Research article

Seed Nutrient and Leaf Mineral Content of Jack Bean (*Canavalia ensiformis* L.) Cultivated with Organic and Bio-fertilizers in Grumusol Soil

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Abstract

Keywords

grumusol soil;

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seed nutrient;

soil amendment

The aim of this study was to determine the seed nutrient content and leaf mineral status of jack bean cultivated in grumusol soil treated with bio-fertilizers and soil ameliorants. The research was conducted on marginal land in Playen Village, Yogyakarta, Indonesia which is at an altitude of 250 m above sea level. The experimental research was conducted with a 2 x 2 x 2 factorial design. The first factor was the type of bio-fertilizers consisting of mycorrhiza and *Rhizobium*. The second factor was the kind of ameliorants consisting of chicken manure and green manure. The third factor was the dose of bio-fertilizers consisting of 10 g kg^{-1} seeds, and 20 g kg^{-1} seeds. Two treatments which were chicken manure and green manure both without bio-fertilizer were used as controls. The results indicated that a combination of green manure and *Rhizobium* 20 g kg^{-1} seeds produced the highest protein seed content (28.68 %). The green manure and *Rhizobium* 10 g kg^{-1} seeds resulted in the highest carbohydrate seed content (59.98%), while the combination of chicken manure and *Rhizobium* 10 g kg^{-1} seeds produced the highest lipid seed content (2.62%). Moreover, the results indicated that application of chicken manure and mycorrhiza with a dosage of 20 g kg^{-1} seeds resulted in the highest leaf N content (4.04%), application of green manure and mycorrhiza 20 g kg^{-1} seeds resulted in the highest leaf P content (0.79%), whereas application of chicken manure and *Rhizobium* 10 g kg^{-1} seeds produced the highest leaf K content (1.41%). The application of chicken manure resulted in fewer nodules than green manure application.

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1. Introduction

Jack bean (*Canavalia ensiformis* L.) produces seeds that can be used as human food and animal feed. This plant can grow in a variety of soil types. Crop of jack bean can grow well in arable and in marginal soil [1]. Jack bean is one of the under-exploited tropical dry beans that can be grown in marginal soils and under semi-arid to arid conditions [2]. This plant can produce seeds containing crude lipid in the range of 3.1-6.0%, crude fiber 7.34-9.98%, crude protein 29.8-32.2%, and nitrogen free extractives in the range of 50.77-54.28% [3].

Indonesia, like other developing countries, has problems dealing with not only increasing food demand but also the reduction of arable agricultural lands in line with increasing residential demand and other public facilities [4]. The increasing population has an increasing food demand that is putting pressure on the agricultural sector to produce enough food. To handle these problems, the Indonesia government now motivates farmers to expand their planting areas in marginal lands such as coastal sandy lands, peat lands, and grumusol soils. As is the case in Indonesia, in the two regions of South Asia and South Africa, without adequate adaptation measures it is likely to have negative effects on some important crops which can create food insecurity for large human populations [5].

Fast soil moisture loss due to evaporation and infiltration can be one of the main problems in crop cultivation in coastal sandy lands. To increase soil permeability and soil humidity, the use of mulch and compost, as well as soil conditioners, is recommended in coastal sandy lands [1]. Manures and clay application to the soil is important to promote better plant growth in coastal sandy lands [6, 7]. Like the growth of plants in coastal sandy soil, the growth of plants in grumusol soil is difficult due to the infertility of the soil. Grumusol soil has a low content of organic matter, typically in range of 0.06-4.5%, low nutrient content, and develops crack up to 5 inches wide when it dries out and grumusol soil becomes very hard when dry [8].

Currently, transformations in agriculture globally are occurring very quickly, and one example of this was the discovery of plant growth promoting rhizobacteria (PGPR) fertilizers. PGPR is a group of rhizosphere bacteria used as biological fertilizers in agricultural activities [9]. Chemical and organic sources provide important input in cultivation activities to improve plant growth, yield and quality parameters [10, 11]. The application of manures as soil ameliorant can be recommended for both coastal sandy soil and grumusol soil to increase soil fertility. These ameliorants can be applied in soils to increase physical and chemical soil fertility [12]. The usage of organic fertilizers such as manures offer more benefits compared to the use of chemical fertilizers [13]. Excessive use of chemical fertilizers for a long period of time reduces soil quality and damages the environment [14]. Organic fertilizers not only can increase soil fertility, but also can improve the ecosystem, environment and soil health conditions [15, 16]. The utilization of organic compost was very important for the growth of pigeon-pea cultivated in cassiterite mine soil [17]. The application of goat manure could result in better growth and yield of melon [18]. Manures, as sources of organic matters, have many functions, and the relative importance of which differs with soil type, climate, and land use [19].

The purpose of this study was to increase the fertility of grumusol soil using organic materials, namely manure and biological fertilizers that could increase the growth and yield of the jack bean plant. The formation of root nodules and the nutritional content of the jack bean seeds were important parameters observed in this study.

2. Materials and Methods

2.1 Research site and period

This experiment was conducted from March until September 2019, and this experiment was carried out in grumusol soil located in Playen Village, Yogyakarta, Indonesia. The research area has an altitude of 250 m above sea level and it has soil pH 6.7, daily minimum temperature 27^{o}C and maximum temperature 31^{o}C, air humidity 54-95%, and wind velocity of 9.5 km h^{-1}.

2.2. Land preparation and experimental design

The land preparation consisted of soil plowing to 20 cm depth using a tractor, with plotting of the area. The size of each plot was 3 x 4 m, and each block had a total (2 x 2 x 2) + 2 (control) of 10 plots. The research used 2 x 2 x 2 factorial experiment arranged in randomized complete block design with 3 replications. The first factor was the kinds of soil amendment consisting of 2 levels: chicken manure (A1), and green manure of *Gliricidia sepium* (A2). The second factor was the types of bio-fertilizers consisting of 2 levels: mycorrhiza (B1), and *Rhizobium* (B2). The third factor was dosages of bio-fertilizers consisting of 2 levels: 10 g kg^{-1} seeds (D1), and 20 g kg^{-1} seeds (D2). Two applications, chicken manure and green manure both without bio-fertilizer (B0) were used as controls.

2.3. Plant planting and plant maintenance

Before planting, seeds were treated with mycorrhiza or *Rhizobium* at the appropriate dosages, which were either 10 g or 20 g kg^{-1} seeds. Treated seeds of jack bean (*Canavalia ensiformis* L.) were planted in each plot in spaces 60 x 40 cm. Each planting hole contained one seed. After one week, the seeds that failed to grow were replaced by new seeds. Weed control was done manually. Well water was used for watering the plants when there was no rain for several days.

2.4. Data collection and analysis

Parameters observed include nodule numbers, i. e. effective nodules that had pink colour after cutting with razor [20], growth parameters, i.e. plant dry weight, and yield parameters, i.e. seed yield ha^{-1}. Observation of nodules was conducted at 4 weeks after planting whereas dry weight of plant biomass was observed at the harvesting stage. Proximate composition of seeds was observed [3] and included were protein, carbohydrate, lipid, and ash content. Leaf N, P, and K contents were observed on dried leaves destructively. Analysis of variance was used to analyze data and this was continued with Duncan's Multiple Range Test, DMRT 5% [21].

3. Results and Discussion

The results of the experiment showed that there were interactions between kinds of ameliorants and either kinds or dosage of bio-fertilizers that affected seed protein, seed carbohydrate, seed lipid, leaf NPK content, and active nodule number per plant (Table 1). Plants with application of green manure in combination with *Rhizobium* at a dosage of 20 g kg^{-1} seeds (A2B2D2) produced seeds with the highest protein content (28.68%). This seed protein content was lower than the crude protein content of jack bean observed by Doss *et al.* [3], which was in the range of 29.8-32%. Nevertheless, this protein content (28.68 %) of jack bean was higher compared to bush bean, long bean, and winged bean under vermicompost treatment. Protein content was 26.50%, 24.74%, and 22.04% for bush bean, long bean, and winged bean, respectively [22]. Jack bean can be a potential source of protein, mineral element, and energy supplement in livestock feeds, and it has the potential to be used for human consumption [3].

Plants with application of green manure in combination with *Rhizobium* at a dosage of 10 g kg^{-1} seeds (A2B2D1) produced seeds with the highest carbohydrate content (59.98%) whereas plants with application of chicken manure in combination with *Rhizobium* in dosage of 10 g kg^{-1} seeds (A1B2D1) produced seeds with the highest lipid content (2.62%). This seed lipid-protein content was lower compared to crude lipid content of jack bean in Doss *et al.* [3], which was in the range of 3.1-6.0%.

Plants with application of chicken manure in combination with mycorrhiza with dosage of 20 g kg^{-1} seeds (A1B1D2) produced the highest leaf N content (4.04%). Plants with the application of green manure in combination with mycorrhiza at dosage of 20 g kg^{-1} seeds (A2B1D2) produced the highest leaf P content (0.79%) whereas plants with application of chicken manure in combination with *Rhizobium* at dosage of 10 g kg^{-1} seeds (A1B2D1) produced the highest leaf K content (1.41%). These results were in line with the results of the research conducted by Htwe *et al.* [23], which indicated that the bio-fertilizer significantly increased the N, P, and K uptakes of mung bean, cowpea, and soybean.

Table 1. Seed protein, seed carbohydrate, seed lipid, leaf N, P, and K contents, and effective nodule number

Treatment combination	**Seed protein content (%)**	**Seed carbohydrate content (%)**	**Seed lipid content (%)**	**Leaf N content (%)**	**Leaf P content (%)**	**Leaf K content (%)**
A_1B_0	27.28^{Bcd}	55.77^{cd}	1.48 ^{g}	4.00 ^{B}	0.59 ^{e}	1.25 ^{f}
$A_1B_1D_1$	26.70 ^{Dc}	56.84 ^{c}	2.48 ^{ab}	3.49 ^{D}	0.68 ^{c}	1.37 ^{c}
$A_1B_1D_2$	25.42 ^{E}	58.49 ^{b}	2.25 ^{cd}	4.04 ^{A}	0.59 ^{e}	1.38 ^{bc}
$A_1B_2D_1$	26.04 ^{E}	57.11 ^{c}	2.62 ^{a}	3.12 ^{F}	0.67 ^{c}	1.41 ^{a}
$A_1B_2D_2$	24.78 ^{E}	58.62 ^{b}	2.06 ^{d}	3.02 ^{H}	0.65 ^{cd}	1.32 ^{e}
A_2B_0	24.78 ^{E}	58.38 ^{b}	2.35 ^{bc}	3.46 ^{D}	0.71 ^{b}	1.39 ^{b}
$A_2B_1D_1$	28.16 ^{Ab}	56.66 ^{c}	1.72 ^{ef}	3.27 ^{E}	0.64 ^{d}	1.38 ^{bc}
$A_2B_1D_2$	27.58 ^{Abc}	56.74 ^{c}	1.83 ^{e}	3.66 ^{C}	0.79 ^{a}	1.37 ^{c}
$A_2B_2D_1$	24.78 ^{E}	59.98 ^{a}	1.55 ^{fg}	3.47 ^{D}	0.66 ^{c}	1.35 ^{d}
P (ρ > F)	0.0013	0.0007	<0.0001	<0.0001	<0.0001	<0.0001

Note: Means in columns followed by the same letters are not significantly different by DMRT 5%

There is no interaction between ameliorants and either bio-fertilizers type or bio-fertilizers dosage on seed ash content, seed yield ha^{-1}, and plant dry weight (Table 2). The results of the experiment (Table 2) indicated that chicken manure (A1) produced higher seed ash content than green manure (A2). Plants without application of bio-fertilizer (B0) produced higher ash content of seeds than those with application of either mycorrhiza (B1) or *Rhizobium* (B2). Application of bio-fertilizers at the dosage of 10 g kg^{-1} seeds (D1) produced higher ash content of seeds than application of bio-fertilizers at dosage of 10 g kg^{-1} seeds (D2). All treatments of this research resulted in seeds containing ash content lower than those mentioned in Doss *et al*. [3], which contained ash content in the range of 3.56-5.93%.

Table 2. Seed ash content, seed yield ha^{-1}, plant dry weight, and nodule number

Treatments	Seed ash content (%)	Seed yield ha^{-1} (ton)	Plant dry weight (g)	Nodule number
Kinds of Ameliorants (A)				
A1: Chicken manure	3.53 ^{a}	3.05 ^{a}	38.27 ^{a}	17.07 ^{b}
A2: Green manure	3.25 ^{b}	2.71 ^{b}	36.83 ^{a}	24.20 ^{a}
P (ρ > F)	<0.0001	<0.0001	0.6508	0.0276
Types of Bio-fertilizers (B)				
B0: Control	3.98 ^{a}	2.65 ^{b}	36.43 ^{a}	21.83 ^{a}
B1: Mycorrhiza	3.27 ^{b}	2.76 ^{b}	39.51 ^{a}	16.87 ^{a}
B2: *Rhizobium*	3.21 ^{b}	3.11 ^{a}	36.15 ^{a}	23.79 ^{a}
P (ρ > F)	<0.0001	0.0175	0.5791	0.0585
Dosage of Bio-fertilizers (D)				
D1: 10 g kg^{-1} seeds	3.29 ^{a}	2.77 ^{a}	36.06 ^{a}	18.37 ^{a}
D2: 20 g kg^{-1} seeds	3.19 ^{b}	3.09 ^{a}	39.60 ^{a}	22.29 ^{a}
P (ρ > F)	0.0125	<0.0001	0.1266	0.2676

Means in columns followed by the same letters are not significantly different by DMRT 5%

Application of chicken manure (A1) resulted in higher seed yield ha^{-1} that application of green manure (A2). Plants with the application of *Rhizobium* (B2) had higher seed yield ha^{-1} than the application of either mycorrhiza (B1) or control (B0). There was no significant difference in seed yield ha^{-1} between applications of bio-fertilizer in dosage 10 g kg^{-1} seeds (D1) and 20 g kg^{-1} seeds (D2). The applications of ameliorants (A), bio-fertilizers (B), as well as dosage of bio-fertilizers (D) resulted in no significant differences in plant dry weight. These results coincided with the results of the research conducted by Htwe *et al*. [23], which indicated that the application of bio-fertilizers significantly increased the number of pods and seed yield of mung bean and soybean but did not significantly increase the yield and yield components of cowpea. Relatively similar results were also found for the foliar application of organic fertilizers in green bean plants [24-26].

There was no interaction between the application of ameliorants and bio-fertilizers (kinds and dosages) on nodule number per plant. Plants treated with mycorrhiza and *Rhizobium*, as well as those without bio-fertilizers, showed no significant differences in nodule number. The application bio-fertilizer at dosages of 10 g kg^{-1} and 20 g kg^{-1} seeds resulted in similar nodule numbers. This result was in contrast with the results of Sarawa *et al*. [20], who stated that various concentrations of M-bio fertilizer were effective in increasing fresh and dry weight of nodules and effective nodules.

Plants with the application of chicken manure had less nodules than those with the application of green manure. Among the compost fertilizers, chicken manure has the highest N content. This result was in line with research conducted by Yamil and Shakya [27], who indicated that the application of vermicompost and compost along with *Rhizobium* resulted in less root nodules, indicating suppression of nitrogen fixation in the presence of the high nitrogen content of the organic manures. Furthermore, other researchers stated that integration of 75% of the recommended dose of fertilizer with vermicompost at the rate 1 t ha^{-1} and phosphate solubilizing bacteria produced a significantly higher number of nodules $plant^{-1}$ and dry weight of nodules $plant^{-1}$ [28]. The application of nitrogen and phosphorus in combination with *Rhizobium* increased nodule numbers of soybean [29], and applied N fertilizers significantly and linearly reduced all attributes of nodules [30]. Furthermore, treatment with nitrogen at 20 kg N ha^{-1} significantly reduced the number of nodules at 2 weeks after planting [31]. The results of this study indicate that the application of organic matter with a high nitrogen content inhibits the formation of root nodules.

4. Conclusions

The application of green manure in combination with *Rhizobium* at 20 g kg^{-1} seeds produced the highest protein content of seeds (28.68%). Application of green manure in combination with *Rhizobium* at 10 g kg^{-1} seeds produced the highest carbohydrate content of seeds (59.98%). The application of chicken manure in combination with *Rhizobium* at 10 g kg^{-1} seeds produced the highest lipid content of seeds (2.62%). Treatment of chicken manure in combination with mycorrhiza at a dosage of 20 g kg^{-1} seeds produced the highest leaf N content (4.04%). Treatment of green manure in combination with mycorrhiza at dosage of 20 g kg^{-1} seeds produced the highest leaf P content (0.79%). Treatment of chicken manure in combination with *Rhizobium* at a dosage of 10 g kg^{-1} seeds produced the highest leaf K content (1.41%). The chicken manure treatment produced fewer nodules than the green manure treatment. The kind and dosage of bio-fertilizers resulted in the same number of nodules.

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