

Research Article

Soil organic matter status and penetration resistance at alley cropping system on degraded acid dryland

R. D. Yustika^{*}, Muchtar

Indonesian Soil Research Institute (ISRI), Jl. Tentara Pelajar 12A, Bogor 16114, Indonesia

* corresponding author: rd_yustika@litbang.pertanian.go.id

Abstract: Soil has important functions, one of which acts as a growing medium for plants so the soil environment should be able to support the growth and development of the plants in taking water and nutrient needs. The purpose of this study was to elucidate the effect of alley cropping on improvement of soil organic C status, and its impact on soil penetration. Observations of soil organic C status were done in 2008, 2011, and 2014, while observations of soil bulk density, C/N ratio, and penetration were conducted in 2014. Soil penetration was measured using penetrometer. Alley cropping systems applied were *Flemingia congesta*, *Leucaena glauca*, and *Gliricidia sepium*. The results showed that the presence of hedgerow trees in alley cropping systems could supply organic materials periodically and could increase the content of organic C. The results of measurements of soil penetration in the surface layer (0-5 cm) showed low penetration values. The penetration value increased with increasing soil depth with the highest penetration value was at the depth of 15 cm.

Keywords: *alley cropping, soil penetration, resistance organic C.*

Introduction

Soil has an important function that acts as a growing medium for the roots of plants, and other sources of nutrient use and storage of water needed for plant growth. Plants require supportive environment for growth. In optimum environmental conditions, plant roots will grow lengthwise to take the needs of water and nutrients necessary for optimal growth during the generative and vegetative periods. Crop productivity is determined by soil physical, chemical, and biological properties.

Organic matter has important roles in improving soil physical, chemical, and biological properties. Roles of organic matter in improving soil chemical properties include provision nutrients, increase soil CEC, forming complex compounds with metal ions that poison plants (Suriadikarta and Simanungkalit, 2006). Roles of organic matter in improving soil physical properties are improving soil aggregation, improving soil structure, creating conditions that support plant roots, regulating soil moisture, improving soil porosity, improving ability of soil

to retain water, and reducing runoff and erosion. Organic matter can also improve soil biological properties because of its role as a source of energy and food for microorganisms so as to increase the number and diversity of microorganisms. Microorganisms have benefits in the process of decomposition and weathering. Organic matters can be obtained from green manure originating from crop residues after harvest and pruned.

Legume plants can act as hedgerow trees in alley cropping system which produces organic materials. Type hedgerow tree include *Flemingia congesta*, *Leucaena glauca*, and *Gliricidia sepium*. The existence of hedgerow trees in alley cropping system is expected to supply organic matters periodically. Disturbance on soil physical properties can impair root growth. Compact and dry soil will make plant roots difficult to grow and thereby can inhibit plant growth. Soil penetration reflects the power of plant roots to penetrate the soil. Soil penetration can be measured using penetrometer or penetrometer.

The extent to which plant roots can enter the soil is influenced by several factors, i.e. ability of plant root itself, soil structure, soil texture, soil

density, soil cracks, soil organic matter content, and soil moisture (Kurnia et al., 2006). Measurement of penetration in large amounts require large data storage and adequate. Storage of large amounts of data can be done by using a data logger. The combination of the penetrometer with data logger enables the formation penetrometer development tool with large storage capacity measurements. The addition of organic matter is expected to improve soil properties and supports the development of roots to provide nutrients and water for plants. The purpose of this study was to explore the effect of alley cropping on the improvement of soil organic C status and its impact on soil penetration.

Materials and Methods

The study was conducted at Taman Bogor Experimental Station that has an Ultisol soil order. The coordinates of *Flemingia congesta* hedgerow tree were 05 ° 00 '22.5 "N 105 ° 29' 23.6" E. Those of *Leucaena glauca* hedgerow tree were at 05 ° 00 '21.7 "N 105 ° 29' 23.6" E, and those of *Gliricidia sepium* hedgerow tree were 05 ° 00' 20.9 "N 105 ° 29' 22.9" E. The plot areas were 2000 m², 1000 m², and 1000 m² *Flemingia congesta*, *Leucaena glauca*, and *Gliricidia sepium*, respectively.

The alley cropping systems have been applied since 2008. Cropping pattern in the alley cropping systems of 2008-2009 was cassava, whereas in 2010 was maize. Cropping patterns in the alley cropping systems of 2011 were maize-cassava, and in 2012-2014 were rice-maize-cassava. The entire biomass of the hedgerow trees was returned back to the land as green manure to improve soil physical and chemical properties. Crop residue returned to the land was rice (20%) and maize (60%). The cassava crop residues were not returned back to the land.

Observation of soil organic C status was done in 2008, 2012, and 2014, while observations of soil bulk density C/N ratio, and soil penetration were conducted in 2014. Soil penetration was measured using penetrometer. On each alley cropping plot, the measurement of soil penetration was replicated 12 times. Undisturbed soil samples at a depth of 0-15 cm were collected 2 times at each alley plot for soil bulk density measurement. Then bulk density measurement was performed by gravimetric method (Blake and Hartge 1986). Composite soil samples for measurements of soil organic C were also collected from a depth of 0-20 cm. Measurement of soil organic C was conducted using Walkley and Black method (Association of Official Agriculture Chemists, 2002).

Results and Discussion

Soil physical properties and soil organic matter status

Soil penetration resistance is influenced by soil texture, soil bulk density, and soil organic matter content. Soil of the Taman Bogor Experimental Station is classified as an Ultisol with Typic Kanhapudult subgroup. Ultisols are soils that have argillic or candic horizon with low base saturation (Soil Survey Staff, 1998). Argillic horizon that has been developed through process of thousands of years is an illuvial horizon with clay silicate interlayer has been accumulated through the process eluviation-illuviation (Rachim 2009).

The soil texture is composed of 59.7% sand, dust 15.7%, 24.6% clay (Soeleman et al. 2003). Soil surface layer can be passed by water quickly and also has a low penetration resistance. Soil with dominant sand fraction is generally loose and easily penetrated by roots, but in conditions of damaged soil structure with very low organic matter content, this is not necessarily the case.

Shortage of soil organic matter can make the soil becomes compact, and clotted making that make roots difficult to penetrate. Vaz et al. (2011) pointed out that the penetration resistance increases in soil containing high clay. According to Dexter et al. (2006), sandy clay soil has a higher penetration resistance compared to loamy sand soil. Another factor determining soil penetration resistance is soil bulk density (Canarache 1990; da Silva and Kay, 1997; Dexter et al., 2006). Bulk density is the unit weight of the soil mass per volume that can demonstrate the value of soil density. The high value of bulk density shows that the soil is difficult to pass water and plant roots. Soil bulk density value of the three alley cropping systems ranged from 1.05 to 1.22 g / cm³ (Table 1).

Table 1. Soil bulk density and CN ratio in alley cropping systems

Hedgerow Trees	Bulk Density (g/cm ³)	C/N Ratio
<i>Flemingia congesta</i>	1.10 ± 0.07	14.44
<i>Leucaena glauca</i>	1.05 ± 0.05	11.69
<i>Gliricidia sepium</i>	1.22 ± 0.09	12.85

Sources of organic matter can be obtained from manure, industrial wastes, crop residues and green manures (crop prunings). In situ organic material can be achieved by developing alley cropping system, i.e. food crops are planted between legume trees as hedgerows. The role of legume trees that act as hedges on the alley cropping system can be more effective if they meet the nature that is deeply rooted in order not to compete with the main crop,

rapid growth and after pruning can quickly germinate, capable of producing material forages, and capable of improving nutrient contents (Rahman et al., 2006). Legumes are often used as sources of green manure because in addition to having higher N content than non-legume crops, they also have low C/N ratio that makes them relatively easy to decompose. Thus, the nutrient supply is also expected to be available. Data presented in Table 1 show that C/N ratio of the plants ranged from 11 to 14. This indicates that the hedgerow trees can quickly decompose and serve as a source of organic matter. Prunings of the hedgerow trees studies are presented in Table 2. In 2008, *Leucaena glauca* and *Gliricidia sepium* were not pruned because they were still immature. There was only *Flemingia congesta* prunings. In the

following year (2009), *Gliricidia sepium* began to produce prunings. Starting in 2010, all hedgerow trees produced prunings as green manure. All prunings were returned back to the fields as additional organic matters to improve soil properties. *Flemingia congesta* and *Gliricidia sepium* had larger amount of prunings compared with *Leucaena glauca*. This condition caused the plots of alley cropping planted with *Flemingia congesta* and *Gliricidia sepium* had more sources of organic matter. However, *Leucaena glauca* prunings were more rapidly decompose and provide nutrients needed by the plants because the prunings had C / N ratio of 11.69 compared to the C/N ratio of *Flemingia congesta* prunings (14.44) and *Gliricidia sepium* prunings (12.85).

Table 2. Punings of hedgerow trees

Hedgerow Trees	Fresh of Weight of Prunings (t/ha)						2014
	2008 ¹⁾	2009 ²⁾	2010 ³⁾	2011 ⁴⁾	2012 ⁵⁾	2013 ⁶⁾	
<i>Flemingia congesta</i>	25.7	28.11	16.44	14.43	27.36	75.92	112
<i>Leucaena glauca</i>	0	0	4.35	6.72	7.1	30.16	83
<i>Gliricidia sepium</i>	0	28.34	16.73	15.03	22.32	47.9	140

Soelaeman and Muchtar, 2008, (2) Soelaeman and Muchtar, 2009, (3) Muchtar et al., 2010, (4) Muchtar, 2011, (5) Muchtar, 2012, (6) Muchtar, 2013

The results of measurements of organic C content carried out during three periods in 2008 (Soelaeman and Muchtar, 2008), 2012 (Muchtar, 2012), and 2014, showed the trend of increased levels of soil organic matter in *Flemingia congesta*, *Leucaena glauca* and *Gliricidia sepium* plots

(Figure 1). The content of organic C was influenced by the prunings produced. *Flemingia congesta* which had the highest prunings had the highest organic C content followed by *Gliricidia sepium* and *Leucaena glauca*.

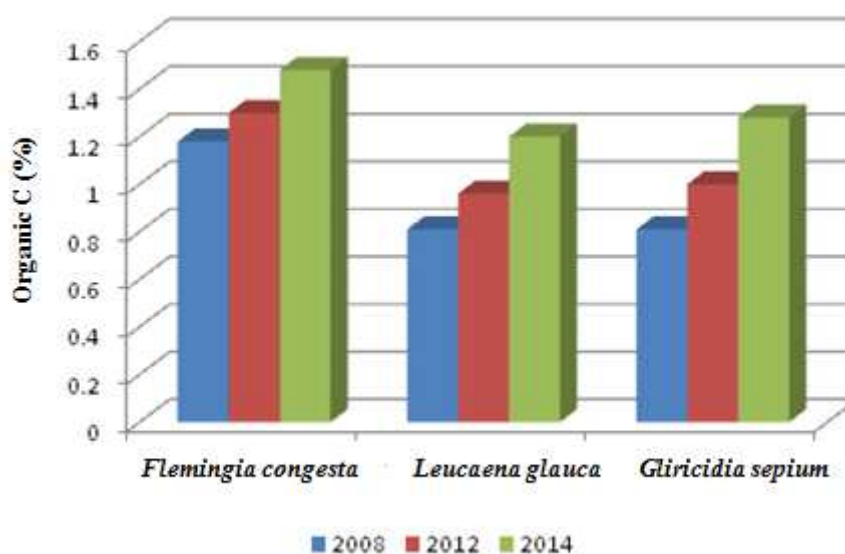


Figure 1. Organic C content in three alley cropping systems

Soil penetration resistance

Plants require a supportive environment for growth. Conducive soil conditions that allow for the roots to absorb nutrients, nutrients and water that support optimal growth both in the generative and vegetative, are needed. The growth of plant roots can be optimal if the fertile soil can meet the needs of macro and micro nutrients. The extent to which plant roots can grow can be measured using soil penetration resistance. A compact and dry soil will have a high penetration resistance which can result in reduced water infiltration into the soil, thus increasing the potential for runoff and erosion.

Moreover, it can affect the germination of plants because the hard soil triggers water stress. These conditions cause the disruption of the stability of plant productivity. The results of measurements on soil penetration in the soil surface layer showed low penetration values (Figure 2).

At a depth of 5 cm, penetration resistance was around 0.68 MPa (*Flemingia congesta*), 0.74 MPa (*Leucaena glauca*), and 0.85 MPa (*Gliricidia sepium*). This indicated that soil of the alley cropping systems was easily to be penetrated by roots, thus allowing plant roots to develop properly.

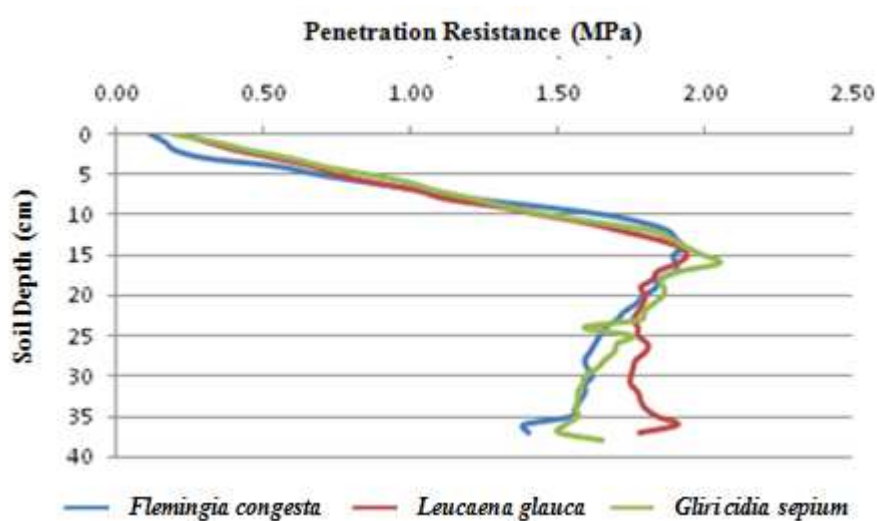


Figure 2. Soil penetration resistance in three alley cropping systems

The value of penetration resistance increased with increasing soil depth. Soil penetration resistance in the three alley cropping plots showed trend of the highest of penetration at a depth of about 15 cm (Figure 2). After a depth of 15 cm, then the trend of penetration decreased. Possibly at a depth of 15 cm was found a layer deposition or argillic clay. The presence of argillic horizon could lead to limited access of plant roots to absorb the nutrient-nutrients in deeper soil layers. Giving legume prunings can affect soil organic matter content.

Organic matter can function as a granulator to improve soil structure because the soil forms a complex with the organic material so that the aggregate becomes more stable. Organic C conditions in 2012 and 2014 increased more than in the beginning of 2008 (Figure 1), the land could then be more loose and could support the development of plant roots. Bariot et al. (1992) stated that alley cropping system that returning

plant biomass plays role in root penetration into the soil. Endriani (2010) reported that application of organic matter through mulching with the application of minimum tillage could reduce soil penetration resistance.

Conclusion

Organic matter from prunings of legume hedgerow trees could increase soil organic C content. This could be seen from the trend of organic C which showed increases in 2012 and 2014 compared to 2008. The results of the measurement of soil penetration resistance in the soil surface layer showed that the soil could be easily penetrated by the roots so the roots were easy to develop. Soil penetration resistance in the three alley cropping plots showed the trend of highest penetration at a depth of about 15 cm.

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