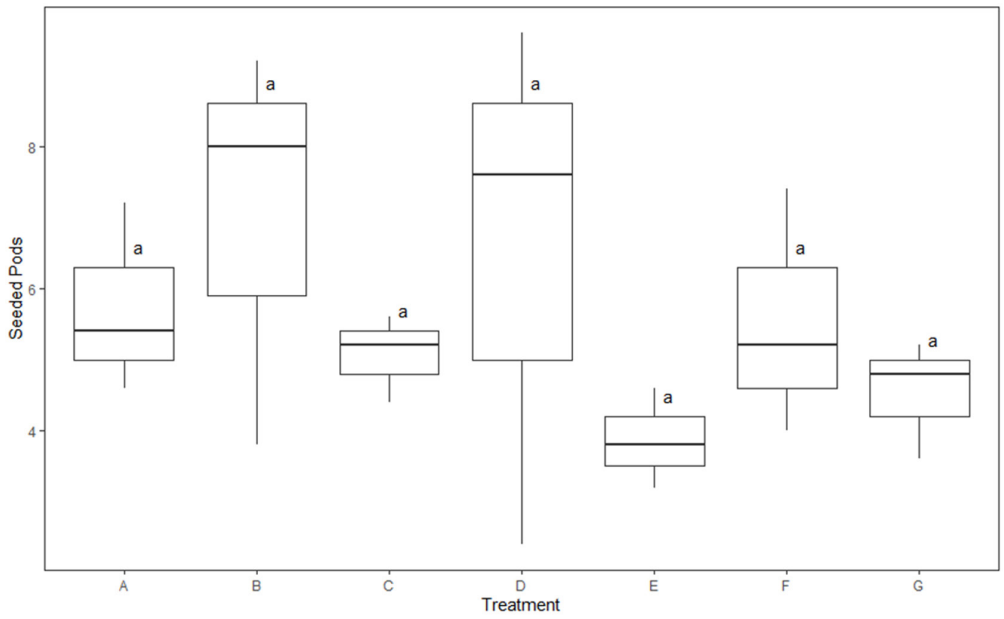
Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

Fig. 3. Comparison of the average productive branches of edamame plant for each treatment based on one-way Analysis of variance RM and Tukey HSD 5%



Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

Fig. 4. Comparison of the average pod weight of edamame plant for each treatment based on one-way Analysis of variance RM and Tukey HSD 5%

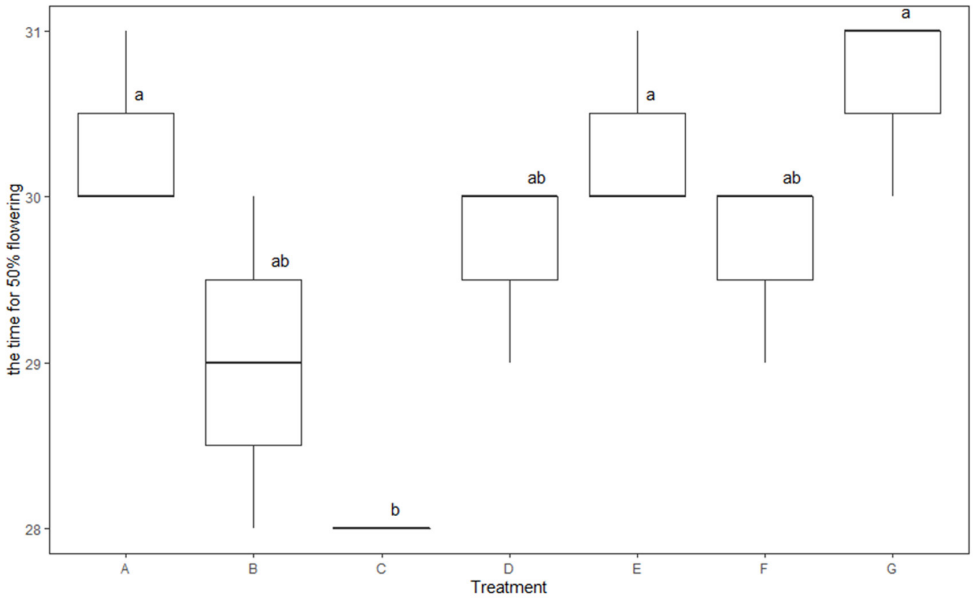


Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

Fig. 5. Comparison of the average seeded pods of edamame plant for each treatment based on one-way analysis of variance RM and Tukey HSD 5%

The leaf count and the sum of productive branches are also close to plants' biomass production, and combining organic and inorganic fertilizers increases the leaf count (Maswar & Soelaeman, 2016; Moe, Moh, Htwe, Kajihara, & Yamakawa, 2019; Tong, Whitehead, & Fawole, 2021). The leaf is the essential part of the plant that facilitates photosynthesis. Soybean is categorized into C3 plant, producing the maximum conversion efficiency of solar energy to biomass at approximately 4.6% at 30°C and 380 ppm atmospheric [CO2] (Zhu, Long, & Ort, 2008). Amalgamation between organic and inorganic fertilizers that inoculated with rhizobia escalated nodulation, shoot biomass, haulms, harvest index (HI), P agronomic usefulness (P-AE), as well as rainwater use efficiency (RUE) (Ulzen et al., 2020).

Based on the pod weight, the application of 20 t/ha of compost combined with 75% inorganic fertilizer is significantly lower than the 10 t/ha of compost mixed with 75% inorganic fertilizer. All treatment combinations in pod weight and seeded pods are not very different compared to the control (Fig. 4 and Fig. 5).



Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

Fig. 6. Comparison of the average time to produce 50 percent flower of edamame plant for each treatment based on one-way Analysis of variance RM and Tukey HSD 5%

Table 1. Summary of organic (compost) and inorganic fertilizers effects on six plant growth and development variables compared to the control (inorganic fertilizer only), based on ANOVA at 5% error.

Each treatment to the control	Plant height	No. of leaves	No. of productive branches	Time to produce 50% flower	No. of seeded pods	Pod weight
B to A	+	+	+	0	0	0
C to A	+	+	+	-	0	0
D to A	0	+	+	0	0	0
E to A	-	0	0	0	0	0
F to A	0	+	0	0	0	0
G to A	0	0	0	0	0	0

Remarks: A (control), B (75% inorganic + 10 t/ha compost), C (50% inorganic + 10 t/ha compost), D (25% inorganic + 10 t/ha compost), E (75% inorganic + 20 t/ha compost), F (50% inorganic + 20 t/ha compost), and G (25% inorganic + 20 t/ha compost)

The highest combination of organic and inorganic manures is not related to yield productivity but tends to increase yield quality. Adding organic manure with inorganic fertilizer (optimum NPK) significantly elevated the fruit quality due to grade fruit chemical composition, such as soluble solids and reduced sugar (Zhang et al., 2020). Roba (2018) stated that organic fertilizer remediates soil's physical and biological activities; however, the nutrient content is lower. On the contrary, inorganic fertilizer provides all necessary nutrients that are directly reachable for plants (Roba, 2018).

Based on the average time to produce 50% flowers, using 10 t/ha of compost combined with 50% inorganic fertilizer has the shortest period. However, it is insignificant compared to the 10 t/ha of compost combined with 75% and 25% of inorganic fertilizers, and the application of 20 t/ha compost with 50% inorganic fertilizer (Fig. 6).

The effect of some organic fertilizers produced an increase in all vegetative, flowering and characteristics, plant height 37.18 cm, leaf area 98.90 cm^2, leaf count 8.50 leaves per plant, length of flower stalk 32.68 cm, fresh weight of flower stalk, and the diameter of the flower stalk 0.91 cm, the duration of the flowers on the plant 18.56 days (Altaee & Alsawaf, 2021). At the flowering phase, the integrated (manure + fertilizer) and manure method had more N in two pools, indicating removing plant-available N from the microbial biomass. The short period of flowering will promote the fruiting stage. The seed quality of fruit also significantly became betters with integrated fertilization, with fruit weight similar to conventional fertilization (Darnaudery, Fournier, & Léchaudel, 2018).

From six plant growth and development variables observed in this research, the number of seeded pods and pod weight showed no differences between treatments to the control. Four remaining variables show the differences (Table 1).

A combination of organic and inorganic fertilizers as a nutrient provides enhanced 9% biomass growth and 10% rice crop yield with 3-7% higher nutrient uptake (Ghosh et al., 2022). Furthermore, combining fertilizers increases productivity without negatively affecting yield quality (Roba, 2018).

CONCLUSION

This study deduces that combining compost and inorganic fertilizers affects the plant height, the sum of leaves, productive branches, and the time to produce 50% of the flower. The sum of seeded pods and pod weight is not affected by all combinations of treatments. The practice of 10 t/ha of compost combined with 50% inorganic fertilizer produces the shortest flowering period. At 42 days after planting, applying 10 t/ha of compost combined with 50% and 75% of inorganic fertilizers made the higher productive branches than the control. In addition, the application of 10 t/ha of compost combined with 75% and 50% inorganic fertilizers provided the highest leaf count and plant height.

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