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Improvement of soil quality using bokashi composting and NPK fertilizer to increase shallot yield on dry land

Sri Anjar Lasmini*[1], Burhanuddin Nasir[2], Nur Hayati[1], Nur Edy[2]

[1]Department of Horticulture, University of Tadulako, Palu - 94117, Indonesia
[2]Department of Plant Pest and Disease, University of Tadulako, Palu - 94117, Indonesia

***Corresponding author: srianjarlasmini@gmail.com**

Abstract

The use of NPK fertilizer and bokashi composting, which is a fermented organic matter combined with microbial stock, have been reported as potential agricultural practices to enhance the farming land and crop production. The aim of this research is to understand the type of bokashi fertilizer and the correct dosage of NPK inorganic fertilizer in improving entisol soil quality and shallot yield in the dry land. The research used the split-plot design, which was divided into two factors. The first factor of the main plot was the bokashi type consisting of two levels: 3 t ha^{-1} of bokashi compost of *Gliricidia* sp. tree leaves (B1); and bokashi cow manure 3 t ha^{-1} (B2). The second factor as the subplot was the NPK inorganic fertilizer dose which were consisted of four levels: without fertilizers (K0), NPK 100 kg ha^{-1} (K1), NPK 200 kg ha^{-1} (K2), and NPK 300 kg ha^{-1}(K3). By combination of these two factors 8 combined treatments with 3 replications totally 24 units were obtained. The result of the research showed that application of 3 t ha^{-1} bokashi cow manure (B2) coupled with NPK inorganic fertilizer at 200 kg ha^{-1} (K2) caused a decrease in evaporation of its land and soil temperature, while increase shallot bulb yield compared with other treatments. The analysis of soil and soil microbes showed an increase in soil fertility by elevated levels of C-organic from 0.66 % to 3.28 %, N-fixing bacteria from 27 x 10^5 CFU ml^{-1} to 47 x10^6 CFU ml^{-1} and phosphate solubilizing bacteria from 20 x10^3 CFU ml^{-1} to 90 x10^3 CFU ml^{-1}. The shallot bulb yield increased from 4.79 t ha^{-1} to 11.74 t ha^{-1}.

Keywords: Bokashi; Dry land; Shallot; Soil quality; NPK inorganic fertilizer.
Abbreviations: N_Nitrogen; P_Phosphorus; K_Potassium, NPK_Nitrogen Phosphorus Potassium; CFU_Colony Forming Unit; CEC_Cation Exchange Capacity; EM_Effective Microorganisms; WAP_Week After Planting; HSD_Honeystly Significant Difference; meq=miliequivalents.

Introduction

Shallot cultivation in the dry land is still facing many obstacles, mainly from biophysical factors such as soil fertility, water shortage and less suitable climate for plant growth, especially on soils that have high porosity, low organic matter as well as the conditions of extreme temperatures. Dry land at Palu valley, including Sigi district, Donggala and Palu encompasses 1.07556 million ha or 15% of the total dry land area out of 7.16962 million ha in Central Sulawesi (Central Bureau of Statistics of Central Sulawesi, 2016). The potency of broad dry land can be optimized for improving crop production by overcoming the existing obstacles. The main limiting factors in the development of shallot cultivation in the dry land are water availability, nutrient retention and low content of organic matter. The dry land characteristic at Palu valley has shown the relatively low binding capacity of soil moisture, so it is not good in water retaining. This condition causes the falling water have percolation directly and capillary water is easily separated because of evaporation. Evaporation rate is very important in saving soil moisture so it can be used for plant growth. The rate of evaporation can be retained by the addition of organic fertilizer (El-Aswad and Groeenevelt, 1985).

The organic ingredient is one of the very important soil constituents that maintain the function of soil to support plant growth. Organic matter above the surface of the soil is usually in the form of litter and partly in decomposed form, while underground is generally in the form of humus compound. Humus has hydrophilic colloid property. It can clump as gel-shape. It plays a role in saving water because it has a high water holding capacity so the soil does not dry quickly in the dry season. Humus is also able to bind water four to six times of its weight and the water bound by humus will be able to reduce the evaporation of water through the soil (Fitter and Hay, 2002).
The high organic content can increase water retaining capacity of the soil. The addition of organic matter can be done by giving organic fertilizer. The benefit of organic fertilizer addition into the soil is to increase nutrients, improve soil properties through increasing soil water content, soil organic carbon, cation exchange capacity (CEC) and pH, improving the soil structure, aeration and water-holding capacity of land and to influence or regulate soil temperatures that can help plant growth (Agegnehu et al., 2016).

Bokashi (organic material rich in microbial biological resources) is the result of organic material fermentation with stocks of effective microorganisms. This can be used as an organic fertilizer to nourish the crops, increase the growth and production of plants (Karimuna et al., 2016; Zaman et al., 2016; Anhar et al. 2018), improve better soil structure (Xiaohou et al., 2008; Hernández et al., 2014; Barajas-Aceves 2016), and increase the volume of water contained and stored in the soil which means increasing the water available to the plants (Djajadi et al., 2011; Yulnafatmawita et al., 2010).

The use of bokashi in plants increased the concentration of P and K and also increased the number, length, and diameter of *Alpinia purpurata* plant stems (Hernández et al., 2014). It also has increased production, dry weight of seeds and weight of 100 corn seeds and peanut crops (Karimuna et al., 2016) and reduced the need for inorganic fertilizers of about 50% in corn crops (Pangaribuan et al., 2011; Yuliana et al., 2015) and the canola plant (*Brassica napus* L.) (Kazemeini et al., 2010). Bokashi manure also has promoted the growth of plant seeds of okra (*Abelmoschus esulentus* (L.) Moench (Uka et al., 2013).

The use of cow dung bokashi as an organic fertilizer on shallot plant is very necessary because it can add nutrients, improve the physical of soil so that the soil becomes fertile, loose and easily processed and improve the ability of soil in the binding of nutrients that cannot be replaced by artificial fertilizers. Bokashi of cow dung contains many elements of nitrogen (N), phosphorus (P) and potassium (K), which most needed by plants, thereby reducing the use of NPK inorganic fertilizers. The aim of this research is to know the bokashi type and dosage of NPK fertilizer under the appropriate recommendation standard in improving soil quality and shallot yield in the dry land.

Results

The influence of the growing environment

Bokashi of cow manure at a dose of 3 t ha^{-1} combined with NPK inorganic fertilizer at a dose of 200 kg ha^{-1} (B2K2) showed the lowest soil evaporation (8.67g) during the day (07:00 am to 12:00 pm) and (5.00g) for the afternoon (01:00 pm to 05:00 pm) (Figure 1). The lowest soil temperature fluctuations was 2.14 ^{0}C (Figure 2).

Influence on soil physical and chemical properties

Bokashi of cow manure at a dose of 3 t ha^{-1} combined with NPK inorganic fertilizer at a dose of 200 kg ha^{-1} (B2K2) has shown the best average value for physical and chemical properties of the soil (Table 1).

Influences on plant growth and yield

Bokashi of cow manure at 3 t ha^{-1} combined with NPK inorganic fertilizer dose of 200 kg ha^{-1} (B2K2) produced the highest of plant high, i.e. 28.12 cm, root length of 16.73 cm, root dry weight of 2.40 g and shallot bulb yield of 11.74 t ha^{-1} (Table 2). The increasing of the shallot bulb was getting along with the increased content of C-organic (Figure 3).

Response on bacteria populations on N-fixation and phosphate solubilizing

Organic fertilizer bokashi can increase the population of beneficial microorganisms. Treatment with 3 t ha^{-1} bokashi cow manure along with NPK inorganic fertilizer at a dose of 200 kg ha^{-1} (B2K2) showed the highest population of N-fixing bacteria and the highest phosphate solubilizing bacteria. The population of N-fixing bacteria was increased from 27 x 10^5 CFU ml^{-1} to $47x10^6$ CFU ml^{-1} and phosphate solubilizing bacteria from 20 x 10^3 CFU ml^{-1} to 90 $x10^3$ CFU ml^{-1} (Table 3).

Discussion

The role of organic fertilizer on the soil is in relation to changes in soil properties i.e. physical, chemical and biological properties of the soil. Bokashi of cow dung treatment with the dose of 3 t ha^{-1} and NPK inorganic fertilizer with the dose of 200 kg ha^{-1} had significant differences on all observed components. The weighing result showed that treatments were able to reduce the rate of evaporation during the day or late evening, as well as decrease in the soil temperature fluctuations. This condition happened because bokashi of cow manure in the soil were able to form soil granulation to play a role in contributing the formation of a stable soil aggregate, so, reduction in absorption of solar energy during the day. Through the application of bokashi organic fertilizer, the previously heavy soil re-structured crumb, the infiltration becomes better and it could absorb water faster to reduce the flow of the surface. Application of bokashi could also increase the content of organic materials which also increase humus levels in the soil. Humus is hydrophilic; therefore, humus can increase water absorption in the soil and improve water storage so the evaporation is reduced. The increase in soil organic matter will improve the ability of soil in holding water; thus, reducing the rate of evaporation that occurs in the soil. The increase in holding water capacity of the soil is related to the application of organic material. It will increase the volume of water contained and stored in the soil, which means increasing the water availability in plants.

Bokashi of cow manure is able to reduce the fluctuation of the soil temperature because it can increase soil porosity so that the soil aeration is better. The high content of organic material in bokashi will increase the water storage of the soil. Holding water by soil organic matter can reduce water loss through percolation and evaporation. In addition, bokashi also helps to reduce the radiation received and absorbed by the soil. The supply of organic matter by mulch can increase the soil water level by 6-7%. The storage of groundwater is greater so it will increase the productivity of the plant (Agbede et al., 2017; Chang et al., 2016; Edwards et al., 2000; Sudaryono, 2001; Wang et al., 2009).

Bokashi fertilizer has also positive effects on root growth by increasing root length and root dry weight in the rhizosphere conditions. Organic matter serves as a granulator to improve soil structure, as source of N, P, K nutrients and other microelements. A good soil structure can guarantee a better root development so the area of nutrient uptake is wider. This can keep the process of photosynthesis optimal

Table 1. Results of soil analysis before and after treatment.

No	Parameter	Before treatment	After treatment							
			B1K0	B1K1	B1K2	B1K3	B2K0	B2K1	B2K2	B2K3
1.	Bulk Density ($g.cm^{-3}$)	1.54	1.48^{b}	1.46^{b}	1.36^{ab}	1.43^{ab}	1.47^{b}	1.38^{ab}	1.28^{a}	1.39^{ab}
2.	Permeability (cm. $hour^{-1}$)	3.67	3.89^{a}	4.07^{a}	5.73^{b}	3.96^{a}	3.92^{a}	5.78^{b}	6.14^{b}	4.02^{a}
3.	Porosity (%)	45.0	49.0^{a}	51.0^{ab}	56.0^{bc}	53.0^{ac}	51.0^{ab}	56.0^{bc}	58.0^{c}	55.0^{bc}
4.	pH (H_2O)	5.87	6.11^{a}	6.35^{a}	6.37^{a}	6.17^{a}	6.14^{a}	6.53^{a}	6.68^{a}	6.27^{a}
5.	C-organic (%)	0.66	1.39^{a}	1.68^{a}	1.71^{a}	1.66^{a}	1.42^{a}	$1{,}88^{a}$	3.28^{a}	1.87^{a}
6.	C/N Ratio (%)	7.02	9.11^{a}	9.22^{a}	10.3^{bc}	10.1^{b}	9.12^{a}	10.8^{c}	11.9^{d}	9.18^{a}
7.	N-total (%)	0.13	0.22^{a}	0.28^{ac}	0.37^{ce}	0.35^{bcd}	0.25^{ab}	$0^{a}.44^{de}$	0.45^{e}	0.36^{ce}
8.	P-total (mg $100g^{-1}$)	40.35	18.8^{a}	20.6^{ab}	22.5^{bd}	20.2^{ab}	21.9^{bc}	23.4^{cd}	24.6^{d}	21.7^{bc}
9.	K_2O (mg $100g^{-1}$)	48.57	$34{,}8^{b}$	38.9^{c}	37.5^{c}	38.4^{c}	32.6^{a}	46.3^{d}	50.5^{e}	37.2^{c}
10.	Sulfur (ppm)	11.00	18.5^{d}	15.3^{ab}	16.7^{bc}	13.6^{a}	13.7^{a}	17.3^{cd}	17.4^{cd}	14.9^{a}
11	CEC (meq $100g^{-1}$)	12.92	17.7^{a}	19.6^{ab}	24.4^{cd}	21.9^{bc}	17.8^{a}	24.3^{cd}	26.6^{d}	23.7^{c}

Numbers followed by the same letter in the same row are not significantly different at the 0.05 α HSD test. B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha^{-1} NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK.

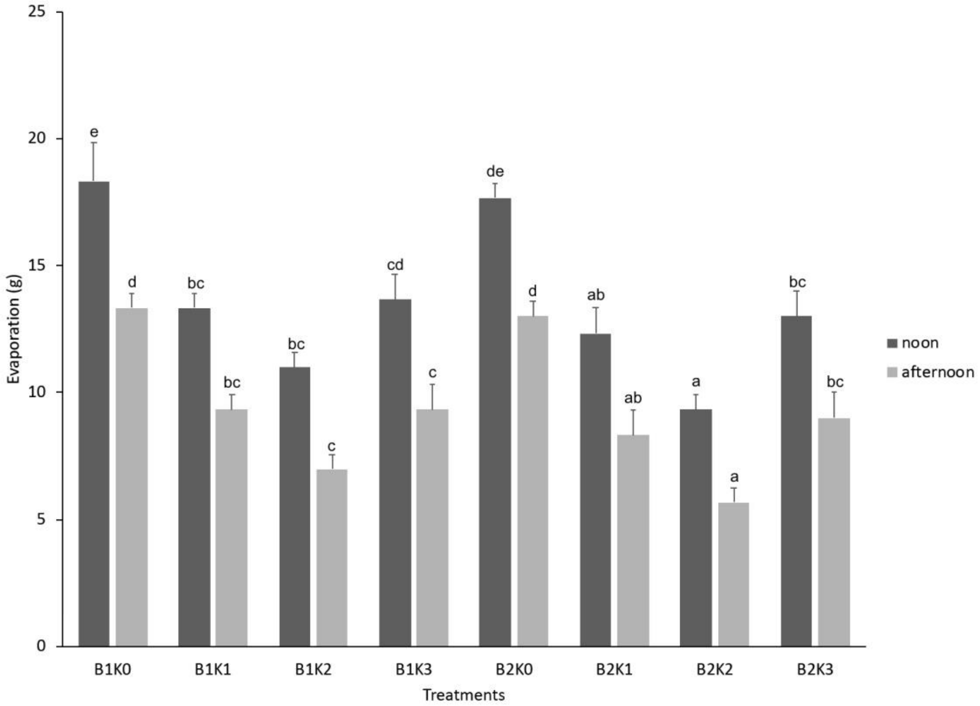

Fig 1. Soil evaporation on the application of bokashi and NPK inorganic fertilizers. B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha^{-1} NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK. Data are means + SD. Similar bar colour followed by the same letter are not significantly different at the 0.05 α HSD test.

Table 2. Growth and yield responses of shallot on the application of bokashi and NPK inorganic fertilizer.

Treatment	Plant High (cm)	Root length (cm)	Root Dry Weight ($g.plan^{-1}$)	Bulbs yield ($t.ha^{-1}$)
B1K0	19.34^{a}	12.53^{a}	0.87^{a}	4.79^{a}
B1K1	23.30^{a}	13.93^{a}	0.92^{a}	5.28^{a}
B1K2	24.95^{a}	14.47^{b}	1.50^{b}	5.52^{a}
B1K3	24.25^{a}	12.80^{a}	1.63^{b}	7.05^{b}
B2K0	$22{,}11^{a}$	13.47^{a}	0.93^{a}	5.69^{a}
B2K1	25.79^{ab}	14.07^{b}	1.53^{b}	6.46^{ab}
B2K2	28.12^{b}	16.73^{bc}	2.40^{c}	11.74^{d}
B2K3	26.03^{ab}	14.73^{b}	1.45^{b}	8.38^{c}

Numbers followed by the same letter in the same column are not significantly different at the 0.05 α HSD test. B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha-1 NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK.

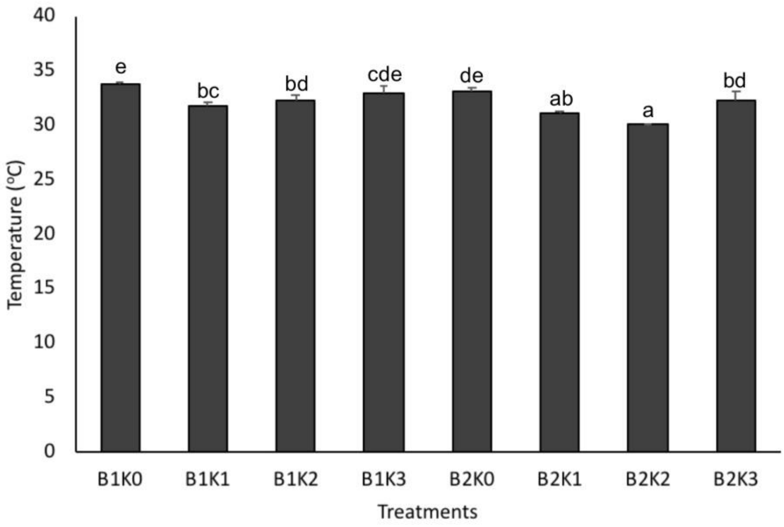

Fig 2. Soil temperature fluctuations on the application of bokashi and NPK inorganic fertilizer. B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha^{-1} NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK. Data are means + SD. Similar bar colour followed by the same letter are not significantly different at the 0.05 α HSD test.

Table 3. N-fixing bacteria populations and phosphate solubilizing bacteria before and after treatment.

Treatment	N-fixing bacteria population (CFU ml^{-1})		Phosphate solubilizing bacteria population (CFU ml^{-1})	
	Before treatment	after treatment	before treatment	after treatment
B1K0	$27x10^5$	$17x10^6$	$20\ x10^3$	$30\ x10^3$
B1K1	$27x10^5$	$25x10^6$	$20\ x10^3$	$70\ x10^3$
B1K2	$27x10^5$	$22x10^6$	$20\ x10^3$	$50\ x10^3$
B1K3	$27x10^5$	$19x10^6$	$20\ x10^3$	$40\ x10^3$
B2K0	$27x10^5$	$21x10^6$	$20\ x10^3$	$60\ x10^3$
B2K1	$27x10^5$	$34x10^6$	$20\ x10^3$	$80\ x10^3$
B2K2	$27x10^5$	$47x10^6$	$20\ x10^3$	$90\ x10^3$
B2K3	$27x10^5$	$31x10^6$	$20\ x10^3$	$80\ x10^3$

B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha^{-1} NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK.

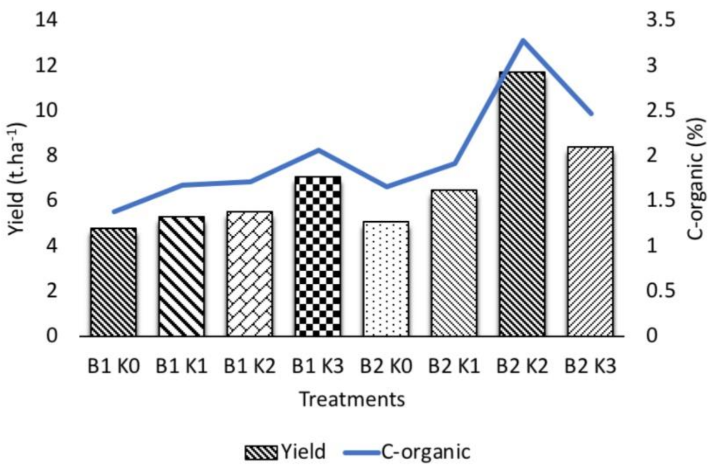

Fig 3. The relationship between the content of soil Organic-C and the increasing of shallot bulbs yield per hectare. B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha^{-1} NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK.

Fig 4. The Development of shallot bulbs at age of 7 WAP on bokashi and NPK inorganic fertilizer treatment. B1: Bokashi leaf of *Gliricidia* sp., B2: Bokashi cattle manure, K0: without NPK, K1: 100 kg ha^{-1} NPK, K2: 200 kg ha^{-1} NPK, K3: 300 kg ha^{-1} NPK.

(Shaheen et al., 2007). This is consistent with those reported by Efthimiadou et al. (2010) that the cow manure can increase the rate of photosynthesis in sweet corn compared with inorganic fertilizers.

Bokashi treatment tends to increase the nutrient content of total N, P, and K, so it will reduce the use of inorganic fertilizers until below of standard recommendation. The increased nutrient showed that the treatment given, mainly organic matter can increase absorption. Thus, it will improve the soil capacity in holding nutrients from the mineralization by microorganisms.

The role of organic fertilizer towards changes in soil chemical properties is well-known. Also, it can increase the cation exchange capacity (CEC) of the soil and improve fertilization efficiency. Organic fertilizer addition can increase the weight of the fruit and also improve soil properties through increasing soil water content, soil organic carbon, cation exchange capacity and pH as well as the increase of P and K in plants and reduce the use of inorganic fertilizers by 50% (Agegnehu et al., 2016; Gobbi et al., 2016; Kaplan et al., 2016; Sumarni et al., 2009; Yuliana et al., 2015; Salo, 2002; Sorensen, 1996; Pire et al., 2001).

The results showed that the interaction between cow manure bokashi (at 3 t ha^{-1}) with NPK inorganic fertilizer of 200 kg ha^{-1} can increase the yield of shallot bulbs per hectare. This means that bokashi and NPK inorganic fertilizer dosage given in this study are appropriate and have positive effects on yield of shallot bulb.

The role of organic fertilizer in improving the physical and chemical properties refers to the increase of organic-C soil and CEC of soil (Agegnehu et al.,2016). This will help the development and activity of plant roots in absorbing the nutrients needed for the growth and development of plants. Adequate soil organic matter and the right dose of N, P, and K will rise chlorophyll content, which further increase the rate of photosynthesis. The increasing of photosynthesis rate will increase the amount of biomass that resulted in the enhancement of food reserves, by which the tuber yield increases (Abdel-Aziz et al., 2016; Al-Sherif et al., 2015; Liu et al., 2017; Mete et al., 2015; Munyahali et al., 2017; Nurudeen et al., 20 15; Singh et al., 2001; Siavoshi et al., 2011; Zayed et al., 2013).

Bokashi fertilizer of cow manure and NPK inorganic fertilizer treatment also increase the population of beneficial microbes such as N-fixing bacteria and phosphate solubilizing bacteria, because the organic material serves as a source of nutrients and energy for soil organisms. In addition, organic fertilizers play a role in changing soil biological properties by increasing the diversity and population of soil organisms (microbial and soil microbes) and increasing soil fertility characterized by increased microbial activity (Lee, 2010; Zhang et al., 2017).

Materials and Methods

Plant materials

The plant materials was shallot (*Allium cepa* L. var, aggregatum). Before planting the shallot, seedbeds were made, which was 1.20 m x 3 m in the north to the south. The distance between the sequences was 60 cm, the distance between plots was 60 cm, and planting distance was 15 cm x 20 cm. The seedbed was made at a depth of 40 cm which could serve as a drainage channel. Shallot planted was watered in the morning and evening, or in accordance with the soil conditions.

Study site and experimental design

The research was conducted in the Guntarano Village, Tanantovea District, Donggala Regency, Central Sulawesi, with an altitude of 110 m above sea level. The type of soil was inceptisol and an average temperature of 39°C. The study carried out from April 2016 to October 2016.

This study used a split-plot design consisting of two factors. For the first factor, the main plots were assigned to the bokashi type, which is consisting of two levels, namely: B1 = 3 t ha^{-1} of Bokashi gliricidia leaf, B2 = 3 t ha^{-1} Bokashi cow manure dose. The second factor as the subplot was NPK inorganic fertilizer dose, consisted of 4 levels, i.e. K0 = without fertilizer, K1 = NPK 100 kg ha^{-1}, K2 = NPK 200 kg ha^{-1} and K3 = NPK 300 kg ha^{-1}. The combination of the two factors created 8 treatment combinations with 3 replications, so there were 24 units of experiment.

Organic fertilizer (bokashi) preparation

Bokashi as effective microorganism compost (Higa and Parr, 1994) was made from cattle manure, leaf of *Gliricidia* sp., and effective microorganism solution (EM4, PT. Songgololangit Persada, Indonesia). According to manufacture, the EM4, contained microorganisms such as Lactobacillus (8.7 x 10^5 cell/ml), phosphate solubilizing (7.5 x 10^6 cell/ml), and yeast (8.5 x 10^6 cell/ml). Additionally, EM4 also contained organic-C (27.05%), N (0.07%), P_2O_5 (3.22 ppm), K_2O (7675 ppm), Ca (1676.25 ppm), Mg (597 ppm), Mn (1.90 ppm), Fe (5.54 ppm), Zn (1.90 ppm), B (< 20 ppm), and Cu (< 0.01 ppm). Bokashi of cattle manure and leaf of *Gliricidia* sp. were made in different composting boxes at room temperature. The effective microorganism solution (EM4) was prepared followed by the manufacture instruction (5 ml of EM4+10 ml of molasses + 1985 ml of dechlorinated water). The cattle manure and leaf of *Gliricidia* sp. were sprayed by EM4 solutions and mixed. Bokashi was remixed after 2 days to control the temperature that should not go above 40^{o}C in fermentation.

Traits measured

The observed variables include: (a) changes in physical and chemical properties of soil (Eviati et al., 2009: Kurnia et al., 2006), (b) soil evaporation which were measured by gravimetry method (Prijono, 2008), (c) soil temperature, (d) plant height, (e) root length, (f) the dry weight of roots, (g) shallot bulbs yield per hectare, and (h) the total population of N-fixing bacteria and phosphate solubilizing bacteria (Sasrawati et al., 2006).

Data analysis

The obtained data was analyzed by F-test to know the effect of treatment. If there is a significant difference between the treatments then it was tested by the honestly significant difference (HSD) at the level of 5%.

Conclusion

Bokashi of cow manure treatment at dose of 3 t ha^{-1} combined with NPK inorganic fertilizer application of 200 kg ha^{-1} can reduce the evaporation rate and soil temperature fluctuation, and also increase the yield of shallot. Results of soil and microbial analysis showed that an increase in soil fertility increased levels of C-organic from 0.66% to 3.28%, N-fixing bacteria from 27 x 10^5 CFU ml^{-1} to 47 x 10^5 CFU ml^{-1}, phosphate solubilizing bacteria from 20 x 10^3 CFU ml^{-1} to 90 x10^3 CFU ml^{-1} and shallot yield increased from 4.79 t ha^{-1} to 11,74 t ha^{-1}.

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