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Research Article

Nitrogen released from mixtures of sago pulp waste and *Gliricidia sepium* pruning on a Dystrudept of Central Moluccas and its effect on maize growth

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Abstract

The agricultural sector is the mainstay of the economy in Central Moluccas. However, most agricultural soils on the island have low soil fertility. One of the efforts that farmers can make to improve soil fertility is to apply organic matter, which is widely found in Central Moluccas. This study aimed at elucidating the effect of mixing high-quality organic material (*Glicidia sepium* pruning) with low-quality organic material (sago pulp waste) on the improvement of available nitrogen in an acid soil (Dystrudept) and growth of maize. Two experiments were carried out in a laboratory and a greenhouse. The compositions of the mixtures of sago pulp waste (A) and pruning of *Gliricidia sepium* (G) were A_0 G_{100}; $A_{20}G_{80}$; $A_{40}G_{60}$; $A_{60}G_{40}$; $A_{80}G_{20,}$ and $A_{100}G_0$. Six treatments and one control (no application of residues) were arranged in a completely randomized design. The results showed that the application of the mixture of 20% and 80% of *Gliricidia sepium* pruning ($A_{20}G_{80}$) increased the cumulative amount of mineral N in the soil higher than that of the other organic material mixtures, which in turn improved maize growth.

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Introduction

The agricultural sector is the mainstay of the economy in Central Moluccas. However, most agricultural soils on the island have low soil fertility due to low pH (<5) and low nitrogen and organic matter contents. Waas et al. (2016) stated that the Dystrudepts found in Central Moluccas was a very acidic soil reaction (pH<4.5) to acid (pH 5.5-4.5), low to very low organic matter content (<1%). The soil, however, has the potential for the development of superior agricultural commodities, both food crops, horticulture and plantations (Risal et al., 2018). One of the efforts that farmers can make to improve soil fertility is to apply organic matter in the form of sago pulp waste which is widely found in Central Moluccas. The high fibre plant residue from the stems of the sago plant (*Metroxylon sago*) resulting from the starch extraction process has the potential as a local organic material, which annually produces 26.4 tons of sago pulp waste from 20 trees ha^{-1} (Alfons and Bustaman, 2005) or 153 t ha^{-1} of one hectare (Alfons, 2013). Fresh sago pulp waste contains: 26% organic C; total N 0.28%; available P 1.03%; K 0.29%; Ca 3.84%; Mg 0.05% (La Habi et al., 2014); lignin 20.67% (Kiat, 2006); the highest C/N ratio is 70 (Tatipata and Jacob, 2013). Sago pulp waste is allowed to accumulate for years after being decomposed into compost which can provide nutrients for plant growth (Syahtria et al., 2016). Plant residues that are incorporated into the soil will undergo mineralization (Wieder et al., 2013). Plant parameters that control mineralization are nitrogen, carbon, lignin and polyphenol contents (Mafongoya et al., 2011; Castellano et al., 2015), besides climates and soil microbial activities (Palm et al., 2001). Because sago pulp waste is classified as an organic material of low quality having low nitrogen content (0.82%), high lignin (20.67%) and high C/N ratio (46), its decomposition process takes 4-6 months (Syakir 2005; Alfons, 2013) so that the release of nitrogen from sago pulp waste runs very slowly and is not in synchrony with the plant demand for nitrogen.

In addition to sago pulp waste, organic material that is widely available around agricultural land in Central Moluccas is *Gliricia sepium* pruning. It has been widely reported that the fresh pruning leaves of *Gliricidia sepium* have 3.5%-4.8% N (Powers and Tiffin, 2010; Gei et al., 2013; Li et al. 2016), C/N ratio of 9.8, 12.5% lignin, and 2.4% polyphenol (Mundus et al., 2008; Powers and Tiffin, 2010). *Gliricidia sepium* pruning decomposes and releases nitrogen very fast into the soil; within seven days, 30% N was released (Kaba et al., 2019), and within 24 weeks, about 60% N was released (Chirwa et al., 2006), so it is not in synchrony with plant demands for nitrogen. Nitrogen-rich plants decomposed much faster than nitrogen-poor plants (Korsaeth et al., 2001). In order to synchronize N released from legume pruning with plant demand for nitrogen, changing the quality of organic materials by mixing high-quality organic matter with low-quality organic matter is a way to accelerate the decomposition and mineralization of N of organic matter to improve plant growth (Mapfumo et al., 2007; Murungu et al., 2011).

This study was aimed at elucidating the effect of mixing organic materials of different qualities, i.e., *Glicidia sepium* pruning and sago pulp waste, on the improvement of available nitrogen in acid soil and growth of maize.

Materials and Methods

Experiment 1: Mineralization of nitrogen from mixtures of sago pulp waste and Gliricidia sepium pruning (an incubation experiment)

A non-leaching incubation experiment was conducted at the Soil Biology Laboratory, Faculty of Agriculture, Pattimura University. Air-dried sago pulp waste (A) and *Gliricidia sepium* pruning (G) were mixed with the proportions (%w/w): A_0G_{100}; $A_{20}G_{80}$; $A_{40}G_{60}$; $A_{60}G_{40}$; $A_{80}G_{20,}$ and $A_{100}G_0$. Each mixture with a dose equivalent to 100 kg N ha^{-1} was incorporated into 100 g of air-dried soil and placed in a 250 mL plastic bottle. The soil used for this study was Dystrudept collected from Hatu village, West Leihitu Sub-district, Ambon Island. The soil is located in a hilly area, with an altitude of 37 m above sea level and the land use is a mixed garden. The soil has the following characteristics: pH = 5.0, organic C = 1.3%, total N = 0.16 %, C/N ratio = 8, organic matter = 2.01% and clay texture. The sago pulp waste was taken from Tulehu village, Salahutu Sub-district - Ambon Island in fresh condition (1-day harvest). The results of chemical analysis showed that the sago pulp waste contained 45.13% of organic C, 0.56 % of total N, 16.23% of lignin and 6.12% of polyphenol. *Gliricidia sepium* pruning (young twigs and leaves) were obtained from Suli Village, Salahutu Sub-district, Ambon Island. The results of chemical analysis showed that the *Gliricidia sepium* pruning contained 25.93% of organic C, 2.86% of total N, 8.68% of lignin and 2.78% of polyphenol. The chemical composition of sago pulp waste and *Gliricidia sepium* pruning mixtures (A_0G_{100}; $A_{20}G_{80}$; $A_{40}G_{60}$; $A_{60}G_{40}$; $A_{80}G_{20}$ and $A_{100}G_0$) were analyzed for C, N, lignin and polyphenol contents. The plastic bottle containing soil and the organic material mixture was incubated at room temperature (27ºC) for 8 weeks. During the incubation period, the water content was maintained at 70% of the water holding capacity. Six treatments and one control were arranged in a completely randomized design with three replications. At 1, 2, 4, 6 and 8 weeks of incubation, soil samples were taken destructively for the determination of soil mineral N (N-NH_4^+ and N-NO_3^-) using the Kjeldahl method (Bremer and Mulvaney, 1982). Data obtained were subjected to analysis of variance (ANOVA) followed by the Duncan Multiple Range Test at 5% significant level. Correlation analysis was performed using the SPSS package program.

Experiment 2: Effect of mixtures of sago pulp waste and Gliricidia sepium pruning on maize growth (a pot experiment)

A pot experiment was conducted in a glasshouse of the Faculty of Agriculture, Pattimura University. Each of the mixture of sago pulp waste (A) and *Gliricidia sepium* pruning (G) as for experiment 1 (A_0G_{100}; $A_{20}G_{80}$; $A_{40}G_{60}$; $A_{60}G_{40}$; $A_{80}G_{20}$ and $A_{100}G_0$), applied at a rate equivalent to 100 kg N ha^{-1}, was mixed with 20 kg of soil in a polybag. The basal fertilizers given were 3.74 g urea (N-fertilizer) polybag^{-1}, 0.21 g SP36 (P-fertilizer) polybag^{-1} and 0.35 g KCl (K fertilizer) polybag^{-1} (Syafruddin, 2015). After 2 weeks of incubation, one seed of maize of Nakula Sadewa 29 variety was planted. Six treatments and one control were arranged in a completely randomized design with three replications. Soil and plant samples were taken destructively at weeks 1, 2, 4, 6 and 8. Soil samples were analyzed for mineral N using the Kjeldahl method proposed by Bremer and Mulvaney (1982) with the addition of oxidized magnesium and Devarda Alloy. Plant height, stem diameter and root length were also measured. The data obtained were subjected to analysis of variance (ANOVA) followed by the Duncan Multiple Range Test at 5% significance level.

Results and Discussion

Chemical composition of the mixtures of sago pulp waste and Gliricidia sepium pruning

The mixtures of sago pulp waste and *Gliricidia sepium* pruning had various chemical compositions (Table 1). The C content, C/N ratio, polyphenol content, lignin content, polyphenol/N ratio, lignin/N ratio and (polyphenol + lignin)/N ratio increased in value with the increasing proportion of sago pulp waste in the mixtures, while N content significantly decreased with decreasing proportion of *Gliricidia sepium* in the mixtures.

The lowest C content of 25.97% was observed in the A_0G_{100} mixture, and the highest C content of 45.13% was in the $A_{100}G_0$ mixture. The lowest N content of 0.32% was in the $A_{100}G_0$ mixture, and the highest N content of 2.89% was in the A_0G_{100} mixture. The C/N ratio obtained ranged from 9.18 (A_0G_{100}) to 141.03 ($A_{100}G_0$). For rapid decomposition and mineralization, organic material should have an N content higher than the critical value, which is between 1.5% to 2.5% (Palm et al., 2001), with a ratio value C/N of less than 20 (Hadas et al., 2004). Thus, the mixtures of sago pulp waste and *Gliricidia pruning* that have an N content higher than the critical value of N were $A_{60}G_{40}$ (1.33%), $A_{40}G_{60}$ (1.85%), $A_{20}G_{80}$ (2.35%) and A_0G_{100} (2.86%). The lowest values of polyphenol content (2.16%), lignin content (7.97%), polyphenol/nitrogen ratio (9.82), lignin/nitrogen ratio (36.29), and (polyphenol + lignin)/nitrogen ratio (46,08) were observed in the A_0G_{100}. To undergo N mineralization, organic material should contain below lignin content 15%, and the polyphenol content is not more than 4% (Palm et al., 2001; Hadas et al., 2004).

Table 1. Chemical composition of mixtures of sago pulp waste and *Gliricidia sepium* pruning.

Mixtures of Organic Materials	Parameters							
	C (%)	N (%)	C/N ratio	Polyphenol (%)	Lignin	Polyphenol /N ratio	Lignin/N ratio	(Polyphenol +Lignin) /N ratio
A_0 G_{100}	25.93	2.86	9.18	2.16	7.97	9.82	36.29	46.08
A_{20} G_{80}	29.77	2.35	12.67	3.88	9.08	17.07	40.06	57.2
A_{40} G_{60}	33.61	1.85	18.17	6.54	10.05	29.73	45.69	75.43
A_{60} G_{40}	37.48	1.33	33.17	7.42	12.77	29.13	60.79	89.54
A_{80} G_{20}	41.29	0.83	49.75	9.14	15.61	36.53	76.84	113.37
A_{100} G_0	45.13	0.32	141.03	6.12	15.24	46.47	82.87	129.34

Notes: A_0G_{100} = 100% *Gliricidia sepium* pruning, $A_{20}G_{80}$ = 20% sago pulp waste and 80% *Gliricidia sepium* pruning, $A_{40}G_{60}$ = 40% sago pulp waste and 60% *Gliricidia sepium* pruning, $A_{60}G_{40}$ = 60% sago pulp waste and 40% *Gliricidia sepium* pruning, $A_{80}G_{20}$ = 80% sago pulp waste and 20% *Gliricidia sepium* pruning, and $A_{100}G_0$ = 100% sago pulp waste.

Cumulative mineral N in the soil (experiment 1)

The cumulative amount of mineral N in soil amended with sago pulp waste and *Gliricidia sepium* pruning mixtures increased from week 1 to week 4 and then decreased from week 6 to week 8 (Figure 1). The increase in the cumulative mineral N that occurred in week 1 to week 4 was in accordance with the composition of the mixtures of sago pulp waste and *Gliricidia sepium* pruning, where the higher the proportion of *Gliricidia sepium* pruning in the mixtures, the higher was cumulative of mineral N in the soil. On the contrary, the higher the sago pulp waste in the mixtures, the lower the cumulative mineral N.

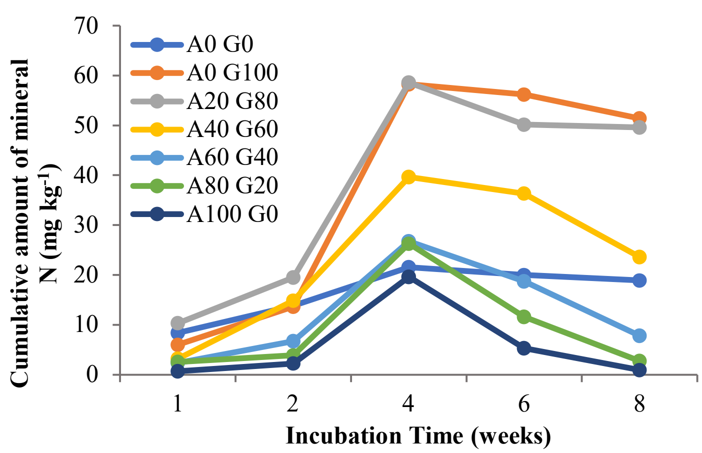

Figure 1. The cumulative amount of mineral N in soil amended with the mixtures of sago pulp waste and *Gliricidia sepium* pruning during 8 weeks incubation. A_0G_{100} = 100% *Gliricidia sepium* pruning, $A_{20}G_{80}$ = 20% sago pulp waste and 80% *Gliricidia sepium* pruning, $A_{40}G_{60}$ = 40% sago pulp waste and 60% *Gliricidia sepium* pruning, $A_{60}G_{40}$ = 60% sago pulp waste and 40% *Gliricidia sepium* pruning, $A_{80}G_{20}$ = 80% sago pulp waste and 20% *Gliricidia sepium* pruning, and $A_{100}G_0$ = 100% sago pulp waste.

The highest cumulative mineral N of 58.62 mg kg^{-1} occurred in week 4, which was observed in the $A_{20}G_{80}$ treatment. The high soil mineral N in the $A_{20}G_{80}$ treatment was influenced by the low C/N ratio (Seneviratne 2000; Cordovil et al., 2005), so that the mixed material mineralized more quickly (Kamkar et al., 2014; Gaisie et al., 2016; Jiang et al., 2017). Likewise, the polyphenol and lignin contents of the material were still below the decomposition limit (Palm et al., 2001; Hadas et al., 2004).

The decreases in the cumulative mineral N found at week 6 and week 8 were strongly influenced by the composition of the mixture of sago pulp waste and *Gliricidia sepium* pruning. The highest cumulative amounts of mineral N at week 6 and week 8 of 56.20 mg kg^{-1} and 51.43 mg kg^{-1}, respectively, were found in the A_0G_{100} treatment. Compared to the highest cumulative mineral N at week 4, namely, in the $A_{20}G_{80}$ treatment (58.62 mg kg^{-1}), or increased 172% compared to the control treatment of 21.53 mg kg^{-1}, the highest cumulative mineral N at week 6 (56.20 mg kg^{-1}) and week 8 (51.43 mg kg^{-1}) decreased, respectively, by 4.13% and 12.27%. The C/N ratio, polyphenol content, and the lignin content of the organic material mixtures have negative relationships with the cumulative mineral N in the soil, while the N content of the organic material mixtures had positive relationships with the cumulative mineral N in the soil (Table 2). Although *Gliricidia sepium* pruning decomposes relatively quickly so that it can contribute nitrogen (Chirwa et al., 2006; Walpola and Arunakumara, 2009; Kaba et al., 2019) as much as 30% within 7 days (Chirwa et al., 2006), the amount of N released from the pruning was not able to increase the cumulative amount of mineral N in the soil at week 6 and week 8.

Table 2. Correlation between the chemical composition of sago pulp waste and *Gliricidia sepium* pruning mixtures with the cumulative amount of N mineralized from the organic material mixtures.

Chemical composition of organic material mixtures	**Coefficient of correlation (r)**				
	Cumulative mineral N in soil (mg kg^{-1})				
	Incubation time (weeks)				
	1	**2**	**4**	**6**	**8**
C (%)	-0.571**	-0.554*	-0.276	-0.431	-0.49 2*
N (%)	0.318	0.572**	0.938**	0.900**	0.817**
C/N ratio	-0.670	-0.766**	-0.511*	-0.655**	-0.619**
Polyphenol (%)	-0.778**	-0.702**	-0.373	-0.554**	-0.637**
Lignin (%)	-0.718**	-0.686**	-0.186	-0.404	-0.479*
Polyphenol/N ratio	-0.795**	-0.747**	-0.417	-0.597**	-0.670**
Lignin/N ratio	-0.745**	-0.740**	-0.256	-0.466*	-0.535*
(Polyphenol+Lignin)/N ratio	-0.770**	-0.749**	-0.318	-0.519*	-0.590**

Notes: **significantly different at $p<0.01$; *significantly different at $p<0.05$.

N released from the mixtures of sago pulp waste and Gliricidia sepium pruning (experiment 2)

During the vegetative growth of maize, the amount of N released from the mixture of organic materials increased from week 1 to week 4; the increase varied depending on the proportion of sago pulp waste and *Gliricidia sepium* pruning in the mixtures. The higher pruning of *Gliricidia sepium* in the mixture significantly increased the amount of N released from the mixture of organic materials, while the higher the sago pulp waste in the mixtures significantly reduced the amount of N released from the mixtures. The highest amount of N released (82.45 mg kg^{-1}), or 156% higher than that of the control treatment, was observed at week 4 for the $A_{20}G_{80}$ treatment, while the lowest (3.41 mg kg^{-1}) was observed at week 8 for the $A_{100}G_0$ treatment (Table 3). The amount of N released from the mixtures of sago pulp waste and *Gliricidia sepium* prunings is closely related to the quality of the material (Cayuela et al., 2009). The $A_{20}G_{80}$ mixture had a high N content of 2.86%, with a low C/N ratio, low polyphenol content, and low lignin content (Table 1). On the contrary, the $A_{100}G_0$ mixture had a low N content of 0.32%, high C/N ratio, high polyphenol content and high lignin content of 141.03, 6.12% and 15.24%, respectively (Table 1), which hindered the N released from organic materials (Liu et al., 2007; Teklay et al., 2007). Interactive effects of residue mixtures can occur when residues of component types with contrasting residue qualities are mixed (Hoorens et al., 2002). Results of this study showed that the effect of organic matter quality on the decrease in N released from the organic matter was prominent at week 6 and week 8. The decreased amount of N availability could be caused by N uptake by plant roots and the amount of N-mineral used by microbes (Harmsen and Schreven, 2010). Microbial needs for sources of N under conditions of N in plant residues are not sufficient to meet microbial needs, so microbes will use inorganic N present in soil solution, thereby reducing the amount of N available to be absorbed by plants (Walley, 2005; Vadakattu and Gupta, 2016).

Table 3. The amount of N released from the sago pulp waste and *Gliricidia sepium* pruning mixtures during the vegetative phase of maize growth.

Mixtures of organic materials	N released from sago pulp waste and *Gliricidia sepium* pruning mixtures (mg kg^{-1}) during the vegetative phase of maize growth (weeks)				
	1	2	4	6	8
$A_0 G_{100}$	4.29 c	26.44 b	32.14 d	26.27 c	22.85 cd
$A_0 G_{100}$	13.93 a	32.60 a	82.41 a	75.11 b	66.04 b
$A_{20} G_{80}$	8.57 b	14.12 c	82.45 a	80.85 a	79.85 a
$A_{40} G_{60}$	3.64 c	7.79 d	44.57 b	37.76 c	26.73 c
$A_{60} G_{40}$	2.32 cd	5.11 de	39.48 c	32.14 d	21.12 d
$A_{80} G_{20}$	1.31 d	3.47 e	26.86 e	16.24 f	8.13 e
$A_{100} G_0$	1.21 d	3.52 e	23.16 e	12.40 f	3.41 e

Notes: numbers followed by different letters are significantly different according to the Duncan Multiple Range Test at 5% level. A_0G_{100} = 100% *Gliricidia sepium* pruning, $A_{20}G_{80}$ = 20% sago pulp waste and 80% *Gliricidia sepium* pruning, $A_{40}G_{60}$ = 40% sago pulp waste and 60% *Gliricidia sepium* pruning, $A_{60}G_{40}$ = 60% sago pulp waste and 40% *Gliricidia sepium* pruning, $A_{80}G_{20}$ = 80% sago pulp waste and 20% *Gliricidia sepium* pruning, and $A_{100}G_0$ = 100% sago pulp waste.

Maize growth (experiment 2)

Plant growth as measured by plant height, stem diameter, and root length increased from week 1 to week 8 (Table 4). The increase was significantly different from the increase in the proportion of *Gliricidia sepium* pruning in the mixtures. In contrast, the decrease was significantly different from the increase in the proportion of sago pulp waste in the mixtures. Maize growth experiences a vegetative growth phase from week 4 until the plant enters the final vegetative stage at 8 weeks after planting, where the plant's need for nitrogen is very high (Ladan and Jacinthe, 2017). Nitrogen is an essential constituent of amino acids, amides, nucleotides and nucleoproteins, and is essential for cell division, cell enlargement and growth.

Table 4. Effects of the application of sago pulp waste and *Gliricidia sepium* pruning mixture on the growth of maize plant.

Mixtures of organic materials	Parameters of maize plants during the growth (weeks)				
	1	2	4	6	8
	Plant Height (cm)				
$A_0 G_0$	23.36 c	35.53 d	48.86 e	84.90 c	107.00 b
$A_0 G_{100}$	27.00 a	44.86 b	69.09 b	102.56 b	102.56 c
$A_{20} G_{80}$	24.87 b	49.20 a	73.73 a	106.87 a	129.16 a
$A_{40} G_{60}$	23.80 c	44.63 b	65.85 c	102.89 b	128.63 a
$A_{60} G_{40}$	23.06 c	39.93 d	60.13 d	69.90 c	101.83 c
$A_{80} G_{20}$	20.83 d	35.23 d	44.83 f	56.10 e	85.03 d
$A_{100} G_0$	19.70 ed	35.36 d	40.00 g	42.83 f	81.46 d
	Stem Diameter (cm)				
$A_0 G_0$	0.05 e	0.08 d	0.22 d	0.46 d	1.29 d
$A_0 G_{100}$	0.13 b	0.14 b	0.35 b	0.49 c	1.25 e
$A_{20} G_{80}$	0.15 a	0.17 a	0.44 a	1.05 a	1.65 a
$A_{40} G_{60}$	0.12 b	0.18 a	0.35 b	0.50 b	1.52 b
$A_{60} G_{40}$	0.08 c	0.13 b	0.25 c	0.16 e	1.43 c
$A_{80} G_{20}$	0.06 d	0.10 d	0.20 e	0.12 f	1.24 f
$A_{100} G_0$	0.03 e	0.06 e	0.07 f	0.07 g	0.85 g
	Root length (cm)				
$A_0 G_0$	9.50 f	19.92 c	34.03 f	104.49 c	89.03 a
$A_0 G_{100}$	21.23 a	25.66 c	81.07 b	129.23 b	95.60 b
$A_{20} G_{80}$	19.13 b	27.20 b	87.97 a	150.26 a	108.10 a
$A_{40} G_{60}$	15.60 c	35.13 a	73.04 c	100.66 d	95.90 b
$A_{60} G_{40}$	12.00 d	19.27 c	66.03 d	85.02 e	93.89 c
$A_{80} G_{20}$	11.96 d	18.60 cd	36.96 fe	72.15 f	62.99 e
$A_{100} G_0$	11.02 e	15.76 d	27.10 g	48.26 g	53.56 f

Notes: numbers followed by different letters are significantly different according to the Duncan Multiple Range Test at 5% level. A_0G_{100} = 100% *Gliricidia sepium* pruning, $A_{20}G_{80}$ = 20% sago pulp waste and 80% *Gliricidia sepium* pruning, $A_{40}G_{60}$ = 40% sago pulp waste and 60% *Gliricidia sepium* pruning, $A_{60}G_{40}$ = 60% sago pulp waste and 40% *Gliricidia sepium* pruning, $A_{80}G_{20}$ = 80% sago pulp waste and 20% *Gliricidia sepium* pruning, and $A_{100}G_0$ = 100% sago pulp waste.

Therefore, plant growth is a function of plant uptake of nutrients, especially nitrogen. According to Sakala et al. (2000), mixing different quality organic matter has the potential to manipulate residue decomposition and regulate the timing of nutrient availability, including the availability of N. By developing better root growth, the plant can absorb nutrients to encourage plant growth through increasing plant meristematic and physiological activities (Akongwubel et al., 2012, so that high absorption causes the plant growth component to be also high (Akitan, 2019) as seen in the parameters, plant height 129.16 cm, stem diameter 1.65 cm and root length 150.26 cm

Conclusion

The application of 20% sago pulp waste and 80% of *Gliricidia sepium* pruning ($A_{20}G_{80}$) increased the cumulative amount of mineral N in an acid Dystrundept of Central Moluccas increased by 172% compared to the control treatment, the amount of N released by 156% higher than the control treatment at 4 weeks, and improved the growth of maize plants in acid soils.

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References

Akintan, C.L. 2019. Agronomic performance of maize (*Zea mays* L.) as influenced by leaf pruning quality in a cut and carry agroforestry system in Akure, Ondo State, Nigeria. *KIU Journal of Humanities* 4(3):199-208.

Akongwubel, A.O., Ewa, U.B., Prince, A., Jude, O., Martins, A., Simon, O. and Nicholas, O. 2012. Evaluation of agronomic performance of maize (*Zea mays* L.) under different rates of poultry manure application in an Ultisol of Obubra, Cross River State, Nigeria. *International Journal of Agriculture and Forestry* 2(4):138-144, doi:10.5923/j.ijaf.20120204.01.

Alfons, J.B. 2013. Study on the utilization of sago ela as organic fertilizer (Elakom-P) on corn plants in dry land agroecosystems in Maluku. *Jurnal Budidaya Pertanian* 9 (2):99-106 (*in Indonesian*).

Alfons, J.B. and Bustaman, S. 2005. Prospects and Directions for Sago Development in Maluku. Ambon: Center for the Study of Agricultural Technology. Agricultural Research and Development Agency, 45 (*in Indonesian*)..

Bremner, J.M. and Mulvaney, C.S. 1982. Nitrogen-Total. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds). *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, 595-624.

Castellano, M.J., Mueller, K.E., Olk, D.C., Sawyer, J.E. and Six, J. 2015. Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. *Global Change Biology* 21(9):3200–3209, doi:10.1111/gcb.12982.

Cayuela, M.L., Sinicco, T. and Mondini, C. 2009. Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil. *Applied Soil Ecology* 41:118-127, doi:10.1016/j.apsoil.2008.10.001.

Chirwa, P.W., Black, C.R., Ong, C.K. and Maghembe, J. 2006. Nitrogen dynamics in cropping systems in Southern Malawi containing *Gliricidia sepium*, pigeon pea and maize. *Agroforestry Systems* 67(1):93-106, doi:10.1007/s10457-005-0949-z.

Cordovil, C.M. d. S. Coutinho, J. Goss, M. and Cabral, F. 2005. Potentially mineralizable nitrogen from organic materials applied to a sandy soil: fitting the one-pool exponential model. *Soil Use and Management* 21(1):65-72.

Gaisie, E. Sadick, A. Agyeman, K. Adjei-Gyapong, Th. and Quansah, G. 2016. Leaf decomposition and the nutrients released from multipurpose trees for crop production. *International Journal of Scientific Research in Science, Engineering and Technology* 2(1):345-352.

Gei, M.G. and Powers, J.S. 2013. Do legumes and non-legumes tree species affect soil properties in unmanaged forests and plantations in Costa Rican dry forests?. *Soil Biology and Biochemistry* 57:264-272, doi:10.1016/j.soilbio.2012.09.013.

Hadas, A., Kautsky, L., Goek, M. and Kara, E.E .2004. Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover. *Soil Biology and Biochemistry* 36(2):255-266, doi:10.1016/j.soilbio.2003.09.012.

Harmsen, G.W. and van Schreven D.A. 1955. Mineralization of organic nitrogen in soil. *Advances in Agronomy* 7: 299-398.

Hoorens, B., Aerts, R. and Stroetenga, M. 2002: Litter quality and interactive effects in litter mixtures: more negative interactions under elevated CO_2. *Journal of Ecology* 90:1009-1016, doi:10.1046/j.1365-2745.2002.00732.x.

Jiang, L., Zhu, J., Qi, Y., Fu, Q., HU, H. and Huang, Q. 2017. Increasing molecular structural complexity and decreasing nitrogen availability depress the mineralization of organic matter in subtropical forest soils. *Soil Biology and Biochemistry* 108:91-100, doi:10.1016/j.soilbio.2017.01.028.

Kaba, J.S., Zerbe, S., Agnolucci, M., Scandellari, F., Abunyewa, A.A., Giovannetti, M. and Tagliavin, M. 2019. Atmospheric nitrogen fixation by gliricidia trees (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) intercropped with cocoa (*Theobroma cacao* L.). *Plant and Soil* 435:323-336, doi:10.1007/s11104-018-3897-x.

Kamkar, B., Akbari, F., Silva, J. and Naeini, S. 2014. The effect of crop residues on soil nitrogen dynamics and wheat yield. *Advances in Plants and Agriculture Research* 1(1):1-7.

Kiat L.J. 2006. Preparation and Characterization of Carboxymethyl Sago Waste and It's Hydrogel [tesis]. Universiti Putra Malaysia. Malaysia.

Korsaeth, A. Molstad, L. and Bakken, L.R. 2001. Modelling the competition for nitrogen between plants and microflora as a function of soil heterogeneity. *Soil Biology and Biochemistry* 33(2):215-226, doi:10.1016/s0038-0717(00)00132-2.

La Habi, M., Prasetya, B., Prijono, S. and Kusuma, Z. 2014. The effect of sago pith waste granule compost and inorganic fertilizer on soil physical characteristics and corn (*Zea mays* L.) production in Inceptisol. *IOSR Journal of Environmental Science, Toxicology and Food Technology* 8(2):32-40, doi:10.9790/2402-08223240.

Ladan, S. and Jacinthe, P.A. 2017. Nitrogen availability and early corn growth on plowed and no-till soils amended with different types of cover crops. *Journal of Soil Science and Plant Nutrition* 17(1):74-90, doi:10.4067/S0718-95162017005000006

Li, X.G., Jia, B., Jieting, L.V. and Li, F.M. 2016. Nitrogen fertilization decreases the decomposition of soil organic matter and plant residues in planted soils *Soil Biology and Biochemistry* 112:47-55, doi:10.1016/j.soilbio.2017.04.018.

Liu, P., Sun, O.J., Huang, J., Li, L. and Han, X. 2007. Nonadditive effects of litter mixtures on decomposition and correlation with initial N and P concentrations in grassland plant species of Northern China. *Biology and Fertility of Soils* 44(1):211-216, doi:10.1007/s00374-007-0195-9.

Mafongoya, P.L. Giller, K.E. and Palm, C.A. 1997. Decomposition and nitrogen release patterns of tree pruning and litter. *Agroforestry Systems* 38(1):77-97, doi:10.1023/a:1005978101429.

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.

Mundus, S., Menezes, R.S.C., de Neergaard, A. and Garrido, M.S. 2008. Maize growth and soil nitrogen availability after fertilization with cattle manure and/or gliricidia in semi-arid NE Brazil. *Nutrient Cycling in Agroecosystems* 82(1):61-73, doi:10.1007/s10705-008-9169-z.

Murungu, F.S., Chiduza, C., Muchaonyerwa, P. and Mnkeni, P.N.S. 2011. Decomposition, nitrogen and phosphorus mineralization from winter-grown cover crop residues and suitability for a smallholder farming system in South Africa. *Nutrient Cycling in Agroecosystems* 89:115-123, doi:10.1007/s10705-010-9381-5.

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(1-2):27-42, doi:10.1016/s0167-8809(00)00267-x.

Chirwa, P.W., Black, C.R., Ong, C.K and Maghembe, J. 2006. Nitrogen dynamics in cropping systems in Southern Malawi containing *Gliricidia sepium*, pigeon pea and maize. *Agroforestry Systems* 67(1):93-106.

Powers, J.S. and Tiffin, P. 2010. Plant functional type classifications in tropical dry forests in Costa Rica: leaf habit versus taxonomic approaches. *Functional Ecology* 24:927-936, doi:10.1111/j.1365-2435.2010.01701.x.

Risal, M., Sitorus, S. and Pravitasari, A.E, 2018. Land Use Planning for Development of Leading Agricultural Commodities in Central Maluku District, Maluku Province http://repository.ipb.ac.id/handle/123456789/95101 (*in Indonesian*).

Sakala W.D., Cadisch, G. and Giller, K.E. 2000. Interactions between residues of maize and pigeon pea and mineral N fertilizers during decomposition and N mineralization. *Soil Biology and Biochemistry* 32(5):699-706, doi:10.1016/s0038-0717(99)00204-7.

Seneviratne, G. 2000. Litter quality and nitrogen release in tropical agriculture: a synthesis. *Biology and Fertility of Soils* 31(1):60–64, doi:10.1007/s003740050624.

Syafruddin, 2015. Management of nitrogen fertilizer application on maize. *Jurnal Litbang Pertanian* 34(3):105-116 (*in Indonesian*).

Syahtria, I., Sampoerno, and Wardati. 2016. Sago waste compost influence on the growth of oil palm trees (*Elaeis guineensis* Jacq.) in the main nursery. *JOM Faperta* 3(2):1-8 (*in Indonesian*).

Syakir, M. 2005. The potential of sago waste as ameliorant and vegetable herbicide in pepper shrubs. Bogor Agricultural University Postgraduate School (*in Indonesian*).

Tatipata, A. and Jacob, A. 2013. Sagu sandy soil remediation in Waisamu which cultivated with local corn using Ela Sagu compost application. *Jurnal Lahan Suboptimal* 2 (2):118−128 (*in Indonesian*).

Teklay, T., Nordgren, A., Nyberg, G. and Malmer, A. 2007. Carbon mineralization of leaves from four Ethiopian agroforestry species under laboratory and field conditions. *Applied Soil Ecology* 35(1):193-202, doi:10.1016/j.apsoil.2006.04.002.

Vadakattu,V.S. and Gupta, R. 2016. Biological factors influence N mineralization from soil organic matter and crop residues in Australian cropping systems. *Proceedings of the 2016 International Nitrogen Initiative Conference*, *"Solutions to Improve Nitrogen Use Efficiency for the World"*, 4-8 December 2016, Melbourne, Australia. www.ini2016.com.

Waas, E.D., Kaihatu, S. and Ayal,Y. 2016. Identification and determination of soil type in the West Seram District. *Agros*18(2):170-180 (*in Indonesian*).

Walley, F. 2005. Nitrogen Mineralization: What's Happening in Your Soil?. Department of Soil Science, University of Saskatchewan, Saskatoon, SK, S7N 5A8 E-mail: walley@sask.usask.ca

Walpola, B.C. and Arunakumara, K.K.I.U. 2009. Effect of particle size of gliricidia leaves and soil texture on N mineralization. *Journal of Agricultural Sciences-Sri Lanka* 4(3):108-114, doi:10.4038/jas.v4i3.1649.

Wieder, W.R., Bonan, G.B. and Allison, S. D. 2013. Global soil carbon projections are improved by modelling microbial processes. *Nature Climate Change* 3:909-912, doi:10.1038/nclimate1951.