EFFECT OF CROPPING PATTERN AND BIOMASS RETURN ON N AND C LABILE FRACTIONS AND CASSAVA (*MANIHOT ESCULENTA* L.) YIELD AT TYPIC HAPLUDULTS

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Abstract. Legume biomass has advantages in maintaining soil organic matter and increasing soil nutrient content. The field research was conducted at Typic Hapludults of East Lampung, Lampung Province, Indonesia, which continuously has been planted with cassava in monoculture for more than 30 years. The experimental design used a split plot with three replications. The main plot was cropping pattern, i.e. 1) intercropping and 2) relay cropping. The sub-plot was type of organic matter, i.e. 1) groundnut biomass, 2) maize biomass, 3) groundnut-maize biomass with ratio of 1:1, 4) groundnut-maize biomass with ratio of 2:1, 5) groundnut-maize biomass with ratio of 1:2, and 6) without organic matter. The result indicated that planting cassava in monoculture continuously for more than 30 years reduced the soil macro nutrients and increased the micro nutrients, particularly Al saturation and Fe. The application of organic matter from groundnut and maize biomass did not affect total N and C organic in the soil, but increased the concentration of the labile fraction of N and C. The labile fraction of N and C in intercropping pattern was higher than that in relay cropping. Intercropping pattern also resulted in the higher cassava yield compared to that in relay cropping.
Keywords: *intercropping, relay cropping, groundnut, maize, cassava monoculture*

Introduction

Cassava is one of the major food crops and it grows in all provinces in Indonesia (Widodo et al., 2015). In recent years, even though cassava (*Manihot esculenta* L.) plantation areas in Indonesia have been decreased, the roots production and its productivity have been increased steadily (Hermiati et al., 2012). Cassava contributes as food, feed, raw material for industrial purposes and it has significant impact on food

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security (Ayetigbo et al., 2018). Cassava had been proven suitable to farming and food system and serve as local staple food in many areas in Indonesia. Therefore, cassava has a potency to be a crucial solution in improving food security. The reduction of food crops production because of unfavorable environmental condition as the impact of climate change (Saediman et al., 2016). In Indonesia, cassava is planted in dry lands under the monoculture cropping system, and it will be harvested at 10-11 months after planting. During the turnaround time between the cassava cropping, the land is left idle. This practice is always presence every year in central production areas. Unfortunately, farmers do not take the yield reduction that occur in that field as a result of continuously practicing the single cropping.

The largest central production areas of cassava in Indonesia are at Lampung Province. In this province, cassava is mostly grown in monoculture. The crops that had been planting for more than 30 years in monoculture have reduced the C organic, total N, Cation Exchange Capacity (CEC), available phosphorus (P), potassium (K), and magnesium (Mg), as well as soil pH, soil aggregates stability, and water holding capacity; while on the other hand it increased the soil bulk density (Wijanarko et al., 2017).

Returning the plant biomass into the soil is one of the efforts to reduce the declining of soil fertility due to cassava monoculture cultivation. It has been known that incorporating legume biomass into the soil is beneficial in maintaining soil organic matter reserves and increasing nutrient content in the soil, particularly N. Franke et al. (2018) reported that returning maize biomass into the soil contribute 50-100 kg N/ha, where only around 5-20% of N could be utilized for the next planting season. The return of soybean and groundnut biomass contributed 47-56 kg N/ha and 48 kg N/ha, respectively (Vanlauwe et al., 2019). Application of plant biomass can increase the nutrients content in the soil, but it is unnecessarily can be utilized by the crops. In Tanzania, by using the ^{15}N isotope dilution method, Chalk et al. (2014) reported that cowpea produced 36 kg N/ha when intercropped with maize and only 19% of N (8 kg N/ha) was transferred to maize. The low amount of nutrients that can be utilized was due to the inconsistency between nutrient availability and the nutrition need by the plants.

Mineralization of organic N into inorganic N is an important factor in determining N availability in the soil. The mineralization rate of soil organic matter is determined by some factors, i.e. soil pH, moisture, temperature, and quality of organic matter (Tian et al., 2010; Utomo et al., 2016; Wijanarko and Purwanto, 2017; Li et al., 2018). Organic matter with low C:N ratio had the rapid rate of mineralization. This characteristic is owned by legume crops. The weakness of this characteristic was that the rapid rate of N availability imbalanced with the crops nutrient need and lead to the loss of nutrient around the roots. Mixing with the organic matter having high C:N ratio, such as maize biomass, can inhibit the mineralization rate.

Planting cassava for forage production in a cassava-maize intercropping accelerates the decrease of soil quality. The yield of cassava and maize in this intercropping system could be improved by increasing the application of nitrogen fertilizer. In fact, the application of nitrogen fertilizer can minimize the decrease of soil nitrogen, but it cannot avoid the decline of crop yield as well as the soil organic matter content (Utomo et al., 2016). The effect of different cropping patterns can be seen by the increase or decrease of soil nutrient availability. Generally, studies related to organic matter are unable to describe nutrient availability, where the application of organic matter does not affect total N and organic C in the soil (Wijanarko and Purwanto, 2017). Meanwhile, the behavior or the forms of organic matter such as N fractions (N-labile and N-organic) and C fraction

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(C-labile) are rarely studied even though they affect soil quality. N and C labile fractions such as micro-biomass, water soluble, and particulate organic matter (POM) are indicators for estimating changes in soil management (organic matter application, fertilization, and cropping system). Labile N and C fractions are sources of nitrogen or carbon for microorganisms and some plants can directly absorb the fractions (Liu et al., 2014). The labile fractions of organic matter are good indicators of soil quality (Li et al., 2018). Based on those reasons, this study was conducted with the aim of knowing the effect of cropping system and the return of legume and/or non-legume biomass on N and C labile fractions and the yield cassava at Typic Hapludults.

Methodology

Experimental Design

The research was conducted at Sukadana Ilir Village, Sukadana Sub-district, East Lampung District in Lampung Province (the GPS coordinates: 5°00'49.0"S, 105°31'30.8"E) with a Typic Hapludults soil type in year of 2012. The experiment was conducted in rainfed upland where cassava monoculture had been planted for more than 30 years. The experiment applied a split plot design with three replications. The main plot was cropping system, i.e.: 1) intercropping and 2) relay-cropping. The sub-plot was types of organic matter, i.e.: 1) groundnut biomass, 2) maize biomass, 3) groundnut-maize biomass with a ratio of 1:1, 4) groundnut-maize biomass with a ratio of 2:1, 5) groundnut-maize biomass with a ratio of 1:2, and 6) without any organic matter. The dosage of groundnut, groundnut-maize, or maize biomass was 5 t/ha in total for each treatment. Land preparation used draft animals (oxen) as the power source, and the practice was intended to obtain the friable soils, free from weeds as well as any debris. Plowing (20-30 cm deep) was done in order to break the soils crust so that the loose aggregates were obtained, improve water penetration and aeration, or increase the oxygen content. After plowing, the harrowing was undertaken to prepare loosen, even and clean beds. Weeding for all crops was based on the operational procedures of each crop species.

The groundnut variety of Jerapah, maize variety of P21, and cassava variety of UJ-3 were used as planting materials (*Table 1*). The plot size for each sub-plot treatment was 5 m × 6 m with plant spacing for groundnut was 40 cm × 15 cm, maize was 80 cm × 75 cm, and cassava of 1 m × 0.75 m. Groundnut and maize received similar amount of single inorganic fertilizers i.e., 34.5 kg N + 36 kg P_2O_5 + 60 kg K_2O per ha. The fertilizers were broadcasted in the furrows that made adjacent to the plant's rows. Meanwhile, cassava received 34.5 kg N + 36 kg P_2O_5 + 60 kg K_2O per ha, which is similar to the local recommendation.

The biomass of groundnut and maize was prepared by harvesting both crops at the same time of maturity, and then the fresh plant materials of groundnut (stems, leaves, roots, pegs) was thinly chopped into 2-5 cm of particle size. The same procedure was undertaken to prepare maize biomass. The amount of both groundnut and maize biomass applied in each sub-plot supposed to refer the treatments.

In relay cropping treatment, groundnut and maize were firstly planted. Both groundnut and maize were harvested at maturity, and then prepared for biomass. The biomass particles of both crops were spread on the soil surface and incorporated into the soil by hand hoeing and left for two weeks before cassava stakes were planted by inserting the stakes in the ridges. In intercropping treatment, groundnut and maize were planted first and cassava stakes were planted 2 weeks after groundnut and maize planting time. After

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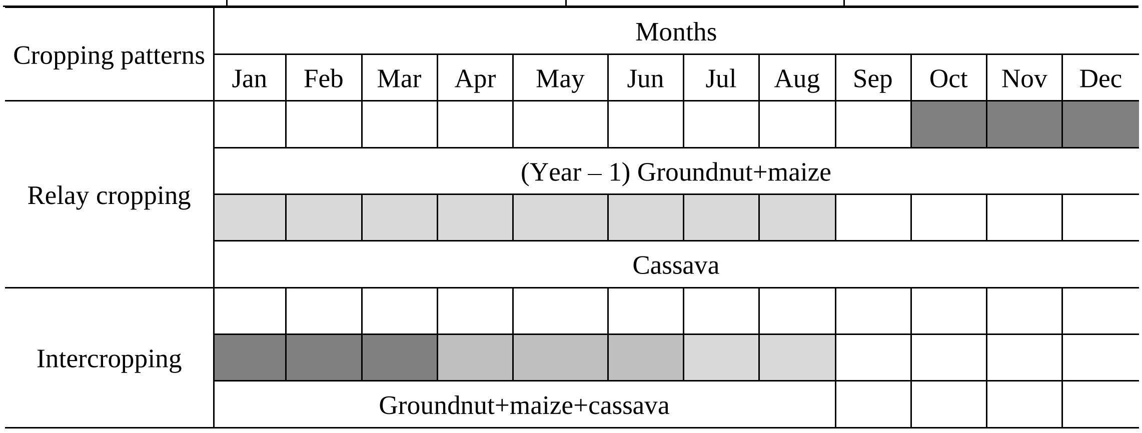
groundnut and maize were harvested at maturity, the fresh plants materials were prepared for biomass. In intercropping treatment, the chopped biomass was evenly spread on the soil surface in between the cassava rows, and then incorporated into the soil by hand hoeing. The relay cropping and intercropping patterns are presented in *Figure 1*.

Table 1. *Detail of species used in the experiment*

Commodity	Groundnut	Maize	Cassava
Variety	Jerapah	P21 or Pioneer 21	UJ-3
History	was released by Ministry of Agriculture in 1998	was released in 2003. P21 is the hybrid maize variety produced by DuPont Pioneer	was released in 2000 and it was introduced from Thailand
Yield potential (t/ha)	1.0-4.0 of dry pods	13.3 of dry grains	20-35 of fresh tubers
Characters	2 seeded pods (Spanish type), rose seed coat color, weight of 100 pods is 45-50 g (medium size), protein and fat content are 21.5% and 43.0%.	The physiological maturity is 95-117 days, orange seed coat color, weight of 1000 seeds is 311 g	harvest age: 8-10 months, yellowish white tuber flesh color, bitter taste, starch content is 20.0-27.0%, ash content 0.13%, fiber content 0.10%.
	resistant to bacterial wilt, tolerant to leaf rust and leaf spot diseases. It has stable yield and adapted to various agro-ecological zones, tolerant to drought stress and acidic soil condition	resistant to leaf rust and gray leaf spot *C. zeae-maydis*, moderately resistent to collapse	moderately resistant to cassava bacterial blight (CBB)
Source	Kasno and Harnowo (2014)	Aqil and A. Muhammad (2014)	Sundari (2010)



Note: In relay cropping: groundnut and maize were planted in October-December, cassava was planted in January; application of groundnut and maize biomass at 1 day after harvest. In intercropping: groundnut and maize were planted in January-March, cassava was planted in January (2 weeks after groundnut and maize were planted); application of groundnut and maize biomass at 1 day after harvest when cassava plants were at around 3-months age. Dark area: the period of groundnut and maize growing season, light area: the period of cassava growing season

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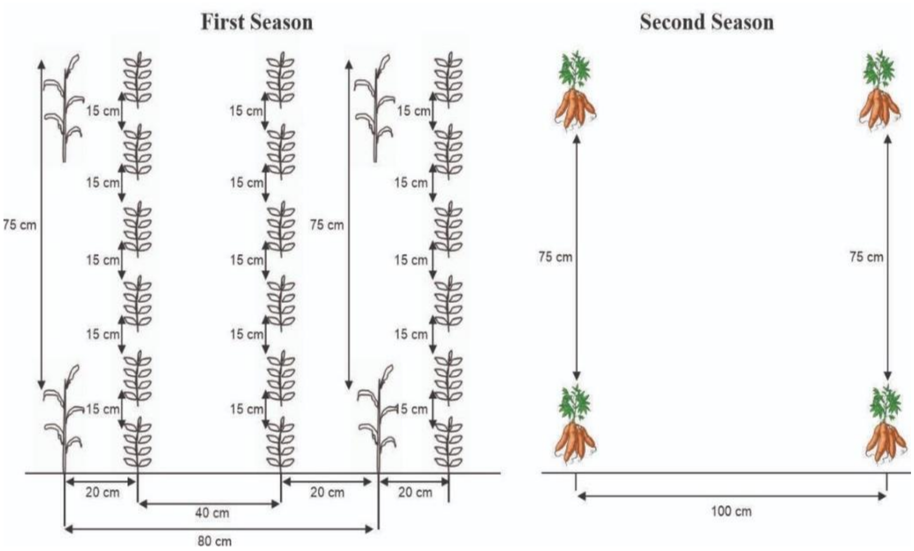
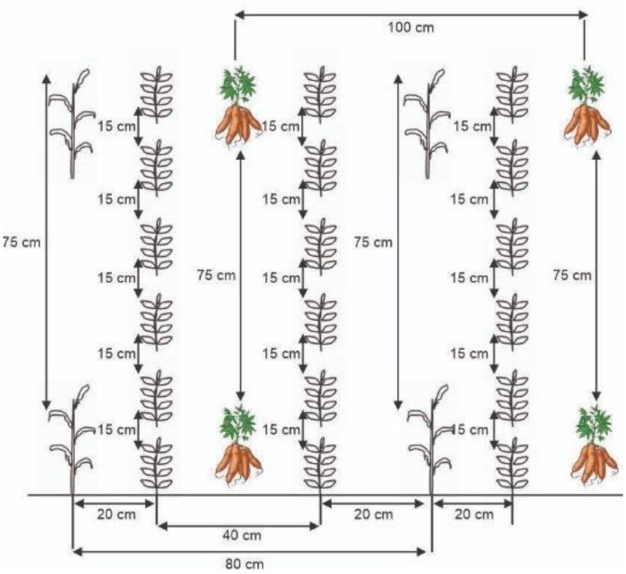
RELAY CROPPING



(a)

INTERCROPPING



(b)

***Figure 1.** **(a)** The treatment of cropping pattern; **(b)** The experimental design: relay cropping (top) and intercropping (below)*

Soil and Plant Chemical Analysis

The analysis of soil chemical covered total N, C organic, and labile fractions including water soluble fractions, micro-biomass C, and fraction of particulate organic matter (POM). The soil samples were taken from 0-20 cm soil depth in each treatment combination. Soil chemical analysis was carried out in The Laboratory of Soil and Crop, the Indonesian Legumes and Tuber Crops Research Institute (Iletri). The water extractable C organic and water extractable N were determined from 4 g of dry soil with 40 ml of deionized water and shaken for 10 minutes with a mechanical shaker. Sample was centrifuged for 5 minutes at 3500 rpm, filtered using Whatman paper and analyzed for water extractable C organic and water extractable N (Hanay et al., 2012).

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Analysis of particulate organic carbon (POC) was determined according to Figueiredo et al. (2010). The air-dried soil sample was filtered using a 2-mm sieve. Then, 20 g of sample was placed in a plastic bottle (volume of 250 ml) and added by 70 ml of sodium hexametaphosphate at a concentration of 5.0 g/l. The mixture was shaken for 15 h in a horizontal shaker. After that, the entire content of the vial was placed in a 53 μm sieve and washed using distilled water. The material retained on the sieve was defined as total particulate organic matter (>53 μm) then was dried at 50°C. After drying, the sample was grounded in a porcelain mortar in order to be able to pass completely through a 0.149 mm sieve. Then the aliquots were weighed and analyzed for their C and N contents representing the POC and N in POM.

Soil microbial biomass of C and N were measured by fumigation–extraction using ethanol-free chloroform as the fumigant followed by extraction using potassium sulfate (K_2SO_4). Extracts of fumigated and non-fumigated soils were analyzed for extractable C organic and N. Soil microbial biomass of C and N was calculated as the difference in the nutrient between fumigated and non-fumigated extracts, and corrected for unrecovered biomass using k factor of 0.35 for microbial C and 0.54 for microbial N (Nottingham et al., 2015). The observation on cassava growth was N uptake at 3 months after planted and cassava yield.

Statistical Analysis

Analysis of variance of the data was processed using a statistical program of MStatC 1.4 version developed by Crop and Soil Sciences Department, Michigan State University. The parameters that showed significantly different ($p<0.05$ and $p<0.01$) were then subjected to a Duncan Multiple Range Test (DMRT) at probability of 5% to find out the differences among the means. Graphic presentation was performed using Microsoft Excel program.

Results and Discussion

The Weather Condition of Experimental Site

The experimental site has a climate type A according to Schmidt and Ferguson with 8 wet months (>100 mm of monthly rainfall) and 1 dry month (<60 mm of monthly rainfall) based on the long term (2003-2012) rainfall data obtained from Taman Bogo Weather Station that is located about 3 km from the experimental site. The data inform that the average of annual rainfall was 2,576 mm with the lowest monthly rainfall was 50 mm in August and the highest rains of 323 mm in January. The average of monthly temperature ranged from 26.8 °C in February to 28.5 °C in November. The average of annual air humidity was 85.3% with maximum humidity was 92.0% occurred in April and minimum of 79.0% in August. During the experiment, the annual rainfall was 2,150 mm, where the monthly rainfall of >100 mm occurred from October to May (as wet months), one dry months with rains <60 mm in August, and three months with amount of rainfall was 66, 77, and 89 mm for June, July, and September respectively. The potential evapotranspiration (ETP) ranged from 139 to 179 mm/month with lowest ETP occurred in June and the highest ETP was in March. The water balance as the difference amount of rainfall and ETP showed the surplus value in December to April, meanwhile the rest of the months (May-November) suffered from deficit values. These suggested that the planting season in the experimental site was from December through to April.

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Soil Chemical Properties

The concentration of entire macro nutrients in the soil planted with monoculture cassava for more than 30 years was categorized low, while the concentration of micro elements, particularly Fe, were very high, especially when these nutrients status were compared to the soil properties at the beginning of year 2000 (*Table 2*). These low concentrations of all macro nutrients reflect that cassava cultivation might lead to both nutrient depletion and soil erosion, and the effects were more serious than those of other food crops under similar condition. Cassava is often being blamed regarding severe soil erosion when planted on sloping land in a wide spacing. Cassava has slow initial growth thus it takes a long time for canopy to protect soil from the impact of raindrop. Among tropical food crops, cassava does not extract large amount of N and P, but removes relatively high amount of K from the soil. When cassava is planted continuously without fertilizer for more than 25 years, the yield of cassava decreased (Sumithra et al., 2013).

Table 2. *Soil chemical properties of the area planted with cassava for more than 30 years in East Lampung*

Soil analysis	At the commence of experiment	At the beginning of year 2000[1)]
pH H_2O	4.60	4.0
Total N (%)	0.04	n.a.
C organic (%)	0.70	0.96
Available P (ppm P_2O_5)	6.80	9.0
CEC (cmol/kg)	4.12	8.24
K (cmol/kg)	0,05	0.06
Ca (cmol/kg)	0.50	0.60
Mg (cmol/kg)	0.15	0.47
Fe (ppm)	382.00	n.a.
Mn (ppm)	38.10	n.a.
Cu (ppm)	7.30	n.a.
Exchangeable Al (cmol/kg)	2.50	2.02
Al saturation (%)	54.00	61.62

Note: n.a. = not available, [1)] Source: Balai Penelitian Tanah (2008)

The research by Wijanarko and Purwanto showed that continuously cultivating monoculture cassava depleted macro nutrients in the soil (Wijanarko and Purwanto, 2017). It could be seen from the negative value of N, P, and K nutrient balance when farmers used only Urea and SP36 (as source of N and P respectively) assuming the cassava yield was 15 t/ha. Study of Polthanee suggested that in Thailand, K and N had negative nutrient balance, while P was positive. Other nutrients depleted from soil were Ca and Mg (Polthanee et al., 2001). The depletion of K, Ca, and Mg caused the soil be more acidic.

Total N and C Organic Concentration

Cropping pattern and the type of organic matter did not significantly affect total N and C organic concentration. It means the planting time for groundnut + maize and cassava, as well as the amount of groundnut and maize biomass incorporated into the soil in cassava crops did not influence the concentrations of total N (*Figure 2*) and C (*Table 3*)

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in the soil after cassava was harvested. The return of organic matter (groundnut, maize, or groundnut-maize biomass) and cropping patterns which did not significantly effect on total N and C organic concentration was in line with the research finding of Wijanarko and Purwanto (2017). The application of organic matter, however more affected the C and N labile fractions (C or N micro-biomass and water soluble). Total C organic measured in the bulked soil sample (C in the Ts) in the 0–5 cm depth did not present a significant difference among crop intensification sequences (Romaniuk et al., 2018). The change in soil organic carbon (SOC) generally occurred only after long period (de Moraes Sa and Lal, 2009), while short term change in total SOC in response to soil management practices was often small and difficult to be assessed (Chen et al., 2016).

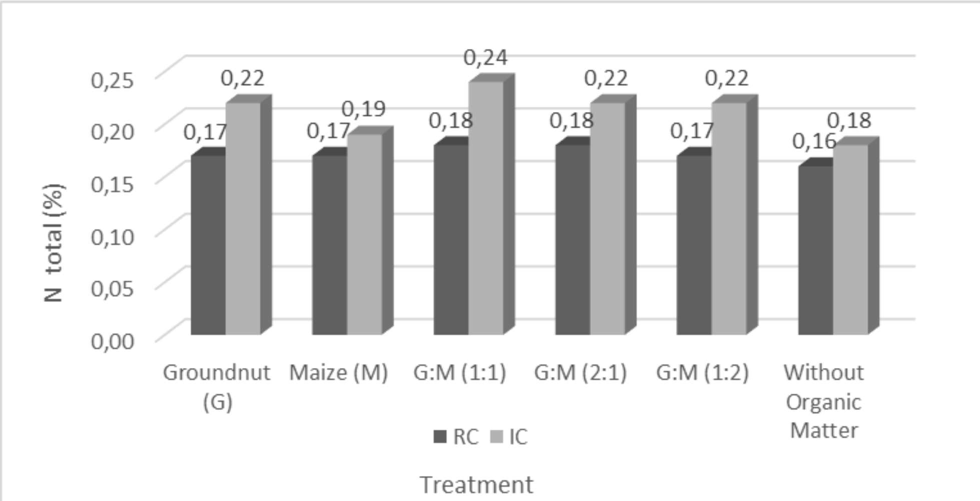

***Figure 2.** Total N concentration (%) due to treatments of cropping pattern and type of organic matter at soil planted with cassava for more than 30 years.* Note: RC = relay cropping, IC = intercropping, G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2. No significant different for both cropping system and organic matter treatments

***Table 3.** C organic concentration (%) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatments	Relay cropping	Intercropping	Means
Without organic matter	0.75 aA	0.75 aA	0.75 a
Groundnut biomass (G)	0.86 aA	0.84 aA	0.85 a
Maize biomass (M)	0.75 aA	0.78 aA	0.77 a
G : M (1:1)	0.82 aA	0.85 aA	0.84 a
G : M (2:1)	0.85 aA	0.84 aA	0.85 a
G : M (1:2)	0.86 aA	0.84 aA	0.84 a
Means	0.81 A	0.81 A	

Note: Number in same column (lowercase letter) or row (uppercase letter) followed by same letter did not significantly different based on DMRT at 5% level; G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2

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Total N and C Labile Fractions Concentration

The labile fractions of organic matter (C and N) have significant influence on the reserves of soil organic matter. They are important sources of energy for microorganisms in the mineralization process (Laik et al., 2009). A change in the quantity from the fractions is an early indicator for estimating the effect of soil management. In the current study, the type of organic matter affected water soluble N in the soil, while cropping pattern and the interaction between cropping pattern and type of organic matter had no significant effect on water soluble N in the soil. The return of groundnut-maize biomass (2:1) had the highest water soluble N in the soil with the increase was 118% as compared to the treatment of without organic matter return (*Table 4*).

Table 4. *Water soluble N (mg/kg) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatments	Relay cropping	Intercropping	Means
Without organic matter	37 cA	43 cA	40 d
Groundnut biomass (G)	63 bA	83 aA	73 b
Maize biomass (M)	40 cA	56 bA	48 cd
G : M (1:1)	63 bA	60 bA	62 bc
G : M (2:1)	93 aA	80 aA	87 a
G : M (1:2)	60 bA	53 bA	56 c
Means	59 A	62 A	

Note: Number in same column (lowercase letter) or row (uppercase letter) followed by same letter is not significantly different based on DMRT at 5% level; G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:*2*

Micro-biomass N was influenced by the cropping pattern and type of organic matter, while its interaction had no significant effect on micro-biomass N (*Table 5*). It is explained that intercropping pattern produced higher micro-biomass N compared to relay cropping pattern. In addition, that the return of biomass groundnut-maize (2:1) in both cropping patterns had the highest micro-biomass N compared to other treatments.

Table 5. *Micro-biomass N (mg/kg) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatments	Relay cropping	Intercropping	Means
Without organic matter	10 cA	11 cA	11 d
Groundnut biomass (G)	16 aB	19 aA	17 ab
Maize biomass (M)	13 bB	15 bcA	14 c
G : M (1:1)	13 bB	16 abA	15 bc
G : M (2:1)	18 aB	20 aA	19 a
G : M (1:2)	13 bB	15 bcA	14 c
Means	14 B	16 A	

Note: Number in same column (lowercase letter) or row (uppercase letter) followed by same letter is not significantly different based on DMRT at 5% level; G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2

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Nitrogen particulate organic matter (N POM) in soil that has been planted with cassava for more than 30 years was influenced by cropping pattern. Meanwhile, the type of organic matter and the interaction between cropping pattern and type of organic time had no significant effect. N POM in intercropping was 14% higher than that in relay cropping (*Table 6*).

Table 6. *N Particulate Organic Matter (N POM) (mg/kg) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatments	Relay cropping	Intercropping	Means
Without organic matter	20 aB	24 aA	22.0a
Groundnut biomass (G)	24 aB	28 aA	26.0a
Maize biomass (M)	23 aB	31 aA	27.0a
G : M (1:1)	25 aA	26 aA	26.7a
G : M (2:1)	27 aA	25 aA	26.0a
G : M (1:2)	22 aB	27 aA	24.3a
Means	23.5 B	26.8 aA	

Note: Number in same column (lowercase letter) or row (uppercase letter) followed by same letter is not significantly different based on DMRT at 5% level; G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2

Cropping pattern and type of organic matter had significant effect on labile N fraction (water soluble N, N POM and micro-biomass N) in soil that has been planted with cassava for more than 30 years, although the interaction had no significant effect. The labile N fraction in this observation gave more sensitive response than the total N analysis due to the effect of cropping pattern and type of organic matter did not significantly affect total N in the soil. The intercropping increased the concentration of micro-biomass N and N POM compared to relay cropping.

Cropping pattern and type of organic matter significantly affected micro-biomass C, while their interaction had non-significant effect (*Table 7*). Micro-biomass C in intercropping was 47% higher than that in relay cropping. The treatment of biomass groundnut-maize (2:1) return resulted in 43% of micro-biomass C higher than that without organic matter return. Lou reported that the application of organic matter increased micro-biomass C rather than the application of N fertilizer (Lou et al., 2011). It was due to the increase of carbon substrate used as an energy source of microorganisms and the improvement on soil physical properties such as the increase of soil porosity which was important for microorganism growth. The application of organic matter with low ratio of C: N increased the number of micro-biomasses. It related to the ease of organic matter to be mineralized.

Carbon particulate organic matter (C POM) was influenced by cropping pattern and type of organic matter, but the interaction was not significantly different (*Table 8*). Intercropping had about 8% of C POM higher than the relay cropping. The return of groundnut-maize biomass (1:1) in intercropping pattern had the highest C POM. (Lou et al., 2011) suggested that C POM concentration was about 15-25% of total C. N fertilization increased C POM, but the application of organic matter or chicken manure increased the higher C POM concentration compared to the only N fertilization. The study

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showed that C POM was a good indicator for assessing soil quality and was more sensitive to the changes in tillage and fertilization compared to total organic matter (Lou et al., 2011).

Table 7. *Micro-biomass C (mg/kg) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatments	Relay cropping	Intercropping	Means
Without organic matter	12 bB	23 abA	17.6 b
Groundnut biomass (G)	19 abA	24 abA	22.0 ab
Maize biomass (M)	15 bA	21 bA	18.3 b
G : M (1:1)	16 bB	29 aA	22.8 ab
G : M (2:1)	21 aB	28 abA	25.2 a
G : M (1:2)	17 abB	24 abA	20.5 ab
Means	17.1 B	25.1 A	

Note: Number in same column (lowercase letter) or row (uppercase letter) followed by same letter is not significantly different based on DMRT at 5% level; G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2

Table 8. *C particulate organic matter (C POM) (mg/kg) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatments	Relay cropping	Intercropping	Means
Without organic matter	27 aB	33 bA	29.6 ab
Groundnut biomass (G)	20 bB	33 bA	27.1 b
Maize biomass (M)	22 abB	38 abA	30.1 ab
G : M (1:1)	25 abB	41 aA	33.0 a
G : M (2:1)	26 aB	35 abA	31.0 ab
G : M (1:2)	26 aB	38 abA	32.7 a
Means	24.6 B	26.6 A	

Note: Number in same column (lowercase letter) or row (uppercase letter) followed by same letter is not significantly different based on DMRT at 5% level; G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2

The results of this study indicated that intercropping pattern had higher C and N labile fractions (water soluble, micro-biomass, and POM) than those of relay cropping. The study about labile fractions ratio of intercropping and relay cropping was very rare. Most of study only discussed the labile fraction of intercropping and relay cropping individually, whereas each had its own advantages in increasing the labile fraction in the soil. Intercropping is a cropping pattern that involves two or more crops in one field. Planting legumes, such as groundnut, in inter-cropping can add N in the soil through N fixation and the dead of root plants or plant litter. This condition can increase the micro-biomass and the availability of N and C in the soil, including increasing higher labile N and C fractions compared to monoculture pattern (Ibrahim et al., 2013; Liang et al., 2014;

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Latati et al., 2017). Study of Nyawade suggested that the intercropping with legumes could increase the labile fractions of organic matter by 12-28%, soluble water C by 7-21%, and micro-biomass by 15-38% compared to those from the intercropping with non-legumes (Nyawade et al., 2019). The result of this study also showed that intercropping increased the quantity and quality of organic matter. Residues of both legumes and tuber crops had high N content which could increase food supply for microorganisms. It increased microorganism activity, so that the micro-biomass labile fraction was higher in intercropping (Loeppmann et al., 2016).

N Uptake and Cassava Yield

The cropping pattern and organic matter treatments did not significantly influence the N uptake of the soil (*Table 9*). The higher N uptake of intercropping pattern compared to the relay cropping due to the intercropping with groundnut or maize could effectively improve the mobilization and uptake of N, P, K, and micronutrients via interspecific interactions in the rhizosphere soil (Inal et al., 2007). Intercropping of cassava and groundnut could improve soil quality through increasing the available N content and the abundance of DA101, Pilimelia, and Ramlibacter in the soil (Tang et al., 2020).

Table 9. *N uptake (kg/ha) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years*

Treatment	Relay cropping	Intercropping	Means
Without organic matter	40.6 aA	49.2 aA	44.9 a
Groundnut biomass (G)	50.3 aA	59.7 aA	55.0 a
Maize biomass (M)	41.6 aA	45.5 aA	43.6 a
G : M (1:1)	53.7 aA	61.5 aA	57.6 a
G : M (2:1)	53.0 aA	65.9 aA	59.5 a
G : M (1:2)	51.0 aA	56.6 aA	53.8 a
Means	48.4 A	55.6 A	

Note: Number in same column followed by same letter is not significantly different based on Duncan Multiple Range Test at 5% level; G:M (1:1) = groundnut-maize biomass, with a ratio of 1:1, G:M (2:1) = groundnut-maize biomass, with a ratio of 2:1, G:M (1:2) = groundnut-maize biomass, with a ratio of 1:2

Cassava yield was influenced by cropping pattern. Intercropping had higher cassava yield compared to that in relay cropping. In average, cassava grown under intercropping obtained 17.5 t/ha of fresh tubers which was 27.1% higher tuber yield than the yields in relay cropping. Intercropping with a return of groundnut-maize (2:1) biomass resulted in the highest yield of cassava, while the lowest yield was obtained from relay cropping without returning of crop biomass (*Figure 3*). (Silva et al., 2016) reported intercropping with maize and legumes provided the highest land equivalence indexes and were recommended for intercropping with cassava crop. The yield of cassava intercropped with maize as well as the status of N, P, and K soil nutrients could be increased by the application of 10 t/ha organic fertilizer (Ayoola and Makinde, 2011).

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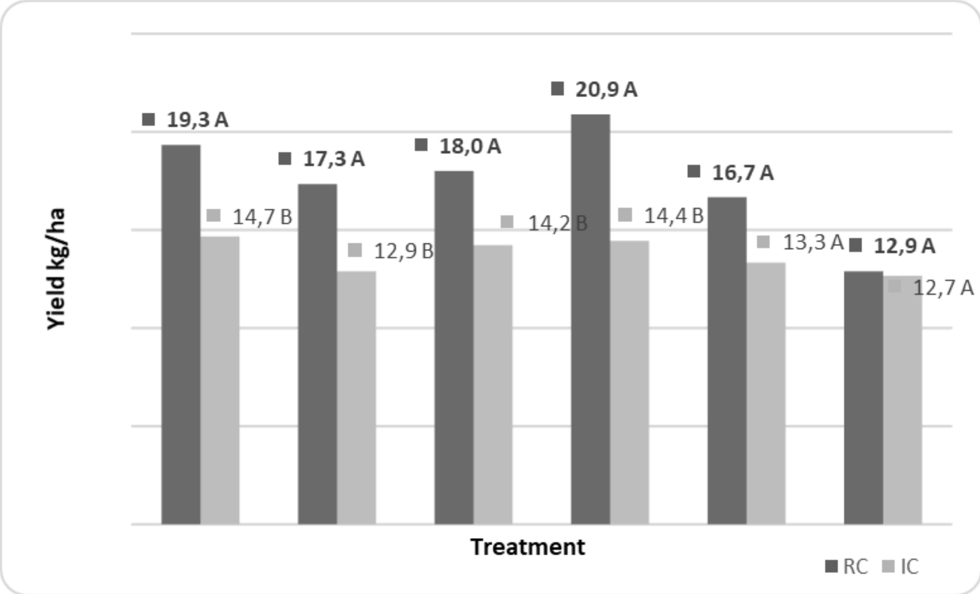

Figure 3. *Cassava yield (t/ha) due to treatments of cropping pattern and type of organic matter at land planted with cassava for more than 30 years.* Note: RC = relay cropping, IC = intercropping, G:M (1:1) = groundnut-maize biomass with ratio of 1:1, G:M (2:1) = groundnut-maize biomass with ratio of 2:1, G:M (1:2) = groundnut-maize biomass with ratio of 1:2. Number followed by same letter is not significantly different based on DMRT at 5% level

Conclusion

Land use for cassava monoculture for more than 30 years reduced the macro nutrients in the soil and increased the micro nutrients content, particularly Fe and Al-saturation availability. The application of organic matter from groundnut and maize biomass did not affect total N and C organic in the soil, but increased N and C labile fractions. N and C labile fractions in intercropping were higher than in the relay cropping. Intercropping also resulted in the higher cassava yield compared to the relay cropping.

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