Agricultural Wastes based-Organic Fertilizers (Bokashi) Improve the Growth and Yield of Soybean (*Glycine max* (L.) Merrill)

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Abstract: This research was conducted at the field research station and in the Laboratory of Agrotechnology, Faculty of Agriculture, University of Halu Oleo, Kendari, Indonesia in 2016. This study aimed to determine the effect of using a variety of Bokashi (compost) fertilizers made from agricultural wastes on the growth and yield of soybean. The study was arranged in a randomized block design (RBD, which consisted of 5 treatments, namely: without Bokashi fertilizer (M0), Bokashi “komba-komba” (*Chromolaena odorata)*(M1), Bokashi “water hyacinth” (*Eichornia crassipes)*(M2), Bokashi sago dregs (M3), and Bokashi burned-rice husk (M4). Research data were analyzed using ANOVA and treatment means were compared using Honestly Significant Difference (HSD). The results showed that the application of Bokashi gave a significant effect on almost all variables observed on growth and yield of soybean. Bokashi burned-rice husk (M4) and sago dregs (M3) give the best effect on the growth and yield of soybean, which reached about 3.1 tonnes per hectare, an increase of approximately 30% compared to the treatment of without Bokashi which only reached 2.4 tons per hectare.

Key-Words: Agriculture waste, bokashi fertilizer, compost, production, soybean

1 Introduction

Soybean (Glycine max L. Merrill) is one of the world’s most important sources of vegetable oil and protein [1], and has many uses and high economic values. Indonesian’s consumption and demand for soybean is very high, required for the production of various daily popular consumed products, such as for tauco, soy sauce, “tempe” (soy cake), tofu, soy milk, and for animal feed industries. Demand for soybeans in Indonesia currently cannot be fulfilled domestically because the production is still low. Low production of soybean is caused by many factors; some of them are lack of quality seeds available, low soil fertility and poor soil physical and chemical properties. Every single effort is needed to increase soybean production.

The development of food production areas in Indonesia are often faced with the problem of suboptimal land, the land that has one or more soil fertility constraints [2]. One type of most common suboptimal soil is dry land ultisols. Ultisols have unfavorable morphological, physical and chemical characteristics, such as a gray color, base saturation < 30 %, a low pH (acidic), high Al saturation which can poison plants, high P fixations, low CEC and overall low soil fertility [3].

Dryland has various soil fertility constraints such as limited water availability, low soil pH, low CEC, and low levels of organic matter that is classified as suboptimal land. One effort that can be done to improve the productivity of suboptimal land is through the improvement of land quality through fertilization, especially of phosphate fertilizer to stimulate root development so that the plants will be more resistant to drought, speed up the harvest and add value nutrients from seed. Applications of nitrogen fertilizer is not unduly influence the results because soybean living in symbiosis with *Rhizobium* bacteria that can automatically bind to the N elements of the air. However, fertilization will be futile if the physical condition of the soil is not good. It was suggested by [4] that there are at least four main technologies for the management of acid soils, namely: (1) calcification, (2) fertilization, (3) organic matter, and (4) the use of plants tolerant to aluminum.

Efforts to increase crop productivity must be synergy with the improvement of soil fertility through fertilizer, especially organic fertilizer. The use of organic fertilizers can help to modify the plant microclimate, which in turn can optimally improve soybean production. Organic matter can improve fertility, structure and will indirectly retain aggregation and porosity of the soil, which means it will maintain the soil's capacity to hold water [5].

Utilization of organic fertilizers is also very important to reduce the use of synthetic fertilizers. It was argued by [3] that the use of organic fertilizer on Ultisols can increase levels of Ca - organic, N and P soil contents. Organic fertilizers can improve the physical, chemical and biological soil properties, such as improving soil aeration, soil cation exchange capacity (CEC), water binding capacity, nutrient supply as a result of mineralization of organic materials, and the energy source for soil microbes. Given the importance of organic materials, hence its use in suboptimal land area is very important.

Agriculture in general often produces wastes, which could potentially pollute the environment [6]. For example, rice mills can produce huge rice husk waste. Only a small fraction of the rice husk wastes is used by farmers for poultry businesses, while most of the them have been abandoned, unutilized, and cause environmental pollution. Another example is the sago dregs waste pollution, as a waste from traditional sago processing activities. Sago dregs wastes are generally abandoned or dumped into rivers, causing bad odors and pollute the river water [7]. The use of fertilizer made from organic materials is an appropriate alternative choice to reduce the negative impacts of agricultural wastes. Public generally has less information and finds it difficult to dispose of or utilize solid and liquid wastes which are derived from sago processing, so that the solid waste piling up and it smelled awful and disturbing the public.

Availability of fertilizers often becomes a bottleneck and in general, the ability of farmers to buy inorganic fertilizers is also very low, especially the need and availability of organic fertilizer for the cultivation of food crops and horticulture are very important. If farmers only rely on livestock manure, then it certainly is not adequate, especially for a relatively extensive farming. Agricultural solid wastes that have become compost can actually be used as fertilizer or plant growing media. Solid wastes of sago and rice industries that have accumulated over the years can be decomposed into compost and can be used as a medium or organic fertilizer.

Simple and inexpensive technology has been available to take advantage of agricultural wastes such as rice husks, sago dregs and other plant materials that are abundant [8], like “komba-komba” [9] and hyacinth, to be processed into organic fertilizers, such as compost and bokashi. Bokashi is compost produced through the fermentation process using Effective Microorganism 4 (EM-4), which is one of the activators to accelerate the composting process [10]. Many research results have indicated that the bokashi is relatively better than the simple composting. In the process of making bokashi, organic matter is decomposed by involving microorganisms in controlled circumstances [11].

The decomposition process of organic matter into organic matter (in ionic form available to plants) generally takes a relatively long time of about 2 to 3 months. Application of organic material that has not been perfectly decomposed may have negative consequences for plants, because there will be competition between microorganisms and plants to get nutrients in the soil. Effective microorganisms-4 (EM-4) can help the process of decomposition of organic material faster which is about 1 to 2 weeks. In addition, this process leaves no residual negative effects, such as bad odor and heat [10]. Base materials for the production of Bokashi can be obtained easily around the farms, like straw, grasses, legumes, rice husk, manure and sawdust.

This study was conducted to utilize agricultural wastes into useful organic fertilizers, while indirectly helping reduce environmental pollution. Specifically, the purpose of this study was to determine the effect of using a variety of Bokashi (compost) fertilizers made from agricultural wastes on the growth and yield of soybean.

2 Materials and Methods

2.1 Making “Bokashi”

Bokashi production process begins with making a solution which is a mixture of EM-4, molasses/sugar and water, with a ratio of 1 : 1 : 1 (v : v : v). Bokashi basic materials (especially plant materials), are cut into small pieces, and then the material is evenly mixed with rice bran on dry floor. Furthermore, the bokashi base material is slowly and gradually watered with a solution of EM-4 to form dough.

The good dough is if clenched by hand, then there is no water coming out, also when the fist is released then the dough re-inflates (water content of about 30%). Next, the dough is laid on the floor as high as 15-20 cm. Mound is then covered with a sack or a plastic tarp over 1-2 weeks. During the process, the material temperature is maintained between 40-50^{o}C. If the material temperature exceeds 50°C, then the cover sack is opened and dough material is inverted, then mound is closed again.

2.2 Land preparation and soil cultivation

Soil was cultivated twice. The first, soil cultivation is done by using a hoe to a depth of 15 cm - 20 cm, for cutting and turning the soil. The second is soil tillage, and then beds were set up with a size of 3 m x 1.5 m by 25 plots. The plot distance in the group was 0.3 m and the distance between groups was 0.5 m.

2.3 Fertilization

Fertilizer treatments used in this study were bokashi hyacinth (*Eichhornia crassipes*), bokashi komba - komba (*Cromolaena odorata*), bokashi sago dregs and bokashi rice husk, with the dose of 10 tons per hectare, equivalent to 4.5 kg per plot. Each bokashi fertilizer was applied one week before planting, together with the preparation of experimental plots, by broadcasting to the surface of the plots and then mixed evenly with soil.

2.4 Soybean planting

Soybean seeds were planted as many as 2 seeds each planting hole with the depth of ± 3 cm. The planting spacing was 40 cm x 20 cm, so that in each plot contained 112 plants.

2.5 Plant maintenance and harvesting

Stitching was done to replace plants that did not grow or died, at the age of 7 days after planting (DAP). Plant spacing was conducted at 10 DAP by cutting the plants so that only 1 plant remains per planting hole. Each plot had 56 plants with a sample of 5 plants per plot.

Watering was done regularly in the afternoon, which was carried out according to the conditions of crops and rainfall. Weeding and pest and disease control was done as needed, when the plants experienced an attack.

Harvesting was done when approximately 95 % pods in each plot have physiologically matured, characterized by a color change of pods from greenish to yellowish brown, and the number of leaves left on the plants around 5-10%.

2.6 Observed variables

The number of plant samples for each plot was 5 plants, taken randomly. The variables measured were plant height (cm), number of leaves, stem diameter (cm), number of total pods per plant, number of productive branches per plant, weight of 1000 seed grains (g) with the moisture content of ± 13 %, and yield per hectare (ton per hectare).

2.7 Research design and data analysis

This research was arranged in a randomized block design (RBD). The treatments used were without bokashi fertilizer (M0), bokashi "Komba - komba" (M1), bokashi hyacinth (M2), bokashi sago dregs (M3), bokashi rice husk (M4), with the dose of 10 tons per hectare, equivalent to 4.5 kg per plot. Each treatment was repeated five (5) times, so that altogether there were 25 experimental units.

Bokashi was applied 1 week before planting, at the time of soil cultivation. Inorganic fertilization was then performed at 14 DAP by providing NPK fertilizer (N 16 %, P 16 % and 16 % K), at a dose of 0.845 tonnes per hectare, or equivalent to 448 g per plot, as additional fertilizers.

Research data were analyzed by analysis of variance, treatment means were compared using Honestly Significant Difference (HSD) test at the level of 95%.

3 Results and Discussion

In general, bokashi fertilizers gave significant effect on all observed variables. Data in Table 1 shows that the highest average of soybean plant height, leaf number and stem diameter at the age of 34 DAP is obtained in treatments M3 and M4, which is significantly different from that of treatments M0, M1 and M2. Bokashi sago dreg and burned rice husk significantly effected soybean plant height at 34 DAP (Table 1).

Table 1. The effect of various bokashi treatments on height (cm), leaf number, and stem diameter (cm) of soybean plants at the age of 34 DAP

Bokashi treatment	Plant height	Leaf number	Stem diameter
Without bokashi (M0)	8.24 b	21.98 b	0.34 b
“Komba-komba” (M1)	9.32 b	22.00 b	0.30 b
Hyacinth (M2)	7.84 b	21.92 b	0.34 b
Sago dregs (M3)	15.28 a	43.25 a	0.48 a
Burned rice husk (M4)	15.52 a	43.21 a	0.50 a
BNJ test	4.27	1.78	0.11

It seemed that both bokashi fertilizers stimulated plant growth and provided a rapid effect on the crop. This is in accordance with the research report by [12], that bokashi had a rapid effect on plants because it directly supplied nutrients for the plants. But this was not the case with bokashi "komba-komba" (*Cromolaena odorata*) and water hyacinth (*Eichornia crassipes*), probably both materials had not completely been decomposed especially for their stems and roots, so that the absorption of nutrients by plants was still not optimal.

Research results showed that the use of various types of bokashi fertilizers on soybean also had significant effect on the increase of the number of leaves (Table 1). Increased leaf number was demonstrated in both bokashi sago dregs and burned rice husk, most likely because both types of bokashi were able to provide macro and micro nutrients, and can maintain the availability of water in sufficient quantities in the soil [13; 14]. Report by [11] also showed that bokashi application effected soybean growth, including the number of leaves, leaf area, plant dry weight and the number of effective root nodules.

Soybean stem diameter significantly increased at the age of 34 DAP. The largest increase in stem diameter occurred as a result of burned rice husk treatment (M4), because it was easy to decomposed and have high nutrient content. In addition, the activity of soil microorganisms is capable of decomposing organic matter. The rate of decomposition of organic material in the treatment without fertilizer Bokashi (M0) seemed to be slower, because in M0 treatment lacked the availability of soil microorganisms that play a significant role in accelerating the decomposition process of organic matter.

EM-4 that were mixed during the process of bokashi making has a role that is quite effective in creating physical and chemical environment suitable for plant growth [15]. According to [16], microorganisms work synergistically to enrich the soil and promote plant growth so that by increasing the activity of soil microorganisms will speed up the rate of decomposition of organic matter in the soil.

The research results showed that bokashi treatment also significantly affected the number of pods. Data in Table 2 shows that the highest average number of pods per plant, number of productive branches per plant and weight of 1000 seeds is obtained in treatments M4 and M3, although for productive branch number and weight of 1000 seeds had no significant difference with that of treatment M1.

Table 2. The effect of various bokashi treatments on the number of pods, number of productive branches, and weight of 1000 seeds of soybean (g)

Bokashi treatment	Number of pod	Number of productive branches	Weight of 1000 seeds (g)
Without bokashi (M0)	14.68 b	1,64 b	78,40 b
'Komba-komba" (M1)	26.24 b	3,16 a	87,46 a
Hyacinth (M2)	20.76 b	1,88 b	83,30 b
Sago dregs (M3)	122.00 a	4,12 a	92,46 a
Burned rice husk (M4)	129.36 a	4,52 a	92,98 a
BNJ test	11.61	1.45	6.30

This indicates that application of bokasi can improve soil conditions that favor plant growth, increase soil biological life and optimize the availability and the balance of nutrient cycling through nitrogen fixation, nutrient absorption, addition and cycling of external fertilizers. The lowest increased number of soybean pods occurred in treatment M0 (without bokashi). This was due to low soil pH and less organic matter [17]. A significant increase in pod number occurred in M3 and M4 treatments (Table 2). The availability of plant nutrients is one of the factors affecting crop productivity. These results indicate that treatment of various types of bokashi fertilizers influenced the increased number of pods per plant.

The highest number of productive branches occurred as a result of bokashi burned rice husk treatment (M4). This is presumably because the burned rice husk contains high C, N elements [8] and other nutrients (unpublished data, 2015). The lowest number of productive branches occurred in the treatment of without bokashi fertilizer (M0). It was reported by [18] that organic matter (animal manure) affected the increased activity of respiration and leaf width, affected the photosynthetic activity, and ultimately affected the yield and dry matter content of the crop. This is also supported by research results of [12], in which organic matter, with higher phosphorous levels, can increase the weight of red chili.

The highest weight of 1000 soybean seeds per plant was obtained at the treatment of bokashi burned rice husk (Table 2). Environmental factors are also believed to play a role in optimizing crop soybean pod filling [19]. The ability of soybean to produce pods is highly dependent on interactions between plants and environmental factors. Organic materials have an important role in soil fertility, among others as a source of plant nutrients, forming a stable structure which has an influence on the growth and development of plants [19]. The lowest weight of 1000 seeds was obtained at treatment without bokashi (M0). This is apparently due to the lack of nutrients available to plants during pod filling (Table 2). Bokashi decomposition produces organic acids, capable of dissolving the compound of Al-P or Fe-P, insoluble becomes soluble, so that it becomes available to plants [20].

Data in Table 3 shows that the highest average soybean yield per hectare is obtained in treatment M4 and M3, which is significantly different from those of treatments M0, M1 and M2.

Table 3. The effect of various Bokashi fertilizer treatments on soybean yield (tonnes per hectare)

Bokashi treatment	Soybean yield (ton ha^{-1})
Without bokashi (M0)	2,392 b
'Komba-komba" (M1)	2,667 b
Hyacinth (M2)	2,652 b
Sago dregs (M3)	3,134 a
Burned rice husk (M4)	3,197 a
BNJ test	0.308

The research results showed that the grain yield per hectare resulted for each treatment was M0 = 2.392 ton ha^{-1}, M1 = 2.667 ton ha^{-1}, M2 = 2.652 ton ha^{-1}, M3 = 3.134 ton ha^{-1}, and M4 = 3.197 ton ha^{-1}. The results showed the highest soybean grain yield per hectare was obtained in treatment bokashi burned rice husk (M4). This is presumably because the decomposed organic material has a significant influence particularly on the generative phase. C : N ratio is usually used as an index of ease of decomposition of organic materials and also as soil biological activity indicators. It is also supported by higher number of leaves, so more photosyntate generated. The process of photosynthesis is directly related to leaf area and leaf area index. The high number of leaves can increase the number of chloroplast that is crucial in increasing the rate of photosynthesis. Photosyntate will be used for the process plant growth, and during the generative period it will be allocated to pod formation and increases the weight of the pods and seeds.

Fig. 1. Soybean pods on the plant (A), the separation of pods from the plant (B), and soybean seeds that have been peeled from the pods (C)

4 Conclusion

The application of Bokashi gave a significant effect on almost all observed variables on growth and yield of soybean. Bokashi burned-rice husk and sago dregs with the dose of 10 ton ha^{-1} give the best effect on the growth and yield of soybean, which reached about 3.1 tonnes per hectare, an increase of approximately 30% compared to the treatment of without bokashi which only reached 2.4 tons per hectare.

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