JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 9, Number 2 (January 2022):3227-3236, doi:10.15243/jdmlm.2022.092.3227
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

Utilization of *Tithonia diversifolia* and sugarcane leaves to improve soil properties and plant growth on a degraded sandy soil of Malang, East Java

Yulfita Farni[1,2*], Retno Suntari[3], Sugeng Prijono[3]

[1] Postgraduate Program, Faculty of Agriculture, Brawijaya University, Jl. Veteran No 1, Malang 65165, Indonesia
[2] Faculty of Agriculture, Jambi University, Jl. Jambi-Ma Bulian KM 15 Mendalo Darat Jambi 36361 Indonesia
[3] Faculty of Agriculture, Brawijaya University, Jl. Veteran No 1, Malang 65165, Indonesia

*corresponding author: yulfitafarni@unja.ac.id

Article history:
Received 24 August 2021
Accepted 27 October 2021
Published 1 January 2022

Keywords:
nutrient uptake
sandy soil
sugarcane leaves
Tithonia diversifolia leaves

Abstract

A study on the addition of organic matter of different qualities was carried out to improve plant growth on a degraded sandy soil of Bambang Village, Wajak Malang, East Java. Two potential sources of organic matter in Bambang Village are *Tithonia diversifolia* and sugarcane leaves. This study aimed at elucidating the changes in some chemical properties of a degraded sandy soil of Malang, East Java, and nutrient uptake and growth of maize plants by applying mixtures of *Tithonia diversifolia* and sugarcane leaves of different quality. Treatments tested in this study were mixtures of *Tithonia diversifolia* leaves and sugarcane leaves at various proportions (%w/w), i.e. 100% *Tithonia diversifolia* leaves (T1), 100% sugarcane leaves (T2), 75% *Tithonia diversifolia* leaves + 25% sugarcane leaves (T3), 50% *Tithonia diversifolia* leaves + 50% sugarcane leaves (T4); without organic matters (T6), and control, without organic matter and inorganic fertilizers (T7). The results showed that the application of *Tithonia diversifolia* and sugarcane leaves affected soil pH, exchangeable soil bases, maize growth, and nutrient uptake. Nutrients taken up by maize plants significantly increased with the addition of *Tithonia diversifolia* leaves, either alone or in combination with sugarcane leaves. The application of 100% sugarcane leaves did not significantly affect maize growth and nutrient uptake.

To cite this article: Farni, Y., Suntari, R. and Prijono, S. 2022. Utilization of *Tithonia diversifolia* and sugarcane leaves to improve soil properties and plant growth on a degraded sandy soil of Malang, East Java. Journal of Degraded and Mining Lands Management 9(2):3227-3236, doi:10.15243/jdmlm.2022.092.3227.

Introduction

Sustainable agriculture on sandy soils is generally constrained by low water and nutrient holding capacity and rapid mineralization (Uzoma et al., 2011; Castan et al., 2016). These constraints are caused by the sandy soil containing coarse soil particles so that macropores are dominant and few micropores. Sandy soils also have low clay and organic matter content (Hou et al., 2013) and low nitrogen and phosphorus nutrients (Ro et al., 2016). Bambang Village, Wajak District, Malang, East Java, has an area of 1761 ha, which is 18.62% of the Wajak district area (Central Bureau of Statistics, 2020). Land use in this area is for the cultivation of seasonal crops and plantation crops (Rokhmawati, 2014). The decline in agricultural productivity in Bambang Village is caused by low organic matter, low nutrient content of N, P, K and sandy loam textured soil, chemical and physical characteristics of soil in Bambang Village, Wajak District, Malang, East Java reported in (Farni et al., 2021). Low water and nutrient retention capacity in sandy soils cause nutrients to be easily lost, especially N, through leaching (Bharwaj et al., 2007). In intensive farming systems, mechanical and agrochemical inputs are generally used to stimulate agricultural production. Efforts that have been made by local farmers in Bambang village to increase land productivity are by using inorganic fertilizers, especially urea fertilizer, which they are more familiar with. Some farmers have also used organic fertilizers such as manure and rice husks. The continuous use of inorganic fertilizers with unbalanced doses will cause soil damage and environmental pollution (Liu et al., 2010; Irfan et al., 2021). The low productivity of sandy soil in Bambang Village with the characteristics of slightly acidic pH, low organic matter, low N, P, K nutrients, low cation exchange capacity and medium bulk density, can be improved by adding organic matter, which is widely available in the village

The application of organic matter to soil is a common practice in sustainable agriculture (Repullo et al., 2012) because soil organic matter is very important to maintain ecosystem productivity (Palm et al., 2001; Zhao et al., 2016). The importance of organic matter in maintaining ecosystem productivity is because organic matter can improve the physical, chemical and biological properties of the soil as well as as a source of plant nutrients (Mrabet et al., 2001; Diacono and Montemurro, 2010). Soil organic matter is crucial for maintaining soil quality as it stabilizes soil structure against erosive forces and increases water capacity and nutrient availability (Wang et al., 2008). Alternative organic matter sources that can be used to solve the problem of soil fertility in Bambang Village are local plant resources. One of the potential biomass as green manure in Bambang Village is *Tithonia diversifolia*. In addition to *Tithonia diversifolia*, organic material that has the potential locally is sugarcane leaf litter, as illustrated by the area of sugarcane plantations in East Java of 170,950 ha with a production of 925,950 tons, while production in Malang Regency is 234,250 (Central Bureau of Statistics, 2020). Sugarcane leaf litter, when returned to the soil, will reduce the amount of N fertilization by 40 kg $ha^{-1}year^{-1}$ (Meier et al., 2003) due to the immobilization of N so as to reduce N losses due to leaching and evaporation.

The use of *Tithonia diversifolia* as green manure has spread in parts of Africa, Latin America and Asia because of its fast growth cycle, high nitrogen fixation capacity and P content, and ability to recycle and supply large amounts of nutrients for subsequent crops (Scrase et al., 2019). The utilization of *Tithonia diversifolia* as green manure because this plant contains macro nutrients that have the potential to improve soil fertility (Mucheru-Muna et al., 2014; Susanti et al., 2017; Kaboneka et al., 2021); improving soil fertility by giving *Tithonia diversifolia* will have implications for increasing plant growth and yield. This has been proven by several research results on several plants, namely maize (Hidayat et al., 2018), carrots (Jeptoo et al., 2013), sweet potatoes (Agbede et al., 2014), broccoli (Rahardian et al., 2017). Nutrients released and their cycles from sources of organic matter added to the soil are very important in maintaining soil fertility and crop production. Nutrients from added organic matter exist in various forms, namely available (can be absorbed up directly by plants without the need for further chemical or biological conversion), unavailable, released quickly in the first year or available for planting for a longer time (Smith et al., 2014).

The pattern of nutrient release from organic matter depends on the amount of nutrients stored in the form of available, unavailable, sooner or later (quality of organic matter) (Vanlauwe and Giller, 2006; Mockeviciene et al., 2021), soil and weather conditions (Nemecek et al., 2011). For example, the release of N from the source of organic matter with low N content, high lignin and polyphenols, is usually slow. Therefore, a strategy for effectively administering organic matter is needed so that the release of nutrients is in accordance with the nutrient needs of the plant. This can be done by combining high-quality and low-quality organic matter to speed up the decomposition and mineralization of organic matter (Mapfumo et al., 2007). Low-quality organic matter has a low N content, high C/N, and lignin ratio; this causes the decomposition process to run slowly, while high-quality organic matter has a relatively high N content, low C/N ratio, and low lignin so that it decomposes rapidly when given as organic matter in the soil. Sugarcane leaves include low-quality organic matter due to their low N content (1%) and high C/N ratio of 24. Tithonia is classified as a high-quality organic material (Opala, 2020; Aboyeji, 2021; Puteri et al., 2021) with N content of 4.17%, lignin 8.89%, and a C/N ratio of 7.02. Combining high-quality organic matter with low quality is expected to meet the nutrients according to the time the plants need. Tithonia and sugarcane leaves are organic matter that is widely available in the village of Bambang. Information on the use of *Tithonia diversifolia* with sugarcane leaves in dry lands with sandy loam soil texture is still limited. On this basis, this study was aimed to examine the effects of combinations of organic matters of different quality on the chemical properties of sandy loam soil and the growth of maize and its nutrient uptake.

Materials and Methods

A pot experiment was conducted in the glasshouse of the Indonesian Legumes and Tuber Crop Research Institute (BALITKABI), Kendalpayak, Pakisaji, Malang, from February to July 2019. Organic matters used for this study were *Tithonia diversifolia* biomass (young leaves and twigs) that were collected from a field in Bambang Village, Wajak District, Malang. For the experiment, the fresh organic matters were mixed (w/w) with the proportions of 100% *Tithonia diversifolia* leaves (T1); 100% sugarcane leaves (T2; 75% Tithonia leaves + 25% sugarcane leaves (T3), 50% *Tithonia diversifolia* leaves + 50% sugarcane leaves (T4), and 25% *Tithonia diversifolia* leaves + 75% sugarcane leaves (T5). All mixtures were subjected to their chemical composition analysis, i.e. nitrogen, carbon, phosphorus, lignin, ash, and polyphenol contents, following the standard methods used by Soil Laboratory of Brawijaya University.

Table 1. Composition of organic matters used in this study.

Organic Matters	**C** (%)	**N** (%)	**K** (%)	**P** (%)	**C/N** ratio	**Lignin (L)** (%)	**Polyphenol (PL)** (%)	**Cellulose** (%)	**L/N** ratio	**C/P** ratio	**(L+PL)/N** ratio	**Ash** (%)
100% *Tithonia diversifolia* leaves (T1)	28.08	4.17	3.62	0.41	7.02	8.89	7.82	15.92	2.13	71.6	4.03	1.8
100% sugarcane leaves (T2)	35.01	1.00	1.23	0.15	39.35	24.26	6.69	34.14	24.26	235.9	34.69	1.33
75% *Tithonia diversifolia* leaves + 25% sugarcane leaves (T3)	42.64	3.37	2.17	0.33	12.65	7.76	8.67	17.92	2.30	130.8	4.88	0.5
50% *Tithonia diversifolia* leaves + 50% sugarcane leaves (T4)	32.36	2.53	2.29	0.28	12.8	8.40	7.01	24.02	3.32	115.9	6.1	1.14
25% *Tithonia diversifolia* leaves + 75% sugarcane leaves (T5)	37.26	1.42	1.75	0.24	26.24	7.58	6.46	34.20	5.33	155.9	9.89	1.72

Mixing of *Tithonia diversifolia* leaves, and sugarcane leaves in various proportions resulted in various quality mixtures (Table 1). Each of the five organic matter mixtures (T1, T2, T3, T4 and T5) was applied to 10 kg of topsoil (0-20 cm) that passed through a 2 mm sieve in a 15 kg plastic pot. The soil used of this study was collected from Bambang Village, Wajak, Malang (8°07′26″S 112°48′53″E / 8.12388°S 112.81471°E), with Entisol soil order. The soil has the following characteristics pH H_2O = 5.1, pH KCl = 4.9, organic C = 1.89%, total N = 0.19%, C/N ratio =10, total P (Bray 1) = 5.87 mgkg^{-1}, exchangeable K= 0,16 cmol kg^{-1}, exchangeable Na = 0.05 cmol kg^{-1}, exchangeable Ca = 3.80 cmol kg^{-1}, exchangeable Mg = 1.37 cmol kg^{-1}, cation exchange capacity = 23.06 cmol kg^{-1}, base saturation = 3%, N-NH_4^+ = 2.10 mg kg^{-1}, N-NO_3^- = 14.31 mgkg^{-1}, bulk density = 1.07 g cm^{-3}, specific gravity= 2.25 g cm^{-3}, porosity = 52.4%, moisture content pF 2.5 = 26%, moisture content pF 4.2 = 7%, soil texture of sandy loam with 70% sand, 20% silt and 10% clay contents.

The five organic matter mixtures (T1, T2, T3, T4 and T5) along with one treatment without organic matter (T6) and one control (T7) were arranged in a completely randomized design with four replications. After two weeks of organic matter application, three maize seeds of Pertiwi hybrid were planted in each pot containing 10 kg soil. At the same time, 150 kg urea ha^{-1}, 100 kg SP36 ha^{-1} and 75 kg KCl ha^{-1} were applied to each pot as basal fertilizers. At 30 days after planting 150 kg urea ha^{-1} was further applied to each pot. A week after planting, thinning was done, leaving one plant with the best growth. Watering was supplied daily according to field capacity conditions. Plant height, number of leaves, and stem diameter were measured at 3, 4, 5, 6, 7 and 8 weeks after planting. At harvest (8 weeks after planting), fresh weight stover, dry weight, P concentration, and K concentration of plant stover, as well as soil chemical properties, were measured. Soil chemical analysis was carried out based on soil and plant analysis procedures (Agricultural Research and Development Agency, 2012). The soil chemical properties analyzed after harvest were soil pH (H_2O 1:1) with a pH meter, total N with Kjeldahl method, organic C with Walkley and Black method, cation exchange capacity (NH_4OAc pH 7.0), available P extracted using Bray-1 solution, and exchangeable K, Ca, Mg and Na were extracted using ammonium acetate extract. Nutrient uptake by maize stover was calculated as follow: nutrient uptake (mg plant^{-1}) = nutrient content in plant (%) x plant dry weight (mg plant^{-1}). Data obtained were subjected to an analysis of variance at the 95% confidence level (α=5%), followed by the DMRT (Duncan Multiple Range Test) at the 5% level. All statistical analyses were carried out with the Genstat package program.

Results and Discussions

Soil chemical properties

The application of tithonia and sugarcane leaves in several proportions insignificantly affected soil pH (Table 2). In general, the application of organic matters tended to reduce soil pH, except for the application of 50% tithonia leaves + 50% sugarcane leaves (T4), soil pH increased by 0.02 compared to the control; this pH was significantly different from the T6 treatment (inorganic fertilizers only). In the T6 treatment, soil pH decreased by 0.28 compared to the control. The greatest decrease in soil pH in the T6 treatment was caused by the immediate hydrolysis of inorganic fertilizers to produce H^+ ions which lowered the soil pH.

The decrease in soil pH is due to the application of organic matters because the organic matters produce organic acids during the decomposition process; these organic acids donate H^+ from the carboxyl group and lower soil pH (Hanc and Chadimova, 2014; Devi and Kwairakpam, 2019). However, if organic matters are applied to acidic soils with high exchangeable Al content, they will increase soil pH because organic acids will bind Al to form complex compounds (chelate), so Al is not further hydrolyzed (Mockeviciene et al., 2021). The application of organic matter from tithonia and sugarcane leaves did not significantly affect the organic C and total N in the soil studied.

Table 2**.** Chemical properties at the end of harvest due to the combination of tithonia leaves and sugarcane leaves on sandy loam soil.

Treatments	**pH (H_2O)**	**Organic C (%)**	**Total N (%)**	**C/N ratio**	**P-Bray1 (mg kg^{-1})**	**K**	**Na (cmol kg^{-1})**	**Ca**	**Mg**
T1	5.29 ab	1.43	0.17	8.16 ab	2.86 a	0.14 b	0.36 b	4.29 c	1.52 abc
T2	5.27 ab	1.73	0.17	9.74 b	3.73 ab	0.12 ab	0.28 ab	3.44 a	4.25 d
T3	5.30 ab	1.32	0.17	7.59 a	2.98 a	0.13 ab	0.37 b	3.71 abc	1.35 ab
T4	5.47 b	1.44	0.16	8.64 ab	5.51 b	0.11 a	0.30 ab	3.55 ab	3.38 cd
T5	5.44 ab	1.30	0.17	7.30 a	3.49 a	0.11 a	0.32 ab	4.22 bc	2.52 bcd
T6	5.17 a	1.41	0.18	7.62 a	2.60 a	0.12 ab	0.32 ab	4.15 bc	2.07 abc
T7	5.45 ab	1.20	0.17	7.04 a	2.10a	0.10 a	0.26 a	3.34 a	0.51 a

Note: Numbers followed by the same lowercase letters in the vertical direction were tested to be no different based on the DMRT test at a significance level of 5%. T1 = 100% *Tithonia diversifolia* leaves; T2 = 100% sugarcane leaves; T3 = 75% *Tithonia diversifolia* leaves + 25% sugarcane leaves; T4 = 50% *Tithonia diversifolia* leaves + 50% sugarcane leaves; T5 = 25% *Tithonia diversifolia* leaves + 75% sugarcane leaves; T6 = without organic matter; T7 = control.

The highest total N content was found in T6 and T4 treatments (Table 2). The highest C/N ratio was found in T2 treatments, which was significantly different from the C/N ratio in T3, T5, T6 and T7 treatments. The increase in organic C after the addition of tithonia and sugarcane leaves ranged from 0.12 to 0.52% compared to the control**;** the highest increase in organic C was found in the T2 treatment. The accumulation of organic C in the soil was greater in the T2 treatment than in the T1 treatment (100% tithonia leaves) and the combination of tithonia and sugarcane leaves (T3 and T4) treatments. This difference was associated with variations in the amount of C input and the chemical composition of organic matter (Table 1). The low accumulations of soil C in the T1 treatment (100% tithonia leaves), and the combination of tithonia and sugarcane leaves (T3 and T4 treatments), and the control (T7) was due to the low C content and low C/N ratio of tithonia leaves. Microorganisms prefer substrates with low C/N ratios, which decompose faster than substrates with high C/N ratios (Leifeld et al., 2002; Dignac et al., 2005). Nisar and Benbi (2020) also stated that the high L/N ratio in straw compost also affected C stabilization in the soil. In this study, the T2 treatment showed the highest L/N ratio compared to other treatments (Table 1).

The lowest L/N ratio (2.13) was indicated by the T1 treatment (100% tithonia leaves). Meanwhile, the proportion of 75% tithonia leaves + 25% sugarcane leaves (T3), 50% tithonia leaves + 50% sugarcane leaves (T4), and 75% sugarcane leaves + 25% tithonia leaves (T5), had L/N ratios of 2.30, 3.32 and 5.33, respectively (Table 1). Net C storage in soil depends on the transformation of C input into soil organic matter and mineralization of soil organic matter through microbial decomposition (Baldock and Skjemstad, 2000). Shisanya et al. (2009) reported that the application of *Tithonia diversifolia* biomass increased soil organic carbon. The available soil P was significantly increased by the administration of tithonia and sugarcane leaves. The soil available P ranged from 2.10-5.51 mg kg^{-1} (Table 2).

The combination of 50% tithonia leaves and 50% sugarcane leaves (T4) recorded the highest soil available P of 5.51%. This result was significantly different from T1, T3, T5, T6 and the control. The increase in soil available P in T4 was 92.65%, 84.89%, 57.87%, 111.92% and 162.38%, respectively, compared to T1, T3, T5, T6 and T7 treatments. The application of tithonia and sugarcane leaves increased the exchangeable bases (K, Na, Ca, Mg) compared to the control treatment. The exchangeable K ranged from 0.10-0.14 cmol kg^{-1} soil, Na 0.28-0.37 cmol kg^{-1} soil, Ca 3.34-4.29 cmol kg^{-1} soil and Mg 0.51-4.25 cmol kg^{-1} soil (Table 2). The exchangeable K in the soil treated with 100% tithonia leaves increased by 40% and 27.27% compared to control and T4, respectively. The exchangeable Na in the soil of T1 and T3 treatments increased by 38.46% and 26% compared to the control (Table 2). The exchangeable Ca in the soil of T1 increased by 28.44% and 24.70% compared to control and T2, respectively. The highest exchangeable Mg (4.25 cmol kg^{-1} soil) was recorded in the T2 treatment (Table 2); such effect was significantly different from other treatments.

The increase in soil available P and exchangeable bases in this study proved that the application of *Tithonia diversifolia* and sugarcane leaves could increase soil productivity. This is related to the chemical composition of the biomass besides containing macro elements, such as N, P and K, *Tithonia diversifolia* leaves also contains Ca and Mg. The research of Adekiya et al. (2019) showed that *Tithonia diversifolia* contained C = 28.6%, N = 3.75% P = 0.39%, K = 4.31%, Ca = 3.22% and Mg = 0.081%. *Tithonia diversifolia* was able to improve soil N, P, K, Ca and Mg and increase crop yields (Kwabiah et al., 2003; Olabode et al., 2007; Adekiya et al. 2020).

Maize growth and nutrient uptake

Plant growth, in terms of plant height, number of leaves, and stem diameter, increased significantly (Table 3). The application of tithonia leaves, either alone or in combination with sugarcane leaves, significantly increased maize plant height at each observation time. The highest plants at the 3rd to 8th week of observation were found in the combination of 75% tithonia leaves + 25% sugarcane leaves. The results of the Duncan test at 5% level at the 5th week of observation, plant height in the T3 treatment significantly increased by 49.10%, 15.25% and 35.77% compared to the control, inorganic fertilizer-only treatment (T6) and 100% sugarcane leaves treatment (T1).

At the 8th week of observation, the T6 treatment had the lowest plant height compared to other treatments. However, it was not significantly different from the control, T2 and T5 treatments. The number of leaves of maize plants increased at all observation times. The combination treatment of tithonia leaves and sugarcane leaves significantly affected the number of leaves of maize plants. The combination of 75% tithonia leaves + 25% sugarcane leaves significantly increased the number of leaves by 28%, 37.03% and 22.5% compared to the control at the 5th, 6th and 8th weeks of observation. At all times of observation, the least number of leaves was found in the T6 and T7 treatments, and these treatments were not significantly different from the treatment of 100% sugarcane leaves (T2). The stem diameter of maize plants with the addition of organic matter from tithonia leaves and sugarcane leaves was significantly different from the control. This significant difference began to be seen at the 4th week after planting. During eight weeks of observation, the average stem diameter was in the range of 3.87-14.75 mm.

The largest stem diameter was recorded in T1 treatment (100% tithonia leaves), and the smallest was in T6 and T7 (control) treatments. The application of 100% sugarcane leaves (T1 treatment) showed the same effect as the T6 and T7 treatments. This was probably caused by sugarcane leaves containing lignin and a high C/N ratio (Table 1), so that the release of nutrients was slow. Sugarcane leaves have a higher lignin content (24.26%) than *Tithonia diversifolia* leaves (8.89%). Organic matters with high lignin concentration decompose more slowly than organic matters with low lignin concentration (Melillo et al., 1982; Benbi and Khosa, 2014). The highest fresh weight of maize plant stover was shown by the T5 treatment (25% tithonia leaves + 75% sugarcane leaves), and it was significantly different from the T2 and T7 treatments but not significantly different from the T1, T3, T4 and T6 treatments (Figure 1).

Table 3. Plant growth due to the application of mixtures *Tithonia diversifolia* leaves and sugarcane leaves.

Treatments	**Observation time**					
	3 WAP	**4 WAP**	**5 WAP**	**6 WAP**	**7 WAP**	**8 WAP**
			Plant height (cm)			
T1	17.25 ab	28.00 b	38.50 bc	57.25 b	67.75 bc	91.75 bc
T2	16.75 ab	20.75 a	30.75 ab	39.00 a	56.25 ab	81.25 ab
T3	20.25 b	28.25 b	41.75 c	58.75 b	72.50 c	97.25 c
T4	20.00 b	25.50 b	35.00 abc	55.75 b	71.75 c	91.50 bc
T5	14.25 a	18.75 a	34.00 abc	41.25 a	62.75 bc	81.25 ab
T6	15.50 a	19.25 a	26.50 a	33.25 a	48.75 a	70.00 a
T7	16.50 ab	18.75 a	28.00 a	35.00 a	56.50 ab	81.00 ab
			Number of leaves (sheet plant $^{-1}$)			
T1	5.00	7.00 c	7.50 bc	8.50 bc	11.00 d	11.75 b
T2	4.50	5.50 a	6.75 ab	7.50 ab	8.75 a	9.75 a
T3	5.00	6.75 bc	8.00 c	9.25 c	10.50 abcd	12.25 b
T4	6.75	6.75 bc	7.75 bc	9.00 c	11.50 d	11.75 b
T5	4.50	5.75 ab	7.50 bc	8.25 bc	10.75 bcd	11.75 b
T6	5.50	5.50 a	5.75 a	6.75 a	9.25 abc	10.00 a
T7	5.25	5.25 a	6.25 a	6.75 a	9.00 ab	10.00 a
			Stem diameter (mm)			
T1	4.50	6.87 b	9.75 c	12.75 c	14.50 c	14.75 c
T2	4.50	5.00 a	6.50 ab	8.62 a	9.88 a	11.00 a
T3	4.37	6.75 b	9.75 c	12.50 c	14.25 c	14.38 bc
T4	4.25	6.00 ab	8.12 bc	11.25 bc	12.50 b	12.88 bc
T5	4.12	5.00 a	7.12 ab	9.25 ab	12.88 bc	13.88 bc
T6	3.87	4.75 a	6.00 a	7.25 a	9.50 a	10.25 a
T7	3.87	4.75 a	6.12 a	7.75 a	9.62 a	10.12 a

Note: Numbers followed by lowercase letters in the vertical direction in the same column were tested no different based on the DMRT test at a significance level of 5%. T1 = 100% *Tithonia diversifolia* leaves; T2 = 100% sugarcane leaves; T3 = 75% *Tithonia diversifolia* leaves + 25% sugarcane leaves; T4 = 50% *Tithonia diversifolia* leaves + 50% sugarcane leaves; T5 = 25% *Tithonia diversifolia* leaves + 75% sugarcane leaves; T6 = without organic matter; T7 = control. WAP = week after planting.

The lowest weight of stover (46.55 g) was observed in the T7 treatment. The highest dry weight of stover (57.42 g) was also found in T5, and it was significantly different from T2, T4 and T7 treatments. The T5 treatment was able to increase the dry weight of the stover by 111.1029%, 84.63% and 44.09%, respectively, compared to the control, T2 and T4 (Figure 1). The significant difference in plant growth parameters (Table 3) and fresh weight of maize plant stover (Figure 1) between those that were treated with organic matter and the control were related to the ability of *Tithonia diversifolia* leaves to supply essential nutrients, such as N, P and K (4.40%, 0.41% and 2.54%; Table 1), while in control with no addition of nutrients. *Tithonia diversifolia* leaves have a high nutritional composition and are rapidly mineralized (Partey et al., 2011). The addition of nutrients, especially N from the decomposition of *Tithonia diversifolia* leaves, is able to support optimal plant growth. Nitrogen compounds are used by plants to form amino acids which will be converted into proteins, forming chlorophyll compounds, nucleic acids and enzymes. Therefore, nitrogen is needed by plants for vegetative growth, such as shoot formation or stem development. Lack of nitrogen causes cell division and cell enlargement activities to be inhibited, causing plants to become stunted. P and K nutrients needed by plants for vegetative growth are not as much as N nutrient. P nutrient can improve plant root growth and stimulate root density. Meanwhile, K nutrient can improve and regulate the opening and closing of stomata. Nitrogen is one of the important elements for optimal plant growth; the main function of nitrogen is as a building block for protein, stimulates vegetative plant growth and gives plants a green colour and regulates and influences the use of other elements

(Hawkesford et al., 2011). The increase in plant height with the application of *Tithonia diversifolia* in this study is in line with previous studies for other crops, such as rice, vegetables (Mustonen et al., 2012) and sesame (Babajide et al., 2012). *Tithonia diversifolia* compost affects the growth and yield of cauliflower (Setyowati et al., 2018). Rusaati et al. (2020) showed that the application of 500 g of *Tithonia diversifolia* leaves + 1.28 g of rock phosphate promoted the growth of rice plants. Ewane et al. (2020) reported that applying leaves and stems of *Tithonia diversifolia* increased the number of shoots, shoot height and diameter, and leaf bud area of plantain Vivo plans compared to the control.

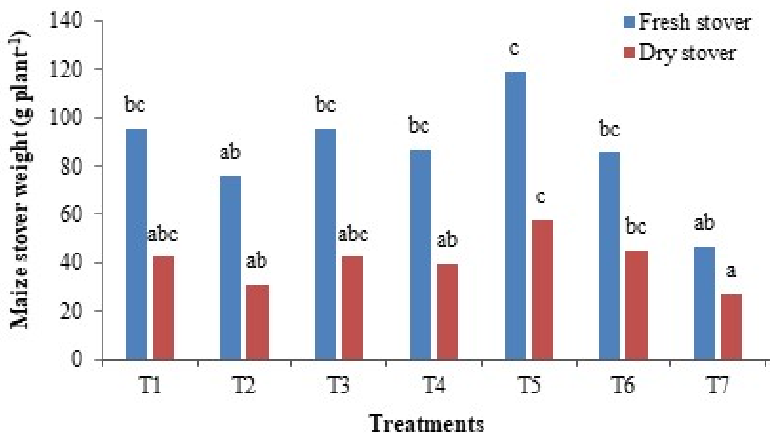

Figure 1. The average weight of fresh stover and dry weight of maize stover due to the application of *Tithonia diversifolia* leaves and sugarcane leaves on degraded sandy loam soil.
Remarks: different letters above the column indicate significant differences based on DMRT test at 5% level T1 =100% *Tithonia diversifolia* leaves; T2 = 100% sugarcane leaves; T3 = 75% *Tithonia diversifolia* leaves + 25% sugarcane leaves; T4 = 50% *Tithonia diversifolia* leaves + 50% sugarcane leaves; T5 = 25% *Tithonia diversifolia* leaves + 75% sugarcane leaves; T6 = without organic matter; T7 = control.

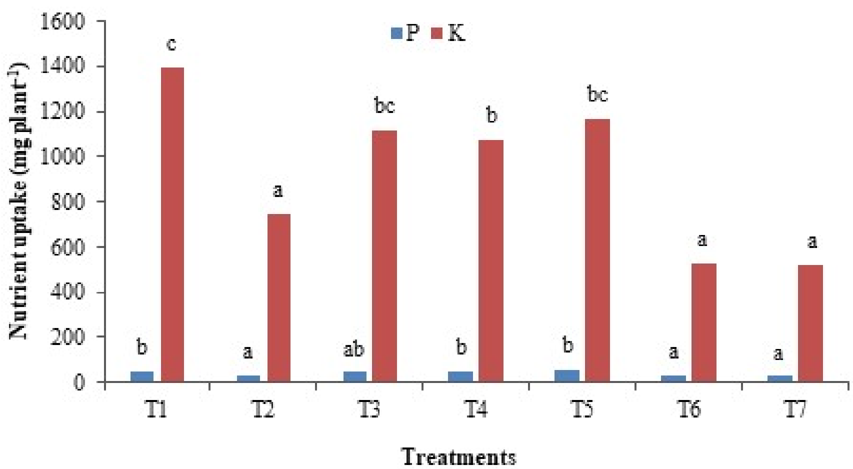

Figure 2 . P and K nutrients uptake due to the application of *Tithonia diversifolia* and sugarcane leaves.
Remarks: different letters above the column indicate significant differences ($p<0.05$) based on the DMRT test. T1 = 100% *Tithonia diversifolia* leaves; T2 = 100% sugarcane leaves; T3 = 75% *Tithonia diversifolia* leaves + 25% sugarcane leaves; T4 = 50% *Tithonia diversifolia* leaves + 50% sugarcane leaves; T5 = 25% *Tithonia diversifolia* leaves + 75% sugarcane leaves;T6 = without organic matter; T7 = control.

Nutrients taken up maize plant in this study ranged from 28.33 to 57.71 mg plant^{-1} (phosphorus) and 522.49-1397.61 mg plant^{-1} (potassium) (Figure 2). The application of *Tithonia diversifolia* leaves, either alone or in combination with sugarcane leaves, in the T1, T4, T5 treatments could increase P nutrient uptake in maize plants compared to the T2, T6 and control. P uptake due to the combination of *Tithonia diversifolia* leaves and sugarcane leaves significantly increased up to 103.70% compared to the control. This increase was found in the T5 treatment, but the effect was not significantly different on P uptake in the T4, T3 and T1 treatments. The application of 25% tithonia leaves + 75% sugarcane leaves (T5 treatment) significantly increased P uptake by 76.69%, 87.49% and 103.70% compared to the T2, T6 and T7 treatments. P nutrient uptake in the T1 treatment significantly increased by 57.13%, 66.75% and 81.15% compared to T2, T6 and T7. The application of 50% tithonia leaves + 50% sugarcane leaves (T4 treatment) could increase P uptake by 51.40%, 60.65% and 74.54% compared to the T2, T6 and T7 treatments. Compared to the T2 treatment (100% sugarcane leaves), the T1, T4 and T5 treatments increased P nutrient uptake by 57.13%, 51.40% and 76.69%, respectively (Figure 2).

The combination of *Tithonia diversifolia* leaves and sugarcane leaves significantly increased K uptake compared to the control (Figure 2). The highest K uptake was observed in the T1 (1397.61 mg plant^{-1}), and the lowest was in control (522.49 mg plant^{-1}). The T1, T2 and T6 treatments significantly increased K uptake by 167.49%, 86.29% and 162.79% compared to the control. The high uptake of K in the T1 treatment was related to the K nutrient content in T1 (3.62%), which was higher than the other treatments (Table 1). In addition to P and K nutrient uptake, *Tithonia diversifolia* treatment also increased N uptake in maize, in which N nutrient uptake with *Tithonia diversifolia* and its combination with sugarcane leaves was able to increase N uptake by 125,98 % to 144.54% (Farni et al., 2021). Farni et al. (2021) reported that the highest cumulative N release was found in T1 treatment (517.15 mg plant^{-1}). The high nutrient uptake in 100% tithonia leaves and its combination with sugarcane leaves was due to high N content and low C/N ratio of tithonia leaves (Table 1) so that the decomposition and nutrient release rates were high (Li et al., 2011; Kaleeem Abbasi et al., 2015; Wang et al., 2017). The findings in this study revealed that nutrient uptake, plant growth and soil chemical properties in the treatment of the application of 100% sugarcane leaves were not significantly different from the control. This was due to the high C/N ratio and lignin content in sugarcane leaves, so that the release of nutrients was slow.

Conclusion

The application of *Tithonia diversifolia*, either alone or in combination with sugarcane leaves, was able to improve soil chemical properties, nutrient uptake and growth of maize plants, but the application of 100% sugarcane leaves, in general, gave the same effect as the control on the parameters tested. This indicates that the administration of sugarcane leaves alone has not been able to support nutrient uptake and plant growth so that technology to accelerate the decomposition process and mineralization of sugarcane leaves is needed.

Acknowledgement

This study was financially supported by BUDI-DN LPDP Indonesia. The gratitude is addressed to the technicians from the Soil Chemistry Laboratory and Soil Physics Laboratory, Faculty of Agriculture, Brawijaya University.

References

Aboyeji, C.M. 2021. Effects of application of organic formulated fertiliser and composted *Tithonia diversifolia* leaves on the growth, yield and quality of okra. *Biological Agriculture & Horticulture,* doi:10.1080/01448765.2021.1960604.

Adekiya, A.O. 2019. Green manure and poultry feather effect on soil characteristics, grow yield and mineral contents of tomato. *Sientia Horticulturae* 257, 108721:1-7, doi:10.1016/j.scienta.2019.108721.

Adekiya, A.O., Agbede, T.M., Olayanju, A., Ejue, W.S., Adekanye, T.A., Adenusi, T.T. and Ayeni, J.F. 2020. Effect of biochar on soil properties, soil loss, and cocoyam yield on a tropical sandy loam Alfisol. *The Scientific World Journal* 9, Article ID 9391630, doi:10.1155/2020/9391630.

Agbede, T.M, Adekiya, A.O. and Ogeh, J.S. .2014. Response of soil properties and yam yield to *Chromolaena odorata* (Asteraceae) and *Tithonia diversifolia* (Asteraceae) mulches. *Archives of Agronomy and Soil Science* 60(2):209-224, doi:10.1080/03650340.2013.780127.

Agricultural Research and Development Agency. 2012. Technical Guidelines for Chemical Analysis of Soil, Plant, Water and Fertilizer. Ministry of Agriculture of the Republic of Indonesia (*in Indonesian*).

Babajide, P.A., Akanbi, W.B., Olabode, O.S. and Olaniyi, J.O. 2012. Influence of pre-application handling techniques of *Tihtonia diversifoli*a Hems. A. Gray residues sesame in south-western Nigeria. *Journal of Animal and Plant Sciences* 15(2):2135-2146.

Baldock, J.A. and Skjemstad, J.O. 2000. Role of the soil matrix and minerals in protecting natural organic materials against biological attack. *Organic Geochemistry* 31(7–8):697-710, doi:10.1016/S0146-6380(00)00049-8.

Benbi, D.K and Khosa, M.K. 2014. Effects of temperature, moisture, and chemical composition of organic substrates on C mineralization in soils. *Communications in Soil Science and Plant Analysis* 45(21):2734-2753, doi:10.1080/00103624.2014.950423.

Bhardwaj, A.K., Shainberg, I., Goldstein, D., Warrington, D.N. and Levy, J.G. 2007. Water retention and hydraulic conductivity of cross-linked polyacrylamides in sandy soils. *Soil Science Society America Journal* 71:406-412. doi:10.2136/sssaj2006.0138.

Castan, E., Satti, P., Gonzales-Polo, M., Iglesias, M.C. and Mazzarino, M.J. 2016. Managing the value of composts as organic amendment and fertilizers in sandy soils. *Agriculture, Ecosystem and Environment* 224:29-38, doi:10.1016/j.agee.2016.03.016.

Central Bureau of Statistics. 2020. BPS Jawa Timur. Available at https://jatim.bps.go.id/ (accessed on 18 August 2021).

Devi, C. and Kwairakpam, M. 2019. Bioconversion of *Lantana camara* by vermicomposting with two different earthworm species in monoculture. *Bioresource Technology* 296, doi:10.1016/j.biortech.2019.122308.

Diacono, M. and Montemurro, F. 2010. Long-term effects of organic amendments on soil fertility. A review. *Agronomy for Sustainable Development* 30:401-422.

Dignac, M.F., Bahri, H., Rumpel, C., Rasse, D.P., Bardoux, G., Balesdent, J., Girardin, C., Chenu, C. and Mariotti, A. 2005. Carbon-13 natural abundance as a tool to study the dynamics of lignin monomers in soil: an appraisal at the Closeaux experimental field (France). *Geoderm*a 128:3-17, doi:10.1016/j.geoderma.2004.12.022.

Ewane, C.A., Meshuneke, A.,Tatsegouock, R.N and Boudjeko, T. 2020. Vertical layers of *Tithonia diversifolia* flakes amendment improve plantain seedling performance. *American Journal of Agricultural Research* 5(95):1-11.

Farni, Y., Prijono, S., Suntari, R. and Handayanto, E. 2021. Pattern of N mineralization and nutrient uptake of *Tithonia diversifolia* and *Saccharum officinarum* leaves in sandy loam soil. *Indian Journal of Agricultural Research*. Article Id**:** A-626, doi:10.18805/IJARe.A-626.

Hanc, A. and Chadimova, Z. 2014. Nutrient recovery from apple pemoce waste by vermicomposting tecnology. *Bioresource Tecnology* 168:240-244, doi:10.1016/j.biortech.2014.02.031.

Hawkesford, M., Horst, W., Kichey, T., Lambers, H., Schjoerring, J., Møller, I.S. and White, P. 2011. Functions of Macronutrients, *Marschner's Mineral Nutrition of Higher Plants*: Third Edition. Elsevier Ltd. doi:10.1016/B978-0-12-384905-2.00006-6.

Hidayat, H.K., Sumarni, T. and Sudiarso. 2018. Effect of paitan fertilizer (*Tithonia diversifolia*) and inorganic NPK on sweet corn (*Zea mays saccharata* Sturt). *Jurnal Produksi Tanaman* 6(5):775-782 (*in Indonesian).*

Hou, Y.X., Hu, X., Yan, W., Zhang, S. and Niu, L. 2013. Effect of organic fertilizers used in sandy soil on the growth of tomatoes. *Agricultural Sciences* 4(56):31-34, doi:10.4236/as.2013.45b00.

Irfan, B.S., Kasal, Y. and Chowdary, D.M. 2021. A review on effects of chemical fertilizers and organic manures on soil fertility*. The Pharma Innovation Journal* 10(8): 504-507.

Jeptoo, A., Aguyoh, J.N and Saidi, M. 2013. Tithonia manure improves carrot yield and quality. *Global Journal of Biology, Agriculture & Health Sciences* 2(4):136-142.

Kaboneka, S., Kwizera, C., Nijimbere, S., Irakoze, W., Nsengiyumva, P., Ndihokubwayo, S. and Habonimana, B. 2021. Direct and residual fertilizer of maize (*Zea may* L.) stover co-composted with *Tithonia diversifolia* (Hemsl.) A. Gray green manure. *International Journal of Advances in Scientific Research and Engineering* 7(7): 6-16. doi:10.31695/ijasre.2021.34042.

Kaleeem Abbasi, M., Tahir, M., Sabir, N. and Khurshid, M. 2015. Impact of the addition of different plant residues on nitrogen mineralization-immobilization turnover and carbon content of a soil incubated under laboratory conditions. *Solid Earth* 6:197-205, doi:10.5194/se-6-197-2015.

Kwabiah, A.B., Palm, C.A., Stoskopf, N.C. and Voroney, R.P. 2003. Response of soil microbial biomass dynamics to quality of plant materials with emphasis on P availability. *Soil Biology and Biochemistry* 35(2):207-216, doi:10.1016/s0038-0717(02)00253-5.

Leifeld, J., Siebert, S and Knabner, I.K. 2002. Biological activity and organic matter mineralization of soil amended with biowaste composts. *Journal of Plant Nutrition and Soil Science* 165(2):151-159, doi:10.1002/1522-2624(200204)165:2.

Li, L.J., Zeng, D.H.,Yu, Z.Y., Fa, Z.P., Yang, D. and Liu, Y.X. 2011. Impact of litter quality and soil nutrient availability on leaf decomposition rate in a semi-arid grassland of Northeast China. *Journal of Arid Environments* 75(9):787-792, doi:10.1016/j.jaridenv.2011.04.009.

Liu, E., Yan, C., Mei, X., Hea, W., Bing, S.H., Dimg, L., Liau, Q., Liua, S. and Fan, T. 2010. Long-term effect of chemical fertilizae, straw, and manure on soil chemical and biological properties in norhwest China. *Geoderma* 158:173-180, doi:10.1016/j.geoderma.2010.04.029.

Mapfumo, P., Mtambanengwe, F. and Vanlauwe, B. 2007. Organic matter quality and management effects on enrichment of soil organic matter fractions in contrasting soils in Zimbabwe. *Plant and Soil* 296**:**137–150, doi:10.1007/s11104-007-9304-7.

Meire, E., Thorburn, P., Goosoon, M., Wegener, M. and Basford, K. 2003. Optimisation of nitrogen supply from sugarcane residues in the wet tropics. 25 June 2003. The University of Queensland, Brisbane, Australia http://www.regional.org.au/au/asa/2003/c/5/meier.htm.

Melillo, J.M, Aber, J.D, and Muratore, J.F. 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. *Ecology* 63(3):621-626.

Mockeviciene, I., Repsiene, R., Volunge, K.A., Karcauskiene, D., Slepetiene, A. and Lepane, V. 2021. Effect of long-term application of organic fertilizers on improving organic matter quality in acid soil. *Archives of Agronomy and Soil Science*, doi:10.1080/03650340.2021.1875130.

Mrabet, M., Saber, N., El-Brahli, A., Lahlou, S. and Bessam, F. 2001. Total particulate organic matter and structural stability of a Calcixeroll soil under different wheat rotations and tillage systems in a semiarid area of Morocco *Soil and Tillage Research* 57(4):225-235, doi:10.1016/S0167-1987(00)00180-X.

Mucheru-Muna, M., Mugendi, D., Pypers, P., Mugwe, J., Kung'u, J., Vanlauwe, B. and Merckx, R. 2014. Enhancing maize productivity and profitability using organic inputs and mineral fertilizer in Central Kenya small-hold farms. *Experimental Agriculture* 50(2):250–269. doi:10.1017/S0014479713000525.

Mustonen, P.S.J., Oelberman, M. and Kass, D.C. 2012. Using *Tithonia diversifolia* (Hemsl.) Gray in a short fallow system to increase soil phosphorus availability on a Costa Rican Andosol. *Journal of Agricultural Science* 4(2):91-100, doi:10.5539/jas.v4n2p91.

Nemecek, T., Dubois, D., Huguenin-Elie, O. and Gaillard, G. 2011. Life cycle assessment of Swiss farming systems: I. Integrated and organic farming *Agricultural Systems* 104(3):217-232 doi:10.1016/j.agsy.2010.10.002.

Nisar, S. and Benbi, D.K. 2020. Stabilization of organic C in an Indo-Gangetic alluvial soil under long-term manure and compost management in a rice–wheat system. *Carbon Management* 11(6):533-547, doi:10.1080/17583004.2020.1824483.

Olabode, O.S., Ogunyemi, S., Akanbi, W.B., Adesina, G.O and Babajide, P.A. 2007. Evaluation of *Tithonia diversifoli*a (Hemsl) A. Gray for soil improvement. *World Journal of Agricultural Sciences* 3(4):503-507.

Opala, P.A. 2020. Recent advances in the use of *Tithonia diversifolia* green manure for soil fertility management in Africa: a review. *Agricultural Reviews* 41(3):256-263, doi:10.18805/ag.R-141.

Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch, G. and Giller, K.E. 2001. Organic inputs for soil fertility management in tropical agroecosystems : application of an organic resource database. *Agriculture. Ecosystems & Environment.* 83:27–42.

Partey, S.T., Quashie-Sam, S.J., Thevathasan, N.V. and Gordon, A.M. 2011. Decomposition and nutrient release patterns of the leaf biomass of the wild sunflower (*Tithonia diversifolia*): a comparative study with four leguminous agroforestry species. *Agroforestry Systems* 81:123–134 doi:10.1007/s10457-010-9360-5.

Puteri, A.R, Setyowati, N., Fahrurrozi and Muktamar, Z. 2021. Growth and yield of sweet corn (*Zea mays* L. saccharata) as affected by incubation time of preparation for tithonia (*Tithonia diversifolia*) enriched liquid organic fertilizer. *IOP Conference Series: Earth and Environmental Science* 637, doi:10.1088/1755-1315/637/1/012090.

Rahardian, T.S., Sumarni, T. and Suryanto, A. 2017. Utilization of paitan (*Tithonia diversivolia*) and krinyu (*Chromolaena odorata*) green manures in increasing broccoli (*Brassica Oleracea*) yield. *PLANTROPICA: Journal of Agricultural Science* 2(2):108-116 *(in Indonesian).*

Repullo, M.A., Carbonell, R., Hidalgo, J., Rodriguez-Lizana, A. and Ordonez, R. 2012. Using olive pruning residues to cover soil and improve fertility. *Soil and Tillage Research* 124:36-46, doi:10.1016/j.still.2012.04.003.

Ro, S., Becker, M. and Manske, G. 2016. Effect of phosphorus management in rice–mungbean rotations on sandy soils of Cambodia. *Journal of Plant Nutrition Soil Science* 179(4):481-487, doi:10.1002/jpln.201600043.

Rokhmawati, A. 2014. Analysis of Lesti watershed land use based on GIS (Geographical Information System). *Jurnal Rekayasa Sipil* 2(1):18-24 (*in Indonesian*).

Rusaati, B.I., Kang, J.W., Gendusa, A.P., Bulakali, B.P., Lumande, K.J., Rolly, N.K., Park, J.W., Rehema, M.E., Masumbuko, N.C., Iragi, K.G., Nangalire, N.O. and Bahati, C.A. 2020. Influence of the application of Tithonia diversifolia and phosphate rocks on the performances of rainfed rice. *Korean Journal of Agricultural Science* 47:403-414, doi:10.7744/KJOAS.20200029.

Scrase, F.M., Sinclair, F.L., Farrar, J.F., Pavinato, P.S. and Jones, D.L. 2019. Mycorrhizas improve the absorption of non available phosphorus by the green manure *Tithonia diversifolia* in poor soils. *Rhizosphere* 9:27-33, doi:10.1016/j.rhisph.2018.11.001.

Setyowati, N., Sudjatmiko, S., Muktamar, Z., Fahrurrozi, F., Chozin, M. and Simatupang, P. 2018. Growth and yield responses of cauliflower on tithonia (*Tithonia diversifolia*) compost under organic farming practices. *International Journal of Agricultural Technology* 14(7):1905–1914.

Shisanya, C.A., Mucheru, M.W., Mugendi, D.N. and Kung'u, J.B. 2009. Effect of organic and inorganic nutrient sources on soil mineral nitrogen and maize yields in central highlands of Kenya. *Soil and Tillage Research* 103(2):239-246, doi:10.1016/j.still.2008.05.016.

Smith, J., Abegaz, A., Matthews, R., Subedi, M., Orskov, B., Tumwesige, V. and Smith, P. 2014.What is the potential for biogas digesters to improve soil fertility and crop production in Sub-Saharan Africa?, *Biomass and Bioenergy* 70:58-72, doi:10.1016/j.biombioe.2014.02.030.

Susanti, D., Widodo, H. and Hartono, E.S. 2017. Effect of green manure for moonflower (*Tithonia diversifolia*) and manure on the production of ekinase (*Echinase purpurea*) *Buletin Penelitian Tanaman Obat dan Rempah* 28(2):127-136 (*in Indonesian*).

Uzoma, K.C., Inoue, M., Andry, H., Zahoor, A. and Nishihara. E. 2011. Influence of biochar application on sandy soil hydraulic properties and nutrient retention. *Journal of Food Agriculture & Environment* 9(2):1137-1143.

Vanlauwe, B. and Giller, K. 2006. Popular myths around soil fertility management in sub-Saharan Africa. *Agriculture, Ecosystems & Environmen*t 116(1-2):34-46, doi:10.1016/j.agee.2006.03.016.

Wang, M., Hao, T., Deng, X.,Wang, Z., Cai, Z. and Li, Z. 2017. Effects of sediment-borne nutrient and litter quality on macrophyte decomposition and nutrient release. *Hydrobiologia* 787:205–215, doi:10.1007/s10750-016-2961.

Wang, Q., Bai, Y., Gao, H., Je, J., Chen, H., Chesney, R.C, Kuhn, N.J. and Li, H. 2008. Soil chemical properties and microbial biomass after 16 years of no-tillage farming on the Loess Plateau, China *Geoderma* 144:502-508, doi:10.1016/j.geoderma.2008.01.003.

Zhao, S.C., Li, K.J., Zhou, W., Qiu, S.J., Huang, S.W. and He, P .2016. Changes in soil microbial community, enzyme activities and organic matter fractions under long term straw return in north-central China. *Agriculture Ecosystem and Environment* 216:82-88, doi:10.1016/j.agee.2015.09.028.