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The effect of soil conditioner and growth booster on the agronomic characters and number of nodules of black soybean

Abstract. Soil Conditioner & Growth Booster (SCGB) is a potion that was made to be used as a soil conditioner and plant growth promoter. SCGB is made from organic matter, biological fertilizers, soil ameliorants, and microelements. This research aims to determine the best dosage of SCGB on the agronomic characters, effective nodules, and black soybean variety 'Detam-1' yield. This research was conducted in the experimental field of the Faculty of Agriculture, Winaya Mukti University, Sumedang, Indonesia. This experiment used a simple randomized block design (RBD) with six treatments (0, 3, 6, 9, 12, 15 kg/ha) and repeated 4 times. The observation was conducted on a number of effective root nodules, plant height, number of leaves, 100-grain weight, number of pods, seed weight per plant, and seed weight per plot. The result showed that SCGB application significantly improved agronomic characteristics of black soybean plants, increasing the number of effective nodules by 147% to 168% compared to untreated plants. A dose of 3 kg/ha SCGB showed the best results in increasing 35% on yield seed weight per hectare compared to without application of SCGB.

Keywords: Agronomic performance · Black soybean · Effective nodule · SCGB

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Introduction

Black soybean is one of the soybean varieties (*Glycine max* (L.) Merr.) used as raw materials for healthy drinks and foods. This variety is used for obesity and hyperglycemia diets because it has a high protein and low-fat content and contains antioxidants, namely anthocyanins and isoflavones (Li et al., 2024; Ganesan & Xu, 2017; Mitharwal et al., 2024; Yamashita et al., 2024). Black soybeans are generally used by the soy sauce industry in Asia countries (Ginting, 2021). Amino acids and volatile compounds in black soybeans affect the unique taste of soy sauce (Shin et al., 2019).

Many farmers cultivate soybeans using synthetic nitrogen, phosphorus, and potassium fertilizers without balancing with organic fertilizers and micronutrients. Cultivation like this not only endangers plant health but can also reduce the soil's physical, chemical, and biological quality. Therefore, we must maintain plant and soil health by adding micro fertilizers, soil ameliorants, organic fertilizers, and biofertilizers.

In small concentrations, micro fertilizers, such as boron (B), manganese (Mn), and zinc (Zn), have various benefits for plants. Boron affects soybean germination, growth, and yield (Dameto et al., 2023). Manganese can increase soybean resistance to stress (Jiang et al., 2023). Zinc not only increases soybean resistance to stress but also fortifies soybean seeds so that people do not experience symptoms of Zn deficiency (Dai et al., 2020).

Soil ameliorants can maintain soil quality, which can ultimately maintain crop yields. It can be in the form of biochar, which helps increase soil porosity, increase soil aggregate stability, increase water availability, increase cation exchange capacity (CEC), and increase root nodules and soybean plant yields (Blanco-Canqui, 2017; Domingues et al., 2020; Turmuktini et al., 2020; Turmuktini et al., 2022). Humic acid and dolomite have almost the same function and increase soybean yields (Ampong et al., 2022; Lenssen et al., 2019; Pimolrat et al., 2020; Takamoto et al., 2023). Organic fertilizers can increase soil nutrients, as nutrients for beneficial soil microorganisms, and improve soil physical properties, increasing soybean growth and yields (Assefa & Tadesse, 2019; Onyenali et al., 2020). Several organic materials can be used as fertilizers, such as sugarcane filter cake, guano, and palm ash (Marwa et al., 2021; Dotaniya et al., 2016; Zahrah & Kustiawan, 2022).

Biofertilizers are known to increase soybean growth and yield. Phosphate-solubilizing bacteria can dissolve unavailable P, increasing soybean productivity (Shome et al., 2022). Nitrogen-fixing bacteria can provide N for soybeans, thereby reducing the dose of N fertilizer and increasing crop yields (Cordeiro & Echer, 2019).

The enormous benefits of micro fertilizers, soil ameliorants, organic fertilizers, and biofertilizers for soybean plants prompted the research team to create a combination of these materials called Soil Conditioner and Growth Booster (SCGB). These materials consist of micro fertilizers (B, Mn, and Zn), soil ameliorants (coconut shell biochar, dolomite, and humic acid), organic fertilizers (sugarcane filter cake compost, guano fertilizer, and palm ash), and biological fertilizers (phosphate-solubilizing bacteria and nitrogen-fixing bacteria). SCGB is expected to increase the effective nodules, growth, and yield components, and yield of black soybeans.

Materials and Methods

The research was conducted from March to June 2023 at the experimental field of the Faculty of Agriculture, Winaya Mukti University, Sumedang Regency, West Java Province, Indonesia, with an altitude of 850 meters above sea level (asl) and rainfall type C (slightly wet). The soil has criteria for moderate N and P content, while the K content is low but has a high CEC (Table 1). The laboratory equipment used is an analytical balance, ruler, oven, grain moisture meter, and plant cultivation tools in the field. The materials used are soybean seeds of 'Detam-1' variety; SCGB (the mixture consists of B, Mn, Zn, coconut shell biochar, dolomite, humic acid, sugarcane filter cake compost, guano fertilizer, palm ash, phosphate-dissolving bacteria, and nitrogen-fixing bacteria) (Table 2); rice straw compost as a SCGB diluent; urea; SP-36; and KCl. Botanical pesticides in the form of garlic extract, pesticides with active ingredients Profenofos 500 EC, lambda-cyhalothrin 106 g/l + thiamethoxam 141 g/l, Fipronil 50 SC, Propineb 70 WP, carbofuran 3G, and brofflanilide 53 SC were used alternately to control pests and diseases that attack plants.

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Table 1. Results of soil analysis at the experimental field

Parameter	Value	Unit	Criterion
pH (HCl 25%)	6.1	mg/100 g	Slightly acid
Organic-C	2.16	%	Medium
Total N	0.30	%	Medium
C/N	7.20		Low
P_2O_5 (HCl 25%)	35.00	mg/100 g	Medium
K_2O	18.00	mg/100 g	Low
CEC	37.24	cmol/kg	High
Ca-exchange	7.16	cmol/kg	Medium
Mg-exchange	2.12	cmol/kg	High
K-exchange	0.35	cmol/kg	Low
Na-exchange	0.0054	cmol/kg	Very low

Note: Soil fertility criteria based on Balittanah (2009)

The experiment used a randomized block design (RBD) composed of 6 SCGB dose treatments, namely 0 (A), 3 (B), 6 (C), 9 (D), 12 (E), and 15 kg/ha (E), which were repeated four times. Data were analyzed using variance analysis (ANOVA), and testing was continued using Duncan's Multiple Range Test at a 5% significance level. Correlation analysis was conducted on the number of effective root nodules, yield components, and black soybean yields using the Pearson correlation test at a 5% significance level.

Table 2. The profile of soil conditioner & growth booster (SCGB) characteristics

Parameter	Value	Unit
Organic-C	19.56	%
C/N	19	
Moisture Content	14.96	%
N	1.02	%
P_2O_5 (HCl 25%)	6.28	%
K_2O	0.52	%
Ca	7.16	%
Mg	2.19	%
CEC	35.02	cmol kg^{-1}

Note: Measurement based on Balittanah (2009) protocol

The experiment began with land preparation, including soil cultivation and making plots measuring 1 m x 1 m, with a distance between treatments and replications of 30 cm each. SCGB was first mixed with 2 tons of rice straw compost ha-1 according to the treatment dose, then inserted into the planting hole with a distance of 25 x 25 cm. The seeds were coated with 20 g/kg biofertilizer until it adhered evenly to the seeds, and then two seeds were planted per hole. One week later, the seeds were thinned to 1 seed per hole. The fertilizers given were 50 kg/ha urea, and 75 t/ha KCl and SP36 when the plants were 15 days after sowing (DAS) (half dose urea, SP36, and KCl), and 35 DAS (continued half dose urea). Another maintenance is weeding, and pest and disease control is carried out when weeds grow, or there are pest and disease attacks. Harvesting occurred after physiological maturity characteristics appeared, namely dry brown pods and hard seeds with a maximum water content of 25%. Observations were made on the number of effective nodules, the percentage increase in effective root nodules, agronomic characters, and plant yields. Effective root nodules are root nodules that can fix nitrogen, as indicated by the pink color of the nodules (Jin et al., 2022). The percentage increase in effective root nodules is the difference between the effective root nodules given SCGB and the control in percentage form. The agronomic characteristics observed were plant height and number of leaves (as growth components); number of pods per plant and weight of 100 grains (as yield components). Plant height and number of leaves were observed at 3, 4, 5, and 6 weeks after planting (WAS), while the number of pods and weight of 100 grains were observed at harvest. Plant yields were observed at harvest: seed weight per plant and seed weight per plot.

Results and Discussion

Results. The statistical analysis showed that the SCGB dose significantly affected the number of effective nodules and effective nodules increase (%). The 3-15 kg/ha SCGB treatment gave more effective nodules than the control (Table 3).

SCGB also showed a significant difference compared to the control on the growth of black soybeans, namely in height and number of leaves (Table 4). The 3 kg/ha dose gave a higher plant height than the control at ages 3, 4, and 5 WAS. A higher dose (6-15 kg/ha) could only give a difference in height at age 6 WAS. In contrast, almost all SCGB doses showed a difference in the number of leaves at ages 3-6 WAS, but the 3 kg/ha dose showed a difference in the number of leaves at age 6 WAS.

The components of the black soybean plant yield were also influenced by SCGB (Table 5).

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The number of pods per plant increased after being given 3-15 kg/ha SCGB, but the highest number of pods was given by a dose of 3 kg/ha, although it was not different from 6 and 9 kg/ha. The heaviest 100-grain weight was also given by a dose of 3 kg/ha SCGB but was not different from 6, 9, and 15 kg/ha. The increase in yield components due to SCGB also increased crop yields. The heaviest seed weight per plant was given by 3-9 kg SCGB. Doses of 3 and 9 kg/ha gave the highest seed weight per plant but were not significantly different from 6 kg/ha. In the correlation analysis, the number of root nodules affected the growth components (plant height and number of leaves), yield components (number of pods and 100-grain weight), and also black soybean yield (seed weight per plant). Plant height and number of leaves as growth components affected all yield components and crop yields. Seed weight per plant as a crop yield also affected other crop yields, namely seed weight per plot (Table 6).

Table 3. The effect of soil conditioner & growth booster (SCGB) application on the number of effective nodules and effective root nodules increase (%)

Treatments	Number of Effective Nodules	Effective Nodules Increase (%)
A (0 kg/ha)	2.25 a	0 a
B (3 kg/ha)	5.56 b	147 b
C (6 kg/ha)	5.50 b	145 b
D (9 kg/ha)	5.75 b	155 b
E (12 kg/ha)	6.05 b	168 b
F (15 kg/ha)	6.00 b	166 b

Note: The average values marked with the same lowercase letter in the same column indicate no significant difference according to Duncan's Multiple Range Test at a 5% significance level.

Table 4. Effect of soil conditioner & growth booster (SCGB) application on black soybean plant height and number of leaves from 3-6 weeks after sowing (WAS)

Treatments	Plant Height (cm)			
	3 WAS	4 WAS	5 WAS	6 WAS
A (0 kg/ha)	14.20 a	18.10 a	21.76 a	28.63 a
B (3 kg/ha)	16. 10 b	20.50 b	25.20 c	34.55 b
C (6 kg/ha)	15.21 ab	19.25 ab	23.50 abc	33.75 b
D (9 kg/ha)	15.05 ab	19.48 ab	23.51 abc	32.79 b
E (12 kg/ha)	15.17 ab	19.60 ab	22.70 ab	32.58 b
F (15 kg/ha)	15.19 ab	19.85 ab	24.21 bc	32.72 b
	Number of Leaves			
	3 WAS	4 WAS	5 WAS	6 WAS
A (0 kg/ha)	2.38 a	3.50 a	4.46 a	9.42 a
B (3 kg/ha)	2.70 b	4.10 c	6.66 b	13.56 b
C (6 kg/ha)	2.79 b	3.85 b	6.00 b	12.04 ab
D (9 kg/ha)	2.55 b	3.91 b	6.19 b	11.80 ab
E (12 kg/ha)	2.66 b	3.68 ab	5.89 b	11.06 ab
F (15 kg/ha)	2.70 b	3.84 b	5.94 b	11.08 ab

Note: The average values marked with the same lowercase letter in the same column indicate no significant difference according to Duncan's Multiple Range Test at a 5% significance level.

Table 5. Effect of soil conditioner & growth booster (SCGB) application on soybean plant yield components

Treatments	Number of Pods	100-grain weight (g)	Seed Weight per Plant (g)	Seed Weight per Plot (g)
A (0 kg/ha)	25.63 a	11.60 a	7.84 a	268.67 a
B (3 kg/ha)	50.18 d	14.90 c	13.70 c	362.57 c
C (6 kg/ha)	49.59 d	13.50 bc	12.98 c	331.51 abc
D (9 kg/ha)	41.20 cd	13.34 bc	13.66 c	350.50 c
E (12 kg/ha)	37.19 bc	12.05 ab	9.68 ab	281.39 ab
F (15 kg/ha)	35.63 b	13.10 bc	10.23 b	281.94 ab

Note: The average values marked with the same lowercase letter in the same column indicate no significant difference according to Duncan's Multiple Range Test at a 5% significance level.

Table 6. Correlation matrix between the number of root nodules, growth components, and yield components of black soybean

	Number of Effective Nodules	Plant Height	Number of Leaves	Number of Pods	Seed Weight per Plant	Seed Weight per Plot
Number of Effective Nodules	1					
Plant Height	0.619*	1				
Number of Leaves	0.517*	0.851*	1			
Number of Pods	0.659*	0.535*	0.434*	1		
Seed Weight per Plant	0.600*	0.509*	0.442*	0.841*	1	
Seed Weight per Plot	0.399	0.512*	0.486*	0.703*	0.796*	1

Note: correlation values followed by an * indicate a significant correlation at the 5% significance level.

Discussion. SCGB treatment can increase the number of effective root nodules of black soybeans. The increase in nodules is because SCGB contains nitrogen-fixing bacteria. With a supportive environment, inoculation of nitrogen-fixing bacteria that ar symbiotic with soybeans can increase the number of effective root nodules (Gebremariam & Tesfay, 2021; Argaw, 2016; dos Santos Sousa et al., 2022). This increase could provide sufficient nitrogen supply for plants (Singh et al., 2022).

SCGB also increases plant height and the number of leaves in black soybeans. Sufficient nitrogen from effective root nodules can be used as a component of proteins and enzymes in the plant body to improve its growth (Oliveira et al., 2017; Gou et al., 2023). Nitrogen also forms chlorophyll in leaves, increasing the number of leaves (Ye et al., 2025). The significant correlation between the number of effective root nodules with plant height, and the number of leaves also evidences growth increase. In addition to nitrogen-fixing bacteria, phosphate-solubilizing bacteria can improve growth by providing energy (Pan & Cai, 2023). However, this study did not observe phosphate uptake, so further research is needed.

Organic fertilizers also provide various nutrients for growth (Table 2). Organic matter can be energy for microorganisms that are good for plants, including phosphate-solubilizing bacteria (Gunina & Kuzyakov, 2022). Organic fertilizers and soil ameliorants increase the cation exchange capacity, providing various nutrients for plants (Cooper et al., 2020). This material can also improve the physical properties of the soil. However, this study has not revealed whether the soil's physical properties have improved after SCGB application.

Micro fertilizers, such as B, Mn, and Zn contained in SCGB, can increase plant growth with a small dose, while too high a dose can cause poisoning (Kaur & Garg, 2021; Santos et al., 2017; Landi et al., 2019). The possible toxicity of micro fertilizer caused SCGB doses of more than 3 kg/ha to increase plant height no longer, even though the number of leaves was the same as the control. The increase in the number of effective nodules and growth components also causes the yield and yield components to increase. This is evidenced by the significant correlation between the number of effective nodules and growth components with the yield and yield components, except for the number of effective nodules with seed weight per plot. The number of effective nodules likely affects seed weight per plot more indirectly than directly, namely through the effect on growth components, yield components, and seed weight per plant.

Conclusion

SCGB dose of 3 kg/ha gave the best number of effective nodules, yield components, and crop yield compared to the control. This research must be continued to determine the effect of SCGB on nutrient absorption, soil physical properties, and toxicity of microelements B, Mn, and Zn.

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