JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
ISSN: 2339-076X, Volume 2, Number 4 (July 2015): 377 - 382
DOI:10.15243/jdmlm.2015.024.377

Research Article

Combined applications of biochar and legume residues to improve growth and yield of sweet potato in a dry land area of East Java

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Abstract: Production of sweet potato in the dry land areas of East Java is low because of low levels of soil fertility in the region. One of alternatives to improve crop production in the area is the use of local sources of organic matters. The purpose of this study was to investigate the effects of combined biochar and residues of *Mucuna pruriens* L., *Psophocarpus tetragonolobus* L., *Phaseolus lunatus* L. and *Dolichos lablab* LB., on growth and yield of sweet potato in dry land area of East Java. A field experiment was conducted in the farmers' field at Gondanglegi village, Bandarkedungmulyo District of Jombang. The treatments tested were mixtures of each of four legume residues and biochar with the following proportion (% dry weight), 50% legume residues + 50% biochar, 75% legume residues + 25% biochar, and 100% legume residues + 0% biochar. A control treatment with no application of legume residues and biochar was also included in the experiment. Each mixture of legume residues and biochar was applied in a 2 x 3 m field plot at a rate of 5 t/ha. Seedlings of a local variety of purple sweet potato were planted in each plot with a planting distance of 80 cm between rows and 30 cm in row. Thirteen treatments were arranged in a randomized block design with three replications. The results showed that after 4 months, application of combined biochar and residues of *M. pruriens, P.tetragonolubus, P. lunatus, D. lablab* affected soil fertility and growth of sweet potato on dry land areas. The combination of 2.5 t *D. lablab* residues/ha and 2.5 t biochar/ha produced the highest yield of sweet potato by 16.53 t/ ha, an increase of 347.9% when compared to the control treatment with no addition of legume residues and biochar.

Keywords: *biochar, M. pruriens, P.tetragonolubus, P. lunatus, D. lablab*

Introduction

Sweet potato (*Ipomoea batatas* L. Lamb.) is a source of carbohydrates that can be harvested at 3- 8 months. In addition, sweet potatoes also contain A and C vitamins and anthocyanins that are beneficial to health (Zuraida and Supriati, 2001). In East Java, sweet potato is cultivated on dry land. Nevertheless, sweet potato production in this region still low due to low levels of soil fertility in the region. The low level of fertility of the soil caused by low soil organic matter content (less than 1%), and low P-element content available due to fixation by calcium. Improvement of crop productivity can actually be done with the addition of inorganic fertilizers into the soil. However, the socio-economic conditions of local communities limit them to the use of fertilizers. In addition to low organic matter content of the soil leads to lower buffering capacity of the soil so that fertilizer use efficiency is low. Improvement of crop productivity on calcareous dry land can also be done by adding organic matter, either in the form of commercial compost, manure and cop residues. However, the socio-economic conditions of society causes cattle rising are not concentrated in one place. Livestock grazing is open (free range) in forestland due to limited grazing (Handayanto and Ariesoesilaningsih, 2002).

It is known that organic matters have two main functions, namely the direct supply of nutrients through the decomposition process, and indirectly increase the levels of soil organic matter that can improve soil physical properties and regulate the supply of nutrients later in the day (Handayanto et al., 1994). However, the availability of organic material that is popular in the community, such as crop residues, is very limited. Regarding the above problems, it is necessary to find other sources of organic materials that are available for "in-situ". The results of exploration diversity of flora on dry land of Brantas watershed conducted by Arisoesilaningsih et al. (2001) showed that at least 260 species of plants found, among *Mucuna pruriens* L., *Psophocarpus tetragonolobus* L., *Phaseolus lunatus* L. and *Dolichos lablab* LB., that are resistant to drought and can grow rapidly. The plant efficiency in converting sunlight energy into chemical energy and ability of free N_2 fixation has also been reported by Arisoesilaningsih et al. (2001).

Results of studies conducted by Pratikno et al. (2001) Alhasni and Handayanto (2002), Lindawati and Handayanto (2002), Sunaryo and Handayanto (2002) and Joko (2006) showed that a variety of local biomass plant that grows throughout the year on dry land as organic matter could increase the productivity of land in the land dry. However, the addition of fresh organic matter (biomass) continuously to maintain soil fertility can increase the amount of carbon emissions into the atmosphere as a result of the decomposition of organic material (Widowati et al., 2011). Therefore, we need an effort to reduce carbon emissions increase due to the decomposition of organic matter and at the same time maintaining soil fertility. One alternative is to combine organic materials with biochar.

Biochar is charcoal porous substance material derived from living organisms (Gani 2009). Research results Widowati et al (2012) showed that the use of biochar from manure and litter to increase rice production and reduce the need for fertilizers Sukartono et al. (2012) states that the land is treated with biochar consistently improve the content of C is also more stable than the land that is not treated with the addition of biochar. The purpose of this study was to investigate the effects of combined biochar and residues of *Mucuna pruriens* L., *Psophocarpus tetragonolobus* L., *Phaseolus lunatus* L. and *Dolichos lablab* LB., on growth and yield of sweet potato on dry land.

Materials and Methods

A field experiment was conducted at Gondanglegi village of Bandarkedungmulyo District, Jombang from September 2014 to May 2015. Soil of the area is classified as an Entisol with the following characteristics: pH of 4.2, 0.36% organic C, 0.08% total N, 0.62% organic matter, 30.32 mg total P / kg, 0.11% total K, and CEC of 11.06 me / 100g. Materials used for this study were legume residues of *M. pruriens*, *P.tetragonolubus*, *P. lunatus,* and *D. lablab*, rice husk biochar, and local variety of purple sweet potato. Chemical composition of legume residues used for this study is presented in Table 1. The rice husk biochar that was obtained the laboratory of Rural Bioenergy of Tribhuwana Tunggadewi University of Malang has the following characteristics; 1.39% organic-C, 0.36% total-N, 2.41% organic matter, 0.12% P, and 0.74% K.

Table 1. Chemical composition of legume residues used for this study

Composition	Legume Residues *)			
	Mp	Pt	Pl,	Dl
C (%)	32.42	29.49	32.07	34.00
N (%)	3.24	3.84	2.47	3.17
C/N	10	8	13	11
P (%)	0.29	0.37	0.20	0.28
K (%)	0.88	0.68	0.54	0.75

*) Mp = *M. pruriens*, Pt = *P. tetragonolubus*, Pl = *P. lunatus*, Dl = *D. lablab*

M. pruriens, P. tetragonolubus, P. lunatus, and *D. lablab* residues were air-dried for 7 days, chopped to 2-4 cm, and then mixed with biochar in accordance with the respected treatments. The treatments tested were mixtures of each of four legume residues and biochar with the following proportion (% dry weight), 50% legume residues + 50% biochar, 75% legume residues + 25% biochar, and 100% legume residues + 0% biochar. A control treatment with no application of legume residues and biochar was also included in the experiment. Thirteen treatments were arranged in a randomized block design with three replications. Each mixture of legume residues and biochar was applied in a 2 x 3 m field plot at a rate of 5 t/ha. Seedlings of a local variety of purple sweet potato were planted in each plot with a planting distance of 80 cm between rows and 30 cm in row. Before planting the sweet potato, each plot received 25 kg N / ha (in the form of urea), 20 kg P_2O_5 / ha (in the form of superphosphate 36), and 25 kg K_2O / ha (in the form of KCl) as basal fertilizers. During the experiment, weed control, pest control, and irrigation were carefully managed to ensure that these factors did not limit plant growth. Plant growth parameters measured at 30, 60, 90 and 120 days were stem length, number of primary branches per plant, and number of leaves.

Fresh tuber weight, tuber number and weight of stover (wet and dry), and the carbohydrate content in the tubers were measured at harvest (4 months after planting). The contents of total N and available P in soil were also measured at harvest. The data obtained were subjected to analysis variance followed by 5% last significance different test.

Results and Discussion

Soil pH, nitrogen, and phosphorus

Application of combined biochar and legume residues did not significantly influence soil pH, but it significantly influenced the contents of soil available-P and mineral-N soil after 4 months (at harvest) (Table 2). The highest content of NH_4^+ (62.34 mg kg) was observed for 100Pl + 0B treatment, while the highest content of NO_3^- (69.35 (mg/kg) was observed for 100Dl + 0B treatment. This difference seems to be due to the different quality of legume residues applied. Data presented in Table 1 show that the N content of *D. lablab* residues is higher than that of P. lunatus. Handayanto et al. (1995) suggested that the release of nutrients from organic matter through the process of decomposition and mineralization associated with the quality of the organic material itself.

Table 2. Effect of legume residue and biochar application on pH, N content and P content of the soil after 120 days.

Treatments*)	pH		N-NH_4^+ (mg/kg)		N-NO_3^- (mg/kg)		Available P (mg/kg)	
Control	4.50	a	5.52	a	5.52	a	53.18	ef
50 Mp + 50 B	4.83	a	12.00	ab	5.42	a	41.36	bcde
75 Mp + 25 B	4.80	a	12.67	ab	10.75	abc	33.98	ab
100 Mp + 0 B	4.89	a	13.79	b	14.18	bc	42.43	bcd
50 Pt + 50 B	4.93	a	14.30	b	46.09	cd	52.16	def
75 Pt + 25 B	5.10	a	24.02	c	5.42	a	38.04	abc
100 Pt + 0 B	4.78	a	46.88	d	6.36	ab	70.23	h
50 Pl + 50 B	4.70	a	15.76	b	14.97	c	43.89	bcde
75 Pl + 25 B	4.57	a	52.19	d	65.41	e	32.19	a
100 Pl + 0 B	5.27	a	62.34	e	62.25	de	66.48	gh
50 Dl + 50 B	4.93	a	61.00	e	65.41	e	45.36	cde
75 Dl + 25 B	4.52	a	47.28	d	55.95	d	59.99	fg
100 Dl + 0 B	4.56	a	50.12	d	69.35 f	ef	63.52	gh

Figures accompanied by the same letter in the same column indicate no significant different at 5% level.
*) Control= no added legume residue + biochar, 50Mp+50B = 50% *M.pruriens* + 50% biochar, 75Mp+25B = 75% *M.pruriens* + 25% biochar, 100Mp+0B = 100% *M.pruriens*, 50Pt+50B = 50% *P.tetragonolubus* + 50% biochar, 75Pt+25B = 75% *P.tetragonolubus* + 25% biochar, 100Pt+0B = 100% *P.tetragonolubus* , 50Pl+50B =50% *P.lunatus* + 50% biochar, 75Pl+25B = 75% *P.lunatus* + 25% biochar, 100Pl+0B = 100% *P.lunatus* , 50Dl+50B= 50% *D.lablab* + 50% biochar, 75Dl+25B = 75% *D.lablab* + 25%t biochar, 100Dl+0B= 100% *D.lablab*

Frankenberger and Abdelmagid (1985) noted that the content of N required to immediately occur N mineralization should be higher than 1.73% and the value of C / N ratio is lower than 20. Results of a study conducted by Dewi et al. (2014) showed that pruning of *D. lablab* and *P. lunatus* could replace urea fertilizer in the provision of N by 66% and 36%, respectively. This means that *D.lablab* and *P.lunatus* biomass can minimize the risk of N losses due to leaching or volatilization. The highest content of soil available P (70.23 mg / kg) was measured at treatment 100Pt + 0B treatment. Data presented in Table 1 indicate that the P content of *P. tetragonolubus* is higher than that of other legume residues. As reported by Arisoesilaningsih and Soejono (2015), application of *P.tetragonolubus* increased availability of soil P in the dry land area of South Malang. However, the rate of mineralization of this organic material was relatively low because of its relatively high C / P ratio.

Growth of sweet potato

The longest sweet potato stem (19.96 cm) was observed for 75Pl + 25B treatment at 120 days (Table 3). Statistical analysis indicated that application of combined biochar and legume residues significantly ($p<0.05$) affected the sweet potato stem length at 30, 60, 90, and 120 days. The stem length of all treatments increased considerably after 30 days, and then decreased after 90 days (Table 3). This decrease was because of the drying up of the stem after 60 days. All treatments resulted in the increase of primary branches from 30 to 60 days. At 90 days, the number of primary branches of the control and

100Dl + 0B treatments increased, but 120 days all treatments experienced the decrease in the number of primary branch as the plants were drying up (Table 4). Treatment 75 PL + 25 B on the observation of 120 days was the best treatment with the highest number of primary branches.

Table 3. Effect of legume biomass and biochar application on sweet potatoes stem length after 120 days.

Treatments*)	Length of stem (cm)							
	30 days		60 days		90 days		120 days	
Control	96.13	abc	140.21	a	127.67	ef	10.22	a
50 Mp + 50 B	130.60	ef	217.13	cde	118.00	cdef	18.51	de
75 Mp + 25 B	90.75	a	223.29	cde	120.67	def	17.12	cde
100 Mp + 0 B	130.13	ef	136.90	a	90.00	a	18.93	de
50 Pt + 50 B	118.93	cde	196.58	bcd	90.71	ab	10.40	a
75 Pt + 25 B	151.33	f	213.55	cde	88.67	a	12.73	ab
100 Pt + 0 B	115.43	bcde	212.98	cde	96.80	abc	17.26	cde
50 Pl + 50 B	106.20	abcd	238.43	de	136.00	f	13.00	ab
75 Pl + 25 B	104.94	abcd	223.09	cde	100.26	abcd	19.96	e
100 Pl + 0 B	137.33	ef	187.15	bc	92.12	ab	14.94	bcd
50 Dl + 50 B	119.74	de	256.00	e	130.00	ef	18.62	de
75 Dl + 25 B	130.69	ef	156.60	ab	111.46	abcde	13.79	abc
100 Dl + 0 B	94.67	ab	208.00	cd	113.00	bcde	17.14	cde

Remarks: *) See Table 2, Figures accompanied by the same letter in the same column indicate no significant different at 5% level.

Table 4. Effect of legume biomass and biochar application on the number of primary branch of sweet potato after 120 days.

Treatments*)	Number of primary stems							
	30 days		60 days		90 days		120 days	
Control	2.90	a	3.86	a	4.07	abc	1.85	ab
50 Mp + 50 B	4.50	cde	5.59	cd	3.67	ab	2.40	bcd
75 Mp + 25 B	3.59	abc	5.37	bcd	4.02	ab	2.75	cd
100 Mp + 0 B	4.09	bcd	5.66	de	3.73	ab	2.86	cde
50 Pt + 50 B	5.30	ef	7.45	f	3.59	ab	2.22	bc
75 Pt + 25 B	4.57	def	4.61	abc	3.52	ab	1.85	ab
100 Pt + 0 B	4.10	bcd	6.76	ef	4.13	abc	2.16	bc
50 Pl + 50 B	3.85	abcd	4.37	ab	3.16	a	1.12	a
75 Pl + 25 B	3.43	ab	5.93	de	5.10	cd	4.35	g
100 Pl + 0 B	4.27	bcd	5.56	cd	4.07	abc	3.14	def
50 Dl + 50 B	4.73	def	5.79	de	4.46	bc	3.14	def
75 Dl + 25 B	5.42	ef	5.91	de	4.13	abc	3.66	fg
100 Dl + 0 B	5.52	f	4.98	abcd	6.12	d	3.56	ef

Remarks: *) See Table 2, Figures accompanied by the same letter in the same column indicate no significant different at 5% level.

The number of sweet potato leaves in all treatments increased at 30-60 days, but it then decreased at 90-120 day (Table 5). This decrease is due to sweet potato leaves begin to turn yellow and fall off. The 50 Dl+50 B treatment produced the highest amount of leaves (122 pieces).

Yield of sweet potato

Statistical analyses showed significant differences results on the value of the number of tubers, tuber weight, weight stover (wet and dry), and production, while the carbohydrate levels in all treatments showed no significant differences (Table 6).The number of tubers produced in each treatment was not followed by the weight of tubers per plant. The number of tubers in the control, 50Pt+50 B, 100 Pt+0B, 75Pl+25B and 75 Dl+25B treatments were higher than that on other treatments. However, the high number of tubers was not followed by the weight of tubers per plant. Dewi et al. (2014) reported that in relation of the variations in plant growth, the addition of organic matter provided a significant influence on the weight of maize canopy. In this case, dose combination treatment of organic material affected the weight of stover (wet and dry) of the sweet potato crop. The Dl50+B50 treatment produced the highest stover weight when compared to other treatments. This was because the biomass of *D. lablab* that was able to release the N-mineral more than legume residues used in this study, which in turn influenced the crop N uptake (Dewi et al., 2014). Data of the average yield of sweet potato (Table 6) show that the lowest yield (3.69 t / ha) was observed at the control treatment, and the highest (16.53 t / ha), was for the DL50+50B treatment amounting an increase of 347.9% compared to the control treatment.

Table 5. Effect of legume biomass and biochar application to the amount of sweet potato leaves after 120 days.

Treatments*)	Number of Leaves							
	30 days		60 days		90 days		120 days	
Control	54.93	ab	149.00	a	117.86	a	92.33	a
50 Mp + 50 B	67.60	bc	151.67	a	125.08	a	93.33	a
75 Mp + 25 B	66.07	bc	209.24	abc	200.26	c	109.75	abc
100 Mp + 0 B	92.20	d	174.85	ab	136.71	ab	97.20	ab
50 Pt + 50 B	90.67	d	163.00	bc	131.68	a	115.62	bc
75 Pt + 25 B	93.78	d	170.70	a	127.56	a	96.00	a
100 Pt + 0 B	70.80	bc	139.67	abc	117.47	a	105.00	abc
50 Pl + 50 B	47.80	a	154.67	abc	135.35	ab	105.33	abc
75 Pl + 25 B	54.35	ab	159.00	c	135.95	ab	117.67	c
100 Pl + 0 B	80.27	cd	151.00	c	153.08	ab	120.00	c
50 Dl + 50 B	67.27	bc	192.33	c	190.40	c	122.00	c
75 Dl + 25 B	93.67	d	160.33	abc	146.20	ab	104.26	abc
100 Dl + 0 B	63.50	abc	163.56	c	170.99	bc	121.00	c

Remarks: *) See Table 2, Figures accompanied by the same letter in the same column indicate no significant different at 5% level.

Table 6. Effect of legume biomass and biochar application to the production of sweet potato after 4 months

Treatments*)	Number of tuber		Weight of tuber		Yield (t/ha)		Carbohydrate (%)	
Control	5	b	88.6	a	3.69	a	30.92	a
50 Mp + 50 B	4	ab	132.5	ab	5.52	ab	31.89	a
75 Mp + 25 B	3	ab	145	ab	6.04	ab	33.23	a
100 Mp + 0 B	2	a	167	bc	6.95	bc	33.49	a
50 Pt + 50 B	5	b	312.4	e	13.01	e	33.69	a
75 Pt + 25 B	2	a	181.85	bc	7.57	bc	31.51	a
100 Pt + 0 B	5	b	261.8	de	10.90	de	28.32	a
50 Pl + 50 B	3	ab	128.7	ab	5.36	ab	28.62	a
75 Pl + 25 B	5	b	245.4	d	10.22	d	33.37	a
100 Pl + 0 B	4	ab	208.4	cd	8.68	cd	28.02	a
50 Dl + 50 B	4	ab	396.8 f	f	16.53	f	32.64	a
75 Dl + 25 B	5	b	157	bc	6.54	ab	32.30	a
100 Dl + 0 B	4	ab	317.3	e	13.22	e	33.31	a

Remarks: *) See Table 2, Figures accompanied by the same letter in the same column indicate no significant different at 5% level.

Results of carbohydrate content analysis indicated that the 100Pl+0B treatment yielded the lowest carbohydrate content (28.02%), while the 75Pl+25B treatment produced the highest carbohydrate content (33.37%). Those carbohydrate content values were higher than previous studies of 26.99% reported by Ginter et al. (2011).

Conclusion

Application of combined biochar and residues of *M. pruriens, P.tetragonolubus, P. lunatus, D. lablab* affected soil fertility and growth of sweet potato on dry land areas. The combination of 2.5 t *D. lablab* residues/ha and 2.5 t biochar/ha produced the highest yield of sweet potato by 16.53 t/ ha, an increase of 347.9% when compared to the control treatment with no addition of legume residues and biochar.

Acknowledgements

The first two authors thank the Indofood Research Nugraha 2014/2015 for financial support to undertake this study to fulfill the requirement of bachelor of agricultural sciences at Brawijaya University.

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