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Research Article

Application of bokashi and sunn hemp (*Crotalaria juncea* L.) to improve inorganic fertilizer efficiency on maize (*Zea mays* L.)

A.I. Yuliana*, T. Sumarni, T. Islami

Faculty of Agriculture, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia

* corresponding author: anggi.ind@gmail.com

Abstract: A field experiment was conducted lo learn about the effect of Bokashi and Sunn hemp (*Crotalaria juncea* L.) on maize production and inorganic fertilizer use efficiency on maize. The experiment was conducted in Jatikerto, Malang; at the altitude of 303 m above sea level, in Alfisol soil type, the average daily temperature ranges 21-33^{o}C, from June to October 2013. The experiment was conducted as factorial, designed in a randomized block design (RBD). The first factor was dose of inorganic fertilizer (100% ; 75% and 50% of recommendation dose). The second factor was the organic fertilizer (Without organic fertilizer20 t Bokashi/ ha, 20 t Sunn hemp/ha, 10 t Bokashi/ha + 10 t Sunn hemp/ha). The results showed that application of 20 t Bokashi/ha, 20 t Sunn hemp/ha, and combination of 10 t Bokashi/ha + 10 t Sunn hemp/ha, along with the application of inorganic fertilizer by dose of 100% increased the yields of maize for about 41.8%; 47.6% and 54.7% (10.73 t/ha; 11.17 t/ha, and 11.71 t/ha), respectively. The yield and nutrient use efficiency in the treatment dose of 100% inorganic fertilizer did not have any significant difference from the application of 20 t Bokashi /ha, 20 t Sunn hemp/ha, and 10 t Bokashi/ha + 10 t Sunn hemp/ha along with doses of inorganic fertilization 75% and 50%. Therefore, the organic fertilizer of 20 t Bokashi/ ha, 20 t Sunn hemp/ha, and combination of 10 t Bokashi/ha + 10 t Sunn hemp/ha could reduce the need of inorganic fertilizer for about 50%.

Keywords: *bokashi, maize, inorganic fertilizer, sun hemp*

Introduction

Maize (*Zea mays* L.) is the most important commodity after rice. The national production of maize in 2013 reached 18.51 million ton and decreased for about 0.88 million ton (4.51%) in comparison with in 2012, which reached 19.39 million ton (BPS-Statistics Indonesia, 2014). This was due to the maize production has not fulfilled the domestic need, particularly for raw materials of feed industries, foods and drinks, which increase for about 10% per year. In order to increase the national production of maize, planting the hybrid types is more important than planting free-pollen maize because, on average, the hybrid maize have higher productivity (8 – 13 t/ha) than the free-pollen maize (3.5 – 7.5 t/ha) (Adnan et al., 2010).

The application of hybrid variety has encouraged the farmers to use high dose of inorganic fertilizer without accompanying with the organic fertilizer. Syekhfani (1997) and Winarso (2005) stated that application of excessive and intensive inorganic fertilizer would increase acidity of the soil, decrease organic matters content and essential nutrients availability in the soil, increase micronutrients contents (Fe, Mn, and Al), which are potentially toxic for plants, and hinder d microorganism activities in the soil

Efforts to improve the soil condition can be done by adding some organic matters to increase organic matter content of the soil in order to increase ability of the soil to absorb and exchange the nutrients in the soil. Therefore, the application of inorganic fertilizer would be more efficient due to the released nutrients will be absorbed by the organic matters and become available for the plants, so that the plants will grow and develop optimally, as well as produce high yields. More than 2% organic matter of the soil will generate further agricultural system (Hairiah et al., 2000). The organic matters can be managed from various

sources, such as Bokashi and green manure of Sunn hemp (*Crotalaria juncea* L).

Bokashi is stable manure that is processed through fermentation using EM-4 technology, which contains bacterial culture that could disperse the organic matters faster, so that the contained nutrients in Bokashi would be able to be used by the plants immediately. Adding Bokashi will increase organic-C of the soil and nutrients in the plants (Endriani, 2003; Kadarwati dan Riajaya, 2009). Meanwhile, Sunn hemp is a well-known green manure which can improve soil fertility and increase organic matter content in the soil. The application of Sunn hemp as green manure has been used in 1960s, but the existence of green revolution program, which promises increasing production in short-term, has moved the farmers to use inorganic fertilizer. They have done it up to now, so that the plant was abandoned and the population keeps decreasing. In fact, Sunn hemp is potential to increase organic matter content of the soil, increase stability of aggregate and water content of the soil, increase the availability of P and CEC in the soil. Besides that, the application of Sunn hemp is able to increase population of microorganisms in the soil (Sumarni, 2008; Djajadi, 2011; Yulianti dan Hidayah, 2011). This research reviewed the effects of application of Bokashi and Sunn hemp on yield of maize and the reduction of inorganic fertilizers used for cultivating maize.

Materials and Methods

The research was conducted from June to October 2013 at the Jatikerto experimental farm of the Faculty of Agriculture, University of Brawijaya. The experimental farm is located at the altitude of 303 m above sea level with the average daily temperature ranging from 21^{o}C to 33^{o}C, and average rainfall of 100 mm/month. Alfisol dominates soil of the experimental farm. Soil analysis and nutrient absorption were done from January to March 2014 at the Laboratory of Chemistry, Department of Soil Science, Faculty of Agriculture, University of Brawijaya. Equipments of the research used sliding caliper, scales, measurement tape, and oven. Materials of the research included maize seeds of Pertiwi-3, Sunn hemp, cattle manure, chaff, molasses, EM-4, NPK fertilizer (15:15:15), urea (45%N), insecticide with active material of profenos 500 g/L and fungicide with active material of propineb 70%.

The research used factorial Randomized Block Design (RBD) that comprised of two factors by three replications. The first factor was inorganic fertilizer (A), which included combination of NPK (15:15:15) and urea (45%N) by three levels: A1 = inorganic fertilizer 100 % (300 kg NPK /ha + 200 kg urea /ha), A2 = inorganic fertilizer 75 % (225 kg NPK /ha + 150 kg urea /ha), A3 = inorganic fertilizer 50 % (150 kg/ha NPK + 100 kg/ha urea). The second factor was organic fertilizer (O) by four levels: O0 = without organic fertilizer, O1 = 20 t Bokashi/ha, O2 = 20 t Sunn hemp/ ha, O3 = 10 t Bokashi/ha + 10 t Sunn hemp/ha.

Observation on chemical properties of the soil included pH, organic matter, N, P, K, and cation exchange capacity of the soil. Observation on yield components of the plant included dry weight of ear, yield of seeds (t/ha), and harvest index. Nutrient uptake and nutrient use efficiency was counted by the equation below (Sumarno, 2007):

$$\text{Nutrient uptake} = \text{nutrient content x plant biomass}$$

$$\text{Nutrient use efficiency} = \frac{\text{yield of harvest (g/plant)}}{\text{nutrient uptake (g/plant)}}$$

The obtained data was analyzed using analysis of variance (F-test) at the level of 5%. If result of the test had significant difference, the data were further analyzed with comparative test between treatments using Least Significant Difference (LSD) at the level of 5%.

Results and Discussion

Result of the research showed interaction between treatment of inorganic fertilizer doses and the application of organic fertilizer at the nutrient adsorption of N, P, and K in maize plants (Table 1). The application of Bokashi and Sunn hemp, whether solely or in combination, under treatment of 100% inorganic fertilizer, resulted in the higher nutrient uptake of N, P, K than other treatments. Meanwhile, the application of Bokashi and Sunn hemp along with the application of inorganic fertilizer by doses of 75% and 50% have brought about similar results of nutrient adsorption with the application of sole inorganic fertilizer by dose of 100%.

It has proven that the organic fertilizers of Bokashi and Sunn hemp would be able to increase efficiency of inorganic fertilizer in providing nutrients, so that the plants could optimally absorb the nutrients. The application of organic inputs can stimulate the microorganism activities in the soil, which play their roles in decomposition process and mineralization of organic matters of the soil, so that they can increase essential nutrients availability in the soil. Besides that, died microorganisms will produce biomass, which contains nutrients, and of course, it will increase

the nutrients availability and maintain the natural cycle of nutrients in the soil. Therefore, the plants can absorb the nutrients optimally (Dawson et al., 2008).

Optimal adsorption of nutrients will increase yield of maize. Results of the research showed that the organic fertilizers of Bokashi and Sunn hemp under the application of 100% dose of inorganic fertilizer were able to increase yield of maize. It can be seen from the increasing dry weight of ear and harvest index compared to doses of 75% and 50% (Table 2). Such conditions affected the increase of grain yield per hectare of maize plants. By the application of 100% inorganic fertilizer, combination of Bokashi and Sunn hemp resulted in the highest yield (54.7%), in which the yield of dry grains were about 11.71 t/ha.

Table 1. Nutrients taken up by maize (g/plant) as a result of interaction between the treatment of inorganic fertilizer doses and application of organic fertilizer.

Nutrient uptake	Dose of inorganic fertilizer	Application of organic fertilizer			
		Without organic fertilizer	Bokashi 20 t/ha	Sunn hemp 20 t/ha	Bokashi 10 t/ha + Sunn hemp 10 t/ha
N (g/plant)	100 % recommended	3.79 ab	4.59 c	4.73 cd	5.05 d
	75 % recommended	3.51 a	3.96 ab	4.03 b	3.93 ab
	50 % recommended	3.51 a	3.62 ab	3.62 ab	3.60 ab
	LSD 5 %			0.45	
P (g/plant)	100 % recommended	2.40 ab	2.95 c	3.03 c	3.22 c
	75 % recommended	2.22 a	2.51 ab	2.63 ab	2.49 ab
	50 % recommended	2.23 a	2.38 ab	2.37 ab	2.27 a
	LSD 5 %			0.30	
K (g/plant)	100 % recommended	2.61 ab	3.16 c	3.25 c	3.46 c
	75 % recommended	2.44 a	2.75 b	2.80 b	2.73 b
	50 % recommended	2.44 a	2.53 ab	2.53 ab	2.51 ab
	LSD 5 %			0.30	

Notes: Numbers followed by the same letters showed no significant difference based on LSD test of 5% (p = 0.05).

Table 2. Mean of yield component on maize yield as a result of interaction between the treatment of inorganic fertilizer doses and application of organic fertilizer.

Variable of observation	Dose of inorganic fertilizer	Application of organic fertilizer			
		Without organic fertilizer	Bokashi 20 t/ha	Sunn hemp 20 t/ha	Bokashi 10 t/ha + Sunn hemp 10 t/ha
Dry weight of ear (g/ear)	100 % recommended	135.50 c	166,17 e	172,40 ef	178,40 f
	75 % recommended	120.97 b	164,67 e	151,93 d	152,67 d
	50 % recommended	112.90 a	136,53 c	144,57 cd	143,87 cd
	LSD 5 %			11.32	
Weight of dry grains (t/ha)	100 % recommended	7.57 bcd	10,73 e	11,17 e	11,71 e
	75 % recommended	6.70 b	8,38 cd	8,50 d	8,34 cd
	50 % recommended	5.32 a	7,46 bc	7,64 bcd	7,53 bcd
	LSD 5 %			2.07	
Harvest index	100 % recommended	0.371 ab	0,457 b	0,469 b	0,475 b
	75 % recommended	0.345 a	0,368 a	0,369 a	0,368 a
	50 % recommended	0.317 a	0,352 a	0,362 a	0,347 a
	LSD 5 %			0.036	

Notes: Numbers followed by the same letters showed no significant difference based on LSD test of 5% (p = 0.05).

It was assumed that Bokashi has provided nutrients during the initial growth of the plants, while Sunn hemp provided nutrients through decomposition process of organic matters and mineralization of N and P, so that if they were supplemented with inorganic fertilizer by optimal dose. Therefore, the nutrient availability would be high and it could support the adsorption optimally. Lactate acid in Bokashi plays its role in decomposition process of Sunn hemp, so that the required nutrients would be released faster and could fulfill the need of the maize plants (Indriani, 2005).

Under the application of inorganic fertilizer by doses of 75% and 50%, the application of Bokashi and Sunn hemp, whether solely or in combination, were able to produce dry grains per hectare and the yield was not different from the treatment of sole inorganic fertilizer by dose of 100%. It proved that Bokashi and Sunn hemp were able to substitute the use of inorganic fertilizer for about 50%. This is because Bokashi and Sunn hemp do not only increase the organic matters content of the soil and cation exchange capacity in the soil, but also provide nutrients for the plants. Therefore, by the application of low inorganic fertilizer (75% and 50%), lack of nutrients in the soil would be fulfilled from mineralization process of Bokashi and Sunn hemp, so that the plants will grow and develop to gain optimal yields. Suge et al. (2011) stated that integration between inorganic fertilizer and organic matters have become the main choice in increasing efficiency of fertilization and providing more balanced nutrients, so that it can be used to support growth of the plants. It is expected that the use of organic matters would be able to improve soil fertility, in which one of them is increasing cation exchange capacity (CEC) of the soil. CEC plays its role in catching ions of the nutrients in the soil, including nutrients that derived from inorganic fertilization, so that they would be available for the plants. Organic matters have much higher CEC than soil clay, so that the nutrients availability for the plants would not easily lose because of leaching process (Handayanto and Hairiah, 2007).

Nutrient use efficiency reflects the ability of the plants to absorb and produce dry grains for each gram of the absorbed nutrients. Results of the research showed interaction between doses treatment of inorganic fertilizer and application of organic fertilizer on nutrients use efficiency of the maize plant (Table 3). The application of Bokashi and Sunn hemp, whether solely or in combination, under treatment of 100% inorganic fertilizer, resulted in the higher efficiency of N, P, and K nutrients than other treatments. This was due to the supplementation of organic matters, such as Bokashi, Sunn hemp, or combination of Bokashi + Sunn hemp would be able to increase the abilities in absorbing, exchanging, and buffering the nutrients in the soil, so that the supplementation of optimal fertilization would lead to optimal nutrient adsorption and produce high yield of grains. High value of nutrient use efficiency can eliminate potential nutrient loss and increase yield of the plants (Baligar et al., 2001).

Table 3. Efficient use of N, P, K by maize as a result of interaction between dose treatments of inorganic fertilizer and organic fertilizer.

Nutrient use efficiency	Dose of inorganic fertilizer	Application of organic fertilizer			
		Without organic fertilizer	Bokashi 20 t/ha	Sunn hemp 20 t/ha	Bokashi 10 t/ha + Sunn hemp 10 t/ha
N (g/g)	100 % recommended	24.93 bc	29,34 d	29,62 d	29,01 d
	75 % recommended	23.97 b	26,46 c	26,41 c	26,61 c
	50 % recommended	19.02 a	25,87 bc	26,41 c	26,26 c
LSD 5 %			2.17		
P (g/g)	100 % recommended	39.31 bc	45,68 e	46,04 e	45,41 de
	75 % recommended	37.85 b	41,69 c	40,48 bc	42,09 cd
	50 % recommended	30.01 a	39,28 bc	40,15 bc	41,52 c
LSD 5 %			3.36		
K (g/g)	100 % recommended	36.12 bc	42,59 d	43,06 d	42,29 d
	75 % recommended	34.46 b	38,09 c	38,03 c	38,29 c
	50 % recommended	27.38 a	37,06 bc	37,86 c	37,61 c
LSD 5 %			2.92		

Notes: Numbers followed by the same letters at the same variable of observation showed no significant difference based on LSD test of 5% (p = 0.05).

Under low application of inorganic fertilizer (75% and 50%), the application of Bokashi and Sunn hemp, whether solely or in combination, were able to provide efficient use of N, P, and K nutrients, which had no significant difference with the values of the nutrient use efficiency under the treatment of sole inorganic fertilizer by dose of 100%. The organic matters have made the nutrient adsorption run optimally even though in low inorganic fertilization. Therefore, supplementation of organic matters, such as Bokashi, Sunn hemp, or combination of Bokashi + Sunn hemp increased efficiency of inorganic fertilization on maize. Therefore, the application of inorganic fertilizer could be reduced and, of course, it will reduce the farmer's dependency on inorganic fertilizers. The important thing that must be remembered is the long-term application of inorganic fertilizer will affect on the decreasing pH of the soil, so that the essential nutrients would not be available for the plants and it would cause inefficient use of inorganic fertilizer. Results of the research proved the decreasing dose of inorganic fertilizer would have positive effect on the change of pH in the soil (Table 4).

Table 4. Values of pH, soil organic matter (SOM), CEC, N, P, and K of the soil due to dose treatments of inorganic fertilizer and organic fertilizer during post harvest observation.

Treatment	Variable of observation					
	pH (H_2O)	SOM (%)	CEC (cmol/kg)	N (%)	P (mg/kg)	K (cmol/kg)
Dose of inorganic fertilizer						
100 % recommended	5.31 a	0.74	22.87 b	0.076	5.59 c	0.283
75 % recommended	5.54 b	0.72	21.28 a	0.075	3.52 b	0.250
50 % recommended	5.53 b	0.71	20.85 a	0.067	2.11 a	0.222
LSD 5%	0.15	ns	0.87	ns	1.00	ns
Application of organic fertilizer						
Without organic fertilizer	5.44	0.58 a	19.98 a	0.061 a	2.65 a	0.194 a
20 t Bokashi/ ha	5.48	0.74 b	21.90 b	0.070 b	4.20 b	0.273 b
20 t Sunn hemp/ha	5.44	0.77 b	22.31 b	0.081 c	3.94 b	0.255 b
10 t Bokashi /ha+10 t Sunn hemp /ha	5.47	0.79 b	22.47 b	0.080 c	4.18 b	0.285 b
LSD 5 %	ns	0.08	1.00	0.009	1.16	0.056

Notes: Numbers followed by the same letters at the same variable of observation showed no significant difference based on LSD test of 5% (p = 0.05); ns= not significant.

It can be seen on the dose treatments of inorganic fertilizers, 75% and 50%, which have higher pH than dose of 100%. It was supposed that the application of high dose of inorganic fertilizers have caused pH of the soil becoming more acid due to the increasing ion H^+ as a result of synthesis process on inorganic substances in the soil. Syekhfani (1997) stated that under low pH of the soil, concentration of base ions K^+, Na^+, Ca^{2+}, and Mg^{2+} were low, availability of phosphorus and nitrate was reduced, and solubility of aluminum, iron, and manganese were increased and poisoned the plants. Besides that, the dose supplementation of inorganic fertilizer on maize with low organic matters will tend to reduce dry weight of seed in maize (Rachman et al., 2008).

Conclusion

The organic fertilizers of Bokashi and Sunn hemp have been able to increase yields of maize. Application of 20 t Bokashi/ ha, 20 t Sunn hemp/ha, and combination of 10 t Bokashi /ha + Sunn hemp 10 t Sunn hemp /ha, along with the application of inorganic fertilizer by dose of 100% increased the yields of maize for about 41.8%; 47.6% and 54.7% (10.73 t/ha; 11.17 t/ha and 11.71 t/ ha), meanwhile the application of inorganic fertilizer by dose of 75% increased the yields for about 10.7%; 12.3% and 10.1% (8.38 t/ha; 8.50 t/ha and 8.34 t/ha). On the other hand, the use of 20 t Sunn hemp/ ha along with the application of inorganic fertilizer 50% increased the yields of maize for about 1% (7.64 t/ha). The yield of maize on treatment without organic fertilizer by dose of 100% inorganic fertilizer did not have any significant difference from the application of 20 t Bokashi/ ha, 20 t Sunn hemp/ ha, and 10 t Bokashi/ha + 10 t Sunn hemp /ha along with doses of inorganic fertilization 75% and 50%. Therefore, application of 20 t Bokashi /ha, 20 t Sunn hemp /ha, and combination of 10 t Bokashi/ ha + 10 t Sunn hemp /ha could reduce the need of inorganic fertilizer for about 50%.

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References

Adnan, A.M., Rapar, C. and Zubachtirodin. 2010. Description of Superior Variety of Maize. Council for Research of Cereals. Maros. p 118. (*in Indonesian*)

Baligar, V. C., Fageria, N.K. and He, Z.L. 2001. Nutrient use efficiency in plants. *Communications in Soil Science and Plant Analysis* 32 (7): 921 – 950.

Dawson, J. C., Huggins, D.R. and Jones, S.S. 2008. Characterizing nitrogen use efficiency in natural and agricultural ecosystem to improve the perfomance of cereal crops in low-input and organic agricultural systems. *Field Crops Research* 107 (1): 89 – 101.

Djajadi. 2011. *Crotalaria juncea* L.: Fiber plants for organic fertilizer and plant nematicide. *Perspective* 10 (2): 51 – 57. (*in Indonesian*)

Endriani. 2003. The Effect of bokashi residue of stable manure (cow's droppings) on physical properties of Ultisol soil and yield of the plants.. *Collection of National Seminar Papers on Results of Specific Technology Review and Research,* Jambi. p 139-143. (*in Indonesian*)

Hairiah, K., Widianto, Utami, S.R., Suprayogo, D., Sunaryo, Sitompul, S.M., Lusiana, B., van Noorwijk, M. and Cadisch, G. 2000. Biological Management on Acid Soil, Reflection of Experiences from North Lampung. International Centre for Research in Agroforestry, Bogor. pp 63 – 79.

Handayanto, E. dan Hairiah, K. 2007. *Biologi Tanah : Landasan Pengelolaan Tanah Seha*t. Pustaka Adipura. Yogyakarta.130p.

Indriani, Y. H. 2005. *Membuat Kompos Secara Kilat*. Penebar Swadaya.Jakarta. 67p.

Kadarwati, F.T. and Riajaya, P.D. 2009. Response of cotton varieties of Kanesia 8 and 9 toward fertilization in intercropping system of maize in dry land. *Agrivita* 31(1): 57-66.

Rachman, A. I., Djuniwati, S. and Idris, K. 2008. The effect of organic matters and NPK fertilizer on nutrient adsorption and production of maize in an Inceptisol of Ternate. *Journal of Soil and Environment* 10(1):7-13

Suge, J. K., Omunyin, M.E. and Omami, E.N. 2011. Effect of organic an inorganic sources of fertilizer on growth, yield and fruit quality of eggplant *(Solanum melongena* L.). *Archieves of Applied Science Research* (6): 470 – 479.

Sumarni, T. 2008. The Role of *Crotalaria juncea* as Amelioran of Soil Fertility in Planting Maize (*Ze mays* L.) Var. Bisma. Dissertation. PPSUB. Malang. p 135. (*in Indonesian*)

Sumarno. 2007. Soil Fertility: Basics of Fertilizer Recommendation. PPSUB. Malang. pp 1 – 31. (*in Indonesian*)

Syekhfani. 1997. Nutrients - Water - Soil - Plants. Department of Soil Science, FP-UB. Malang. p177. (*in Indonesian*)

The Board of Statistical Center. 2014. Production of Rice, Maize, and Soybean (forecasting numbers I 2012). http://www.bps.go.id/brs_file/aram_01juli14.pdf. Accessed on July 10th, 2014. (*in Indonesian*)

Winarso, S. 2005. Soil Fertility-Base of Health and Quality of Soil. Gava Media. Yogyakarta. pp. 269. (*in Indonesian*)

Yulianti T. and Hidayah, N. 2011. Dynamic of *Rhizoctonia solani* on planting area of intercropping between cotton-mungbean and *Crotalaria sp. Journal of Littri* 17 (2):77 – 82. (*in Indonesian*)