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Development and application of secondary vegetation-based biotechnology bokasi plus to increase soybean production on marginal dry land

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Abstract

The relatively low production of soybean in Indonesia is because the cultivations of soybeans are mostly conducted in marginal dry land areas. Effort to increase productivity of marginal dry land through the application of appropriate, effective, economical and environmentally friendly technologies is a suitable approach to support the growth and production of soybean in a sustainable manner. Biotechnology-based bokasi plus of secondary vegetation is potentially to be developed to overcome the problem. This study aimed to investigate the response of soybean crop to the applications of secondary vegetation-based biotechnology bokasi plus on marginal dry land. The study was conducted in Watuputih, Muna, Southeast Sulawesi Province, with the observed response variables were nitrogen (N) and phosphorous (P) uptake of plants, yield components and yield. Bokasi plus fertilizer affected all observation variables: N and P plant uptake, yield components (number of pithy pods, young pods, empty pods) and the number of seeds per plant and 100-seed weight) and yield (dry weight of pods). Applications of bokasi plus with the dose of 15 tons ha^{-1} gave the best effect on the weight of the dried pods of 702.46 g plot^{-1} (3.35 tons ha^{-1}).

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Introduction

Soybean (*Glycine max* L.) is one of the important food crops in Indonesia to support national food security (Atman, 2006; Atman, 2009). Soybeans contain high protein content of around 40%, and are used as a source of vegetable protein, animal feed and for industrial purposes (Harmida, 2010; Verma *et al.*, 2014). Soybeans are also used as a functional food that can prevent the onset of degenerative diseases such as aging, coronary heart disease and hypertension. Compounds of isoflavones contained in soybeans turn out to function as antioxidants (Yoon and Park, 2014).

Demands for soybeans continue to increase, but domestic production capacity is still relatively low. Soybean production in Indonesia in 2013 reached 780.2 tons from 550.8 ha harvested area, while the soy bean needs of about 2 million tons per year (BPS, 2014). To meet domestic demands, the government must spend state revenues of about US$ 0.5 billion per year. In addition, imports of soybean meal have reached approximately 1.3 million tons per year, costing about US$ 0.2 billion per year (Atman, 2009). The currently low production of soybeans in Indonesia is primarily associated with the physical aspects of land and climate. Most of the cultivated areas of soybean were marginal lands with low fertility levels and with dry climate conditions (Matsumoto *et al.*, 2003; Barus, 2013). However, with a good management and good farming system, marginal dry lands have the potential for developmental regions of soybean (Winardi, 2014; Giono, 2015).

The prospect of development of soybean in Indonesia, especially in Southeast Sulawesi, is quite good. More than 70% of Southeast Sulawesi region was dominated by marginal dry land, potential as a producer of soybeans, but until now their production has not been optimal. Until 2013, soybean production in Southeast Sulawesi was only 3.595 tons resulted from harvested area of 3,735 ha (BPS, 2014). The existence of soybeans needs to be further developed through the efforts of more targeted and sustainable.

Based on above facts, it is reasonable to give attention to improving the productivity of marginal dry land. Environmental engineering of crop growing areas with biotechnological bokasi plus based on local resources, that are widely available and have not been utilized optimally, is a simple technology that is effective, efficient, economical and environmentally friendly, and a real alternative effort to overcome the limitations of marginal dry land (Yuliana *et al.*, 2015). Thus, the increase in domestic soybean production through area extension and application of appropriate technologies (intensification) can be accomplished.

Materials and methods

Study location and materials used

This research was conducted from March to October 2016 at Watuputih marginal drylands, Muna, Southeast Sulawesi, Indonesia. The research materials used were soybean variety Argomulyo and bokasi plus fertilizer.

Experimental design

The research was arranged using a factorial randomized complete block design (RCBD) with three replications. Treatment factors were bokasi plus, consisted of 5 dose levels: H0 = 0 tons ha^{-1}, H1 = 5 tons ha^{-1}, H2 = 10 tons ha^{-1}, H3 = 15 tons ha^{-1} and H4 = 20 tons ha^{-1}.

Experimental procedures

The research work was begun with the preparation of research plots with a size of 3 m x 2.5 m, spacing of 40 cm x 30 cm with 2 seeds per planting hole. Watering was done according to planting conditions. Two weeks after planting, thinning was conducted to choose one plant per hole to be maintained until harvest. Pests and diseases were controlled with insecticides, pesticides or fungicides according to the type of pests and diseases attacked. Plot piling was done before the flowering phase to facilitate the entry of gynophore into the soil.

Statistical analysis

Observed variables included plant N and P uptake that was done on the maximum vegetative growth phase of 49 days after planting (DAP), observations of yield components, and yield conducted after harvest. Data from observations of each variable were analyzed by analysis of variance using the R Program, followed by honestly significant difference test (HSD) at α level of 95% ($P \leq 0.05$), to determine significant differences between values of all observed variables.

Results and discussion

The experiment was conducted on a marginal dry land area with good environmental condition and there were no substantial pests and diseases occurred which simply meant that plant growth was not disturbed.

Table 1. Uptake of N and P of soybean with application of bokasi plus fertilizer.

Bokasi Plus Fertilizer (ton ha^{-1})	N Uptake ($g\ plant^{-1}$)	P Uptake ($g\ plant^{-1}$)
0	0.279 a	0.022 a
5	0.360 a	0.027 a
10	0.431 c	0.035 b
15	0.453 c	0.041 b
20	0.426 b	0.039 b

Means followed by the same letters in the same column were not significantly different by HSD test at α level of 0.05 ($P \leq 0.05$).

Nutrient uptake of N and P

The analysis results on the effect of the application of bokasi plus fertilizer on plant N and P nutrient uptake are presented in Table 1. It appears in Table 1 that the absorption of plant N and P increased along with the increasing levels of treatment dose except at the highest dose level of 20 tons ha^{-1}. This could mean that the levels of plant N uptake can be a sign for soybean crop tolerance towards marginal dry land.

The highest N and P uptake was achieved at the application of bokasi of 15 ton ha^{-1}.

Table 2. Number of pithy pods, young pods and empty pods of soybean plants with the applications bokasi plus fertilizer.

Bokasi Plus Fertilizer (ton ha^{-1})	Pithy Pods (pod)	Young Pods (pod)	Empty Pods (pod)
0	16.49 a	7.67 a	8.13 a
5	25.22 a	4.46 b	7.17 b
10	28.08 b	2.74 c	6.32 c
15	34.72 c	2.43 c	6.20 c
20	33.94 c	2.42 c	6.33 c

Means followed by the same letters in the same column were not significantly different by HSD test at α level of 0.05 ($P \leq 0.05$).

Research showed that in general the absorption of plant N and P increased with the increasing levels of treatment dose, but slightly decreased at a higher dose (Table 1). This is in line with statements that the ability to absorb mineral nutrients on a stress condition is a form of adaptation to nutrient deficiency stress (Marschner, 1995; Rahni, 2012; Bsoul *et al.*, 2016). However, at the highest dose level, the plants are allegedly not able to optimally utilize or absorb nutrients resulted from decomposition of bokasi due to the plants experiencing burnout. Although the organic material is excessive, the plants will only absorb nutrients as needed (Rahni, 2012).

Plant responses to application of bokasi plus were due to the role of the fertilizer in increasing the availability of nutrients and supported the creation of a good growing environment for plants. Increased uptake of N in plant tissue with bokasi plus fertilizer treatment occurred because of the availability of N in the soil has increased, supported by a better root system after treatment. The increasing availability of nutrients in the root zone also caused an increase in nutrient uptake (Rahni and Karimuna, 2014). Increased uptake of N with treatment of fertilizer bokasi plus was influenced by the content of N fixing microbes (*Azospirillum* and *Azotobacter*) in the fertilizer either through the mechanism of symbiotic and non-symbiotic able to increase the availability of N in the soil so as to increase the uptake of N plants (Simanungkalit, 2006; Rahni, 2013; Rashid *et al.*, 2013).

Table 3. Weight of 100 seeds and soybean pod yield due to the application of bokasi plus fertilizer.

Bokasi Plus Fertilizer (ton ha^{-1})	Weight of 100 Seeds (g plant^{-1})	Pod Yield (g plot^{-1})	Pod Yield (ton ha^{-1})
0	13.97 a	267.93 a	1.28 a
5	15.65 b	451.87 b	2.15 b
10	17.37 b	587.82 b	2.80 b
15	20.43 c	702.46 c	3.35 c
20	18.18 b	693.63 b	3.30 b

Means followed by the same letters in the same column were not significantly different by HSD test at α level of 0.05 ($P \leq 0.05$).

The application of bokasi plus is also suspected very efficient in providing some essential nutrients, especially P nutrient. Bokasi plus fertilizer can allegedly increase the P available in the root zone. There was a positive correlation between plant N and P uptakes if the P uptake in plant tissue increases the N uptake will also increase (Habi, 2012; Rahni and Karimuna, 2014). P absorption is closely related with metabolic processes, P is absorbed by the roots and move quickly to the stems and leaves to join the metabolic system. The development of the root system, especially the production of roots and root hair growth is influenced by the distribution of nutrients, especially phosphate will increase nutrient uptake by plant roots.

Bokasi plus fertilizer can increase plant nutrient uptake through organic processes undertaken by some microbes contained therein by providing phosphates and other mineral nutrients for plants in a sustainable manner. The increase in P uptake by plant tissues occurred because inoculants in the form of microbial-soluble phosphate and mycorrhiza are capable of producing organic acids and phosphatase enzymes that can bind elements that chelate phosphate so that it becomes available to plants (Zahra *et al.*, 2003; Gothwal *et al.*, 2007; Silvia *et al.*, 2007).

Pithy pods, young pods and empty pods per plant

The analysis results on the effect of bokasi plus fertilizer on the number of pithy pods, young pods and empty pods per plant are presented in Table 2. Data in Table 2 show that the number of young and empty pods on bokasi treatments of 10 – 20 tons ha^{-1} did not differ significantly except for the control and the lowest dose treatment (5 tons ha^{-1}). This happened because the application of bokasi plus fertilizer above the lowest dose level is suspected to adequately fulfill the need of plants for the formation and the filling phases of pods and seeds. In general, the number of young pods and empty pods decreased with the increasing levels of bokasi treatment dose. The highest number of pithy pods was achieved at the application of bokasi of 15 tons ha^{-1}

Research data in Table 2 showed that the application of bokasi plus fertilizer above (10-20 ton ha^{-1}) the lowest dose level was suspected to adequately fulfill the need of plants for the formation and the filling phases of pods and seeds. It was related to the activity of photosynthesis and translocation of photosynthates to the pods and seeds (Rahni, 2013). High photosynthetic activity will produce high photosynthate so its translocation to the pods and seeds increases and eventually be able to reduce the number of young and empty pods.

In addition to providing P nutrient, bokasi plus fertilizer also serves as a source of organic matters that is very important for the growth and development of soybean plants (Shaheen *et al*., 2017). The bokasi will improve soil structure and increase soil pH so that nutrients, especially P for the formation and filling of seeds became available to plants (Rahni and Karimuna, 2014). However, the addition of a higher dose level will not lead to further increased higher yields.

The number of seeds per plant is determined not only by the number of seeds per pod (genetic trait), but also determined by the number of pithy pods. The increase in number of filled pods will increase the number of seeds per plant which will further increase crop yields. This is related to the photosynthetic activity and photosynthate translocation into pods for seed filling.

The application of bokasi plus fertilizer will ensure the availability of organic matters and nutrients needed by plants during the formation and pod filling. However, the application of bokasi plus fertilizer that exceeds the needs of the plant (the dose is too high) it can be detrimental to the plant itself. Excessive P element will inhibit the growth of the plant canopy, and the excessive N can continue to stimulate vegetative growth although plants have entered the reproductive phase (Rahni and Karimuna, 2014). As a result, there is competition in photosynthate utilization between vegetative and reproductive organs. In indeterminate plants, competition against the products of photosynthesis by generative growth will reduce crop yields.

Weight of 100 seeds and pod yield

The analysis results on the effect of application of bokasi plus fertilizer on the weight of 100 seeds and pod yield are presented in Table 3. The application of bokasi plus fertilizer with the dose of 15 tons ha^{-1} resulted in the heaviest seeds per plant, per plot and per hectare.

The application of bokasi plus of 15 tons ha^{-1} resulted in the highest dry pod weighs of 702.46 g $plot^{-1}$ (3.35 tons ha^{-1}) (Table 3), which was similar to soybean yield resulted by earlier research using different bokasi fertilizers (Wijayanto *et al*., 2016; Wijayanto *et al*., 2017). In general, the soybean yield increased with the application of bokasi plus fertilizer. The resulting seed weight was influenced by the size of the seed, the higher the seed weight means the greater the seed size. Sources of photosynthate seed filling can be derived from the results of the current photosynthate (grain filling phase) and the overhaul of carbohydrate reserves in other parts (remobilization). Phosphorus will translocate within the body of plants and can be distributed from the old tissues to the younger ones (Gardner *et al*., 1991).

Mycorrhizae contained in bokasi plus have an important role in the absorption of phosphate. Phosphorus has an important role as an important energy transfer molecule in the body of the plant (Gupta and Shubhashree, 2014). The application of bokasi plus fertilizer besides increasing the organic matters and nutrients, also contributes auxin to the plant. Auxin is assumed to influence the translocation of carbohydrates (assimilate) to the seed during pod filling stage (Nguyen *et al*., 2016; *Suliartini et al*., 2018). Research results showed that the application of organic matters was capable of triggering the production of PGPR phytohormone which can stimulate plant health, growth and yield (Rahni, 2013; Haggag and Abouziena, 2016).

Conclusion

The research results showed that biotechnology products in the form of bokasi plus fertilizer, which can be made from secondary vegetations growing dominantly around the farms and is generally regarded as weeds, can be developed and is effective to increase soil nutrient, economical and environmentally friendly. The research has shown that soybean highly responses to bokasi plus application. Bokasi plus fertilizer affects plant N and P uptake, yield components (number of pithy pods, young pods, empty pods and weight of 100 seeds) and yield (weight of dry pods). Applications of bokasi plus with the dose of 15 tons ha^{-1} gave the best effect on weight of dry pods of 702.46 g $plot^{-1}$ (3.35 tons ha^{-1}).

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