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Biomass of Various Tropical Legume Cover Crops Increase Soil Quality of Dryland Soils in Badung Bali, Indonesia

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Abstract
Two field experiments were conducted to study the effects of tropical legume cover crops on soil quality in dryland farming areas at Angantaka village, Badung regency, Bali Province of Indonesia from June to November 2013. In the first experiment, three tropical legume cover crops (LCC) (*Centrosema pubescens L.(Cp), Mucuna pruriens L.(Mp)* and *Pueraria javanica L. (Pj)*) and one control (without LCC) were arranged in a randomized complete block design with four replicates. Variables measured were the quality of LCC biomass, C-absorbed and fixed-N by LCC. The LCCs were harvested after three months, which were then incorporated into the soil according to the treatments set for the second experiment. Design for the second experiment was a Split-plot with four replicates, where residues (biomass) of three LCC (results of the first experiment) were assigned as the main plot and four times of biomas incorporation (0,10, 20 and 30 days) as the subplot. Results showed that *Pj* was the best LCC crop among others (*Cp* and *Mp*) due to its highest quality. *Pj* also had the highest absorbed-carbon (58.50 t ha^{-1}), fixed-N (490.21 kg ha^{-1}), biomass FW and DW (304.83 and 116.99 t ha^{-1}) among LCC species. The treatment of *Pj* with 30 days biomass incorporation significantly improved the soil quality as indicated by the highest soil moisture content (40.25%) and porosity (79.90%), organic-C (1.95%), total N (0.09%), available-P (15.71 mg kg^{-1}), exchangeable-K (2.07 mg kg^{-1}) and soil respiration (63.94 meC-CO_2 $kg^{-1}day^{-1}$).

Keywords: Biomass, Tropical legume cover crop, Soil quality

1. Introduction

In the tropic, farm lands with intensive cultivation without conservation efforts will result in 60-80% loss of organic carbon (Lal, 2006). Therefore, serious efforts are needed to increase soil organic carbon and finally the soil quality in drylands to achieve sustainable food crop productions. Soil physical, chemical and biological characteristics are indicators of soil quality (USDA, 1996).

One of the effort is the use of legume cover crops in crop farming system as a catch crop or fill crop during fallow (Dinga *et al*., 2006; Sarrantonio, 2007; Steenwerth and Belina, 2008; Acosta, 2009; Wang *et al*., 2010; Olson *et al*., 2010). Cover crop is a plant specially planted to cover the soil from erosion damage and to improve physical and chemical characteristics of the soil. Legume over crops has faster growth, adaptive to to low soil fertility, soil nitrogen supplier, absorb carbon effectively through photosynthesis activity, source of soil organic matter through biomass produced, and has higher biomass quality compared to non-legume species. In the long term, legumes contribute to maintain soil carbon content and soil quality improvement sustainably (Steenwerth *et al*., 2008; Wang *et al*., 2010; Olson *et al*., 2010). There are many tropical legume cover crops and used in orchards and also as forage such as Centrocema pubescens, Mucuna pruriens, Crotalaria juncea, Pueraria javanica, Phaseolus lunatus and others.

As fallow crops the use of soil cover crops play important roles in scavenging soil nutrients and save them temporarily until finally return them back to the soil, then to increase nutrients and organic carbon and to be available for the next crops. As soil cover they function to (1) resist or reduce damage action of rainfall drops and run-off on the soil surface, (2) increase soil organic matter through fallen dead stems and twigs.

There are limited research on the use of tropical LCC to improve soil quality on dryland soils in Indonesia, particularly in Bali. Dryland farming areas in Angantaka village in Badung regency, Bali province is one of farming area with poor soil quality, due to low organic-C, N, P and K. This area has potential to be developed for growing annual food crops and the use of tropical LCC is believed to be able to increase soil organic-C. Organic-C in the soil indicates the content of organic materials in the soil as a standard for agricultural land management (Bot and Bonittes, 2005). The higher the organic-C content the better the quality of the soil (Six *et al*., 1998; Blair *et al*., 1998). Increased organic-C in the soil (>2.5%) will influence soil quality (physical, chemical and biological properties) to be better in order to obtain better growth and high yields of crops. Therefore the present experiments were conducted to evaluate the potential of tropical LCC as cheap and easy to manage for improving soil quality in the areas.

2. Materials and methods

2.1 Study Area

Two field experiments were conducted from june to november 2013 at the dryland farming areas of angantaka village, badung, bali (008° 44' 45"s-115°10' 09"e, 3 m above sea level). The land was abandoned for long time and the soil has a very low organic-c (0.45 %), n (0.005%), available p (12.62 mg kg^{-1}) . Meanwhile the exchangeable-k (1.18 mg kg^{-1}), was high but soil ph was neutral (6.9). Soil moisture content at field capacity was 20.84% and soil texture was clayly silt (soil chemical laboratory of faculty of agriculture brawijaya university, malang, 2013). The analysis of lcc biomass, soil physical and chemical properties were conducted in the laboratory of soil biology, chemical and physics, faculty of agriculture brawijaya univeristy, malang (2013). Analysis of soil biological properties was conducted in laboratory of soil science, faculty of agiculture udayana university, denpasar (2013).

The first experiment was conducted to study the potential of various legume cover crops, which was conducted from June to August 2013. Experiment II was conducted from September to November 2013 to study the residual effect of LCC biomass on soil quality. In the first experiment, three tropical LCC viz. *Centrosema pubescens L. (Cp), Mucuna pruriens L.(Mp)* and *Pueraria javanica L.(Pj)* and one control (No LCC) were arranged in a randomized complete block design with four replicates. Variables measured were biomass production and the quality of LCC species, absorbed-C and fixed-N by LCC. The LCCs were harvested after three months, and the biomass were then incorporated into the soil according to the treatments set for the second experiment.

Design for the second experiment was a Split-plot with four replicates, where residues (biomass) of three LCC (results of the first experiment) were assigned as the main plot and four biomas incorporation periods (0,10, 20 and 30 days) as the subplot. Variable of soil physical (soil moisture content, bulk density and porosity), chemical (organic-C, total N, available-P and exchangeable-K,) and biological quality (soil microbe respiration) of the soil were measured after 30, 20, 10 and 0 days biomass incorporation. Soil moisture content, bulk density and porosity were respectively measured using the method of gravimetry, organic-C (Walkley and Black), N (Kjeldahl), available-P (Bray II) and exchangeable-K (NH_4OAc1N pH 7). Plate method was used to measure soil microbe respiration.

2.2 Statistical analysis

Statistical analysis was conducted using Cohort and MstatC computer software and comparation of means were done using Duncan's Multiple range test and Least Significant Different analysis at 5% level (Gomez and Gomez, 1984). Data were transformed where necessary. Figures were drawn using Excel software.

3. Results and discussion

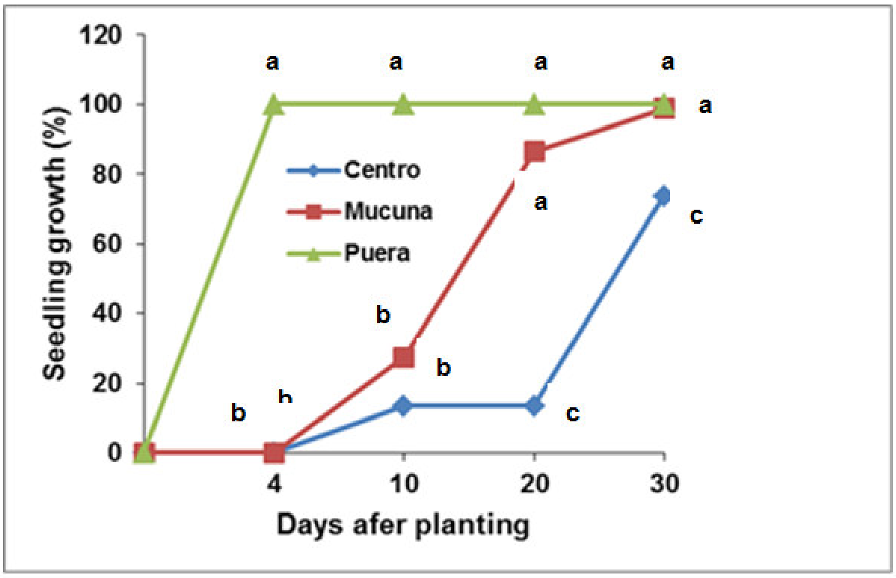
3.1 LCC Biomass Quality and Production

Results of biomass quality analysis (experiment I) showed that *Pueraria javanica* L. or *Pj* was the best species among the others (*Mucuna pruriens* L. and *Centrosema pubescens* L.) due to its best quality such as higher moisture content (72.06%), total N (3.85%), total P (0.25%), K (1.66%), total C (49.88%), Ca (3.58%), but lower C/N *ratio* (9.36) and C/P *ratio* (364.00) (Table 1). Additionally, *Pj* also had the highest absorbed carbon (58.50 t ha^{-1}) (Fig.2) and fixed N (490.21 kg ha^{-1}) (Fig.3). *PJ* gave the highest biomass production (FW and DW of 304.83 and 116.99 t ha^{-1}) (Fig.1) compared to the other species. Hairiah *et al*. (2003) reported that LCC could provide 2-3 t ha^{-1} organic materials at the age of 3 months and produced 3-6 t ha^{-1} when was left for 6 months. In the present experiment the LCC produced higher organic materials in 3 months.

The high bio-chemical quality of LCC biomass found in the present experiment was indicated by relatively higher content of N, P, K and Ca, and lower C/N ratio and higher C/P ratios (Table 1). This lower C/N ratio, which was lower than critical value, would be the main energy resources for microbes to conduct their biological process to degrade the biomass, compared to LCC species with lower quality. Palm *et al*. (1997), Handayanto (1997) and Rachman *et al*. (2006) stated that legumes are high organic materials resources due to their high N content (>2.5%), low C/N ratio (<20), lignin (<15%) and *polyphenol* (<4%), therefore they were easily decomposed by microorganisms in the soil.

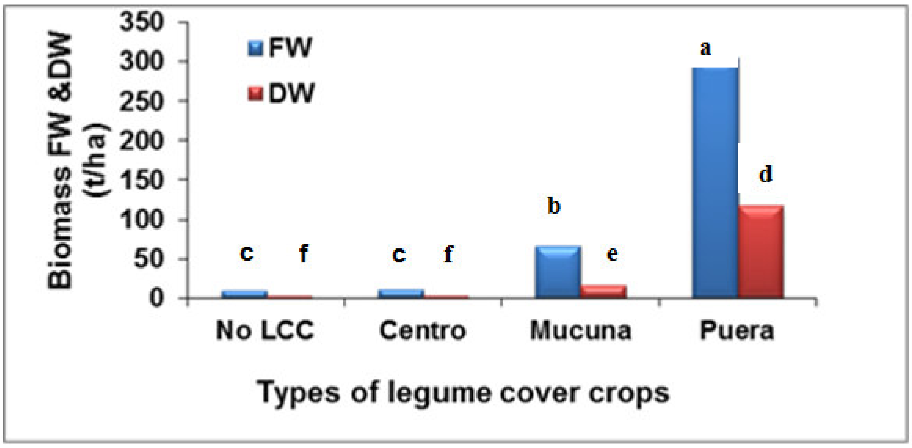
Tabel 1. The Quality of LCC biomass

No.	Chemical content	Unit	LCC		
			C.pubescens (Cp)	*M. pruriienss* (Mp)	*P. javanica* (Pj)
1	Moisture content	%	69.80	74.40	61.60
2	Total N	%	1.31	1.71	1.85
3	Total P	%	0.58	0.12	0.12
4	Total C	%	43.42	40.82	38.88
5	C/N		33.14	23.87	21.36
6	C/P		74.86	340.17	324.00
7	K	%	1.25	0.76	0.66
8	Ca	%	1.47	1.50	1.52
9	Mg	%	0.06	0.01	0.03
10	Lignin	%	11.92	14.28	8.02
11	Polyphenol	%	5.94	8.14	5.10



Notes: Points on each line with the same letters at the same day of planting are not significantly different at 5% LSD

Figure 1. Percentage of LCC seedling growth up to 30 days after planting



Notes: Histograms of each FW or DW with the same letters are not significantly different at 5% LSD

Figure 2. Fresh and Dry weights of Legume cover crops

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3.2 LCC seedling growth, biomass fresh and dry weight, absorbed-C and fixed-N

Pj species had the earliest and fastest growth compared to the other LCC species. The seedlings had already 100% emerged at four days after sowing, while the other species achieved that 30 days after planting (Fig.1). *Pj* species also had the the highest biomas FW and DW (304.83 and 116.99 t ha^{-1}) (Fig.2), absorbed-C (58.50 t ha^{-1}) (Fig.3) and fixed-N (490.21 kg ha^{-1}) (Fig.4), among all LCC species. Those qualities of *Pj* species were significantly (P<0.05) higher than those of *Mp* and *Cp* species.

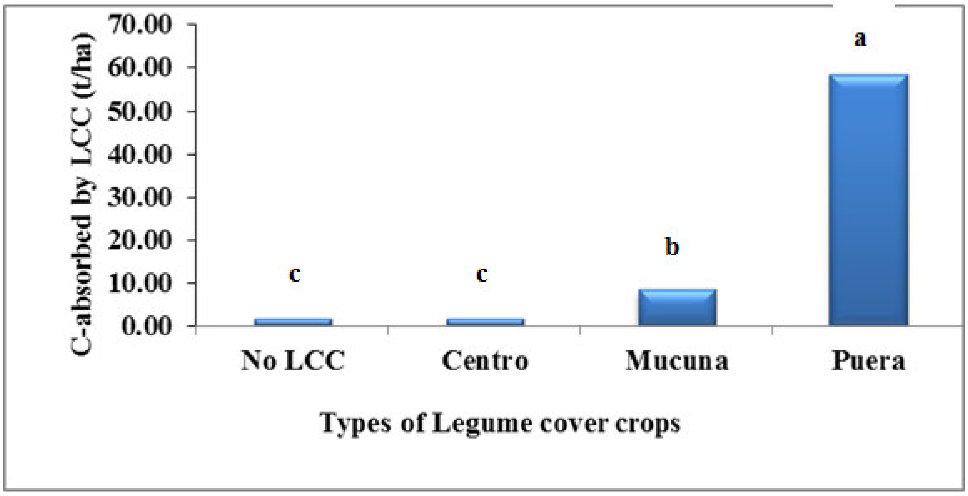

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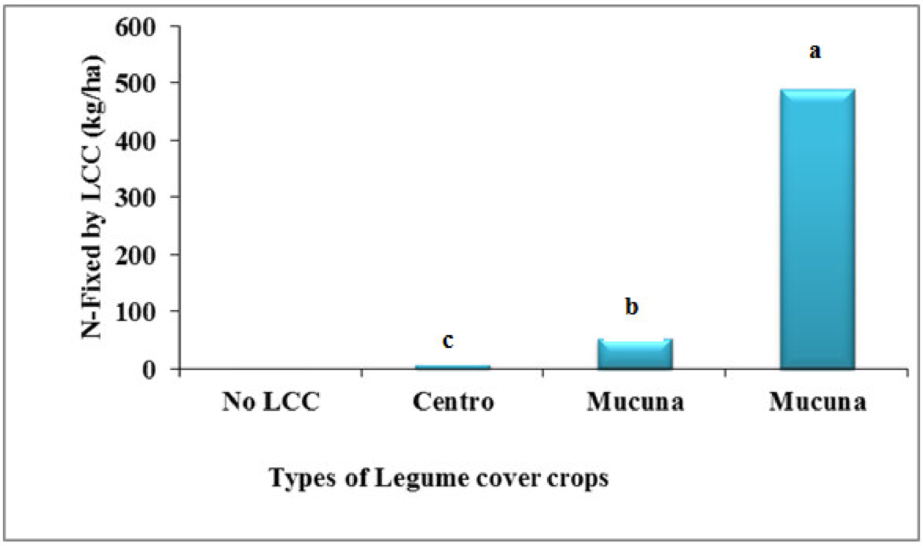
Fig. 3. C-absorbed by Legume cover crops



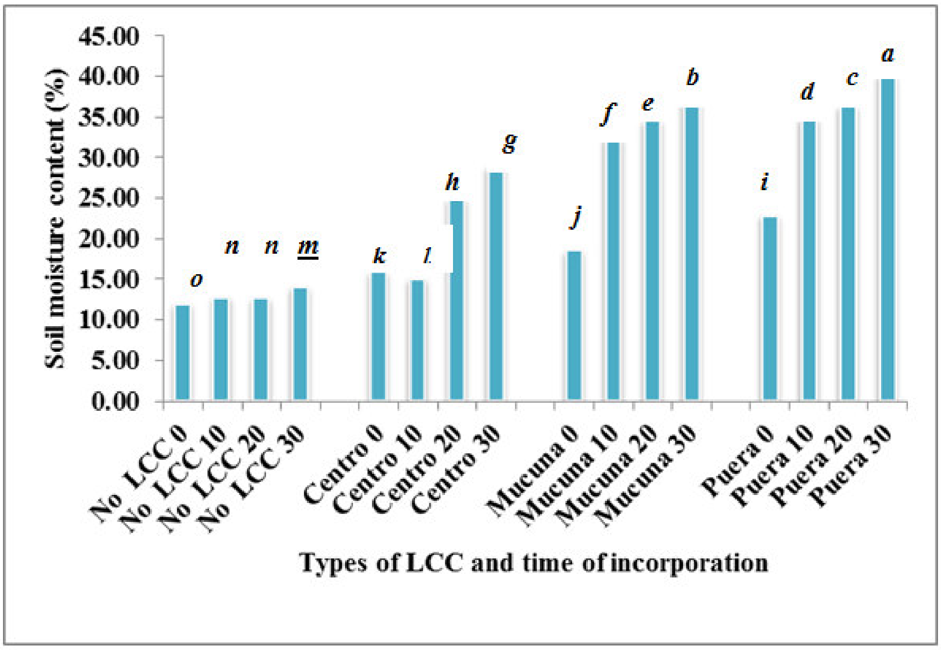
Notes: Histograms with the same letters are not significantly different at 5% LSD

Fig. 4. N Fixed by Legume cover crops

3.3 Effect of LCC biomass incorporation

3.3.1 Soil Physical quality

The interaction effects between LCC species and the time of biomass incorporation were significant (P<0.05) on variables of soil quality. The *PJ* species with biomass incorporation for 30 days (Puera 30) significantly (P<0.05) resulted in higher soil quality compared to the other incorporation treatments as indicated by higher physical, chemical and biological qualities. Soil moisture content and porosity were the highest (49.25% and 90.91% respectively) (Fig. 5 and Fig. 7) while the soil bulk density was the lowest (0.532 cm^{-3}) under the treatment of Puera 30 (Fig.6). The lower soil bulk density and higher porosity indicating the loose soil.

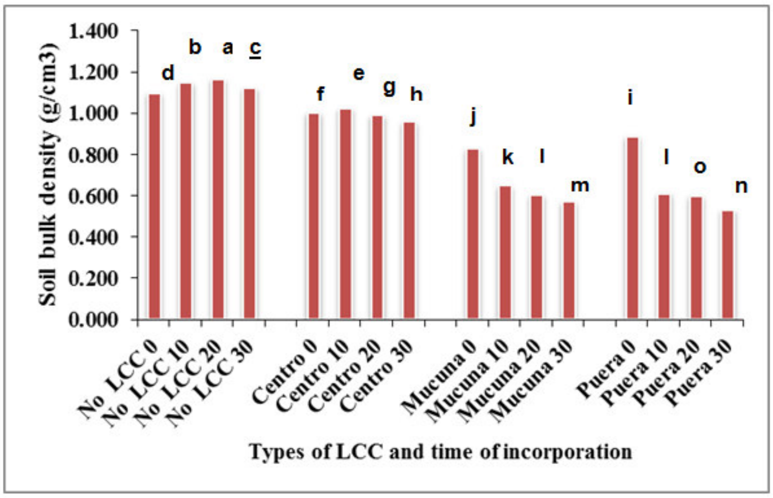


Notes: Histograms with the same letters are not significantly different at 5% Duncan's Multiple Range Test

Fig. 5. Soil moisture content under each LCC type and times of residue incorporation

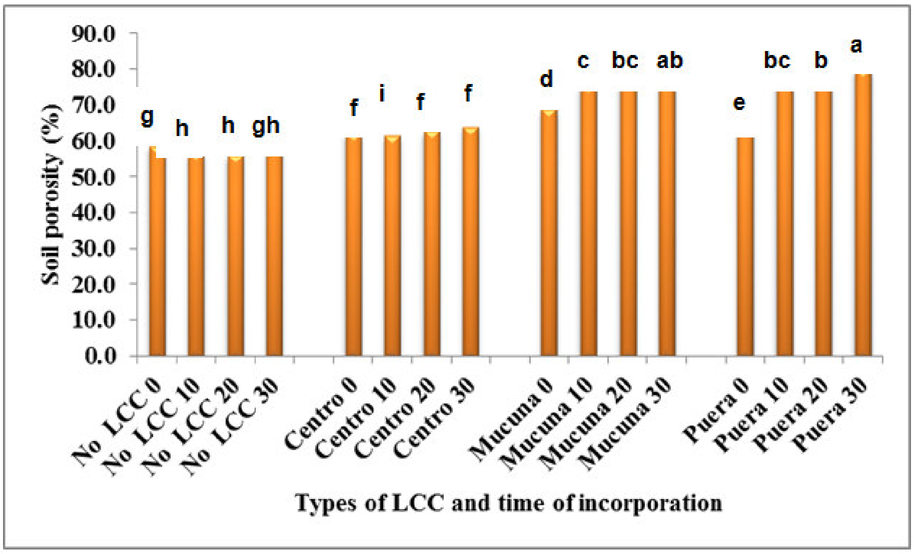
PJ species used in the present experiment had the lowest C/N ratio (9.36) compared to the other LCC types (Table 1), therefore could have been easily decomposed by soil organisms. The C/N ratio determines the rate of decomposition, because carbon (C) and nitrogen are important for microorganisms to conduct the decomposition process. Carbon is needed by microorganisms as the energy source and nitrogen as proteins. A biomass with high C/N ratio is slower to be decomposed (Sulistiyanto *et al.,* 2005). High C/N ratio indicates low N in the organic materials therefore the available N will first be used for their physiological requirements.

Organic materials with lower C/N ratio (such as legumes) generally undergo faster decomposition with 50% materials have been decomposed in three weeks (Hairiah and Murdiyarso, 2007). This situation could have been the reason for the effect of biomass incorporated into the soil in the present experiment, which was more significant after 30 days compared to 10 and 20 days of incorporation.



Notes: Histograms with the same letters are not significantly different at 5% Duncan's Multiple Range Test

Figure 6. Soil bulk density under each LCC type and times of residue incorporation

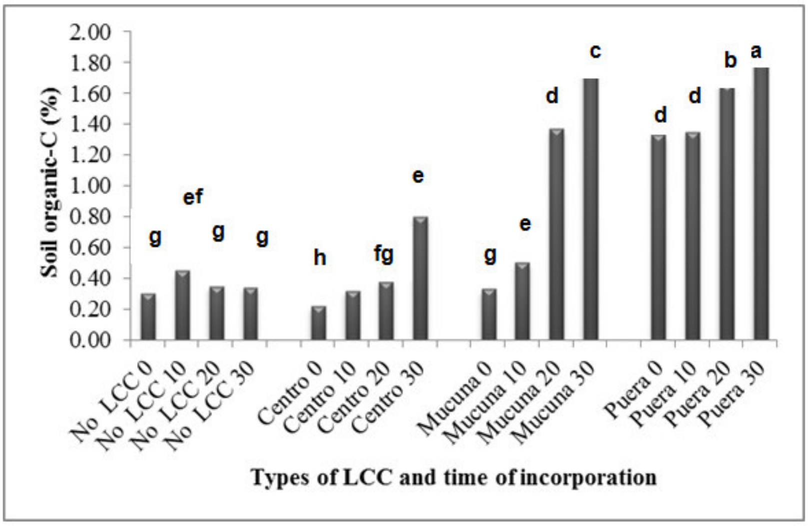


Notes: Histograms with the same letters are not significantly different at 5% Duncan's Multiple Range Test

Fig. 7. Soil porosity under each LCC type and times of residue incorporation

3.3.2 Soil chemical quality

Among the treatments, Puera 30 resulted in the highest soil organic-C (1.75%) (Fig. 8), total N (0.09%) (Fig. 9), available P (15.71 mg kg^{-1}) (Fig. 10) and exchangeable K (2.07 mg kg^{-1}) (Fig. 11). The highest value of those chemical components were due to the highest chemical quality of *Pueraria javanica* (Tabel 1), which completely released those nutrient at 30 days of incorporation. Higher soil organic-C, total N, available-P and exchangeable-K under the treatment of Puera 30 was associated with high quality (Tabel 1) and production of Pj biomass (Fig.2 and Fig.3). In the present study, the decomposition was believed to occur before 30 days after biomass incorporation and the nutrients were released more than 50% by the time of 30 days after biomass incorporation, especially with the good quality biomass of LCC such as *Pueraria javanica* L.(*Pj*).

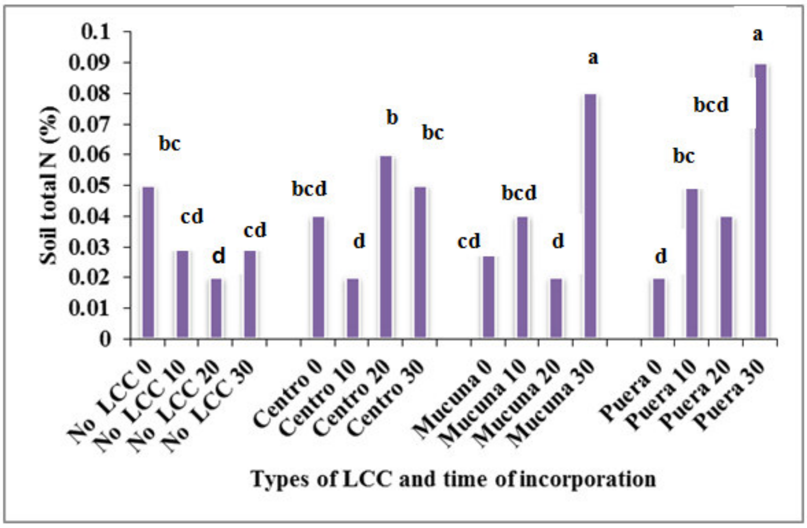


Notes: Histograms with the same letters are not significantly different at 5% LSD

Fig. 8. Soil organic-C under each LCC type and times of residue incorporation

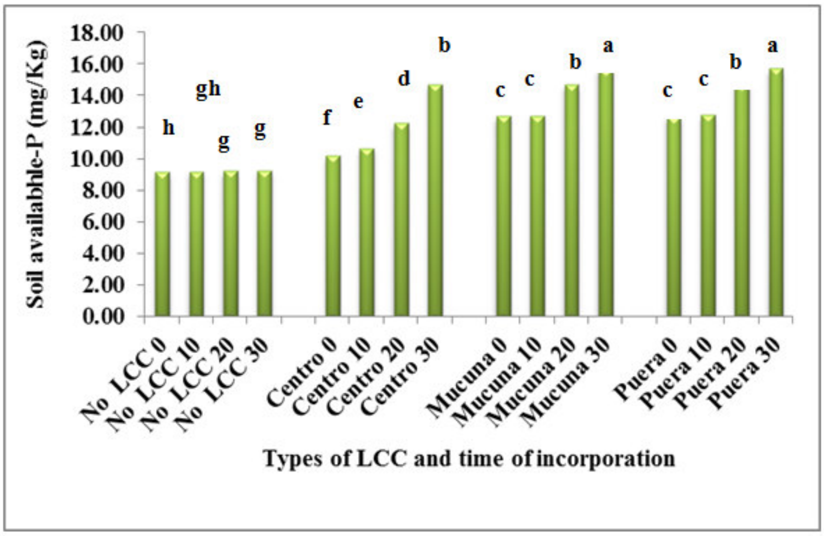
3.3.3 Soil biological quality

High organic-C in the soil increased the activity of microbes, indicated by higher soil respiration under the treatment of Puera 30 (63.94 MeC-CO^2 kg^{-1} day^{-1}, Fig. 12) compared to the others. Those high microbe activities may consequently enhanced the decomposition and finally released the nutrients. This condition indicated that due to the high quality and production, *Pj* biomass became the source of food and good materials for soil microbes to be decomposed and finally resulted in plenty of nutrients released to improve the soil quality. In addition, lower lignin and polyphenol contents in *PJ* species (Table 1) could increase the rate of decomposition. High lignin and polyphenol contents in organic materials would inhibit the mineralization process due to their protein binding that determine the easiness of decomposition by soil microbes (Stevenson 1994; Hadyanto *et al*., 1997).



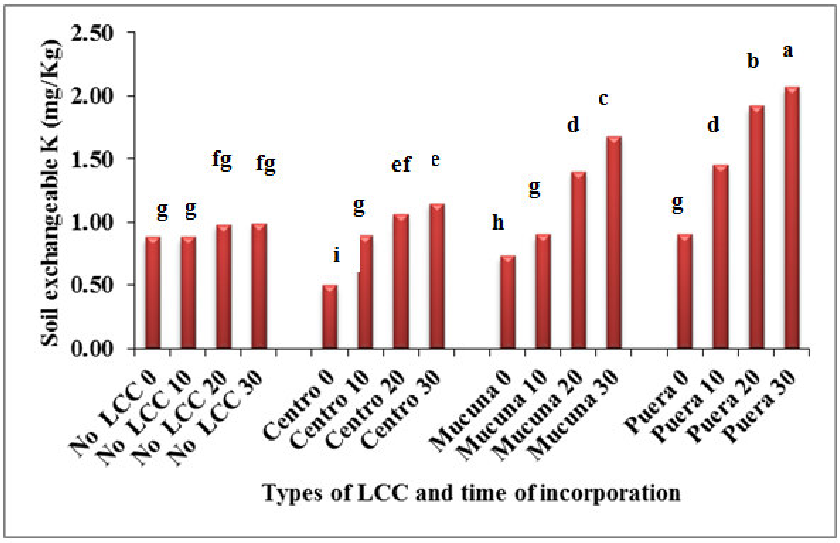
Notes: Histograms with the same letters are not significantly different at 5% Duncan's Multiple Range Test

Fig. 9. Soil total N under each LCC type and times of residue incorporation



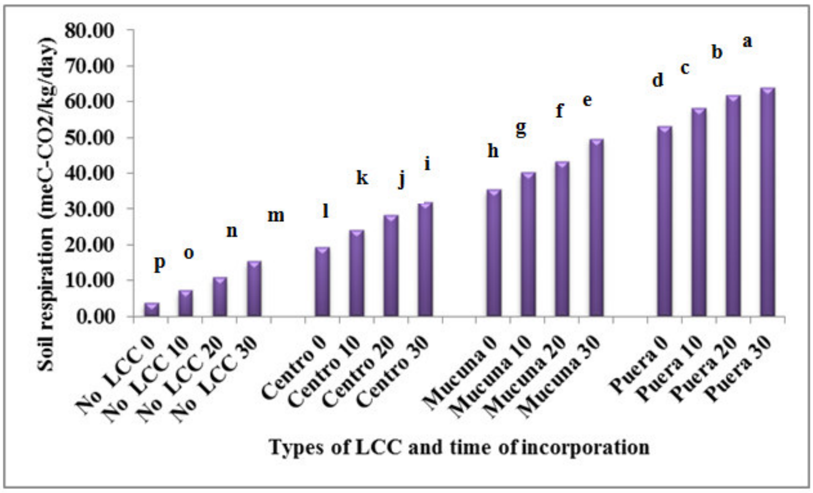
Notes: Histograms with the same letters are not significantly different at 5% Duncan's Multiple Range Test

Fig. 10. Soil available-P under each LCC type and times of residue incorporation



Notes: Histograms with the same letters are not significantly different at 5% LSD

Fig. 11. Soil exchangeable K under each LCC type and times of residue incorporation



Notes: Histograms with the same letters are not significantly different at 5% LSD

Fig. 12. Soil respiration under each LCC type and times of residue incorporation

4. Conclusion

Species of *Pueraria javanica* L. was the best and suitable LCC to improve soil quality among all LCC species. The biomass residues of *Pueraria javanica* L. significantly improved the soil quality through increasing physical, chemical and biological quality of the soil at 30 days after biomass incorporation.

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