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Research Article
Integration of Bali Cattle and Soybean on Tidal Swamp Land

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Abstract

Objective: The purpose of this study was to analyze the integration of Bali cattle and soybean on a tidal swamp using eco-techno farming. **Materials and Methods:** This study was performed in two observation steps. The first step was the addition of bio-slurry and cattle waste compost for soybean cultivation using Saturated Soil Culture (SSC) technology on a tidal swamp. A randomized block design was used for four amelioration treatments, No Ameliorant (NA), Lime Ameliorant (LA), cattle waste Compost Ameliorant (CA) and bio-slurry ameliorant (SA) with four repetitions. The observed variables were soybean production, soybean waste production (tons) and farmers' income (IDR). The second step was to analyze the utilization of soybean biomass as a supplemental feed for Bali cattle. The study was designed with three feeding treatments in a randomized block design with three repetitions. The soybean-feeding treatments were Swamp Grass (SG), Soybean Biomass (SB) and Soybean Biomass Silage (SBS). The observed variables were the Average Daily Gain (ADG), Dry Matter Intake (DMI) and Feed Conversion Ratio (FCR). **Results:** Soybean production and soybean biomass of NA differed significantly from those of LA, CA and SA. There were no significant differences in soybean production and soybean biomass among LA, CA and SA. The ADG and FCR did not differ among the treatments. Bali cattle given SBS showed greater daily DMI and protein intake than did cattle given SB or SG. **Conclusion:** The integration of the Bali cattle and soybean on tidal swamp land and the utilization of SA and CA increased both soybean production and farmers' income by decreasing the production costs compared with the LA and NA treatment groups. Soybean biomass can be used as a feed supplement for Bali cattle, thus avoiding the burning of soybean biomass.

Key words: Integration, ameliorant, bio-slurry, compost, feed supplements

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Currently, the demand for soybeans in Indonesia still requires importation. Based on Agriculture Statistics[1], the soybean production target for 2015 had been approximately 1,500,000 t. In 2014, the cultivated area was 615,685 ha and soybean production was 954,997 t. In 2015, the cultivated area was 624,848 ha and soyabean production 982,967 t. Despite the increase in production, the levels remain insufficient to reach the established production target. Soybean production is low because of farmers' lack of interest in planting a crop with such low productivity. Thus, it is necessary to implement technology to increase soybean productivity by utilizing tidal swamps and Saturated Soil Culture (SSC) technology on soybean crops[2].

Tidal swamp land is a sub-optimal land type that plays an important role in agriculture development, not only by supporting the national production but also by diversifying village industry, increasing farmers' income and developing various regions[3]. In the near future, tidal swamp land will become very strategic and important for the development of agriculture and for supporting national food resilience and agribusiness[4]. As a sub-optimal land type, tidal swamp land is appropriate for the development of soybean cultivation and for implementing technologies related to land conservation, water management, amelioration, organic matter management and fertilization[1].

The integration of beef cattle and soybean production using an eco-techno agricultural model can be implemented using SSC technology, which is a cultivation method that provides continuous irrigation, maintains a constant water depth and creates a soil layer under saturated conditions. This technology has been reported to prevent pyrite oxidation on a tidal swamp and to increase soybean productivity[2]. In an integrated system, crops and livestock interact to create synergy, with recycling allowing the maximum use of the available resources. Crop residues can be used for animal feed, production and processing of livestock and livestock by-products can enhance agricultural productivity by concentrating the nutrients that improve soil fertility, thereby reducing the use of chemical fertilizers[5]. Cattle waste in solid or even liquid form can be utilized as organic fertilizer resources (ameliorant) for soybean crops. Thus, this technology produces a life cycle whose components contribute to each other, thereby improving the efficiency of agribusiness. A system with integration between livestock and crops creates a cycle. Waste production from a component thus becomes another resource for further components. The implementation of sustainable agriculture requires integration of crops and cattle based on the environment[6].

The integration of livestock with crop production was intended to establish a sustainable farming system with optimal resource use. The achievement of this goal would maximize the degree of self-sustainability of the systems because a variety of products would be obtained with minimum input to maintain soil fertility. Further, the varied activities that occur on an integrated farm would provide employment opportunities for all members of the extended family[7].

The purpose of this study was to analyze the integration of Bali cattle with soybean on a tidal swamp through eco-techno farming. In the context of SSC technology, the utilization of bio-slurry and cattle waste compost as ameliorants may help increase soybean productivity on a tidal swamp. Furthermore, it was hypothesized that the addition of bio-slurry and cattle waste compost as an ameliorant resource would replace lime (dolomite), which is imported from outside regions and increases the productivity cost. Subsequently, soybean biomass could be used as a feed supplement for Bali cattle to avoid the burning of soybean biomass.

MATERIALS AND METHODS

This study was conducted on tidal swamp land in Simpang village of Berbak, sub-district Tanjung Jabung, Timur district, Jambi province, Indonesia, from April, 2014 to August, 2015. The location of the tidal swamp was categorized as C overflow with a pyrite depth <50. This study was part of a series of studies on the integration of beef cattle with soybean, corn and rice paddies on a tidal swamp in a single planting season. Two steps were conducted to assess the integration of Bali cattle with soybean: Examining the addition of bio-slurry and cattle waste compost towards soybean productivity and considering the potency of soybean biomass as a feed supplement for Bali cattle.

Addition of bio-slurry and cattle waste compost towards soybean productivity, soybean biomass and farmers' income by using SSC technology on a tidal swamp: The purpose of this study was to analyze the effects of the addition of bio-slurry and cattle waste compost on soybean productivity, soybean biomass and farmers' income using SSC technology on a tidal swamp.

Soybean production and soybean biomass: This study was conducted using a randomized group design (1 factor consisting of 4 treatments and 4 repetitions). Treatments were implemented using the following ameliorant sources: NA: A field that did not use ameliorant, LA: A treatment with lime ameliorant applied in a field, CA: A field that used cattle waste compost and SA: A field that used bio-slurry ameliorant. This study used the Anjasmoro soybean variant with a planting distance of 40×12.5 cm, fertilized with 200 kg SP36 ha^{-1} and 100 kg KCl ha^{-1}. Soybeans were sprayed with 10 g urea L^{-1} water at 2, 4 and 6 weeks after planting to support acclimatization. According to Noya *et al.*[8], Anjasmoro is a variety that is tolerant of high levels of Al and is adaptable to tidal swamp areas.

On the day of planting, seeds in each treatment group were inoculated with 5 g of *Rhizobium* sp., kg^{-1} seeds. The main plot was 4×50 m and was surrounded by furrow irrigation. The irrigation furrows for saturated soil culture had a width of 30 cm and a water depth of 25 cm. Temporary flooding was created at 15 cm below the soil surface. In the saturated soil culture, water was provided at planting time and the culture was maintained under wet conditions. A sketch of the SSC[9] is presented in Fig. 1.

Farmers' income: The farmers' income was qualitatively determined using the following calculation:

Farmers' income = Soybean production (tons)×Soybean prices (IDR)-Soybean production costs (IDR)

Efficacy of soybean biomass as a feed supplement for Bali cattle: The purposes of this study were to analyze the efficacy of using soybean biomass as a feed supplement for Bali cattle and to analyze the effect of feed supplementation on Bali cattle productivity.

Nine male Bali cattle were used in this study, which used a block randomized design with three feeding treatments in three repetitions. The feeding treatments were swamp grass *ad libitum* (SG), swamp grass *ad libitum*+2 kg Soybean Biomass (SB) and swamp grass *ad libitum*+2 kg Soybean Biomass Silage (SBS). The soybean biomass silage was composed of soybean biomass, rice bran, salt, molasses and probiotics. The nutrient compositions of the SG, SB and SBS are provided in Table 1.

Table 1: Nutrients in SG, SB and SBS provided to Bali cattle

	Treatments		
Nutrient composition (%)	SG	SB	SBS
Dry matter	21.61	23.66	26.86
Ash	6.21	8.73	9.06
Crude protein	10.50	6.69	9.60
Crude fiber	27.61	32.50	31.12
TDN	41.46	48.85	50.57

TND: Total digestible nutrition

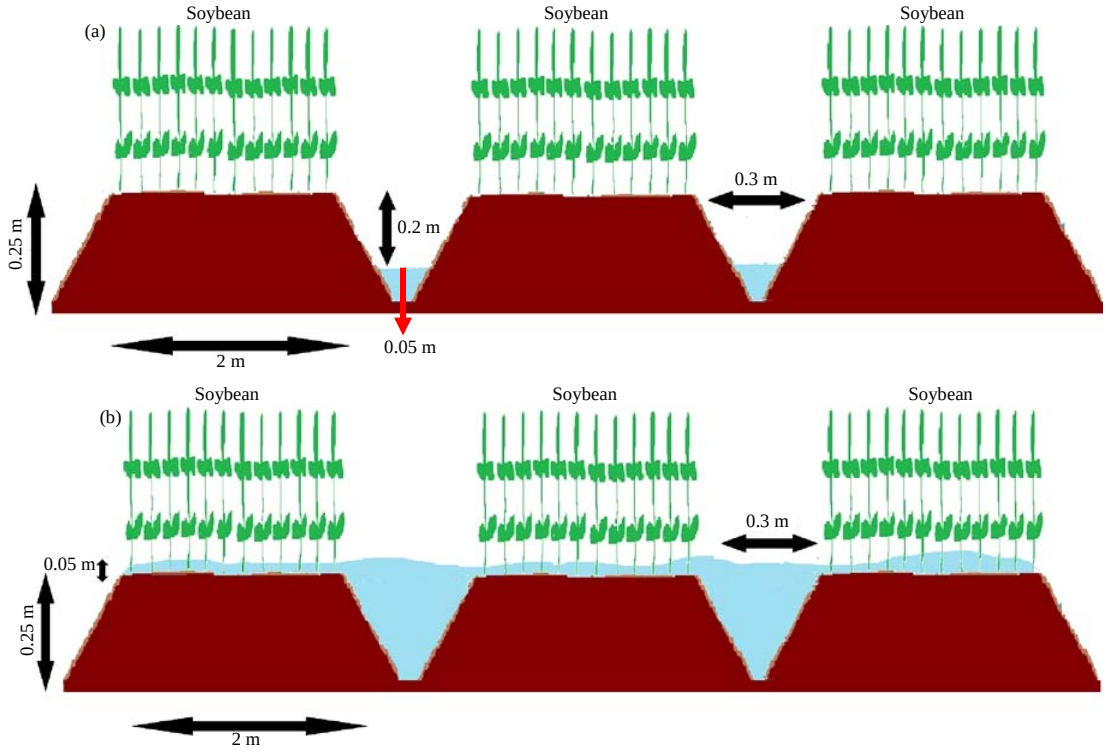

Fig. 1(a-b): Sketch of (a) Saturated soil culture and (b) Temporary flooding

Observed variables:

- Soybean production was the result of soybean production (t) and soybean biomass involved the biomass production of soybean (t), cost of production (IDR ha^{-1}) and farmers' income (IDR ha^{-1})
- Productivity of Bali cattle was measured as the daily weight gain (g day^{-1}), daily Dry Matter Intake (DMI) (g day^{-1}) and Feed Conversion Ratio (FCR)

Data analysis: All data were analyzed using one-way analysis of variance (ANOVA) according to the General Linear Model (GLM) procedure for randomized block designs by using SAS[10] 9.3. If a significant difference was observed, the data were further analyzed using Duncan's multiple range test[11].

RESULTS AND DISCUSSION

Effects on soybean productivity of adding bio-slurry and cattle waste compost via SSC technology in a tidal swamp

Soybean production: Table 2 shows the production of soybean and soybean biomass, production cost, revenue and farmers' income from soybean farming when using SSC with various ameliorants on a tidal swamp. The utilization of SSC technology increased the soybean production per hectare by 1.89-2.68 t compared with soybean production without SSC technology[1], resulting in soybean production of 1.5 t ha^{-1} from the tidal swamp. These results revealed an increase in soybean production of approximately 74% with the use of SSC technology.

Treatment with ameliorants (LA, CA and SA) differed significantly from the absence of ameliorants (NA), but no significant differences among the ameliorants were observed. The use of SA produced better results than treatment with CA or LA. The NA treatment resulted in the lowest soybean production.

The addition of ameliorant to the tidal swamp was necessary given the high acid content in the soil. Therefore, the addition of several ameliorants, such as lime and compost could be used to increase the soil pH. Lime was added to the tidal swamp to increase the soil pH and overcome the Al toxicity. Furthermore, compost contributed to repairing the physical characteristics of the soil and caused the roots to grow much better, allowing the nutrients to be more easily absorbed by roots[4]. The application of compost increased the soil pH and the available nutrients in the soil and bound Al in acidic soil[12]. The organic materials contained in the compost included carbon compounds for microbial growth, thus, the microbial activities occurring at the root positively affected the mineralization of nutrients, thereby increasing the availability of nutrients to the crop. Furthermore, the addition of organic materials in soybean planting increased the rhizobacterial population in the soybean crops[13]. Rhizobacteria that live in acidic soils with high Al contents produce organic acid, which can chelate Al[14]. The number of nodules has been reported to be affected by calcium[15] and P availability[16] in soybean crops planted with rhizobium[5].

Increasing the soybean productivity in a tidal swamp requires reducing the level of pyrite and increasing the availability of macronutrients. The level of pyrite can be decreased by altering the surface water level, thus, using SSC technology can make the soil conditions increasingly reductive[8]. This technology can prevent pyrite oxidation in tidal swamp lands by providing continuous irrigation throughout the furrows. Consequently, the water surface would remain the same and would create a water-saturated layer on the land. This condition can enhance soybean productivity in tidal swamp land[2].

Farmers' income: Using SSC technology to increase soybean production by using various ameliorants could increase income. The highest income was gained from the use of SA, CA and LA. In contrast, the lowest income received by farmers resulted from the NA treatment (Table 2).

The SA and CA resulted from solid waste processing and took the form of organic fertilizer that could be subsequently used as an ameliorant to increase soybean productivity in the tidal swamp. In contrast, LA used by the farmers must be imported from outside regions, resulting in additional production costs that also subsequently affect farmers' income.

According to Priyanti[17], the integrated system is beneficial due to the utilization of grass, straw and cattle waste as feed

Table 2: Soybean production and soybean biomass, production cost, revenue and farmers' income with the use of SSC technology and various ameliorants on a tidal swamp

Parameters	NA	LA	CA	SA	SEM	p-value
Soybean production (t ha^{-1})	1.89	2.62	2.61	2.68	0.0721	0.0001
Soybean biomass production (t ha^{-1})	4.32	5.41	5.45	5.59	0.1184	0.0001
Production cost (IDR ha^{-1})	3,078,800	4,278,000	3,078,000	3,078,000	-	-
Revenue (IDR ha^{-1})	11,623,500	16,113,000	16,051,500	16,482,000	-	-
Farmers' income (IDR ha^{-1})	8,544,700	11,834,200	12,972,700	13,403,000	-	-

Table 3: Average weight gain, daily dry matter intake, daily protein intake and feed conversion in Bali cattle given SG, SB and SBS

Parameters	SG	SB	SBS	SEM	p-value
Daily Dry Matter Intake (DMI) (g day^{-1})	4785	5746	6951	382.81	0.05
Daily Protein Intake (DPI) (g day^{-1})	502	560	719	45.01	0.00
Daily Weight Gain (DWG) (g day^{-1})	155	193	253	21.20	0.30
Feed Conversion Ratio (FCR)	30.8	29.83	27.44	2.52	0.89

for the cattle. In addition, this system produces organic fertilizer, which increases soil fertility. The cattle and crop integration system may also increase farmers' income[6,18].

Efficacy of soybean biomass as a feed supplement for Bali cattle: The implementation of SSC technology in tidal swamp lands produces approximately 4.32-5.59 t ha^{-1} of soybean waste. This soybean waste could serve as supplemental feed for Bali cattle (Table 1).

Based on this study, Bali cattle could consume 2 kg head^{-1} day^{-1} of soybean biomass, thus, the soybean biomass produced could be used as a feed supplement for 22 Bali cattle per planting season. However, this soybean biomass is usually dumped without being utilized and is burned during the planting season.

To develop an environmentally friendly agriculture system, eco-techno farming could be implemented in the form of integrating cattle and soybean crops. The beef cattle business would be more efficient if maintenance management were integrated with the utilization of crops as sources of cattle feed. Beef cattle in turn, produce fertilizer, which can increase crop production and the crops can provide forage for the cattle[19]. Implementing this model could prevent burning during the planting season. If soybean biomass were utilized as a feed supplement for Bali cattle, it would not pollute the environment.

Dry Matter Intake (DMI) and protein intake: The analytical results concerning the utilization of SG, SB and SBS as a feed supplement for Bali cattle to increase productivity are provided in Table 3.

Bali cattle whose feed was supplemented with SBS showed greater DMI and Daily Protein Intake (DPI) than cattle in the other treatments. Bali cattle that were given SB showed greater DMI and DPI values than those given SG. The maximum feed consumption depends on the nutrient balance during digestion[18,20] and the high and low levels of feed consumption also depend on feed palatability[17]. Feed palatability and the amount of feed eaten by the cattle increase the nutrient consumption to levels higher than the minimum needs, therefore, it would be a useful mechanism in increasing cattle body weight[21].

Body weight gain: There were no differences in daily weight gain among the treatment groups. The addition of SBS showed a slightly higher Average Daily Gain (ADG) compared with SB and SG. Processing of the soybean biomass to silage increased the protein content of soybean biomass (2.90-7.89%). The composition of SBS included rice bran, salt, probiotics and molasses and the composition of the supplement has been reported to determine animal productivity[22]. Phuc and Hieu[23] reported that molasses can be used as the exclusive energy source in the diet of growing pigs and can replace rice bran without any negative effect on performance. The addition of a good-quality feed supplement increases daily body weight gain and accelerates growth[24]. The soybean biomass silage did not significantly increase body weight gain in cattle. Therefore, it was necessary to change the silage formula so that it could increase the ADG for the cattle.

Feed conversion ratio: The SBS treatment showed lower FCR values than the SB and SG treatments, however, these differences were not significant. The FCR was high in this study, indicating that the increase in cattle weight from feed intake was inefficient. The efficiency of feed use was affected by several factors, including the ability of cattle to digest feed, the type of feed used and the provision of sufficient nutrients for primary life, growth and body function. Better-quality feed would lead to greater efficiency in terms of energy and production[6]. Feed conversion not only reflected the physical effects in the utilization of nutrient element but also had a determining value for the farmer.

CONCLUSION

The integration of Bali cattle and soybean crops on tidal swamp land via the implementation of the eco-techno farming model has several benefits:

- It increases the productivity of Bali cattle and soybean, as well as farmers' income
- The use of lime as an ameliorant could be replaced with cattle waste compost and bio-slurry ameliorants, which reduce the production cost through the utilization of compost and SSC technology

- Soybean waste could be used as a feed supplement for Bali cattle, which could prevent the burning of soybean waste during the planting season

SIGNIFICANCE STATEMENTS

Tidal swamps are sub-optimal lands that play an important role in agricultural development, not only supporting the national food supply but also providing several opportunities for the growth of village industries, diversification of growth, increasing farmers' income and developing various regions. This study was conducted to evaluate the integration of Bali cattle and soybean on tidal swamp land using the eco-techno farming model. This model implements agricultural technology in which the environmental conditions are addressed by using Saturated Soil Culture (SSC) technology. Here, cattle waste compost and bio-slurry were used as ameliorants to increase soybean production in tidal swamp land. Based on the present results, these ameliorants could replace lime ameliorant, which is imported from outside the region. Further, soybean waste silage can also be used as a feed supplement for Bali cattle. This integrated model could increase the productivity of Bali cattle and soybean and increase farmers' income.

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