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Soybean Production Optimization of Palm Oil Shellbiochar and Compost Using Response Surface Methodology

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Abstract:

Black soybean production can be increased by increasing the planting area like idle fields or deployed land. Such land generally has limitations such as low water availability or low soil fertility. Soil fertility can be improved through organic matter input such as compost. Compost application can improve soil fertility but has a relatively short effect; therefore another effort is needed to support sustainable agriculture programs. Another alternative is the use of biochar. Several studies have been shown that biocharhas a long-term effect on improving soil fertility.The study was conducted in Sukamakmur Village, District of Binjai, Regency of Langkat, which is a rainfed rice field. The soil type isAndisol. The study used a factorial randomized block design (RBD) with 3 replications. The first factor is palm oil solid waste compost (K) which consists of 4 levels and the second factor is biochar which consists of 4 levels. Optimization was carried out using the Response Surface Method to get the optimal soybean production response. The response design was carried out through the Minitab 14 program to determine fixed and independent variables. The fixed variable is black soybeans production, while the independent variable is Solid waste compost as factor 1 (X1) and Palm oil Shell Biochar as factor 2 (X2).The optimum production of black soybeans on rainfed land was obtained at doses of 2-6 tons/ha biochar combined with 6 tons/ha of compost. Increased production of black soybeans through the application of biochar and compost is due to improvements in soil fertility.

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I. INTRODUCTION

Black soybeans production can be increasedthrough agriculture intensification and extensification. Extensification can be done by increasing the planting area on vacant land or idle production, such as rain-fed rice field. Utilization of rice rain-fedland after rice production for black

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soybean is considered potential because it can increase the cropping index (IP). North Sumatra has rainfed rice fields wider than irrigated rice fields. According to BPS (2016) data, irrigated rice field area is covering 135,872 ha while the rain-fed rice fields reach 149,547 ha.

Cultivation of black soybeans in rainfed rice land withdrought potency is considered very risky. Another problem is low soil fertility, high acidity, and high levels of Al and Fe which make P available are very low (He and Dijkstra, 2014). The use of organic matter to increase nutrient absorption can be done but the benefits are short-term due to because the decomposition rate of organic matter is very fast, especially in tropical regions such as Indonesia (Afrida et al, 2015). The alternative to solve the problems is by combining the application of organic matter such as palm oil solid waste with biochar. Biochar has a largesurface area (Barrow, 2012), very porous morphology (Gang et al, 2012), the functional groups are able to reduce bioavailability (Vithanage et al, 2017) and leaching heavy metals through adsorption and other physicochemical reactions (Wang et al, 2018) as well as improve soil fertility by improving soil properties (Mensah and Frimpong, 2018).

One source of biochar is palm oil shell. Palm oil is one of Indonesia's mainstay commodities which has a very rapid development. Province of North Sumatra has many palm oil processing plants, therefore produces a lot of waste, both solid, liquid and shell from palm fruit. One efforts to improve soil fertility is utilizing solid waste from palm oil mill to improve to the number of soil nutrients (Nizar et al, 2018), while palm oil shell biochar can provide a habitat for soil microbes (Warnock et al, 2007) to improve soil biological properties. The use of biochar combined with solid waste compost is expected to be a solution for improving soil fertility (Abas and Ani, 2014) in a sustainable manner because biochar can survive up to 1000 years in the land (Lehmann and Joseph, 2009). In addition, the use of biochar can reduce waste pollution from palm oil mill and greenhouse gas emissions (Sohi.,et al, 2009), as well as support food security by reducing the risk of drought and flooding (Shackley et al, 2009).

The surface response method (surface methodology/RSM response) was used to find out the best combination of palm oil solid waste compost with palm shell biochar. RSM can considerable satisfy to explore the right approach to the relationship between responses and input variables for the determination of optimal conditions for the system/research (Liu et al, 2012). Through this method, researchers do not need large amounts of data and can shorten the time (Sampaio et al, 2006).

II. RESEARCH METHODS

The study was conducted in Sukamakmur Village, District of Binjai, Regency of Langkat, which is a rainfed rice field. The soil type is Andisol. Andisol is a developing soil, generally black and has a cambic horizon, bulk density is less than 0.85 gr cm^{-3}, containing a lot of amorphous material, or more than 60% consists of vulcanic ash, cinders, or other pryroclastic components.

The material is black soybean seed Detam-1, palm oil solid waste (composted using local microorganisms), palm shell biochar, herbicides, insecticides, fungicides and chemicals for laboratory analysis. The tools used in the study were analytical scales, ovens, meters, hoes, soil drills, spectrophotometer, and other tools that support this research.

The study used factorial randomized block design (RBD) with 3 replications. The first factor is palm oil solid waste compost (K) which consists of 4 levels, namely K_0 = 0 g $plot^{-1}$ or equivalent to 0 tons ha^{-1} (control); K_1 = 1200 g $plot^{-1}$ or equivalent to 2 tons ha^{-1}; K_2 = 2400 gplot-1 or equivalent to 4 tons ha^{-1} and K_3 = 3600 $gplot^{-1}$ or equivalent to 6 tons ha^{-1}. The second factor is biochar which consists of 4 levels, namely: B_0 =

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0g plot^{-1} or equivalent to 0 tons ha^{-1} (control); B_1 = 1500 g plot^{-1} or equivalent to 2.5ton ha^{-1}; B_2 = 3000g plot^{-1} or equivalent to 5 tons ha^{-1} and B_3 = 4500g plot^{-1} or equivalent to 7.5 tons ha^{-1}.

Optimization Using the Response Surface Method

This study uses the Response Surface Method (RSM) to get optimal soybean production response. There are four stages in the RSM application (Montgomery, 2001). The response design was constructed with Minitab 14 program to determine fixed and independent variables. The response design was carried out through the Minitab 14 program to determine fixed and independent variables. The fixed variable is black soybeans production, while the independent variable is Solid waste compost as factor 1 (X_1) and Palm oil Shell Biochar as factor 2 (X_2) (Table1).

Table 1. Codes of fixed and response variables

X_1	X_2	Y (pods filled /plant)
0.0000	0.0000	52.0
7.5000	0.0000	62.1
0.0000	6.0000	65.2
7.5000	6.0000	68.7
-1.5533	3.0000	58.1
9.0533	3.0000	63.2
3.7500	-1.24264	65.8
3.7500	7.24264	69.4
3.7500	3.0000	60.0
3.7500	3.0000	64.4
3.7500	3.0000	69.9
3.7500	3.0000	69.6
3.7500	3.0000	62.9
3.7500	3.0000	69.3
3.7500	3.0000	68.0
3.7500	3.0000	69.6

III. RESULTS AND DISCUSSION

The analysis results of the surface response method are presented in Table 2. The table show that regression has a significant effect and the equation shows lack-of-fit has no significant effect.

Table 2. Analysis of Varian's for Response Surface Quadratic Model

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	244.07	244.07	48.81	3.45	0.045
Linear	2	131.59	151.45	75.73	5.36	0.026
Square	2	101.59	101.59	50.80	3.59	0.067

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Interaction	1	10.89	10.89	10.89	0.77	0.401
Residual Error	10	141.30		141.30	14.13	
Lack-of-Fit	3	41.18	41.18	13.73	0.96	0.463
Pure Error	7	100.13		100.13	14.30	
Total	15		385.38			

The regression model obtained can be acceptable with the low model gap. The regression equation is:
$Y\text{-}55{,}6995 + 3{,}0337\ X_1 + 1{,}6455\ X_2\ \text{-}0{,}2533X_1^2 – 0{,}1467X_1X_2$...(1)
with R^2 =63,3%.

The equation (1) shows that there is no effect of X_2^2 so that a single compost application for increasing soybean production is not recommended. Based on the values of lack of fit, it is known that there is no model gap as indicated by lack of fit valueF_0 (0.96) <F_{table} (4.35). The value of F_{table} can be seen from the F distribution table. The optimum dose can be seen from the contour and surface plot of response as presented in Figures 1 and 2.

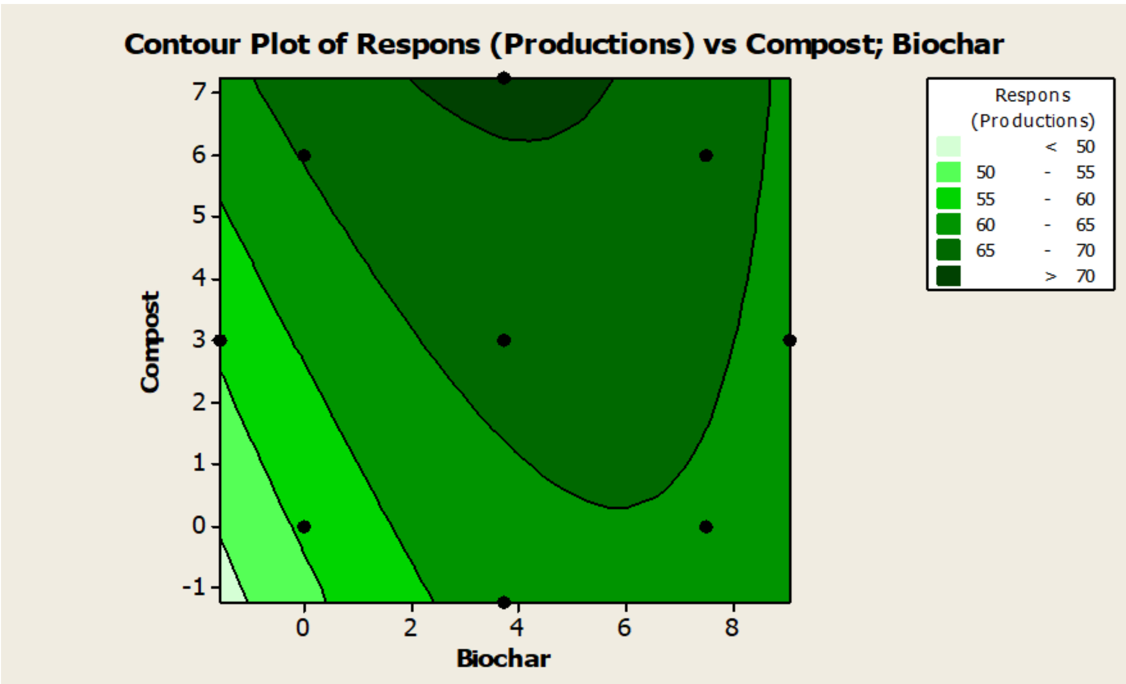

Figure 1. Contour plot of response from biochar and compost

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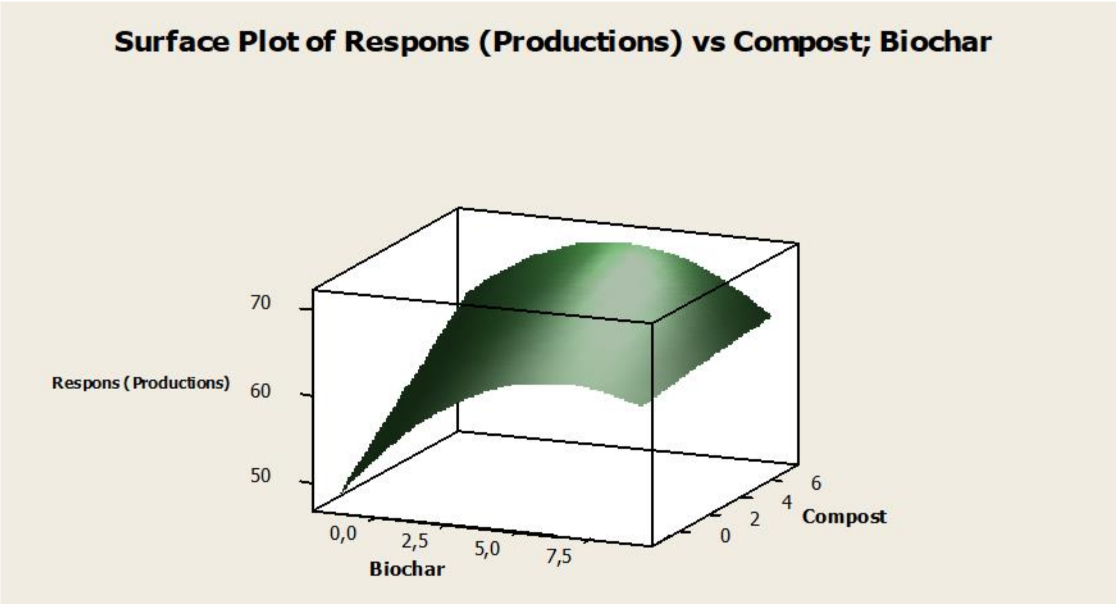

Figure 2. Surface plot of response from biochar and compost

Figures 1 and 2 show that optimum production is obtained at doses of 2-6 tons hectare-1 biochar combined with 6 tons hectare-1 of compost. Figure 1 also shows that the biochar application is more decisive in increasing black soybean production. Soybean production has reached 60-65 pods plants-1 with a single application of biochar 2 tons hectare-1 (without compost). Meanwhile, the compost applications at a dose of 3 tons hectare-1 without biochar reach the production of 60-65 pods plants-1. These results indicate that RSM can determine the optimum response. Another optimization experiment was carried out by Zhang, et al (2007) in a study of pyridoxine (PN), which one of three groups of vitamin B6. Increased soybean production due to the application of biochar and solid waste compost is due to improved soil fertility which can be seen in table 3.

Table 3. The parameterof the soil due to the treatment of oil palm shell biochar and compost of palm oil solid waste

Treatment	Soil acidity	The water content in Field Capacity	Water content available	The watercontent in the permanent wilting point
K_0B_0	4.95a	28.05a	22.01a	2.14
K_0B_1	5.09a	29.23a	23.61a	2.63
K_0B_2	5.01a	29.50a	24.41abc	2.07
K_0B_3	5.02a	28.75a	22.83ab	2.30
K_1B_0	4.98a	39.74b	28.15fg	2.59
K_1B_1	5.54b	28.47a	26.55c-g	2.34
K_1B_2	5.55b	28.48a	27.81efg	2.37
K_1B_3	6.05c	26.78a	25.71c-f	2.18
K_2B_0	4.96a	43.91b	28.42g	2.79
K_2B_1	5.51b	30.50a	28.56g	2.97
K_2B_2	5.57b	30.16a	28.32g	2.24
K_2B_3	6.04c	27.73a	25.26bcd	2.27

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K_3B_0	4.93a	45.30c	28.20fg	2.62
K_3B_1	5.56b	30.33a	28.01efg	2.22
K_3B_2	5.52b	29.81a	27.64d-g	2.37
K_3B_3	6.12c	29.91a	27.43d-g	2.07
Average	5.37	31.67	29.25	2.39

Note: Numbers followed by the same letters in the same parameter column are not significantly different according toHonestly Significant Test (HSD) at α = 5%.

In general, the treatment without solid waste compost has low soil pH. The lowest pH was found in treatment K_0B_0 namely 4.95 which were not significantly different from the treatments K_0B_1, K_0B_2, K_0B_3, K_1B_0, K_2B_0 and K_3B_0. These results indicate that the absence of organic matter from solid waste compost and biochar cannot increase soil pH. The highest pH was found in treatment K_3B_3 which was not significantly different from treatments K_2B_3 and K_1B_3. These results indicate that Biochar application is able to increase soil pH (Ding et al, 2016). Tambunan et al. (2014) also stated that Biochar can increase soil pH by neutralizing the soil pH. Siringoringo and Siregar (2011) also suggested that 5% of biochar can neutralize soil pH.

In the parameters of water field capacity, the highest value was found in treatment K_3B_0 which was significantly different from all other treatments. The lowest water content at field capacity was found in treatment K_1B_3 which was not significantly different from treatments K_0B_0, K_0B_1, K_0B_2, K_0B_3, K_1B_1, K_1B_2, K_1B_3, K_2B_1, K_2B_2, K_2B_3, K_3B_1, $K_3B_2$and K_3B_3. These results indicate that application of solid waste compost can increase the water content in field capacity but biochar can reduce the soil water content in field capacity. This is because biochar is able to increase soil macropore. Prasetyo et al. (2014) showed that the amount of mesopores increases with an increasing dose of biochar. In contrast to the water content in the field capacity, the highest available water content was found in treatment K_2B_1 which was not significantly different from treatment of K_1B_0, K_1B_1. K_1B_2, K_2B_0, K_2B_1, K_2B_2, K_3B_0, K_3B_1, K_3B_2, and K_3B_3 but were significantly different thanK_0B_0, K_0B_1, K_0B_2, K_0B_3, and K_2B_3. This shows that the application of compost (K_1, K_2 and K_3) can increase the available water content.

IV. CONCLUSION

Through Response Surface Methodology, the optimum production of black soybeans on rainfed land is obtained at biochar dose of 2-6 tons hectare^{-1} combined with compost 6 tons/ha. Applications biochar 2-6 tons hectare^{-1} and compost palm mill solid waste 6 tons hectare^{-1} can improve soil fertility through increased pH, increased water content in field capacity, available water content and water content at permanent wilting points so that increased production of black soybeans.

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