Application of Cow Manure Combined with Rice Husk Ash to Increase Soybean (Glycine max (L.) Merr) Production in Indonesia Ultisol

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Application of Cow Manure Combined with Rice Husk Ash to Increase Soybean (*Glycine max* (L.) Merr) Production in Indonesia Ultisol

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Abstract: This study aims to determine the ability of CM (Cow Manure) combined with RHA (Rice Husk Ash) to provide a significant effect on the growth and production of soybean planted in an ultisol. It was conducted in a pot experiment at the Experimental Site of the Faculty of Agriculture, Sriwijaya University, Indralaya, Indonesia between September 2019 and February 2020 using completely randomized design factorial with two factors which were two rate levels of RHA at 3.75 and 7.5 tons·ha^{-1} and three rate levels of CM at 0, 10, and 20 tons·ha^{-1}. It is important to note that each combination was repeated three times, thereby, leading to a total of 18 pots. The variables studied were plant growth and yield which are represented by plant height, the total number of pods, number of filled pods, seed weight per plant, and soybean produced. The results showed that CM combined with RHA was effective in increasing nutrient availability and reducing soil acidity. It was discovered that CM had a significant effect on soil pH, plant height, the total number of pods, number of filled pods, seed weight per plant, and soybean produced while RHA did not have any significant difference on all the variables observed. However, the combination of 10 tons·ha^{-1} CM with 3.75 tons·ha^{-1} RHA was observed to be the best combination treatment to increase the growth and production of soybean in ultisol as indicated by its ability to produce 2.58 tons·ha^{-1} soybean.

Key words*:* Rice husk ash, cow manure, soybean, ultisol.

1. Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the most important food crops in Indonesia after rice and corn due to its protein content which is up to 40% [1]. It is also a highly nutritious food and a source of low cholesterol, normally used as material for germinated soya or "tempe", and very popular in the country. Its ability to provide plant protein and status as an essential food ingredient makes it an important commodity in the Indonesian food industry [2]. In recent years, soybean production is estimated at 600 to 700 thousand tons per year but demand is approximately 2.0 million tons. It was also reported that the national production of the crop in 2009 was only 1.3 tons·ha^{-1} with a range of 0.6 to 2.0 tons·ha^{-1} and this means its production is lower than demand [3]. Moreover, a total of 998.7 thousand tons was produced in 2015 with mean productivity of 1.56 tons·ha^{-1} [4] while 2.6 million was imported in 2021 [5]. This was supported by the findings that its production in South Sumatra was 16,818 tons·ha^{-1} with mean productivity of 1.51 tons·ha^{-1} [6]. It is also pertinent to note that soybean productivity in dry land is lower than in paddy fields due to the drought factor during the process of forming and filling the pods [7]. Meanwhile, the cultivation of soybean outside of Java is mostly through the use of ultisol which is one of the acidic soils in Indonesia occupying approximately 21% of the total land area which is estimated at 40 million ha. This soil has a low pH below 5 but has high solubility of Al, Fe, Mn, and low alkaline saturation, as well as low organic matter content and further washing of K^+, Na^+, NH_4^+, and Mg^{2+} elements,

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thereby, causing the soil to be poor. The organic matter content of this soil also decreases further rapidly after it has been cleared and the activity of microorganisms is also very low, thereby, making it difficult to decompose the organic matter [8]. The ultisol from Nigeria was also reported by [9] to have a low total N and organic C but high P. It is, therefore, important to note that the low productivity of soybeans in ultisol is due to several factors but the main factor is the low availability of macronutrients required for the growth and production of the crop [10]. This soil was found to have a significant potential for soybean growth but its utilization is limited by its low pH which is normally 4.0 while soybean can only grow and reproduce effectively at a soil pH of 5.8-7.0 [11] and experience slow growth at a pH lesser than 5.5 due to Al abundance. This means there is a need to increase the pH of ultisol and a previous experiment conducted using lime at the rate of 3.26 tons·ha^{-1} was only able to produce 2.85 tons per ha [10]. Therefore, there is the need to apply other alternatives such as the ash derived from rice husk.

A lot of potassium is needed by crops [12] such as soybean but a greater part of this element is normally lost from the topsoil, thereby, reducing the quantity available for the crops. Meanwhile, the ashes from burnt agricultural waste have been discovered to have the good potential to serve as an inexpensive alternative source of K fertilizer which normally leads to the reduction in the cost of procuring fertilizers. According to Yulfianti [13], RHA (Rice Husk Ash) contains 1% N, 2% K nutrients, high silica, and alkaline elements, and it is normally obtained from burning rice husks. A previous study by Sundari [14] showed that the addition of RHA at a dose of 3.75 tons·ha^{-1} was able to produce the highest number of soybean leaves 8 WAP (Weeks after Planting) while the addition of 7.5 tons·ha^{-1} was discovered to have caused significant difference to the height of soybean plant [15]. Another method that can be used to increase the nutrients in ultisol is applying CM (Cow Manure).

The application of CM to acidic soils was reported to have the ability to increase the number and activity of soil microorganisms, provide some nutrients for plant growth [16], increase humus, and improve soil structure [17]. A previous study also showed its ability to increase legume production by 3.37% while the quantity recommended for soybean is 10-20 tons·ha^{-1} [18]. This means CM is one of the organic materials that can be used to increase the macro and micronutrients required for plant growth and also to improve loosen soil, correct soil structure, increase soil porosity, enhance soil aeration, increase the composition of soil microorganisms, and facilitate the growth of plant roots [19].

CM contains 0.40% N, 0.20% P_2O_5, 0.10% K_2O [20], 1.04 % total N, 0.85% P, and 0.75% K [16]. Its ability to increase soil porosity and enhance the activity of microorganisms has been discovered to cause a rapid change in organic matters in the soil. This means its application allows the intake of energy by plants, thereby, leading to the optimal development of their organs [21]. The nitrogen contained in CM is useful for leaf development while the phosphorus and calcium are important to the stimulation of root growth and protein preparation [22].

This shows that it is possible to overcome the fertility problems associated with ultisol by applying organic materials derived from combining CM with RHA. Therefore, this present study was conducted to determine the dose of CM to be combined with RHA to ensure the high growth and production of soybeans.

2. Materials and Method

This pot experiment was conducted at Experimental Site, Faculty of Agriculture, Sriwijaya University using CM, RHA, and ultisol. The soil sample was collected at a depth of 0-30 cm from the Arboretum, Faculty of Agriculture, Sriwijaya University, sieved using a 2 mm mesh after which 10 kg was measured for the experiment conducted from September 2019 to February 2020.

A completely randomized design factorial with two factors which include two rate levels of RHA at 3.75 tons and 7.5 tons·ha^{-1} and three rate levels of CM at 0 ton, 10 tons, and 20 tons·ha^{-1}. It is important to note that each combination was repeated three times, thereby, leading to a total of 18 pots. The 10 kg sieved soil was treated with CM and RHA according to the rates two weeks before planting in a field capacity. Meanwhile, inorganic fertilizers including N, P, and K were applied at a dosage of urea 100 kg, SP-36 100 kg, and KCl 75 kg·ha^{-1} respectively for one week before planting. Moreover, the Anjasmoro variety of soybean seeds was placed in the planting hole at a depth of ±2.5 cm with each pot having 3-4 seeds and covered with soil. The plants were maintained through watering, weeding, and protection from pests during the period of the experiment. It is important to note that the watering was in the afternoon, embroidering was conducted to replace seeds that did not germinate, and weeding was through manual cleaning around the plant. The soybeans were harvested after certain signs have been observed such as evenly brownish-yellow pods, dry leaves, and most parts of the plants, and when the pods are easy to crack.

The variables measured include the soybean growth and yield which are proxied by plant height, the total number of pods, number of filled pods, seed weight per plant, and soybean produced. Moreover, the analysis of the soil at the primordial stage of soybean was conducted at the Laboratory of Chemistry, Biology, and Soil Fertility, Faculty of Agriculture, Sriwijaya University with a focus on the pH, N-total, C-organic. The RHA and CM were also analyzed based on the pH, N-total P and K-available and C-organic while the initial soil analysis before the experiment focused on the pH, N-total, P-available, C-organic, K-exchangeability, Al-exchangeability, and soil particle distribution.

The data obtained were analyzed using the ANOVA (Analysis of Variance) and a further test was expected to be conducted using the LSD (Least Significant Difference) Test at 5% level when the results showed a significant effect between treatments.

3. Results and Discussion

3.1 Ultisol Characteristics

The soil used for this greenhouse experiment was collected from Arboretum Garden of Agriculture Faculty, Sriwijaya University, and classified into ultisol with low pH of 4.08 combined with low total nitrogen as indicated in Table 1. The soil was observed to be acidic as indicated by 0.51 Cmol(+) kg^{-1} of Al exchangeability but those with higher pH with the value ranging from 5.0-5.2 were found in Nigeria [9]. Moreover, Prasetyo et al. [23] reported that the ultisol from East Kalimantan, Indonesia has pH 4.5 and high content of Al exchangeability and is included in the marginal soil category which is distributed mostly in the upland area of the country. It has also been previously reported that ultisol normally shows acid to very acid reaction, have a low content of organic matter, and low base saturation [23].

Low pH is the direct cause of non-optimal growth of soybean and the indirect cause of the low level of N, P, K, Ca, and Mg nutrients in the soil [24]. According to Dierolf et al. [25], soybeans are less tolerant in highly acidic soil (pH < 4.5) and very sensitive in low fertile soil [10]. This is due to the fact that soil pH is closely related to nutrient content such that low pH normally leads to low nutrient content and crop production because N, P, K, Ca and Mg are not easily available to plants in these soils [26].

The soil texture was observed to be dominated by 86.4% sand but a previous study showed that ultisol normally has approximately 68% sand particle distribution [28], thereby, reducing its ability to bind water and soil elements and increasing its potential to leach nutrients. This further leads to very low N-total, P-available, and K-exchangeability, which further lowers soil fertility required for plant growth. One of

Table 1 The characteristics of the ultisol used for soybean cultivation.

Variables	Unit	Result*	Criteria**
pH H_2O (1:1)	-	4.08	Very acidic
N-total	%	0.022	Very low
C-organic	%	4.52	High
P-available	mg kg^{-1}	5.8	Low
K-exchangeability	Cmol(+) kg^{-1}	0.12	Very low
Al-exchangeability	Cmol(+) kg^{-1}	0.51	
Texture			Loamy sand
Particle distribution			
Sand	%	86.4	
Dust	%	8	
Clay	%	5.6	

* Analysis result of the Laboratory of Chemistry, Biology, and Soil Fertility, Department of Soil, Faculty of Agriculture, Sriwijaya University (2020).
** Criteria [27].

Table 2 Some properties of CM and RHA.

Variables	Unit	Result*
CM		
pH H_2O (1:1)	-	8.11
N-total	%	3.38
C-organic	%	13.54
C/N	-	4.01
RHA		
pH H_2O (1:1)	-	8.40
N-total	%	0.14
C-Organic	%	10.53
C/N	-	75.21

* Analysis of the Laboratory of Chemistry, Biology, and Soil Fertility, Department of Soil, Faculty of Agriculture, Sriwijaya University (2020).

the possible ways to enhance the fertility of ultisol is by applying CM and RHA to improve the chemical properties of the soil and provide some nutrients that are not available in the soil.

3.2 Characteristics of CM and RHA

CM is abio-organic material produced from the combination of cow feces and urine, and the one used in this research was collected from a local farm. Feedlot cattle have the ability to generate manure up to 5%-6% of their body weight which is approximately 5.5 kg dry mass per animal per day [29]. The CM used in this experiment has an alkaline reaction with a pH value of 8.11 and this was observed to be almost similar to the findings of Budianta et al. [16], which showed a pH of 8.43. Moreover, the total N and C-organic were recorded to be 3.38% and 13.54% respectively while the C/N ratio was 4.01 as indicated in Table 2. This means it can be used as organic fertilizer with its high content of organic matter expected to accelerate the process of mineralization or weathering of RHA in order to improve the condition of the ultisol. This further indicates that CM is not only an agricultural waste but also an organic fertilizer resource [30] as indicated by its low C/N which allows its easy decomposition.

Rice husk is the shell produced during the process of dehusking paddy and it normally produces ash when burnt at approximately 600 °C. The characteristics of RHA used in this study are presented in Table 2 and its N-total and C-Organic contents were recorded to be 0.14% and 10.53% respectively while the pH was found to be 8.40 which is higher than the value for CM and the C/N was 75.21. This indicates RHA has not been decomposed and experienced incomplete combustion as indicated by its high content of C-organic. The combination of CM and RHA is, therefore, expected to suppress the negative properties of ultisol.

3.3 The Changes in Some Chemical Properties of the Soil at the Primordial Stage of Soybean

The application of RHA and its combination with CM was observed not to have any significant effect on soil pH, total N, and C organic while the application of only CM had a significant effect on soil pH as indicated in Table 3. The soil pH had further effects on plant growth and biomass production [31]. The results showed that 20 tons·ha^{-1} of CM produced the highest soil pH of 4.93 which is 0.85 higher than the original pH of the ultisol which was 4.08 while the lowest pH recorded without the CM was 4.30. This signifies the application of CM was able to increase soil pH, and this is in line with the findings of Wong and Swift [32] that organic matters have the ability to increase soil pH due to the uptake of protons and Al by organic anions and decarboxylation. Moreover, the increase recorded in the soil pH due to the application of CM and RHA is probably because of the alkaline nature of both materials with 8.11 and 8.40 respectively, thereby, using their OH^{-1} to change the condition of the soil. This is in line with the results of Butterly et al. [33] that alkalinity released by agricultural residue can change soil pH. It is, however, important to note that the soil is still acidic despite the increment in the pH and this is not suitable for soybean growth considering the fact that Uko et al. [9] already showed that the suitable pH for the growth of the crop is 5.8-7. This means soybeans can still grow at a pH lesser than 5.5 but the growth will be very slow due to the acidic metal toxicity but it is possible to overcome this problem by applying ash or lime to the soil. This was confirmed by Yulfianti [13] that RHA can be used to increase soil pH and the same trend was reported for CM by Susanti et al. [34]. Even though the application of CM with RHA was discovered not to have any significant effect on soil pH, the two amendments applied at the highest rate

Table 3 The change in some chemical properties of the soil used for the primordial planting of the soybeans.

CM and rice husk (ton·ha^{-1})	Variables		
	Soil pH	N-total (%)	C-organic (%)
0 and 3.75	4.32	0.03	5.98
10 and 3.75	4.58	0.04	5.77
20 and 3.75	4.90	0.03	5.30
0 and 7.5	4.29	0.02	5.41
10 and 7.5	4.52	0.03	6.40
20 and 7.5	4.96	0.04	6.24
RHA			
3.75	4.60	0.04	5.69
7.5	4.59	0.03	6.01
CM			
0	4.3^{a}	0.02	5.69
10	4.55^{a}	0.04	6.08
20	4.93^{b}	0.03	5.77
LSD CM 5% level	0.28	0.03	0.73
LSD RHA 5% level	0.22	0.02	0.89

Values followed by the same letter show insignificant difference at 5% LSD test.

increased soil pH to 4.96 while only the RHA at 3.75 and 7.5 tons·ha^{-1} without CM was unable to increase the pH. Moreover, the two applied together did not change the total N and C organic as presented in Table 3 while only the CM changed the C organic content from 21.67%-25.66%, and this also shows the ability of the CM to increase the C organic content.

Table 3 shows that the two amendments have no significant effect on the N-total and C-organic of the soil used for the soybean plants with the highest N-total value recorded with the combination of 10 tons·ha^{-1} CM with 3.75 tons·ha^{-1} RHA, 20 tons·ha^{-1} CM with 7.5 tons·ha^{-1} RHA, and 10 tons·ha^{-1} CM and 3.75 tons·ha^{-1} RHA each with 0.04%. It is important to note that the N-total is the sum of the N available in NH_4^+, NO_3^- [35] and the N element is a macronutrient needed by plants to support their vegetative growth with its deficiency observed to have the capacity to cause disrupted growth and decreased seed production. It was discovered from this study that the N-total value of the soil increased due to the application of RHA compared to the 0.02% recorded in the original soil. Some combinations of RHA with CM also increased the N-total while some reduced it because the N element needed by the soil had been partially absorbed by the plant. It is important to reiterate that the lack of N can cause stunted plants, limited root growth, yellow leaves, and falling of the leaves. However, a previous study showed that the content of N-total is normally influenced by organic matter such that the presence of high organic material usually leads to a high N-total value and vice versa [36]. Furthermore, this study found the highest soil organic C with 6.4% in the treatment with 10 tons·ha^{-1} CM and 7.5 tons·ha^{-1} RHA, and this also shows the ability of the CM to provide soil organic carbon. According to Syukur and Indah [37], the application of organic fertilizers can basically increase the C-organic content in the soil while Hanafiah et al. [38] showed the possibility of losing C in the soil through CO_2, harvest, soil biota, and erosion. Meanwhile, the absence of organic matter usually reduces its ability to hold water and provide macro and micronutrients needed by plants, thereby, reducing the ability of the plants to be green and allow them to have small stems. This indicates the relationship between the C-organic and organic matter is directly proportional such that a higher C-organic content indicates the presence of higher organic matter in the soil.

3.4 Effect of CM and RHA on Plant Growth and Yield

3.4.1 Plant Height

The plant height of soybean was measured at 8 WAP and found to range between 29.47 and 48.87 cm which is below the 64-68 cm for the Anjasmoro variety described. This is in line with the findings of Mustikawati et al. [7] that the average plant height of soybean is between 46.79-47.52 cm while higher values ranging from 53.9 to 65.6 cm were recorded for different varieties in another study [1]. The variance analysis conducted in this present study showed that the combination of CM and RHA did not have any significant effect on plant height but only CM had a significant influence as indicated in Table 4. It is, however, important to note that the plant height of soybean is normally influenced by genetic and environmental factors [39].

The application of 10 tons·ha^{-1} CM was observed to have provided the highest height of 48.87 cm and the value was discovered to be reduced as the CM content was increased. It is important to note that the highest plant height obtained is below 64 cm for Anjasmoro and this can be associated with low soil fertility because the soil pH of 4.55 recorded at the same content of CM is also not optimal for soybean growth. Moreover, the highest plant height with the use of RHA was found to be 42.81 cm and recorded at 3.75 tons·ha^{-1} followed by 42.01 cm at 7.5 tons·ha^{-1}. Meanwhile, Budianta et al. [10] found that the soybean planted on acidic soil of tidal soil with 3.26 tons·ha^{-1} lime had a height of 69.98 cm. It is also important to note that the CM used in this study contains 3.38% N as indicated

Table 4 Plant height of soybean at 8 WAP.

CM (tons·ha^{-1})	Plant height (cm)		Effect of CM
	RHA (tons·ha^{-1})		
	3.75	7.5	
0	29.47	33.90	31.68[a]
10	53.17	44.57	48.87[b]
20	45.80	47.57	46.68[b]
Effect of RHA	42.81	42.01	
LSD of CM 5% level			5.77

Values followed by the same small letter in the column are not significantly different at 5% LSD.

Table 5 Total number of pods per plant.

CM (tons·ha^{-1})	Total number of pods (per plant)		Effect of CM
	RHA (tons·ha^{-1})		
	3.75	7.5	
0	7.00	5.33	6.17[a]
10	38.33	39.67	39.00[b]
20	46.00	46.67	46.33[b]
Effect of RHA	30.44	30.56	
LSD CM 5% level			27.57

Values followed by the same small letter in the column are not significantly different at 5% LSD.

in Table 3 and Fahri [40] reported that the provision of this element in the soil through fertilization can be used to enhance vegetative growth, especially leaves, increase stem height and root growth, fast effect to stimulate the growth of the top of the plant, and green color of the leaves [40]. It has also been previously shown that urea fertilizer is required in soybean cultivation with Susilawati et al. [41] explaining that the use of 75 kg·ha^{-1} of urea was able to increase plant height to 68.78 cm compared to 25 kg·ha^{-1} which had 59.24 cm at 7 WAP. Furthermore, the protein content in soybean is high, ranging from 35%-45%, and this implies its nitrogen requirement is also high [42]. Table 4 shows that a higher C-organic content generally ensures better plant height growth. This indicates more content of CM added usually leads to a higher increase in the average plant height.

3.4.2 Total Number of Pods

The ANOVA showed that the treatments containing only the RHA and its combination with CM did not have any significant effect on the total number of pods but those with only CM provided significant effects. This was observed from the fact that the average total number of pods was 7 per plant at the low rate of only RHA to 46.67 per plant at a high rate of RHA with 20 tons·ha^{-1} CM as indicated in Table 5. Meanwhile, Rusmana et al. [2] reported that the total number of pods usually ranged between 16.67 and 29 pods per plant.

RHA at 3.75 tons·ha^{-1} produced a total of 30.44 pods per plant and the difference was found not to be significant when the content was increased with the increase in the pod discovered to be below 1%. Meanwhile, the CM treatment had a significant effect on the total number of pods per plant as indicated by the highest, 46.33, recorded at 20 tons·ha^{-1} while the treatment without CM only had 6.17, thereby, indicating a 650% increment. Moreover, the total number of pods is also influenced by the weight of shoots because they are normally found on long flower stalks which account for 20% of the dry weight of the plant. It is also important to note that the dry weight of the plant shoot also influences pod formation and filled pods per plant while Suprapto [43] also showed that the number of pods per plant normally varies depending on the soil fertility.

Kuntyastuti [44] found the application of 10 tons ha^{-1} CM to have provided 65 pods per plant compared to inorganic fertilizers and this is associated with the ability of this organic fertilizer to provide the nutrients needed by soybean plants in a balanced condition, trigger plant growth, and ensure a good process of photosynthesis. Idris et al. [45] also showed that organic matter is one of the sources of soil colloids which normally increase the soil CEC (Cation Exchange Capacity), thereby, leading to the absorption of elements N, P, and K in order to provide nutrients in the soil. These elements were observed to be uptaken by the plants in this study to support their growth and development.

3.4.3 Number of Filled Pods

The ANOVA also showed that the treatments with only RHA and its combination with CM did not have any significant effect on the number of filled pods while those with only CM had a significant effect as indicated in Table 6.

The highest value of filled ponds per plant, 43.33, was produced by the combination of 7.50 tons·ha^{-1} RHA with 20 tons·ha^{-1} CM while the least, 4, was recorded with only 7.5 tons·ha^{-1} RHA without CM. Meanwhile, CM as a single treatment significantly affected the number of filled pods as indicated by the average yield of 42.83 pods/plant produced at 20 tons·ha^{-1} while the lowest was 5.00 recorded for the treatment without CM. This showed that CM had a positive effect or synergism when combined with RHA. According to Hadisumitro [46], the application of high CM makes N available for plants and stimulates plant growth.

3.4.4 Seeds Weight per Plant

The seed weights per plant were discovered to range between 1.27 and 24.94 g·$plant^{-1}$ as presented in Table 7. The ANOVA showed that the treatment with only the RHA and its combination with CM had no significant effect on seed weight per plant as indicated by the fact that the 3.75 tons·ha^{-1} RHA produced the highest value with an average yield of 13.52 g/plant while 7.5 tons·ha^{-1} had the lowest with 8.82 g/plant. Meanwhile, CM treatment significantly affected the seed weight per plant with the highest value recorded as 18.16 g/plant at 10 tons·ha^{-1} while the lowest, 1.64 g/plant, was recorded when this manure was not applied. This is presumably because one of the nutrients needed by soybean plants is not fulfilled to stimulate flowering and fertilization, thereby, limiting the effect of the manure applied at different levels on the weight of the seeds per plant.

Seed weight per plant is influenced by the differences in soil fertility and climatic conditions, and Djuniwati et al. [47] reported that its average value can be increased with an increase in the dose of organic matter used. Moreover, soybean plants are usually responsive to organic matter when the soil organic C content is low, and the increase in seed weight per plant was also observed to be influenced by an increase in the number of pods per plant.

Table 6 Number of filled pods per plant.

CM (tons·ha^{-1})	Number of filled pods (per plant)		Effect of CM
	RHA (tons·ha^{-1})		
	3.75	7.5	
0	6.00	4.00	5.00^a
10	38.67	36.00	37.33^b
20	42.33	43.33	42.83^b
Effect of RHA	29.00	27.78	
LSD CM 5% level			19.19

Values followed by the same small letter in the column are not significantly different at 5% LSD.

Table 7 Seeds weight per plant.

CM (tons·ha^{-1})	Seed weight (g·plant^{-1}) RHA (tons ha^{-1}) 3.75	7.5	Effect of CM
0	2.00	1.27	1.64^a
10	24.94	11.38	18.16^b
20	13.62	13.79	13.71^b
Effect of RHA	13.52	8.82	
LSD CM 5% level			6.02

Values followed by the same small letter in the column are not significantly different at 5% LSD.

Table 8 Soybean production.

Dose of CM (tons·ha^{-1})	Soybean production (tons·ha^{-1}) Dose of RHA (tons·ha^{-1}) 3.75	7.5	Effect of CM
0	2.13	1.93	2.03^a
10	2.29	2.16	2.22^a
20	2.29	2.44	2.44^b
Influence of RHA	2.24	2.22	
LSD CM 5% level			0.30

Values followed by the same small letter in the column are not significantly different at 5% LSD.

3.4.5 Soybean Production

The soybeans produced were found to be in the range of 1.93 to 2.58 tons·ha^{-1} as indicated in Table 8. The ANOVA showed that the treatments with RHA and its combination with CM did not have any significant effect on soybean production while those with only CM had significant effects. It was discovered that the highest average yield from the RHA was 2.24 tons·ha^{-1} at 3.75 tons·ha^{-1} while the lowest was 2.22 tons·ha^{-1} at 7.5 tons·ha^{-1}. Meanwhile, CM had a significant effect on soybean production with the highest average yield of 2.44 tons·ha^{-1} recorded at 20 tons·ha^{-1} and the lowest, 2.03 tons·ha^{-1}, found in the treatment without CM. This, therefore, signifies the application of CM had a higher effect on yield compared to only RHA due to its more nutritional value.

The utilization of CM was able to increase soybean production by 20.20% at 20 tons·ha^{-1} and 9.36% by 10 tons·ha^{-1} compared to the treatment without CM as indicated in Table 8. This is in line with the findings of Pambudi [18] that organic fertilizer was able to increase soybean production by 37.5% from 1.3 tons·ha^{-1} to 2.08 tons·ha^{-1}. The low yields were observed to be caused by stunted growth in terms of plant height, number of pods, number of non-empty pods, and number of seeds because soybean is very intolerant in acidic soils [48]. Its production is also strongly influenced by cultivation techniques, pest control, and fertilization, and this implies fertilization is one of the best ways to provide a balanced quantity of nutrients to ensure vegetative and generative growth [49].

4. Conclusions

The application of RHA was observed not to have any significant effect on the growth and production of soybean in the ultisol from South Sumatra while CM had a significant effect on soybean production by 20.20% from 2.03 to 2.44 tons·ha^{-1}. The combination of 20 tons·ha^{-1} CM with 7.50 tons·ha^{-1} RHA was found to be the best treatment as indicated by its ability to produce 2.44 tons·ha^{-1} of soybeans. This, therefore, indicates that CM has the ability to increase the growth and yield of soybean planted in acidic ultisol.

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