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Research Article

Improvement of sweet potato yield using mixtures of ground fish bone and plant residues

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Abstract : The Indonesian government begins to promote food diversification program. The government expects the Indonesian people can consume food crops other than rice, such as wheat, potatoes and sweet potatoes. While, the level of production of sweet potato production decreased in the period of 2012-2015 with total production of only 2,218,992 t/ha. In an effort to increase the production of sweet potato, improvements are needed through application of organic fertilizers like composts. The purpose of this study was to explore the effect of composted manure with ground fish bone, legume residues, and *Tithonia* on soil chemical properties and sweet potato production includes tuber weight and levels of starch sweet potato crops. The results showed that application of 5 t compost/ha and 35 kg *Trichoderma* biofertilizer/ha increased pH, water content, organic carbon, total N, available P, total Kl, CEC, exchangeable Ca, plant height, tuber weight and levels of sweet potato starch.

Keywords : *biofertilizer, compost, sweet potato production*

Introduction

In Indonesia, most people consume rice as a staple food. Based on the central body of statistics, in 2013 in a week of rice consumption in Indonesia reached 1,624 kg / capita. But the longer, the level of consumption of rice with rice production in balance. In recent years, the Indonesian government began to promote food diversification program by consuming other food crops such as potatoes and tubers such as yams. sweet potato production levels according to the Central Bureau of Statistics in 2012 and 2015, sweet potato production has decreased every year. Central Bureau of Statistics predicts that the production of sweet potato is only 2,218,992 t/ha (CBS, 2014).

Factors affecting the level of productivity include soil conditions, and the availability of nutrients for the cultivation of sweet potatoes. Therefore, necessary repairs among other things are the application of organic fertilizers like compost and biofertilizers that can decompose organic matter in the soil so that it can produce the organic material needed by plants sweet potato. Organic fertilizers can improve the properties - physical soil properties such as permeability, a porosity of the soil, soil structure, water holding capacity and cation of land, improve the nature - soil chemical and physical properties, improving the ability to save water, improve ease of processing and soil fertility. (Roidah, 2013).

This study was aimed to explore the effect of composted manure with ground fish bone, legume crop residues, and *Tithonia* on soil chemical properties and sweet potato production

Materials and Methods

Materials used for the study

This research was conducted in October 2015 until July 2016 in the experimental field, and laboratories of the Faculty of Agriculture, and Brawijaya University at Malang. The materials used in this study included soil, compost, *Trichoderma* biofertillizer, inorganic fertilizer, and sweet potato seeds of ‘Sari’ variety. *Trichoderma* biofertilizer used in this study is produced by PT. Agritani Makmur Mandiri, Jakarta. The sweet potato seeds were obtained from Balitkabi Malang.

Soil and biological fertilizer analyses

Initial soil sample to be analyzed was drawn at random in five points that represented the land and then composited. The collected soil samples were then air for three days, ground and sieved to pass through a 2 mm sieve. The soil samples were then used for analyses of pH (glass electrode), organic C (Walkley and Black), water content, total N (Kjeldahl), available P (Bray), total K (HCl 25%), CEC and exchangeable K (extract of NH_4OAc 1 N pH 7), exchangeable Ca (EDTA titration).

The results of the analysis of initial soil showed the chemical properties of soil as follows: pH 5.98, water content 10.7%, 0.34% organic C, 0.0164% total P, 0.0196% total K, 2.0 ppm of available K, 8.82 ppm of exchangeable Ca, 0.076% N, and CEC of 29.90 cmol/kg. A sample of *Trichoderma* biofertilizer that had been sieved to pass through a 0.5 mm was analyzed for pH (glass electrode), moisture content, C-organic (Walkley and Black), total P and total K (HCl 25%), exchangeable Ca (EDTA titration), total N (Kjeldahl), CEC (NH_4OAc extract 1 N pH 7). Results of the analysis showed the biofertilizer chemical properties as follows: pH 7.73, 23% water content, 17.84% C organic, 9.6% P, 0.2% K, 3.2% exchangeable Ca, 12.44% N, and CEC of 10,01 cmol/kg.

Treatments and experimental design

Treatments tested in this study were combinations of 5 t compost /ha (ground fish bone, *Tithonia* leaves and *Gliricidia* leaves) with two doses of *Trichoderma* biofertilizer i.e. 25 kg and 35 kg/ha. The six treatments were arranged in a randomized block design with three replicates. Each treatment was given 150 kg/ha NPK fertilizer consisting of 15% N, 15% P, 15% C and 10% S that was applied at 7 and 30 days after planting (DAP). On each plot consisting of two rows, five sweet potato seeds were planted in each row. Therefore, there were 10 sweet potato seedlings in each plot. Maintenance of the sweet potato cultivation included watering, replanting, weeding and pest control from early planting to harvest.

Plant height / length was measured at 1, 5, 9, 13, and 15 weeks after planting. At the time of harvest (age of 15 weeks), soil samples were collected for analysis of the chemical properties of the soil that included total N, total K, pH, C organic, available P, CEC and exchangeable Ca. Yields of sweet potato (tuber weight and starch content) were measured at 15 weeks. The data obtained were subjected to statistical analysis (analysis of variance) using the F test at 5% level with the application of GENSTAT, followed by Duncan test at 5% level.

Results and Discussion

Compost

The composts used for this study were mixtures of *Tithonia diversifolia* leaves, *Gliricidia maculate* leaves, ground fish bone, and cow dung. The composting process took five weeks from the start of composting to mature compost that was characterized by odorless, blackish brown colour compost, and constant compost temperature. The chemical composition of the compost is presented in Table 1.

Table 1. The chemical composition of compost

Parameter	Value
pH	6.63
Water content (%)	19.14
Organic C (%)	14.34
Total P (%)	5.29
Total K (%)	1.30
Ca (%)	4.20
Total N (%)	1.42
C/N ratio	10.09
Polyphenol (%)	1.48
Lignin (%)	13.92

The compost made was in compliance with the quality standard of compost according to the parameters pH, water content, C organic, N total, total P, total K and Ca contents. The chemical compositions were in accordance with the Decree of Agriculture Ministry no: 28 / Permentan / SR.130 / B / 2009. The decree states that mature and good quality compost is that having more than 12% of C organic, 15-25% moisture content, pH 4 -8, N, P and K contents of less than 6%. The polyphenols content (1.48%) and lignin content (13.92%) of the compost were also in accordance with the appropriate quality standard of easily decomposed organic materials. According to Nduwayezu et al. (2005), the standard content of polyphenols is less than 4% and the lignin content is less than 15%. *Gliricidia* prunings are well known easily decomposed organic materials than can release nutrients because of their low lignin content. The decomposition process will be rapid if the litter has a lignin content of less than 15%.

Soil properties

Application of compost *Trichoderma* biofertilizer affected soil properties. Results of analysis showed that application of B and F treatments improved soil properties compared to the A control treatment. The changes of properties of the soil are presented in Table 2.

Soil pH

The T treatment, which was a combination of 35 kg *Trichoderma*/ha and 5 t compost mixture (*Tithonia, Gliricidia* and ground fish bone) /ha had the higher pH (6.40) compared to the A control (6.12). According to Hutomo et al. (2015) organic fertilizers are more capable of improving soil fertility compared to inorganic fertilizer because in addition to the release of nutrients gradually also include other materials such as organic carbon, nitrogen, phosphate, potassium, calcium, which will increase the pH value. Plants will be easier to absorb nutrients in a state of neutral pH. The pH value indicates soil acidity and alkalinity. The high number of H^+ ions will result in the high soil acidity. Soil with a low pH (acid) indicates the present of metals such as Al^{3+}. Organic fertilizers such as composts have a role in binding the heavy metals in the soil so that the heavy metal content in the soil, especially Al^{3+} will be reduced and the H^+ ions generated by Al^{3+} will be reduced as well. Therefore, the soil pH will be neutral and allows plants to uptake nutrients.

Table 2. Soil properties

Treatments	pH H_2O (1:1)		C Organic (%)		Water Content (%)		Total N (%)		Available P (ppm)		Total K (%)		CEC (cmol/kg)		Exch. Ca (ppm
A	6.12	a	0.46	a	10.98	a	0.081	a	10.20	a	0.0255	a	40.84	a	9.09
B	6.16	ab	0.52	a	11.81	b	0.087	ab	11.74	ab	0.0285	b	45.06	b	9.18
C	6.15	ab	0.73	ab	12.04	b	0.098	b	12.34	ab	0.0292	bc	44.56	b	9.12
D	6.29	b	0.82	ab	12.18	b	0.093	ab	13.30	ab	0.0296	bc	44.93	b	9.16
E	6.27	ab	0.84	ab	12.34	b	0.093	ab	15.82	b	0.0291	bc	45.30	b	9.13
F	6.40	b	0.97	b	13.02	c	0.099	b	17.02	b	0.0302	c	46.46	b	9.21

Description : numbers followed by same letters in the same column show no significant difference in treatment duncan test 5%. A (control), B (biofertilizer 25 kg/ha), C (biofertilizer 35 kg/ha), D (compost 5 t/ha), E (compost 5 t/ ha and biofertilizer 25 kg/ha), F (compost 5 t/ha and biofertilizer 35 kg/ha).

Soil carbon organic

The highest C-organic value (0.97%) was observed in the F treatment (combination 35 kg *Trichoderma* biofertilizer/ha and 5 t compost mixture /ha), while the lowest (0.46%) was observed for the A treatment. These C organic contents were considered low as the values were less than 1%. Application of organic matter is able to increase the nutrient contents in the soil. The organic material in the form of crop residue will be stored in the soil and the nutrients in the organic matter will taken up by plants as required by the plant so that the availability of nutrients in the soil will not quickly disappear.

According to the study of Hafifah et al. (2016), the application of *Tithonia diversifolia* green manure and cow dung significantly contributed to changes in pH, C organic, total N, available P and total K in soil. This was in line with the application F treatment (5 t compost mixture of *Tithonia*, *Gliricidia* and ground fish bone/ha) with 35 kg *Trichoderma* biofertilizer 35 kg/ha which had the highest C organic content (0.97%). Green manure is one of the kinds of organic fertilizer. According to Jasmine et al. (2008), compost has a role in increasing the organic matter because the macro element content is low. Therefore, compost can influence the increase in organic matter content when it is applied to the soil.

Soil water content

Application of compost and biofertilizer increased soil water content compared to the control treatment. The treatment that increased water content in the topsoil was application of 5 t compost/ha compost and 35 kg *Trichoderma* biofertilizer/ha. Results of analysis of variance indicated that there significant water content differences ($p<0.05$) among treatments. The lowest water content (10.98%) was observed for treatment A, while the highest water content (13.02%). The increase of water content in the soil could be caused by the water content of the compost and biofertilizers applied. The water content of the compost applied was 19%. The relatively high water content in the compost was probably generated from the fresh organic materials for the compost (*Gliricidia* leaves, *Tithonia* leaves, and cow dung). According to Baskoro (2010), water content in soils amended with compost tends to be high compared to that without compost application. Application of crop residue compost by broadcasting on soil surface can also serve as a mulch to protect the soil from sun heat. Therefore, the process of water loss due to evaporation is inhibited and the water content tends to be high.

Soil total N

Treatment F (combination of 35 *Trichoderma* biofertilizers kg/ha and 5 t ompost mixture /ha) had the highest total N content (0.099%), while the lowest total N content (0.081%) was observed for the A (control) treatment. These values, however, are considered very low. Changes in total N content was due to the release of N supplied by the compost. During decomposition, compost releases compounds in the forms of nutrients that can be taken up by plants. This will increase N content in the plants. It has been known that nitrogen involves in the process of absorption of light through the formation of chlorophyll (Pahlavi et al, 2016). According to Agyarko et al. (2013), in order to get maximum yield, organic and inorganic fertilizers should be impartialy applied to increase soil N content.

Soil available P

Treatment F (combination of 35 kg *Trichoderma* biofertilizer/ha and 5 tcompost mixture/ha) had the highest value of available P (17.02 ppm), while treatment A (control) had the lowest P value of 10.20 ppm. In addition to compost, biofertilizer was also able to increase the availability of nutrients in the soil. According to Irawan et al. (2016), the increased concentration of available P was because of the manure that affect the decomposition process so that the organic acids will assist in the release of P bound. The decomposition process is carried out by microorganisms. The decomposition process will convert organic compounds into available nutrients that are available to plants. Wahyudi (2009) reported that *Tithonia* compost had a powerful effect in reducing P absorption and increasing available P. The decrease in P absorption and the increase in available P were related to changes in Al content in the soil. The decrease in P absorption and the increase the P-available were because of the decreased content of exchangeable Al because of chelate formation by humic acid and fulvic acids. The formation causes weak reactivity Al against P. Microbes also produce phosphatase enzymes that play a role in outlining P bond to OH and H_3PO_4 which helps the decomposition of humus and make more phosphorus available to plants.

Soil total K

Results of analysis variance on total K in a variety of treatments showed a highly significant difference (Table 3). The F treatment yielded the highest C content (0.0302%) in comparison to other treatments. The C, D and E treatments yielded relative similar contents of total K (0.0292%; 0.296% and 0.0291%, respectively). However, the values were higher than those of the A and B treatments (0.0285% and 0.0276%, respectively).The increased content of K was related to the present of K *Tithonia* leaves, *Gliricidia* leaves, ground fish bone, and cow manure although in relatively small amounts. Biofertilizer as organic material was also able to support the increase of N, P and K contents. According to Ariyanto (2011), cow manure fermented with EM-4 could supply high amounts of potassium. *Tithonia diversifolia* can be used as green manure or compost for N, P, K contained in similar plants with nutrient content of manure. Its utilization can improve soil fertility, increasing organic C, N, P, and K in the soil (Purwani, 2010)

Soil CEC

Application of compost mixture with *Trichoderma* biofertilizer was able to increase cation exchange capacity of the soil. Results of analysis of variance showed significant differences ($p < 0.05$) between treatments.The F treatment resulted in the highest CEC value of 46.46 cmol/kg. The B, C, D and E treatments had relatively similar CEC values but were higher than that of treatment A with each value by 45.06 cmol/kg and 44.56 cmol/kg, 44.93 cmol/kg and 45.30 cmol/kg. The A treatment had the lowest CEC value of 40.84 cmol/kg. The above results indicate that application of organic fertilizers was able to increase soil CEC value.This is because the applied organic fertilizer underwent process of decomposition that affected soil organic matter properties. The decomposition process produced basic cations. Hartati et al. (2014) reported that, *Tithonia diversifolia* leaves NPK inorganic fertilizer significantly increased soil organic matter content, CEC value, and the weight of dry grain at harvest.

Soil exchangeable Ca

Results of analysis of variance showed no significant differences in exchangeable Ca content between treatments (Table 3). However, there were increases in exchangeable Ca contents of the B, C, D, E and F treatments compared to the A treatment (control). The highest exchangeable Ca value (9.21 ppm) was observed at the F treatment F, while the lowest value (9.09 ppm) was at the A treatment. The amounts of Ca in *Gliricidia* and *Tithonia* leaves were not as high as the amounts N, P and K. In addition, the addition of ground fish bone that was not up to 15% of the total of compostable material did not affect the availability of Ca in the soil. Other factors that could affect the availability of calcium in the soil was the absorption of the existing soil Ca by plants, and the Ca leaching. According to Ginting et al. (2013), application of *Tithonia* improved soil fertility / productivity by reducing Al, as well as improving soil pH, organic matter, N, P, K, Ca and Mg in the soil. Atekan and Surahman (2005) reported that application of *Gliricidia* prunings (*Gliricidia sepium*) into acid mineral soils improved soil chemical properties, as demonstrated by the increase in the total base cations (Ca, Mg, and K).

Plant height

At harvest (5 weeks), the F treatment (combination of 35 kg *Trichoderma* biofertilizer/ha and 5 t compos mixture/ha) produced the highest length of 154.33 cm. The lowest length of the plant was observed for the A (control) of 97.67cm. Organic fertilizera having high N content will have rapid decomposition and mineralization rates so that the nutrients required by plants are easily available. In addition to the input of the compost, biofertilizer also affected the growth of plants because of their growth hormones such as auxin, and cytokinins giberalin. Amara et al. (2015) also reported that application of farmyard manure increased the vegetative growth of potato.Based on the research results of Banner (2012); solid organic fertilizer provides the best growth due to such treatment can improve the organic C content of the soil. Increased organic C can create good physical condition for the development of roots and increases the activity of microorganisms that are beneficial for the development of the roots so the plant roots will be easier to absorb nutrients in the soil. Organic fertilizer affects the growth of plants because the organic fertilizer compounds have the nutrients available to plants. Sweet potato plant requires more nutrients nitrogen to the process of the formation of tubers.

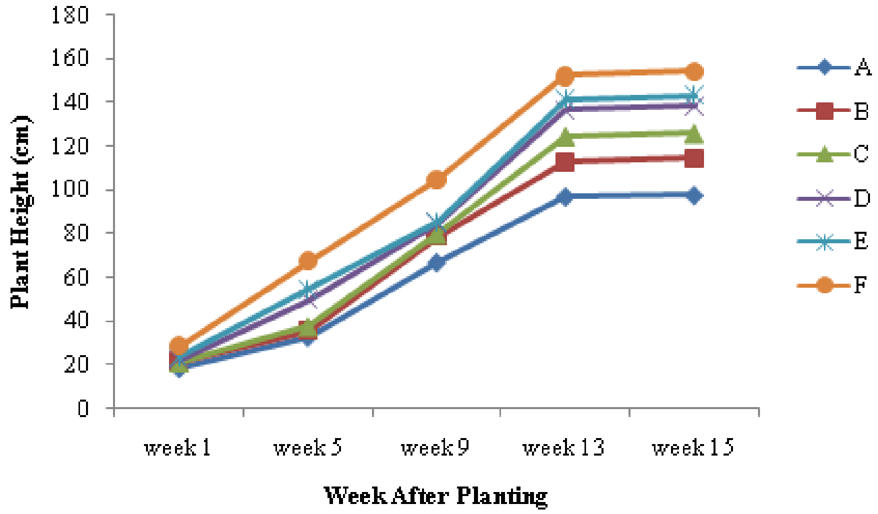

Figure 1. Plant height

Description : A (control), B (25 kg biofertilizer /ha), C (35 kg biofertilizer /ha), D (5 t/ compost ha), E (5 t compost / ha and 25 kg biofertilizer /ha), F (5 t compost /ha and 35 kg biofertilizer /ha)

Yields of sweet potato

Application of compost and biofertilizer in this study was able to increase the weight of sweet potato tuber and starch content of sweet potato tubers (Table 3). All treatments, except A, showed improvement in in yield compared to control (treatment A) that produced 32.0 t tuber/ha. Tuber weight in the treatment B was 31.7 t/ha that was almost similar to that of treatment C of 32.0 t/ha. The D and E treatments had almost similar tuber weights of 32.6 t/ha and 32.7 t/ha, respectively. The treatment F showed the highest tuber weight compared with other treatments with a value of 33.2 t/ha. Yields of tuber weight for all treatments, except A, were higher than an average yield of 30.5 t/ha reported by Center for Agricultural Research and Development (2012). This is because the application of compost mixture and biofertilizer that was able to provide the nutrients required by plants during the growth process. According to Pahlevi et al. (2016), potassium plays an important role in the enlargement process the tubers for their participation in the process of translocation of assimilates from the source to the storage section (tuber). Djalil et al. (2004) also reported that sources of potassium can increase the production of sweet potato tubers.

Table 3. Weight of sweet potato tuber and sweet potato starch content

Treatment *)	Weight of Tuber (t/ha)		Starch Content (%)	
A	30,83	a	32,50	a
B	31,70	ab	33,17	b
C	32,00	ab	33,83	c
D	32,63	bc	34,34	d
E	32,70	bc	34,55	d
F	33,30	c	35,22	e

*) see Table 2

As for tuber weight, the B, C, D, E and F treatments produced higher starch content than control (A treatment) of 32.50%. The highest starch content (35.22%) was observed for the F treatment. This value was higher than that reported by Agricultural Research and Development Institute (2012) of 32.48% for the “Sari” variety. Potassium is a key nutrient that plays an important role in starch formation. This potassium is mostly supplied by application of organic matter (Tamtomo et al., 2015).

Conclusion

Application of 5 t compost/ha and 35 kg *Trichoderma* biofertilizer/ha improved soil chemical and physical properties which in turn increased tuber weight and starch content of sweet potato by 8%.

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