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Soil improvement potential of weeds biomass applied as green manure in marginal land

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Abstract. *Hamdani AD, Sulistiyowati E, Khusnuryani A. 2017. Soil improvement potential of weeds biomass applied as green manure in marginal land. Trop Drylands 1: 12-16.* Weeds have been long considered to have negative effect on crops due to competition. Yet, the presence of weeds can be used to build up organic matter and chemical contents of degraded soil. This study aimed to assess the potential of three weed species, i.e. *Chromolaena odorata*, *Mikania micrantha*, and *Synedrella* nodiflora, to be applied as green manure to improve soil quality in marginal land, and to assess the best form of their practical application. Two forms of weed biomass application, fresh and dried chopped, were examined in a pot experiment containing soil from degraded land in Patuk, Gunung Kidul, Yogyakarta, Indonesia, and spinach (*Amaranthus tricolor* L.) as the test crop. The pots were laid out in a randomized complete block design with six replications. Laboratory analysis showed that manurial properties between the weeds were statistically similar, with the average of organic C, N, P and K at 36.9, 3.3, 0.1 and 1.6%, respectively. Of the chemical contents considered, the content of all chemicals measured in experimental soil had increased, particularly the available K_2O from 3.33 to the average of 46.33 ppm. The spinach growth and yield resulting from the treated soils were superior to that from untreated soils. However, there were no significant differences in the plant's response between the types of weeds. Rather, better growth and yield of spinach have resulted from soil treated with dried chopped weed biomass. Thus, weed biomass can be used to improve soil organic matter and therefore should be incorporated with soil fertility maintenance.

Keywords: *Chromolaena odorata*, green manure, *Mikania micrantha*, soil fertility, *Synedrella nodiflora*

INTRODUCTION

The adverse effect of intensive utilization of land for cultivation, particularly related to continued removal of nutrients from soil, in combination with highly use soil-degrading agrochemicals, remains the biggest challenge in developing sustainable agriculture system. Both practices have made it difficult to maintain or enhance soil fertility, which is determined by sufficient availability of nutrients, water, air and microflora in soil to support plant growth. Such problems are more prominent on the soils classified as marginal land which have low potential soil fertility. Therefore, inexpensive systems to continually rejuvenate degraded soils are needed to support sustainable agriculture.

Technically, soil fertility can be maintained or improved by adding organic or inorganic fertilizer, or a combination of both. Nonetheless, many argue that organic amendments are more beneficial than inorganic fertilizer to develop sustainable agriculture system in the long run. Even though the application of organic fertilizer does not always fulfill the nutrient needed since its effectivity depends on many factors, such as the decomposition and nutrients release rates, the application of organic inputs can still improve soil quality in term of physical and biological elements (Hayat et al. 2010; Egbe et al. 2012).

One of the sources of organic fertilizer is plant biomass. Most of the green manures applied for cultivation are generated from biomass of the leguminous plants since they can enrich the soil content of Nitrogen that is required in large supply by most crops (Liu et al. 2008). However, the availability of legume plant biomass is limited so alternative plant sources as base materials for green manure are needed. Another group of plants that can be considered as potential plant materials is weeds. Most weeds are inexpensive, do not require much care, have rapid growth rate and are highly adaptive to various environments. Since they are available in abundance, the large amount of biomass required in their application as green manure can be fulfilled.

Weeds are often considered an enemy of the cultivation process. However, some studies demonstrated that a farmed land that has been allowed to lie idle and occupied by weeds is more productive when cultivated again than it did before because the presence of weeds can build up organic matter and chemical contents of soil. For example, Olabode et al. (2007) reported that yields from okra (*Abelmoschus esculentus*) in pots treated with crushed weeds tithonia (*Tithonia diversifolia*) were 40% higher than those without any amendments. Similarly, Jama et al. (2000) demonstrated that green manure from tithonia improved soil fertility and increase the availability of soil N, P and K. Application of *Erigeron annuus* (L.) improve

soil pH and nutrient concentrations in the acid soils of southern China (Liu et al. 2008). Likewise, Patel (2012) also mentioned the potential utilization of weed *Eichhornia crassipes* as materials for green manure. Therefore, when weeds are harvested it can be applied as green manure while on the other hand reducing their competition with the main crops with the expected results of better growth and yield of the cultivated crops.

The highly abundance of weeds should be considered as an advantage to help building up the impoverished soils, especially to solve the problem of soil fertility in marginal land. However, not every weed might be potential as green manure base material. The suitability of plant material for soil amendment depends on the occurrence of high N, P and K concentrations in plant tissues (Gachengo et al. 1999; Tomar et al. 2012). For example, most green manure is plant biomass generated from legume family because they contain high level of N in their tissues. In addition, the quality of green manure is also determined by the relative proportions of lignin, the high rate of decomposition and nutrient release (Olabode et al. 2007). Tithonia, for instance, was considered as a better source of plant materials/biomass for green manure than *Senna spectabilis* (senna) because the release rate of N and P from tithonia is higher than from senna (Gachengo et al. 1999).

In this experiment, we assessed the extent to which organic matters or biomass of three species recognized as weeds, i.e. *Chromolaena odorata*, *Mikania micrantha*, and *Synedrella nodiflora*, can be used to improve the fertility of experimental soil from marginal land in Patuk, Gunung Kidul, Yogyakarta, Indonesia. These weeds species were selected because of their availability in a large supply, had high biomass and were expected to decompose easily due to their low lignin contents. Also, two forms of applications, i.e. fresh and dried chopped weeds, were tested to determine the best mode of their practical application. The application was without fermentation based on the previous study results (Olabode et al. 2007) that soils treated with crushed tithonia showed higher N concentration over the soils treated with fermented tithonia. This could be another strong point since unfermented process would simplify the application of green manures.

MATERIALS AND METHODS

Soil sampling and analysis

The soil samples were collected in September 2015 from the 0-20 cm horizon of all plots in Patuk, Gunung Kidul, Yogyakarta. Physical and chemical characteristics of the soils were determined according to standard methods in BPTP Yogyakarta. Physical analysis included determination of soil texture (sand, dust, clay) using hydrometer method. As for chemical characteristics, the total N was determined by Kjeldahl method, available P_2O_5 was determined by Olsen method, available K_2O was determined by water-soluble extraction, potential P_2O_5 and K_2O were determined by extraction using 25% HCl, and organic carbon was determined by Walkley and Black method.

Plant sampling and analysis

Three species of weeds used in this study were *Chromolaena odorata*, *Mikania micrantha*, and *Synedrella nodiflora*. The weed samples were collected randomly from several farming areas in Sleman, Yogyakarta and then pooled. The plants were harvested at ground level, but only the leaves were used as green manures. Chemical analysis of the weed samples was done according to standard methods in BPTP Yogyakarta. The total N was determined by Kjeldahl method, P was determined by spectrometer, K was determined by AAS, and organic carbon was determined by Walkley and Black method.

Pot experiment

Two treatments, corresponding to two forms of weed preparations (i.e. fresh and dried chopped) for each type of weed, were compared to the control groups of pots without any soil amendments (negative control) and pots supplemented with inorganic fertilizer. Those were fitted into a randomized complete block experiment. There were 24 pots such that three pots represented each group with six replications. Each of the pots was filled with soil taken from the experimental area in Patuk, Gunung Kidul, Yogyakarta, and the roughly chopped leaves (fresh weight) with a ratio of 10:1. The pots were then incubated for two weeks before planting and during the time were watered every morning and afternoon. After two weeks, samples from soils treated with chopped weeds biomass were collected for analysis of available nutrient status in BPTP Yogyakarta.

For the fresh chopped treatment, the chopped leaves were directly mixed thoroughly with the soil, while for the dried chopped treatment; the chopped leaves were mixed with the soil after being dried in the sun for two days. Nothing was added to the soil assigned as the negative control pots while the positive control pots were supplemented with NPK fertilizer (60 kg ha^{-1}) according to the users' guide.

The spinach seeds were sowed in advance for two weeks, before planting in the pots. Each pot was watered as needed as well as the mulching. Data collected included plant height, number of leaves, root length, and fresh weight.

Data analysis

The plant and soil data were analyzed statistically using the analysis of variance (ANOVA) using IBM SPSS Statistics 21. The difference of treatment result was assessed using Duncan test for separating the mean of treatments at 5%.

RESULTS AND DISCUSSION

Physical and chemical characteristics of the soil used in this study were presented in Table 1. The analysis on soil physical properties showed that the soil was dominated by clay content, which reached up to 47%, followed by sand content of as much as 27% and 25.67% of dust, hence the experimental soil was categorized as clay soil. The N, P, K,

and organic carbon of soil were generally very low, implying that the level of soil fertility was also very low.

Meanwhile, the tissue nutrient concentrations of *Chromolaena odorata*, *Mikania micrantha*, and *Synedrella nodiflora* used in this study were presented in Table 2. Overall, the N, P, K and organic C tissue contents were statistically similar. The highest organic C was found in *C. odorata*, respectively 8.26 and 7.42% better than *M. micrantha* and *S. nodiflora*. Likewise, *C. odorata* was also 6.58 and 6.92%, respectively better than *M. micrantha* and *S. nodiflora* in N tissue contents. Meanwhile, *M. micrantha* was better than *C. odorata* by 60% P and 77.78% K, also 82.61 and 27.27% better in K tissue contents than in *C. odorata* and *S. nodiflora*, consecutively. With regard to the same ratio of C/N in those weeds, the succulent level of *C. odorata*, *M. micrantha* and *S. nodiflora* were the same, indicating a similar rate of decomposition process. Therefore, *C. odorata*, *M. micrantha* and *S. nodiflora* could have similar manurial potential.

The occurrence of N, P, K and organic C concentrations in all selected weeds were considered high. When compared to the reported values of other sources of green manures, the nutrient contents of *C. odorata*, *M. micrantha* and *S. nodiflora* were comparable to tithonia (*Tithonia diversifolia*), the weed that considered as a high-quality organic source for green manure, which contained 31.76% organic C, 4.46% N, 0.61 P and 3.75% K (Hafifah et al. 2016). However, the nutrient status of plants varied with soil characteristics, geographical conditions and ecological status of the plants. The occurrence of very high nutrient concentration in plant materials can be obtained from fertile soil. For example, N concentration in *C. odorata* samples used in this study was higher than that found in the same species collected from the savanna of Nigeria (3.4 as opposed to 1.76, respectively) (Olabode et al. 2007). Therefore, the effective use of plant materials as green manure should consider the conditions of plant source location, coupled with the availability of plants and the level of nutrient deficiency of treated soil.

The chemical characteristics of soil after incubated with the chopped weeds for two weeks (Table 3) showed the increasing level of N, P, K and organic C, particularly on available K_2O that drastically increase from 3.33 ppm to an average of 46.33 ppm. Overall, the level of soil fertility had increased from very low to low with the addition of chopped weeds.

From the three plant species used in this research, *C. odorata* has the highest potential to increase soil chemical properties. Previous research regarding *C. odorata* showed a similar trend. For example, Nawaz and George (2004) reported that organic compost of *C. odorata* was able to increase crop biomass, and interestingly, this compost had similar effect to the use of cattle manure. When it was used as green manure, *C. odorata* was reported to increase NPK uptake and nutrient efficiency in paddy cultivation (Murthy et al. 2010).

Mikania micrantha showed allelopathic properties when it was used as green manure as it has been reported to have allelopathic effect on some weeds in crop fields (Weng 1964). Ullah et al. (2014) administered extract of *M. micrantha* to *Fymbristylis miliacea* weed and reported that it significantly lower Fymbristylis population. This gives less preferable effect as green manure compared to the other two plant species used in this experiment.

Murthy et al. (2010) asserted that the use of weeds as organic manure could increase the quality of soil chemical properties. The data shown in Table 3 confirmed that statement.

In terms of C and N properties, it seems that dried chopped *C. odorata* gave slightly better C and N improvement. This result is almost in close conformity with the findings of the usage of *C. odorata* for increasing the yield of rice (Paraye 2002). This manurial practice could help in enhancing biochemical activity of microorganisms living in sandy loam and sandy clay soils (Paraye 2002), exactly similar to the type of soil used in this research. In terms of amendment of available P_2O_5, and K_2O, as well as potential P_2O_5 and K_2O, all weeds used, could improve soil chemical properties. Sandy-clay soil is typically low in available phosphorous, hence in traditional farming practice, farmers tend to supply the need of P from inorganic sources. However, in alkaline soil, like clay, P reacts with Fe and Al and creates insoluble P. The use of green manure could reduce this risk, because it increases availability of P and reduces soil capacity to react with P, and thus P is more readily available for plants (Mweta et al. 2007).

Of the plant response considered (Figure 3, Table 4), plant growth and yields from soil supplemented with chopped weeds were superior to that from soil without the addition of fertilizers, for all the measured parameters, and were parallel with those treated with NPK fertilizer. And among the treated soil, better plant growth and yields were observed from soil added with dried chopped weeds than fresh weeds, but not significantly different according to the types of weeds used.

Table 1. The initial physical and chemical properties of soil used for the study

Property	**Value**
pH	7.00
Particle Density (g cc^{-1})	2.61
Organic Carbon (%)	0.65
Total Nitrogen (%)	0.08
C/N Ratio	8:1
Available P_2O_5-Olsen (ppm)	7.33
Potential P_2O_5-25% HCl (mg $100g^{-1}$)	55.33
Available K_2O-Olsen (ppm)	3.33
Potential K_2O-25% HCl (mg $100g^{-1}$)	5.33
Sand (%)	27.00
Silt (%)	25.67
Clay (%)	47.00

Table 2. Chemical properties of *Chromolaena odorata*, *Mikania micrantha*, and *Synedrella nodiflora.*

Weed species	**Manurial properties (%)**				
	Org. C	**N**	**P**	**K**	**C/N**
Mikania micrantha	35.81	3.19	0.16	2.1	11:1
Chromolaena odorata	38.77	3.4	0.09	1.15	11:1
Synedrella nodiflora	36.09	3.18	0.1	1.65	11:1

Table 3. The effect of weeds application on chemicals soil characteristics

Form of weed biomass	Organic C (%)	Total N (%)	Available P_2O_5 (ppm)	Available K_2O (ppm)	Potential P_2O_5 (mg 100 g^{-1})	Potential K_2O (mg 100 g^{-})
Negative control	0.65^{a}	0.07^{a}	7.33^{a}	3.33^{a}	55.33^{a}	5.33^{a}
Mikania micrantha						
Fresh chopped	0.89^{ab}	0.10^{b}	9.33^{a}	48.67^{b}	75.67^{a}	12.00^{bc}
Dried chopped	0.97^{ab}	0.11^{bc}	11.67^{a}	43.33^{b}	63.67^{a}	9.67^{b}
Chromolaena odorata						
Fresh chopped	1.06^{ab}	0.12^{c}	9.00^{a}	49.33^{b}	69.67^{a}	9.00^{b}
Dried chopped	1.27^{b}	0.13^{c}	12.00^{a}	41.00^{b}	61.33^{a}	9.67^{b}
Synedrella nodiflora						
Fresh chopped	1.00^{ab}	0.11^{bc}	8.67^{a}	47.67^{b}	60.67^{a}	10.00^{bc}
Dried chopped	1.09^{ab}	0.11^{bc}	16.00^{a}	48.00^{b}	58.00^{a}	13.00^{c}

Note: Means along the column with the same superscript are not significantly different by Duncan test ($\alpha = 0.05$)

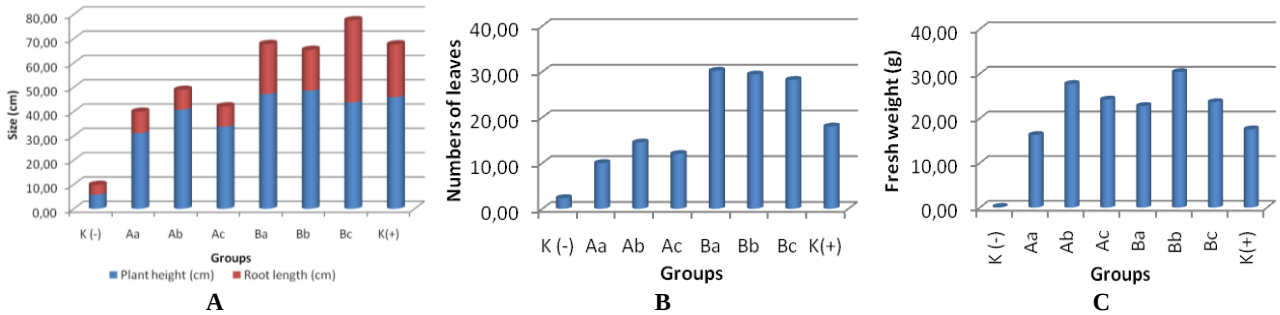
It was not surprising since the manurial properties of *C. odorata*, *M. micrantha* and *S. nodiflora* were similar. However, better results observed from soil treated with dried chopped weeds than those from fresh chopped were inconsistent with the finding of Olabode et al. (2007). This could be caused by different modes of application. Olabode et al. (2007) applied crushed fresh and ground dried to the soil while in this study we used the roughly chopped weeds for practical applications. When incorporated with the experimental soil, the dried chopped weeds were more easily broken into smaller pieces, hence increasing the surface area for decomposition and fastening the process, as opposed to the fresh ones. Therefore, the soil nutrient supplies required for plant growth were more readily available in the soil incorporated with dried chopped weeds.

We concluded from the present study results that the weeds *Chromolaena odorata*, *Mikania micrantha*, and *Synedrella nodiflora* have the potential to be used as green manures to improve soil fertility. According to this study, dried chopped weeds were more preferable to without drying process. This application should, therefore, be incorporated with weeds management for more efficient ecosystems services.

Table 4. The effect of weed biomass application on spinach growth and yields.

Form of weed biomass	Plant height (cm)	Root length (cm)	Numbers of leaves	Fresh weight (g)
Negative control	5.83^{a}	4.00^{a}	2.33^{a}	0.19^{a}
Mikania micrantha				
Fresh chopped	31.12^{b}	8.82^{a}	10.00^{ab}	16.27^{b}
Dried chopped	47.20^{d}	20.60^{b}	30.20^{c}	22.77^{b}
Chromolaena odorata				
Fresh chopped	40.78^{bcd}	8.15^{a}	14.50^{ab}	27.71^{b}
Dried chopped	48.60^{d}	16.80^{b}	29.40^{c}	30.58^{b}
Synedrella nodiflora				
Fresh chopped	33.80^{bc}	8.33^{a}	12.00^{ab}	24.21^{b}
Dried chopped	43.80^{bcd}	33.80^{c}	28.20^{c}	23.63^{b}
Positive control	46.00^{cd}	21.67^{b}	18.00^{bc}	17.54^{b}

Note: Means along the column with the same superscript are not significantly different by Duncan test ($\alpha = 0.05$).



A **B** **C**

Figure 3. Plant growth and yields response of spinach planted in soil treated with chopped weeds as opposed to soil without any amendments (negative control) and soil supplemented with NPK fertilizer (positive control). The measured parameters included plant height and root length (A), the number of leaves (B), and fresh weight (C) at the harvest time of 40 days after planting. A= fresh chopped weeds treatment group; B = dried chopped weeds treatment group; a = *Mikania micrantha*; b = *Chromolaena odorata*; c = *Synedrella nodiflora*

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