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Response of Growth and Yield of Soybean to Urea Application Frequency and Coffee Husk Compost Dosage in Coastal Land

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ABSTRACT

Utilizing marginal land, such as coastal areas, offers a viable approach to increasing soybean production. However, coastal lands are often characterized by low nutrient content and high porosity, necessitating effective strategies to optimize crop growth and yield. This study aimed to examine the interaction between urea application frequency and coffee husk compost dosage, identifying the best combination for enhancing soybean performance on coastal land. The research was conducted from November 2023 to February 2024 in Bengkulu City, Indonesia, at an elevation of approximately 5 meters above sea level. A Randomized Complete Block Design (RCBD) was employed with two factors: coffee husk compost dosage (0, 10, 20, and 30 tons ha^{-1}) and urea application frequency (0, 1, 2, and 3 times, at 100 kg ha^{-1}). Results revealed a significant interaction between compost dosage and urea frequency, influencing several growth parameters, including plant height, pod number per plant, fresh and dry shoot weight, fresh and dry root weight, and seed weight per plant. Compost doses of 20 and 30 tons ha^{-1}, along with 2 or 3 applications of urea, notably increased leaf number, productive branch number, and seed yield per plant. These findings indicate that optimizing both urea application frequency and coffee husk compost dosage can significantly improve soybean productivity on nutrient-poor coastal soils. This highlights the importance of integrated nutrient management for enhancing crop yield in marginal environments.

INTRODUCTION

Soybean (*Glycine max* L.) is an essential crop that plays a significant role both as a source of national revenue and income for farmers. It also provides health benefits such as reducing cancer risk, improving bone health, regulating blood sugar, and promoting blood circulation (Rahayu, 2022). Soybeans contain high protein levels ranging from 35-45% (Sholeh & Istiqomah, 2021), making them a crucial source of plant-based proteins. With the growing population and increasing awareness of nutrition, the demand for soybeans has risen steadily over the years (Sholeh & Istiqomah, 2021).

Despite this demand, the soybean harvest area in Indonesia has decreased over time, with 493,546 hectares in 2018, 285,265 hectares in 2019, 182,072 hectares in 2020, and 134,700 hectares in 2021. This decline in harvest area has led to reduced production, with soybean output dropping from 650,000 tons in 2018 to 212,863 tons in 2021, yielding an average productivity of 1.48 tons ha^{-1} from 2018 to 2021 (Retno & Marsud, 2021). National soybean demand reaches 2.7 million tons annually, while domestic production is only around 963,183 tons (BPS-Statistik Indonesia, 2022). One strategy for increasing soybean production is to utilize marginal lands, such as coastal areas.

Coastal land offers diverse potential for agriculture despite its unique challenges. It is characterized by a sandy texture, loose structure, low nutrient content, poor cation exchange capacity, low water retention, and high daytime soil temperatures, among other constraints (Subagiyo *et al*., 2017; Bertham, 2018). To overcome these challenges, the application of organic matter, such as coffee husk compost, and optimizing the urea application frequency are essential.

Organic fertilizers such as compost can improve the physical and chemical properties of soil by enhancing water retention, promoting root development, and improving the efficiency of chemical fertilizers (Andriani & Harini, 2016). Coffee husk waste is a rich source of organic matter and nutrients like nitrogen (N), phosphorus (P), and potassium (K), making it suitable for compost production (Novita *et al*., 2019). The use of coffee husk compost can increase the macro-and micronutrient contents in the soil, thereby improving plant growth (Fitri *et al*., 2018). Additionally, the application of 30 tons/ha of coffee husk compost has been shown to influence soybean plant height, productive branch number, and pod count (Fitri, 2018), whereas doses of 10 and 20 tons ha^{-1} also improve soybean growth and yield (Fadli *et al*., 2020). Nitrogen (N) is an essential nutrient required for plant growth. Nitrogen deficiency can disrupt cell division, leading to stunted growth (Iswiyanto *et al*., 2023). Urea fertilizer, which contains 46% nitrogen, is highly hygroscopic and dissolves readily in water. However, nitrogen from urea is prone to leaching and volatilization (Santana *et al*., 2021), making the frequency of application critical for effective and efficient use.

Applying 100 kg ha^{-1} urea can significantly enhance soybean plant height, chlorophyll content, nodule formation, and dry seed weight, all of which contribute to higher yields (Sholeh & Istiqomah, 2021). Urea applied at 2 weeks after planting (WAP) improves soybean growth (Sari, 2018), and multiple applications, such as at 1, 2, and 3 WAP, have been shown to increase plant height in cowpea (*Vigna unguiculata* L.) (Amir, 2021).

This study aims to find the interaction between the dose of coffee husk compost and the frequency of Urea application on soybean growth and yield; the best dose of coffee husk compost on soybean growth and yield; and the best frequency of Urea application on soybean growth and yield on coastal land.

MATERIALS AND METHODS

This research was conducted on coastal land from November 2023 to February 2024, located at Jalan Kuala Alam, Nusa Indah Subdistrict, Ratu Agung District, Bengkulu, at an elevation of 5 meters above sea level. The materials used in this study included Anjasmoro soybean variety, coffee husk compost, urea (100 kg ha^{-1} dosage), carbofuran 3%, profenofos 500 g L^{-1}, and cypermethrin 50 g L^{-1}. The equipment used included a machete, sprayer, watering can, hoe, labels, measuring tape, digital scale, raffia string, calculator, and writing tools.

The study utilized a Randomized Complete Block Design (RCBD) with two factors: coffee husk compost dosage (0, 10, 20, and 30 tons ha^{-1}) and urea application frequency (100 kg ha^{-1} dosage) at four levels (0 applications, 1 application at 1 week after planting (WAP), 2 applications at 1 and 2 WAP, and 3 applications at 1, 2, and 3 WAP). This resulted in 16 treatment combinations, each repeated three times, yielding 48 experimental units. Each unit contained five samples, making a total of 240 samples in the experiment.

Soil analysis was conducted prior to planting to determine soil pH, and levels of nitrogen (N), phosphorus (P), potassium (K), organic carbon (C), as well as sand, silt, and clay content. The procedure began with soil sampling from the research field. Samples were collected at a depth of 20 cm from five different points. From each point, 0.2 kg of soil was taken, mixed in a bucket, and thoroughly homogenized. The mixed soil was then taken to the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University, for analysis.

Land preparation began with the removal of weeds, followed by measuring the plots using a measuring tape. The land was tilled to a depth of approximately 15 cm. Each plot measured 1 m x 1.2 m, with a distance of 50 cm between replications and 40 cm between plots, for a total of 48 plots. Coffee husk compost was applied two weeks before planting by evenly spreading it on each plot according to the treatment. The soil was then tilled again.

Planting was carried out by creating holes 2-3 cm deep, with a planting distance of 30 cm x 20 cm. Two seeds were placed in each hole, and 3% carbofuran was applied to each hole before covering it with soil. Urea was applied in one, two, or three applications, depending on the treatment. For one application, urea was applied at 1 week after planting (WAP) at a rate of 100 kg ha^{-1}. For two applications, it was applied at 1 WAP and 2 WAP, each with half the dosage (50 kg ha^{-1}). For three applications, urea was applied at 1, 2, and 3 WAP, each time with one-third of the dosage (33.33 kg ha^{-1}). Urea was applied in furrows made between the plant rows, 10-15 cm away from the stem, and then covered with soil.

Base fertilization was performed at 1 WAP using single fertilizers: TSP (150 kg ha^{-1}) and KCl (150 kg ha^{-1}). Urea was applied according to the treatments. Fertilization was done by creating furrows between plant rows. TSP at 150 kg ha^{-1} positively impacted the number of pods per plant in peanuts (Hamid, 2019), and KCl at 150 kg ha^{-1} improved peanut growth and yield (Siregar & Rahmawati, 2022).

Reseeding was performed at 1 WAP by replacing any non-germinated seeds with pre-prepared seedlings. Thinning was conducted by removing one soybean plant from each planting hole, leaving only one healthy plant. This was done by cutting the plant at soil level using scissors, 1 week after planting.

Sample selection was performed randomly using the simple random sampling method within each experimental plot, with border plants excluded. Five sample plants were selected from each plot. Harvesting was conducted comprehensively once the plants met the harvest criteria, specifically when 95% of the pods in a plot had turned dry brown. The observation variables encompassed both growth-related and yield -related parameters of the plants.

The observation data are statistically analyzed using analysis of variance (ANOVA) at the 5% significance level. Duncan's Multiple Range Test (DMRT) is applied at the 5% significance level to compare the means between treatments.

RESULTS AND DISCUSSION

General overview

Initial soil analysis indicated that the coastal land used for this study consisted of 89.85% sand, 5.15% clay, and 5.01% silt, with an organic carbon content of 1.73%, N at 0.19% (low), P at 4.78 ppm (moderate), K at 0.46 me 100 g^{-1} (moderate), and a pH of 5.68.

Planting was carried out in the second week of November 2023. Each planting hole was sown with two soybean seeds. Replanting was done one week after planting (WAP) to replace any seeds that did not germinate. Thinning was conducted at 2 WAP. At 4 WAP, several pests, such as leaf-rolling caterpillars, were observed, though the infestation was minimal and controlled manually. At 6 weeks, the soybeans had started to flower. At plot number 1, green stink bugs and rice bugs began to infest nearly all plants during the flowering phase. In response, we applied chemical control by spraying insecticides containing 50 g L^{-1} *Cypermethrin* and 500 g L^{-1} *Profenofos* at a concentration of 2 mL L^{-1} across all plants.Throughout the study, various weed species were observed in the research area, including broadleaf and narrowleaf weeds. Weed control was performed manually by hand-pulling and mechanically by using a sickle to cut weeds growing around the plants. The removed weeds were then discarded from the experimental area. Harvesting took place in the third week of February.

Analysis of variance for soybean growth and yield

The analysis of variance at the 5% significance level revealed an interaction between the dosage of coffee husk compost and the frequency of urea application on plant height, the number of pods per plant, fresh shoot weight, dry shoot weight, fresh root weight, dry root weight, and seed weight per plant. The dosage of coffee husk compost had a significant effect on leaf number, the number of productive branches, and the number of seeds per plant. Meanwhile, the frequency of urea application at a rate of 100 kg ha^{-1} significantly affected leaf number, the number of productive branches, and the number of seeds per plant. A summary of the analysis of variance results is presented in Table 1.

Table 1. Summary of variance analysis results for growth and yield of Cucumber due to Azolla fertilizer and inorganic N fertilizer treatments

Variable	F-value			CV (%)
	Azolla	N anorganic	Interaction	
Vine length	42.10 *	1.15 ns	0.90 ns	14.18
Number of leaves	37.69 *	2.32 ns	1.03 ns	16.88
Stem diameter	42.10 *	1.15 ns	0.90 ns	14.18
Number of fruits per plant	6.60 *	1.59 ns	1.01 ns	16.79
Length of fruit	1.24 ns	1.04 ns	1.12 ns	5.98
Fruit diameter	0.02 ns	1.03 ns	0.72 ns	4.86
Fruit weight per plant	1.03 ns	0.20 ns	1.65 ns	11.5
Plant fresh weight	9.59 *	0.65 ns	1.11 ns	29.6
Plant dry weight	14.67 *	1.63 ns	1.20 ns	28.53
Marketable fruit weight	2.15 ns	0.56 ns	0.96 ns	10.93

Note : * = significant ; ns = non-significant

The dosage of coffee husk compost and the frequency of urea application significantly interacted to influence soybean plant height (Table 1). The highest plant height was achieved with a coffee husk compost dosage of 10 tons/ha and a urea application frequency of once. However, this result was not significantly different from other treatments, including 30 tons ha^{-1} of compost with urea applied twice, 20 tons ha^{-1} of compost with urea applied twice and three times, as well as 10 tons ha^{-1} of compost with urea applied 0, 1, and 3 times. Additionally, the treatment of 0 tons/ha compost with urea applied once also resulted in high plant height. All treatments produced plant heights exceeding the varietal description. Coffee husk compost has shown promise as an organic fertilizer for various crops, including soybeans, as demonstrated by Togun & Akanbi (2003).

The combination of coffee husk compost dosage and frequency of urea application effectively provided the necessary N for the plants during the vegetative phase. Coffee husk compost contains approximately 1.27% N, as reported by Novita *et al*. (2019). Fitri (2018) also demonstrated that the application of 10 tons/ha and 20 tons ha^{-1} of coffee husk compost significantly enhanced the growth and yield of velvet bean (Mucuna pruriens). In a similar vein, Amir (2021) illustrated that urea application at 1 and 2 weeks after planting (WAP) had a notable effect on cowpea (*Vigna unguiculata* L.) plant height.

The combined application of coffee husk compost and urea has the potential to optimize soybean growth and yield (Smiciklas *et al*., 2008; Hasnain *et al*., 2020; Togun & Akanbi, 2003). Compost enhances soil fertility, moisture retention, and structure, ultimately improving plant growth and productivity (Smiciklas *et al*., 2008; Ho *et al*., 2022). Moreover, combining organic compost with chemical fertilizers, such as urea, can create synergistic effects, where the compost enhances soil quality and the urea provides readily available N for plant uptake. Determining the optimal ratio of compost to chemical fertilizer, as well as the timing of application, is essential for sustainable agricultural practices (Hasnain *et al*., 2020).

The combination of different doses of coffee husk compost and the frequency of urea application on soybean plant height is shown in Table 2. The results indicate varying effects across treatments, with significant and non-significant differences observed depending on the combination of compost dosage and urea frequency.

For the treatment without compost (0 tons ha^{-1}), the highest plant height was observed with urea applied once (77.26 cm), which was significantly greater than when urea was applied twice (62.13 cm), or three times (70.06 cm).

Table 2. Interaction of coffee husk compost dosage and urea application frequency on plant height

Coffe husk compost dosage (ton ha-1)	Urea application frequency (times)			
	0	1	2	3
0	74.13 b B	77.26 a A	62.13 b B	70.06 b B
10	80.2 a A	83.66 a A	79.46 b AB	83.06 a A
20	75.6 b AB	73.8 b B	82.46 a A	81.86 a A
30	79.73 a A	77.8 b AB	82.06 a A	76.33 b AB

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

However, the treatment without urea application (74.13 cm) was comparable to the one with urea applied three times, showing no significant difference. At 10 tons/ha of compost, plant height was consistently high across all urea application frequencies. The tallest plants were recorded when urea was applied once (83.66 cm), which was statistically similar to the plants with three applications of urea (83.06 cm). The lowest height in this group was observed with no urea application (80.2 cm), although the difference was not significant when compared to other treatments. For 20 tons/ha of compost, the application of urea twice (82.46 cm) and three times (81.86 cm) resulted in the tallest plants, with no significant difference between them. However, plants treated with no urea or with urea applied once were significantly shorter, with heights of 75.6 cm and 73.8 cm, respectively.

At the highest compost dosage of 30 tons/ha, urea applied twice (82.06 cm) produced the tallest plants, similar to the treatment with no urea application (79.73 cm). However, applying urea once (77.8 cm) or three times (76.33 cm) resulted in shorter plants, although these differences were not statistically significant in some cases.

The variation in plant height across the different treatments can be explained by the interaction between the availability of nutrients from both coffee husk compost and urea. Coffee husk compost is rich in organic matter and nutrients, such as nitrogen, which can improve soil fertility, moisture retention, and structure. However, organic nutrients from compost release more slowly compared to chemical fertilizers like urea, which provides readily available nitrogen (Fitri *et al*., 2018 ; Hidayat *et al*., 2020). At lower compost dosages (0 and 10 tons ha^{-1}), urea was more important for supplying the nitrogen needed for plant growth. In these situations, applying urea just once was enough to promote optimal growth. However, applying urea too frequently (like twice or three times) did not result in additional benefits. This may have been because the plants reached a point where they had enough nutrients or experienced an imbalance in nitrogen uptake. At higher compost dosages (20 and 30 tons ha^{-1}), the compost offered more organic nitrogen, which meant that the plants didn't depend as much on urea. Under these conditions, the plants grew better with two or three urea applications, as this combination balanced the slow-release nitrogen from the compost with the quickly available nitrogen from urea (Jiang *et al*., 2023). However, using too much urea might have decreased its effectiveness in some cases, possibly because of competition for nutrients or stress on the plants.

Table 3. Interaction of coffee husk compost dosage and urea application frequency on number of pods per plant

Coffe husk compost dosage (ton ha^{-1})	Urea application frequency (times)			
	0	1	2	3
0	79 b B	80.33 b B	88 b B	94.66 a B
10	89 a B	86.66 b B	89 a B	90 a B
20	98 a A	97.33 ab A	93.66 b B	102.33 a A
30	94.33 b AB	91 b B	101 a A	94.33 b B

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

Overall, the interaction between compost and urea demonstrates that while both contribute to plant growth, the timing and amount of urea application need to be carefully managed depending on the compost dosage to avoid over-application, nutrient imbalances, or diminishing returns in plant height.

Table 3 displays the impact of the interaction between varying doses of coffee husk compost and the frequency of urea application on the number of pods per plant. The data show both significant and non-significant differences among the treatments, indicating that the number of pods is affected by both the indicate significant and non-significant differences among the treatments, with the number of pods influenced by both compost dosage and urea application.

For the treatment without compost (0 tons ha^{-1}), the number of pods per plant increased with the frequency of urea application. The highest number of pods (94.66) was observed with urea applied three times, significantly greater than when urea was applied once or twice, which resulted in 80.33 and 88 pods, respectively. The treatment without urea application produced the lowest number of pods (79), showing a significant difference from the highest frequency treatment. With 10 tons/ha of compost, the number of pods remained relatively stable across all urea application frequencies, ranging from 86.66 to 90 pods per plant. There were no significant differences between treatments in this group, indicating that a single application of urea or even no application still resulted in a comparable number of pods. At 20 tons ha^{-1} of compost, the number of pods per plant was generally higher than in the lower compost groups. The highest number of pods (102.33) was recorded when urea was applied three times, significantly more than when applied twice (93.66). Without urea or with one application, the number of pods remained high (98 and 97.33, respectively), and the differences between these treatments were not significant.

For 30 tons ha^{-1} of compost, the highest number of pods (101) was observed when urea was applied twice, with a significant difference from treatments where no urea or urea was applied once or three times. These other treatments resulted in 94.33 and 91 pods, respectively, indicating that applying urea twice provided the optimal N balance for pod formation. The variation in the number of pods per plant across the different treatments can be explained by the availability of nutrients, particularly N, from both coffee husk compost and urea.

At lower compost dosages (0 and 10 tons ha^{-1}), the number of pods was more influenced by how often urea was applied, as the compost provided less organic nitrogen. When no compost was used (0 tons ha^{-1}), applying urea more frequently—especially three times—resulted in more pods. This indicates that, without enough nitrogen from the compost, the plants needed additional urea to meet their nitrogen needs, particularly during the reproductive phase when the pods are forming.

At higher compost dosages (20 and 30 tons ha^{-1}), the compost provided more organic nitrogen, making the plants less reliant on urea. In the treatment with 20 tons ha^{-1} of compost and three urea applications, the plants produced the most pods (102.33), showing a good balance between organic and inorganic nitrogen. However, in the 30 tons ha^{-1} treatment, the highest number of pods (101) was achieved with only two urea applications. Adding more urea did not increase the number of pods, likely because the plants had enough nitrogen and couldn't use the extra amount effectively. In fact, the excess nitrogen might have caused mild stress, reducing pod production.

Overall, these results highlight the importance of balancing organic and inorganic nitrogen sources to optimize pod formation in soybeans. While compost provides a slower release of nutrients, urea supplies nitrogen rapidly, making the frequency of urea application crucial, especially when compost is applied in lower quantities. However, at higher compost levels, fewer urea applications are needed, as the organic matter in the compost can support plant growth more effectively. According to Andriani *et al.* (2016), the application of organic fertilizers can improve the physical and chemical properties of soil, facilitate root growth, retain soil moisture for longer periods, enhance the efficiency of chemical fertilizer use, and supply essential micronutrients to plants .

The data in Table 4 illustrates the relationship between different dosages of coffee husk compost and the frequency of urea application on the fresh shoot weight of plants (measured in grams).The treatments are grouped by varying compost doses (0, 10, 20, and 30 tons/ha) and the number of times urea was applied (0, 1, 2, or 3 times).

With no coffee husk compost, the fresh shoot weight increases significantly with higher urea application frequency. When no urea was applied, the fresh shoot weight was 25.1 g, while applying urea three times resulted in the highest shoot weight at 47.13 g. This indicates a strong positive effect of urea on shoot growth in the absence of compost (Motasim *et al*., 2024). At 10 tons/ha of coffee husk compost, a high shoot weight (51.1 g) was observed when no urea was applied. However, increasing the urea application to one or two times reduced the shoot weight (35.2 g and 37.1 g, respectively), before rising slightly again with three urea applications (45.1 g).

Table 4. Interaction of coffee husk compost dosage and urea application frequencyon fresh shoot weight

Coffe husk compost dosage (ton ha^{-1})	Urea application frequency (times)			
	0	1	2	3
0	25.1 b	25.06 b	38.26 ab	47.13 a
	B	B	A	A
10	51.1 a	35.2 b	37.1 b	45.1 b
	A	AB	A	A
20	30.63 b	40.43 a	31.7 b	29.33 b
	B	A	B	B
30	38.4 a	37.46 a	25.4 b	28.46 b
	B	A	B	B

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

This suggests a complex interaction between the compost and urea, where lower urea application with compost may inhibit growth, but higher doses seem to compensate.

For plants treated with 20 tons ha^{-1} of coffee husk compost, the highest shoot weight (40.43 g) was observed with a single urea application. Additional or reduced urea applications led to lower shoot weights (29.33 g with three applications and 30.63 g without urea). This pattern indicates that a moderate amount of urea with high compost doses promotes optimal growth. At the highest compost dose (30 tons ha^{-1}), the data shows relatively stable but lower shoot weights compared to other treatments. The fresh shoot weight was highest (38.4 g) with no urea application, but further urea application (up to three times) consistently led to a decline, with the lowest value (25.4 g) observed with two urea applications. This suggests that excessive compost may limit the beneficial effects of urea.

When adding large amounts of organic matter, like coffee husk compost, to the soil, it can cause a nutrient imbalance. High levels of compost may increase the carbon-to-nitrogen (C/N) ratio in the soil, which can lead to N immobilization (Fog, 2008). This occurs because soil microbes decompose the organic material, using nitrogen from the soil, which reduces the availability of N for plant uptake. Nitrogen is a critical nutrient for vegetative growth, and its reduced availability could lead to lower shoot biomass (Grzyb *et al*., 2021).

The interaction between coffee husk compost and urea frequency appears to be complex. In general, moderate levels of both compost and urea promote optimal plant growth. However, excessive compost or urea can have diminishing returns on shoot weight. This suggests that achieving the right balance between coffe husk compost and urea is crucial to maximize plant growth efficiency.

Table 5 presents the impact of different doses of coffee husk compost and varying frequencies of urea application on the dry shoot weight of plants, measured in grams. The treatments are grouped based on four levels of coffee husk compost (0, 10, 20, and 30 tons ha^{-1}) and four urea application frequencies (0, 1, 2, and 3 times).

Table 5. Interaction of coffee husk compost dosage and urea application frequency on dry shoot weight

Coffe husk compost dosage (ton ha^{-1})	Urea application frequency (times)			
	0	1	2	3
0	22.53 b	22.7 b	34.66 b	42.8 a
	B	B	A	A
10	46.36 a	31.93 b	33.63 b	40.9 b
	A	AB	A	A
20	27.8 b	36.7 a	28.76 ab	26.6 b
	B	A	B	B
30	34.83 a	39.93 a	29.03 b	25.8 b
	B	A	AB	B

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

With no coffee husk compost, the dry shoot weight increased progressively as the frequency of urea application increased. When no urea was applied, the dry shoot weight was 22.53 g, but with three urea applications, the dry shoot weight reached 42.8 g, representing the highest weight in this treatment group. This suggests that urea significantly promotes dry shoot biomass in the absence of compost. At 10 tons ha^{-1} of coffee husk compost, the highest dry shoot weight (46.36 g) was observed when no urea was applied. However, the dry shoot weight decreased with one or two urea applications (31.93 g and 33.63 g, respectively) and increased again with three urea applications (40.9 g). This indicates that moderate urea application may have a slightly suppressive effect on dry shoot weight in the presence of compost, but higher urea levels help to counteract this (Irshad *et al*., 2002).

For the 20 tons ha^{-1} compost treatment, the highest dry shoot weight (36.7 g) was observed with a single urea application. In contrast, no urea or multiple urea applications resulted in lower shoot weights (27.8 g with no urea and 26.6 g with three urea applications). This suggests that with higher compost levels, a balanced and moderate amount of urea is optimal for dry shoot production. At the highest compost dosage (30 tons ha^{-1}), the dry shoot weight was highest (39.93 g) with one urea application. Increasing the frequency of urea applications resulted in lower dry shoot weights (25.8 g with three applications), while no urea also led to a lower dry shoot weight (34.83 g). This indicates that high compost levels can benefit from moderate urea application but may be negatively affected by excessive urea (Barker, 1997). The composition and properties of compost are crucial in determining its effects on soil quality. Compost has been shown to enhance soil fertility, improve physical structure, and promote the growth of beneficial soil organisms (Barker, 1997; Jain & Kalamdhad, 2020; D'Hose *et al*., 2012).

The interaction between coffee husk compost and urea application frequency shows that both factors influence dry shoot weight in a complex manner. In general, moderate levels of urea combined with moderate to high compost doses (e.g., 10–20 tons ha^{-1}) tend to yield the best results for dry shoot weight. Excessive compost or urea applications, however, may lead to diminished returns, likely due to nutrient imbalances, as seen in the case of the 30 tons ha^{-1} compost treatment. Careful management of both compost and urea is necessary to optimize dry shoot production.

Table 6 illustrates the effect of different doses of coffee husk compost and varying frequencies of urea application on the fresh root weight of plants, measured in grams. Four levels of coffee husk compost (0, 10, 20, and 30 tons ha^{-1}) and four frequencies of urea application (0, 1, 2, and 3 times) are evaluated to determine their impact on root biomass.

Table 6. Interaction of coffee husk compost dosage and urea application frequency on fresh weight of roots

Coffe husk compost dosage (ton ha^{-1})	Urea application frequency (times)			
	0	1	2	3
0	6.22 b	6.27 b	9.58 ab	11.8 a
	B	B	A	A
10	12.78 a	8.82 b	9.28 ab	11.2 a
	A	B	A	A
20	7.68 b	10.12 a	7.94 b	7.35 b
	B	A	B	B
30	9.61 a	9.38 a	6.33 b	7.13 b
	AB	AB	B	B

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

In the absence of coffee husk compost, the fresh root weight increased with more frequent urea applications. When no urea was applied, the root weight was 6.22 g, while three urea applications resulted in a significantly higher root weight of 11.8 g. This suggests that in the absence of compost, urea plays a critical role in promoting root biomass.

At 10 tons ha^{-1} of coffee husk compost, the highest root weight (12.78 g) was observed without any urea application, indicating that the compost alone provided sufficient nutrients for root growth. However, applying urea once or twice resulted in reduced root weights (8.82 g and 9.28 g, respectively), but the weight increased again to 11.2 g with three urea applications. This suggests that moderate urea application with compost may initially suppress root growth, but higher urea levels can restore growth.

For the 20 tons/ha compost treatment, the highest fresh root weight (10.12 g) was observed with a single urea application. In contrast, no urea or multiple applications resulted in lower root weights (7.68 g with no urea and 7.35 g with three applications). This indicates that a balanced and moderate level of urea is optimal for root development at higher compost doses. At the highest compost dose (30 tons/ha), the fresh root weight was highest with no urea application (9.61 g) and one urea application (9.38 g). Increasing urea application frequency led to reduced root weights (6.33 g with two applications and 7.13 g with three applications). This suggests that excessive urea, combined with a high compost dose, may hinder root growth, possibly due to nutrient imbalances or toxicity effects.

The interaction between coffee husk compost and urea application frequency significantly influences fresh root weight. In general, moderate levels of both compost and urea lead to the most optimal root biomass. The use of organic and inorganic fertilizers is a crucial aspect of modern agriculture, as it aims to optimize plant growth and yield. Organic amendments such as compost have been widely recognized as a vital agricultural fertilizer resource to improve soil health and crop productivity. (Agegnehu *et al*., 2014) Composting of agricultural residues and waste materials can provide a sustainable and environmentally friendly alternative to chemical fertilizers. Crop yields did not benefit from low compost rates during the 3-year duration of the study; however, improvements in some bulk density and porosity indicated that benefits of longer-term, low compost rate additions may accrue over time (Evanylo *et al*., 2008). However, excessive urea, particularly in high compost levels, can reduce root growth, likely due to nutrient imbalances, toxicity, or reduced root respiration. Both inputs are essential to maximize root development and overall plant health.

The treatment of coffee husk compost at a dosage of 10 tons/ha with no urea application resulted in the highest dry root weight. However, this result was not significantly different from the treatments of coffee husk compost at 30 tons/ha with one urea application, 20 tons/ha with one urea application, 10 tons/ha with three urea applications, and 0 tons/ha with three urea applications (Table 7). This outcome is likely because coffee husk compost contains sufficient macro- and micronutrients, promoting cell growth and the development of plant organs such as roots, stems, and leaves. Coffee husk compost is rich in essential nutrients like N, P, and K, which are crucial for the vegetative growth of plants, and coffee husks can be used as compost fertilizer (Novita *et al*., 2019). Meanwhile, the frequency of urea application can increase nitrogen availability during the vegetative growth phase (Pandiagan & Rasyad, 2018). Sipayung et al. (2023) stated that plant dry weight is influenced by vegetative growth, such as the development of roots, stems, and leaves. Nisa *et al*. (2023) added that plant dry weight reflects the macro- and micronutrient content absorbed by the plant.

Table 7. Interaction of coffee husk compost dosage and urea application frequency on dry weight of roots

Coffe husk compost dosage (ton ha^{-1})	Urea application frequency (times)			
	0	1	2	3
0	5.6 b B	5.7 b B	8.7ab A	10.7 a A
10	11.63 a A	8 b B	8.4 b A	10.23 a A
20	6.96 b B	9.16 a A	7.2 b AB	6.66 b B
30	8.76 a B	8.5 a AB	5.76 b B	6.46 b B

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

The interaction between coffee husk compost dosage and urea application frequency significantly affects dry root biomass. In general, moderate compost dosages (10–20 tons ha^{-1}) combined with a balanced urea application (1–2 times) result in the highest dry root weights. Excessive compost or frequent urea applications, particularly at higher compost levels, can reduce root development due to potential nutrient imbalances or toxicity. Therefore, optimizing both compost and urea applications is crucial for maximizing root biomass in dry weight.

The treatment of coffee husk compost at a dosage of 20 tons ha^{-1} with three urea applications resulted in the highest seed weight per plant. However, this result was not significantly different from the treatments of coffee husk compost at 30 tons ha^{-1} with no urea application, 20 tons ha^{-1} with zero and one urea application, and 0 tons ha^{-1} with three urea applications (Table 8). Similarly, the potential soybean yield with the highest coffee husk compost dosage and urea application frequency was 2.3 tons ha^{-1}. Overall, the dosage of coffee husk compost and the frequency of urea application provided optimal results compared to the plant description. However, 30% of the land was used for constructing drainage or ditches between plots, resulting in a potential coastal soybean yield of 1.61 tons ha^{-1}.

Table 8. Interaction of coffee husk compost dosage and urea application frequency on seed weight per plant

Coffe husk compost dosage (ton ha-1)	Urea application frequency (times)			
	0	1	2	3
0	10.82 b B	11.03 b B	12.03 b B	13.03 a A
10	11 b B	11.9 b B	12.23 a B	12.4 a B
20	13.46 a A	13.36 ab A	12.76 b B	14.03 a A
30	12.93 ab A	12.5 b B	13.83 a A	12.96 a B

Note : Values followed by the same letter indicate no significant difference according to DMRT at the 5% level. Lowercase letters are read horizontally. and uppercase letters are read vertically

Febrianti *et al*. (2023) stated that P absorbed by plants during the vegetative phase is allocated for the formation of seeds or fruits. Consistent with the research by Aminah *et al*. (2023), P functions as an energy source for various plant metabolic processes and plays a crucial role in increasing crop yields. Phosphorus also provides abundant photosynthates, which are distributed to the seeds, thus increasing seed yield. Meanwhile, N from urea is essential for plants during the vegetative phase. Saputra (2021) noted that N stimulates vegetative growth, especially of stems and leaves, which influences the plant's generative phase and impacts the number of pods and seed weight per plant. This is supported by Puspasari *et al*. (2018), who reported that nitrogen application during the vegetative phase can increase the number of pods, seeds, and seed weight in soybean plants.

The interaction between coffee husk compost dosage and urea application frequency has a notable impact on seed weight per plant. Higher compost dosages (20 tons ha^{-1}) combined with three urea applications generally produce the highest seed weights. However, for many treatments, the differences in seed weight are not statistically significant, particularly at higher compost levels, suggesting that compost alone can substantially contribute to seed development. Urea application frequency plays a more prominent role when compost is absent or applied at lower doses .

The coffee husk compost used showed a significant response in the number of leaves. Based on the average data, the application of coffee husk compost at doses of 10 tons ha^{-1}, 20 tons ha^{-1}, and 30 tons ha^{-1} tended to result in better soybean plant growth compared to the control treatment with 0 tons ha^{-1} of coffee husk compost (Figure 1). Coffee husk compost contains 1.47% nitrogen (N) nutrients. The nitrogen nutrients found in coffee husk compost are essential for plant growth, particularly in terms of plant height and leaf count. Aminah *et al*. (2023) stated that nitrogen plays a crucial role during the plant growth phase. Research by Fitri (2018) demonstrated that applying coffee husk compost at doses of 10 tons/ha and 20 tons ha^{-1} had a significant effect on the growth and yield of velvet bean plants.

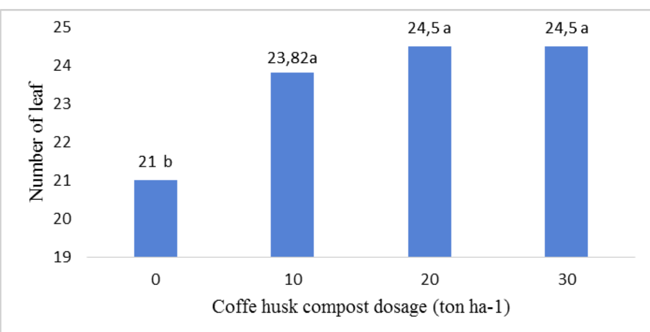

Figure 1. Average number of soybean leaves in each dose of coffee husk compost

Coffee husk, a byproduct of the coffee industry, has gained increasing attention as a potential source of organic matter and nutrients for agricultural applications. One area of interest is the use of coffee husk compost as a soil amendment to improve soybean growth and productivity. Studies have shown that the application of coffee husk compost can have a positive impact on the number of soybean leaves produced compared to a control treatment. (Smiciklas *et al*., 2008).

The increased leaf production observed in soybean plants treated with coffee husk compost can be attributed to the unique chemical composition and nutrient profile of the compost. Coffee husks are rich in organic matter, nitrogen, phosphorus, and other essential nutrients that are beneficial for plant growth (Esquivel & Jiménez, 2011). During the composting process, these nutrients become more readily available for plant uptake, leading to enhanced vegetative growth and leaf development. (Smiciklas *et al*., 2008)

Research has demonstrated that the application of coffee husk compost can provide a sustainable and environmentally-friendly alternative to traditional fertilizers for soybean cultivation. Composting coffee husks not only diverts organic waste from landfills but also offers a cost-effective way to improve soil fertility and soybean production. (Smiciklas *et al*., 2008).

The application of coffee husk compost showed a positive impact on the number of productive branches and seeds per plant. Based on the average data, the application of coffee husk compost at doses of 10 tons ha^{-1}, 20 tons ha^{-1}, and 30 tons ha^{-1} resulted in a higher number of productive branches in soybeans compared to other compost treatments (Figure 2).

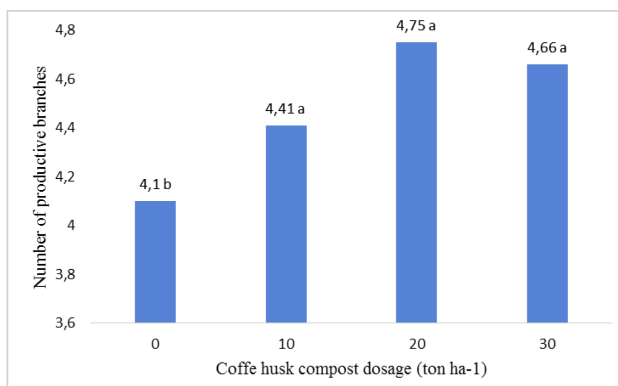

Figure 2. Average number of productive branches soybeans at each dose of coffee husk compost

The average number of productive branches produced by the coffee husk compost treatments was 4.48 branches, which aligns with the varietal description of 2.9-5.6 branches. In terms of the number of seeds per plant, the 20 tons/ha coffee husk compost dose showed better results compared to other coffee husk compost doses (Figure 3). This is likely due to the coffee husks used having undergone complete decomposition, thereby improving the soil's physical, chemical, and biological properties, as well as its nutrient content, supporting plant growth and yield. In this study, the coffee husk compost had a C/N ratio of 19.3. The compost used in this study is suitable for use as organic fertilizer. This is supported by Ningrum *et al*. (2023), who stated that the maturity range for compost is between 10–20. Nisa *et al*. (2023) also noted that complete composting can produce organic material that plants can utilize, with nutrients, especially N, being readily available.

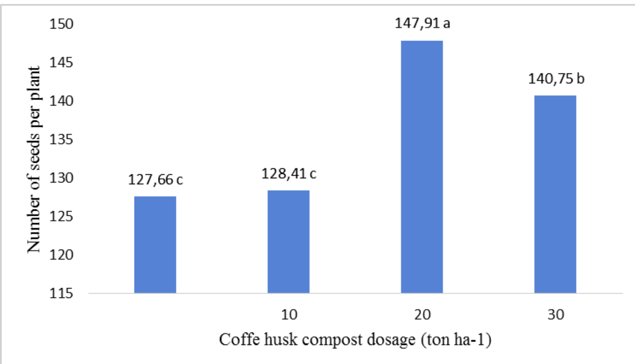

Figure 3. Average number of seeds per plant for each dose of coffee husk compost

The frequency of Urea application, whether 2 or 3 times, did not significantly affect the number of leaves. However, there was a significant difference when comparing the frequency of 0 and 1 Urea applications (Figure 4). This is likely because Urea provides the necessary N nutrients required by the plant. Nitrogen is an essential nutrient that plants need in sufficient quantities during the growth phase (Prakoso *et al*., 2018). Nitrogen plays a role in stimulating the growth of leaves, branches, and the formation of chlorophyll (Sipayung *et al*., 2023).

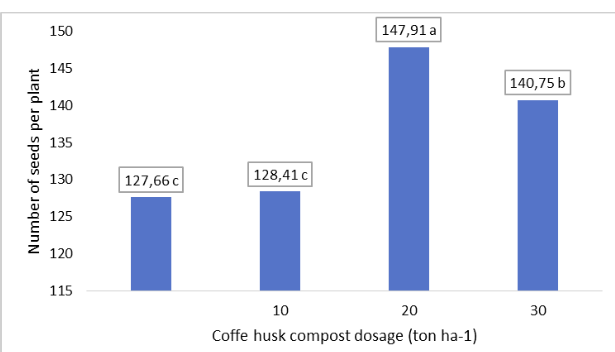

Figure 4. Average number of leaves at Urea application frequency

The application of Urea three times resulted in the highest number of productive branches, although the difference was not statistically significant compared to the application of Urea twice (Figure 5). The average number of productive branches from the Urea application treatments was 4.8 branches, which aligns with the varietal description of 2.9-5.6 branches.

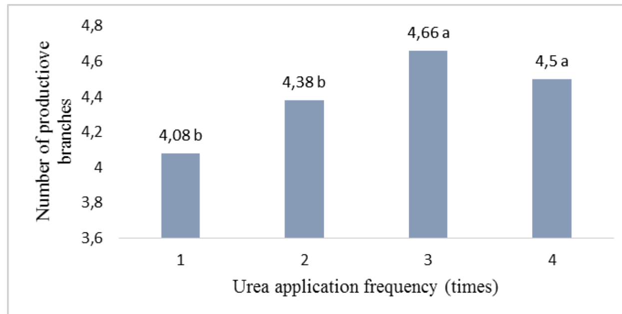

Figure 5. Average number of productive branches at Urea application frequency

For the variable of the number of seeds per plant, the frequency of Urea application twice was not significantly different from three applications (Figure 6). It is suspected that applying Urea twice up to two weeks after planting (WAP) and applying Urea three times from one to three WAP helped reduce Urea losses due to leaching or volatilization in coastal areas and provided N nutrients, thereby supporting soybean growth during the vegetative phase. This is supported by the research of Meitasari & Wicaksono (2017), which found that Urea application aids vegetative growth, including branch formation, and influences the generative phase, such as pod and seed formation. Puspasari *et al*. (2018) added that N application during the vegetative phase can increase the number of pods, seeds, and seed weight in soybean plants.

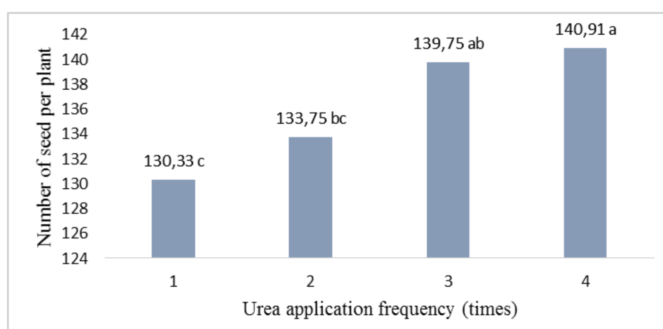

Figure 6. Average number of seed per plant at Urea application frequency

CONCLUSION

Results revealed a significant interaction between compost dosage and urea frequency, influencing several growth parameters, including plant height, pod number per plant, fresh and dry shoot weight, fresh and dry root weight, and seed weight per plant. Compost doses of 20 and 30 tons/ha, along with 2 or 3 applications of urea, notably increased leaf number, productive branch number, and seed yield per plant. These findings indicate that optimizing both urea application frequency and coffee husk compost dosage can significantly improve soybean productivity on nutrient-poor coastal soils. This highlights the importance of integrated nutrient management for enhancing crop yield in marginal environments.

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