Research Article

The Biomass Yield, Chemical Composition and Feeding Value for Cattle of Cassava (*Maniohot esculenta*) and Legume (*Phaseolus calcaratus*) Under Monoculture and Intercropping Systems

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Abstract | The aim of this study was to investigate (i) the total biomass yield (foliage and root), and chemical composition of cassava and a legume (*Phaseolus calcaratus*) under different intercropping systems and harvesting times, and (ii) the feeding value of the mixture of cassava and legume foliage as feed for growing cattle. In experiment 1, forty plots (5.4 x 6.0m) were allocated in a split plot design with four blocks. The main plot treatments were harvesting of legume and cassava foliage at 45 days cutting intervals or at the end when the cassava was harvested for roots. Each main plot was split into five sub-plots for the method of planting the cassava and the legume: CL0 (cassava monoculture), C0L (legume monoculture); C1L1 (one row of cassava intercropped with one row of legume), C2L1 (two rows of cassava intercropped with one row of legume), C1L2 (one row of cassava intercropped with two rows of legume). In experiment 2, the *in sacco* dry matter (DM), crude protein (CP) degradation of the mixture of cassava and legume feed was determined in nylon bags using three rumen fistulated cattle. The results showed that the total dry foliage yield was around 8.84-9.09 tones ha^{-1} and CP yield of 1.82-1.98 tones ha^{-1} of different intercropping systems between cassava and *Phaseolus calcaratus* legume. There was slightly increased dry biomass foliage yield of the intercropping system compared to the monoculture of cassava but significant higher than the value of *Phaseolus calcaratus* legume in the monoculture. The *in sacco* DM, CP degradation of the feed mixture of cassava and legume foliage were high. After 48h incubation the degradation of the mixture of cassava and legumes feed was 73% of DM and 83% of CP. It is concluded that intercropping between cassava and *Phaseolus calcaratus* legume is a solution to increase both quality and quantity of the biomass, thus contribute to improved cattle production.

Keywords | Cassava, Monoculture, Intercropping, Phaseolus calcaratus legume, Feeding value, Cattle

INTRODUCTION

Cattle production plays an important role in the livelihoods of Vietnamese. Cattle production is normally integrated with crop production. One of the obstacles for cattle production is feed resource. Using locally available feed resources such as cassava foliage, leguminous plant, agricultural by products. is considered one of the most important strategies to provide feed for cattle. In Vietnam,

cassava is normally planted in the hilly and mountainous areas where rice is difficult to grow. The area of cassava cultivation is about 532,600 ha per year with a total production of around 10,3 million tones of roots per year (GSO, 2017). In Vietnam, when cassava is grown for foliage in the dry season, it can give 41 tones/ha of fresh leaves, equivalent to about 12 tones per ha of cassava hay (Dung et al., 2005b). Cassava foliage has been made into cassava hay in Thailand and used successfully as a source of un-degraded

protein, with a high content of digestible nutrients for cattle production (Wanapat, 2001). Cassava foliage, especially bitter cassava foliage has been used widely for cattle production in Laos. It is a source of protein and it can reduce methane production and emission from cattle production (Sangkhom, 2017).

Growing cassava as a sole crop can lead to deterioration of soil fertility after several years of planting. Some previous studies have indicated that legumes can be considered as suitable crops for inter-cropping with cassava (Umeh and Mbah, 2010; Pypers et al., 2011; Hidoto and Loha, 2013). They can possibly be used for improving soil fertility through their root nitrogen fixation and returning the crop residues to the soil. Therefore, the legume not only improves soil fertility but also can be used as a protein source in animal feeding.

"Nho Nhe" (*Phaseolus calcaratus Roxb.*) is a leguminous plant that can grow well in the upland in Vietnam such as Lang Son, Bac Giang, Thai Nguyen. Normally, the legume was planted with maize to both produce corn and legume seeds that can be sold on the market as human food. The harvesting time of legume seeds is usually at the end of the year when "Tet" holiday coming. The advantage of the intercropping had led to higher yields of corn in the next crop than sole cropping.

The objectives of the study is to evaluate (i) the effect of frequency of harvesting on total biomass yield (the foliage and root), chemical composition of cassava and "Nho Nhe" legume under an different intercropping systems and harvesting times and (ii) the feeding value of mixture of cassava and legume foliage as feed for cattle.

MATERIALS AND METHODS

LOCATION AND CLIMATE OF THE EXPERIMENTAL SITE

The experiments were carried out at BaVi Cattle and Forage Research Center (CFRC) of the National Institute of Animal Science, Vietnam. It is located in BaVi district, about 60 km in the North West of Hanoi city center. The total area of BaVi district is 421 km^2 in which 80% of sloping land. The soil characteristic at the areas is acid with low fertility. The soil soil characteristic in this area were around pH_{KCl}: 4.12; OM: 4.48%; N_{Total}: 0.16%; K_2O_{Total}: 0.46% and P_2O_5: 0.039%. The climate in the area is tropical monsoon with a yearly rainfall of around 1500 mm, most of which falls from March to October, and with a dry season from November to February. During the field experiment, the total precipitation was 1456 mm and mean daily temperature ranged 17 to 29^{0}C (Figure 1).
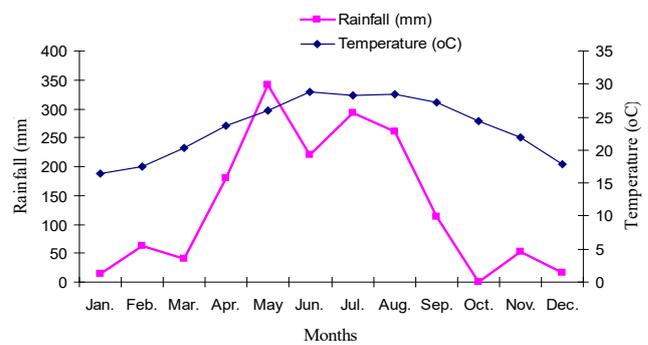

Figure 1: Ambient temperature and rainfall at BaVi area during experimental time (2004)

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EXPERIMENTAL DESIGN AND TREATMENTS

Experiment 1 was carried out as a split plot design with four blocks. Forty plots (5.4 x 6.0m) were allocated for all treatments. The main plot treatments were harvesting of legume and cassava foliage at 45 days cutting intervals or at the end when the cassava was harvested for roots, and each main plot was split into five sub-plots for the method of planting the cassava and the legume: CL0 (cassava monoculture), C0L (legume monoculture); C1L1 (one row of cassava intercropped with one row of legume), C2L1 (two rows of cassava intercropped with one row of legume), C1L2 (one row of cassava intercropped with two rows of legume). The layout of the plots is shown in Table 1.

In experiment 2, the *in sacco* DM, CP feed degradation was determined by incubating 05 g of dry sample of the mixture of cassava and legume feed in nylon bags using 03 rumen fistulated cattle according to the method of Orskov et al. (1980). The degradation was determined at 4, 8, 12, 24 and 48 h of incubation. The mean of three results for each time was used when calculating the rate of degradation. The diet of the animals was similar to the substrates being tested. In the time procedure of withdrawal of bags from rumen, the samples bags were immediately placed in bucket of cold water to prevent further fermentation and to wash off the feed particles adhering to the outside of the bags. All the bags were washed under running cold water in the laboratory until the water became clear. Then the bags were dried to constant weight at 65°C before recording the weight of bags plus incubated samples. The course of degradation of the feed was described by fitting DM loss values to the exponential equation of Orskov and McDonald (1979): P = a+b(1-e-ct). The degradation characteristics of the samples are defined as: A = washing loss (representing the soluble fraction of the feed); B = (a+b)-A (representing the insoluble but fermentable materials); c = the rate of degradation of B (Orskov et al., 1980).

Table 1: The experimental layout, plant arrangement, plant density

Treatment	Type of Harvest-ing	45 days interval harvesting		Harvesting at the end		Rows number/plot		Plant density (plants / ha)	
		Row of Cassava	Row of Legume	Row of Cassava	Row of Legume	Cassava	Legume	Cassava	Legume
CL0	Only	None	Only	None	12	0	63492	0
C0L	None	Only	None	Only	0	12	0	111111
C1L1	1	1	1	1	6	6	31746	55550
C2L1	2	1	2	1	8	4	42328	37037
C1L2	1	2	1	2	4	8	21164	74074

Note: Sole cassava (CL0); Sole legume (C0L); 1 row of cassava intercropped with 1 row of legume (C1L1); 2 rows of cassava intercropped with 1 row of legume (C2L1); 1 row of cassava intercropped with 2 rows of legume (C1L2)

Table 2: The total DM yields cassava foliage and legume and fresh yield of roots at different intercropping systems (IS) and harvesting times (HT) (tonnes ha^{-1})

Treatment	Harvesting time			SEM		Probability		
	I.45	I.0	Mean	HT	IS	HT	IS	HT*IS
Dry foliage yield (tonnes ha^{-1})								
CL0	8.86	0.32	4.59[a]					
C0L	6.39	-	3.19[b]					
C1L1	9.09	0.25	4.67[a]					
C2L1	8.87	0.32	4.59[a]					
C1L2	8.84	0.30	4.57[a]					
Mean	8.41[a]	0.24[b]		0.15	0.23	0.000		
							0.000	0.000
Fresh cassava roots yield (tonnes ha^{-1})								
CL0	12.64	27.53	20.08					
C0L	-	-						
C1L1	10.21	20.05	15.13					
C2L1	9.83	20.03	14.93					
C1L2	8.19	19.61	13.90					
Mean	10.22[b]	21.80[a]		1.14	1.62	0.006	0.062	0.682

I.45 is 45 days interval harvesting after first harvesting at 3 months planting;
I.0 is only harvested foliage as the same time of root harvesting;
Sole cassava (CL0); Sole legume (C0L);1 row of cassava intercropped with 1 row of legume (C1L1); 2 rows of cassava intercropped with 1 row of legume (C2L1); 1 row of cassava intercropped with 2 rows of legume (C1L2)
[a,b] Mean within columns and rows with calculated mean with different superscripts letter differ significantly (P<0.05)

ESTABLISHMENT AND MANAGEMENT

Cassava stems of *Manihot esculanta sp.* variety were prepared as planting material and a 45 x 35 cm spacing between rows and stems cuttings was applied for the treatment of cassava with or without the legume. The length of the cassava stem cuttings was 20-25 cm. The *Phaseolus calcaratus* legume was planted by seed in each row with 20 cm spacing of seeds and in plots according to the respective treatments. The cassava stem cuttings and *Phaseolus calcaratus* legume seeds were planted at the same time. Two weeks prior to planting, the experimental area was ploughed roughly and the soils were smashed to pieces before seeding. Cattle manure was applied only at the start of the experiment at the same level of 5,500 kg/ha fresh weight in all plots, and no other fertilizer was used during the experimental period.

MEASUREMENTS AND ANALYSIS

The cassava foliage and *Phaseolus calcaratus* legume in twenty plots (treatments of frequent harvesting) were harvested first at 3 months after planting by breaking the stem at 30 cm above the ground, and this was followed by four further cuttings at 45 day intervals, giving a total of five cuttings. The cassava foliage and cassava root in forty plots were collected after nine months of planting. Fresh weight of legume and cassava of each harvesting were recorded

immediately after cutting. In the intercropping treatment, the harvested plants were separated into cassava and legume, weighted individually and 1 kg of sample per subplot were randomly collected for chemical analysis. The total biomass yield of treatments of frequent harvest was calculated as the sum of all harvests. For understanding how much additional that is required in monoculture equal the amount of yield achieved in the intercrop, an equation was expressed as form of Land Equivalency Ratio (LER) by Mead and Wiley (1980). In which the yield from both cassava foliage and legume foliage in the monoculture and intercropping was measured: LER= (cassava in the intercropping system / cassava in the monoculture system)+(legume in the intercropping system / legume in the monoculture).

The separate materials of cassava and legume foliage were sundried and then ground by a milling machine. The sample of mixture of cassava and legume foliage was made by mixing the ingredients in proportion based on the ratio of cassava and legume foliage biomass produced (1:3 of legume foliage: cassava foliage as DM basis).

Both cassava and legume samples were analyzed for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF). The DM, CP were determined according to (AOAC, 1990). CP content was analyzed by Kjeldahl method as N * 6.25. The contents of NDF and ADF were determined according to Van Soest and Robertson (1985).

STATISTICAL ANALYSIS

Analysis of variance was used to analyze the data with Minitab software version 13.31, following the statistical model below. When the F-test was significant (P<0.05), the Tukey's Test for pairwise comparisons was used to compare means.

Y_{ijkl} = μ + αi + βj + (β) ij + δk + (δβ) kj + εijk

 Where: μ = The general mean
  αi = The ith block
  βj = The jth treatment of harvesting interval times or the end
  δk = The kth treatment of five methods of planting
  (αβ)ij = The ith block * the jth treatment
  (δβ) kj = The jth treatment of harvesting interval times or the end * the kth treatment of five methods of planting
  ε = The $ε^{th}$ error term.

RESULTS

EFFECT OF DIFFERENT INTERCROPPING SYSTEMS AND HARVESTING TIME ON YIELD OF DM FOLIAGE, FRESH ROOT AND LER

The results of total DM foliage yield and fresh cassava root yield was presented in Table 2. Effects of intercropping cassava and legume on foliage yield according to harvest frequency were shown in Figure 2. Total dry foliage yield was around 8.84-9.09 tonnes ha^{-1} of different intercropping systems between cassava and *Phaseolus calcaratus* legume. There was a significant higher of dry foliage yield between interval harvesting (I.45) compared to the value at the end (I.0). There was slightly increased dry biomass foliage yield of the intercropping system compared to cassava in the monoculture system (P>0.05).
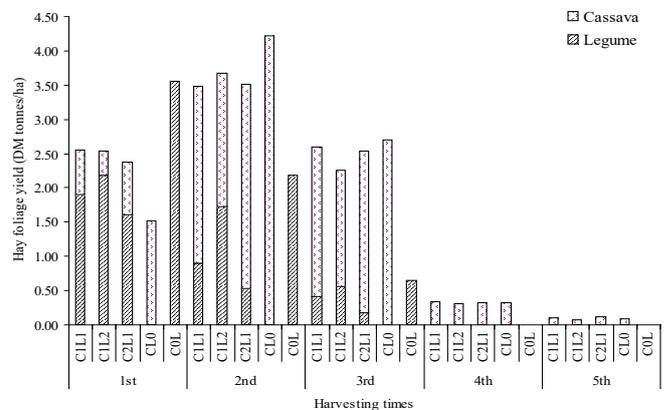

Figure 2: Effect of intercropping cassava and legume on hay yield (DM tonnes/ha) according to harvest frequency.

The fresh cassava root yield when foliage was harvested at the same time as harvesting roots (I.0) was greatly higher than the values of frequently foliage harvesting (I.45) (P<0.05). The mean of fresh cassava root yield of interval foliage harvesting and foliage harvesting at the end were 10.2 tonnes ha^{-1} and 21.8 tonnes ha^{-1}, respectively. These values of intercropping cassava and *Phaseolus calcaratus* legume was slightly lower than cassava monoculture (P>0.05).

Table 3 showed that the value of Land Equivalency Ratio (LER) were varied from 1.4 to 1.8 (on DM basis) and 1.2 to 1.3 (on CP basis) of the intercropping system and were significantly higher than the monoculture (cassava or *Phaseolus calcaratus* legume). The highest value of LER (on DM or on CP basis) was C1L2 which one row of cassava was intercropped with two rows of legume.

Table 3: The effect of different intercropping systems on the amount of cassava and legume production (tonnes ha^{-1}) and Land Equivalency Ratio (LER)

Treatment	Legume production	Cassava production	LER
DM			
CL0	-	8.86[a]	1.00[c]
C0L	5.89[a]	-	1.00[c]
C1L1	3.22[c]	5.87[b]	1.60[ab]
C2L1	2.31[c]	6.56[ab]	1.40[b]
C1L2	4.48[b]	4.36[b]	1.78[a]
SEM	0.30	0.56	0.08
P	0.000	0.001	0.000
CP			
CL0	-	1.56[a]	1.00[b]
C0L	1.42[a]	-	1.00[b]
C1L1	0.81[b]	1.12[ab]	1.32[a]
C2L1	0.58[b]	1.24[ab]	1.21[ab]
C1L2	1.15[a]	0.83[b]	1.36[a]
SEM	0.08	0.12	0.07
P	0.000	0.006	0.004

Note: Sole cassava (CL0); Sole legume (C0L); 1 row of cassava intercropped with 1 row of legume (C1L1); 2 rows of cassava intercropped with 1 row of legume (C2L1); 1 row of cassava intercropped with 2 rows of legume (C1L2)

[a,b] Mean within columns with different superscripts letter differ significantly (P<0.05)

Table 4: The chemical composition of cassava at different intercropping systems (IS) and harvesting times (HT)

Treatment	Harvesting time			SEM		Probability		
	I.45	I.0	Mean	HT	IS	HT	IS	HT*IS
DM (g kg^{-1})								
CL0	235.2	305.9	270.5					
C1L1	227.4	290.2	258.8					
C2L1	224.4	292.6	258.5					
C1L2	224.8	302.8	263.8					
Mean	227.9[b]	297.9[a]		0.56	0.80	0.001	0.688	0.924
CP (g kg^{-1}DM)								
CL0	174.9	161.3	168.1[b]					
C1L1	190.2	179.5	184.9[a]					
C2L1	189.6	169.4	179.5[ab]					
C1L2	191.6	181.8	186.7[a]					
Mean	186.6[a]	168.0[b]		2.13	3.01	0.002	0.008	0.153
NDF (g kg^{-1}DM)								
CL0	407.2	374.3	390.8					
C1L1	412.2	390.2	401.2					
C2L1	415.3	389.9	402.6					
C1L2	397.1	378.8	388.0					
Mean	407.9[a]	383.3[b]		7.16	10.13	0.033	0.667	0.962
ADF (g kg^{-1}DM)								
CL0	270.6	253.9	262.2[b]					
C1L1	282.6	269.2	275.9[a]					
C2L1	284.0	277.1	280.6[a]					

		273.7	264.9	269.3[ab]					
C1L2		273.7	264.9	269.3[ab]					
Mean		277.7[a]	266.3[b]		2.01	2.84	0.002	0.001	0.620

I.45 is 45 days interval harvesting after first harvesting at 3 months planting;
I.0 is only harvested foliage as the same time of root harvesting;
Sole cassava (CL0); 1 row of cassava intercropped with 1 row of legume (C1L1); 2 rows of cassava intercropped with 1 row of legume (C2L1), 1 row of cassava intercropped with 2 rows of legume (C1L2);
[a,b] Mean within columns and rows with calculated mean with different superscripts letter differ significantly (P<0.05).

EFFECT OF DIFFERENT INTERCROPPING SYSTEMS AND HARVESTING TIME ON CHEMICAL COMPOSITION OF CASSAVA

The value of a feed resource for cattle is not only about the yield, but also its chemical composition. The chemical composition of cassava foliage was presented in Table 4. The lower content of DM was found in interval harvesting system (I.45) compared to the value of harvesting at the end (I.0). There was no significant difference of DM content of cassava with or without legume (P>0.05) in the intercropping system. The interval harvesting and intercropping systems had positive influences on the CP content of cassava (P<0.05). In overall the data of CP content of cassava foliage varied from 161 to 192 g kg^{-1} DM. The mean value of CP of interval harvesting and harvesting at the end were 186.6 g kg^{-1} DM and 168.0 g kg^{-1} DM, respectively. The highest value was found in the intercropping system when two rows of legume were intercropped with one row of cassava (C1L2) and clearly increased compared to the value in cassava monoculture (P<0.05). The CP of cassava was tended to increase when the number of legume rows increased. The ADF and NDF contents of cassava foliage was varied from 254 to 284 g kg^{-1} DM and from 374 to 415 g kg^{-1} DM, respectively. The mean value of ADF and NDF of the interval harvesting (I.45) were higher than these values of harvesting at the end (I.0). There was no difference of NDF content between the intercropping system and the monoculture system, but higher value of ADF in the intercropping system compared with the monoculture system (P<0.05) was found in this experiment.

EFFECT OF DIFFERENT INTERCROPPING SYSTEMS AND HARVESTING TIME ON CRUDE PROTEIN FOLIAGE BIOMASS YIELD

Both the interval harvesting and intercropping systems had significant effects on the CP foliage biomass yield (Table 5). The values of CP foliage yield varied from 1.54 to 2.08 tones ha^{-1} in the interval harvesting (I.45) and was greatly higher than the value of harvesting foliage at the end (I.0). The intercropping cassava with *Phaseolus calcaratus* legume had a positive effect on CP foliage yield (P<0.05). The CP foliage yield increased with increasing the number of *Phaseolus calcaratus* legume rows in the intercropping system and was greatly higher than these values of the monoculture system (cassava or *Phaseolus calcaratus* legume). The Figure 3 showed the effect of the intercropping cassava

with legume on CP foliage yield according to harvesting frequency.

The total of dry biomass yield and CP yield produced by foliage and tuber was presented in Table 6. There was a significant effect of the interval harvesting on both dry biomass yield and total CP yield. The mean of total biomass yield and CP yield in interval harvesting (I.45) and at the end (I.0) were 10.4 tones ha^{-1} and 1.86 tonnes ha^{-1}; 6.58 tones ha^{-1} and 0.35 tones ha^{-1}, respectively. The mean value of total biomass yield in intercropping systems was not significantly lower than the value of the cassava monoculture but greatly higher than in the legume monoculture (P<0.001). In the intercropping system, the total CP biomass yield increased with increasing the number of legume rows.
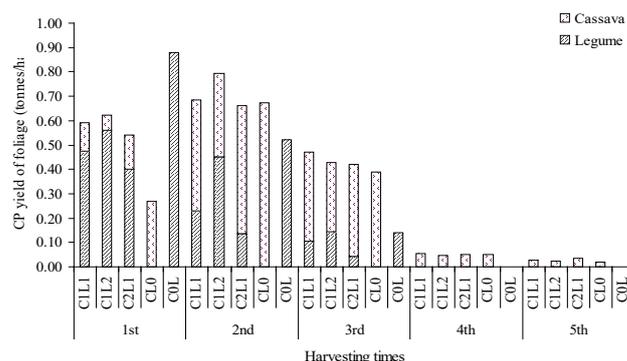

Figure 3: Effect of intercropping cassava and legume on CP yield of foliage (DM tonnes/ha) according to harvest frequency.

The intercropping cassava and *Phaseolus calcaratus* legume was not only increased the total DM foliage yield compared to the monoculture system but also significantly increased the CP biomass yield with increasing the number of legume rows in intercropping systems (Figure 4).

There were a stronger relationship between the biomass yield of the legume with the rainfall (mm) during the experimental period ($R^2 = 0.95$) than between cassava foliage yield with rainfall (Figure 5).

IN SACCO DEGRADATION OF DM AND CP OF THE MIXTURE OF CASSAVA AND LEGUME FOLIAGE

Results of dry matter (DM) and crude protein (CP) and

Table 5: The effect of different intercropping systems (IS) and harvesting times (HT) on total of crude protein (CP) yield of foliage

Treatment	Harvesting time			SEM		Probability		
	I.45	I.0	Mean	HT	IS	HT	IS	HT*IS
Total CP yield of foliage (tonnes ha^{-1})								
CL0	1.56	0.05	0.80[b]					
C0L	1.54	-	0.77[b]					
C1L1	1.93	0.04	0.99[a]					
C2L1	1.82	0.05	0.94[ab]					
C1L2	1.98	0.05	1.01[a]					
Mean	1.77[a]	0.04[b]		0.03	0.05	0.000	0.009	0.022

I.45 is 45 days interval harvesting after first harvesting at 3 months planting;
I.0 is only harvested foliage as the same time of root harvesting;
Sole cassava (CL0); Sole legume (C0L);1 row of cassava intercropped with 1 row of legume (C1L1); 2 rows of cassava intercropped with 1 row of legume (C2L1); 1 row of cassava intercropped with 2 rows of legume (C1L2);
[a,b] Mean within columns and rows with calculated mean with different superscripts letter differ significantly (P<0.05)

Table 6: The effect of different intercropping systems (IS) and harvesting times (HT) on total of dry biomass yield and CP yield produced by foliage and root

Treatment	Harvesting time			SEM		Probability		
	I.45	I.0	Mean	HT	IS	HT	IS	HT*IS
Dry biomass yield (tonnes ha^{-1})								
CL0	11.94	10.78	11.36[a]					
C0L	6.39	-	3.19[b]					
C1L1	11.67	6.55	9.11[a]					
C2L1	11.57	7.27	9.42[a]					
C1L2	10.63	8.28	9.45[a]					
Mean	10.44[a]	6.58[b]		0.44	0.70	0.004	0.000	0.094
CP yield (DM tonnes ha^{-1})								
CL0	1.71	0.55	1.13[a]					
C0L	1.54	-	0.77[b]					
C1L1	2.04	0.40	1.22[a]					
C2L1	1.94	0.41	1.18[a]					
C1L2	2.08	0.40	1.24[a]					
Mean	1.86[a]	0.35[b]		0.04	0.06	0.000	0.000	0.042

I.45 is 45 days interval harvesting after first harvesting at 3 months planting;
I.0 is only harvested foliage as the same time of root harvesting;
Sole cassava (CL0); 1 row of cassava intercropped with 1 row of legume (C1L1); 2 rows of cassava intercropped with 1 row of legume (C2L1); 1 row of cassava intercropped with 2 rows of legume (C1L2);
[a,b] Mean within columns and rows with calculated mean with different superscripts letter differ significantly (P<0.05)

Table 7: *In sacco* degradation of dry matter (DM) and crude protein (CP) of mixture of cassava and legume foliage

Item	Time of incubation (hours)					
	4	8	12	24	48	72
Dry matter (%)						
Mixture feed	27.62	30.70	36.57	60.84	68.79	68.29
Crude protein (%)						
Mixture feed	32.76	37.20	39.89	71.73	82.68	70.13

Mixture feed: Experimental feed consists the Phaseolus calcaratus legume and cassava foliage hay with ratio of 1:3 (DM basis)

Table 8: Washing loss (A), water-insoluble degradability (B), potential degradability (a+b), rate constant (c) and lag phase (L) of mixture of cassava and legume foliage

Item	A (%)	B (%)	A+B (%)	c	Lag time (fraction/h)	ED*
Mixture feed	26.60	45.00	71.60	0.056	5.0	45.10

ED*: Effective degradability

Mixture feed: Experimental feed consists the Phaseolus calcaratus legume and cassava foliage hay with ratio of 1:3 (DM basis)

some characteristics of *in sacco* degradation of the mixture of cassava and legume foliage was presented in Tables 7 and 8. Most of the DM of the mixture feed was lost after 48 hours of incubation. More than 72% DM and 83% CP of the mixture had disappeared after 48 hours incubation. The values of washing loss (A), insoluble but fermentable fraction (B), the rate constant (c) and effective degradability (ED) were high in the mixture.
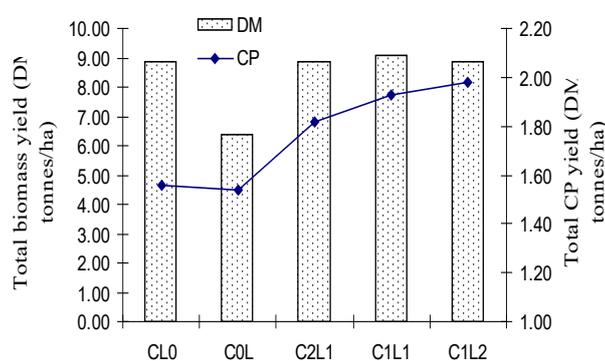

Figure 4: Effect of intercropping cassava and legume on total biomass yield (DM tonnes/ha) and total CP yield (tonnes/ha) of foliage according to harvest frequency.
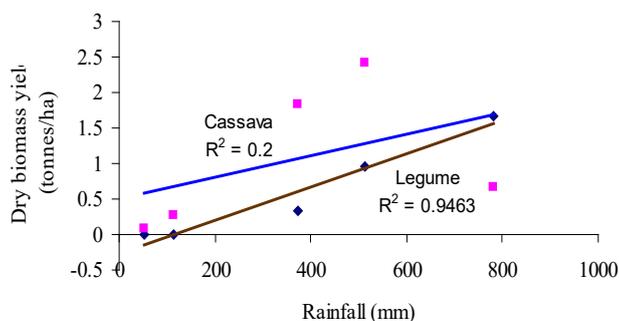

Figure 5: Effect of rainfall (mm) on the dry biomass yield of cassava and legume

DISCUSSION

Hidoto and Loha (2013) suggested that the productivity was higher than expected when cassava was intercropped with grain legumes. In this present study, the increasing of foliage biomass yield as an expected considering. The interval cutting at 45 days after the first harvesting were recommended by Hong et al. (2003). The results has showed that the highest cassava foliage yield was found at 45 days cuttings interval and 10 cm harvesting height (Khang et

al., 2005). Preston and Rodríguez (2004) indicated that high yields of foliage were obtained when cassava was managed as a semi-perennial crop with repeated harvesting of foliage at 2-3 months interval.

The higher value of foliage yield was reported by Wanapat et al. (1997) with 11.8 tonnes ha^{-1} while lower foliage yield than in the present study have showed around 4.8 to 7.3 tonnes ha^{-1} (Kiyothong and Wanapat, 2003; Khang et al., 2005). The foliage biomass yield was greatly varied and was dependent on variety (Tung et al., 2001), plant density, soil fertility, fertilizer application, management (Nguyen and Pham, 2001), cutting interval and height of cutting (Khang et al., 2005). However, Kiyothong and Wanapat (2004) had also found that the foliage biomass yield at first harvesting were greater than those in the second. Highest biomass yield was found at the second harvesting in this study and decreasing following the continuously harvesting. It can be seen that the plant density as well as the competition between two crops were negatively affected first harvesting yield. In principle of two or more growing together, each must have adequate space to maximize cooperation and minimize competition between crop (Sullivan, 2001). With the closely spacing (45x35cm) and the first 3 month slowly growing of cassava used in this present study, an aggressive climbing legume may pull down cassava and more competition of nutrition, water and sunlight with cassava. Although there is no data of legume biomass shown in the present study at the fourth and fifth harvesting, DM and CP foliage yield was affected in all treatments during the last three months of experiment as considering a accident in this study (Figure 2). The intercropping cassava with legume was considered as a suitable solve to increase the productivity per unit of land (Sullivan, 2001) and economic return over solely cassava (Polthanee et al., 2001). In this study the value of Land Equivalency Ratio (LER) were greatly increased with increasing the row number of *Phaseolus calcaratus* legume in the intercropping system. Sullivan (2001) has indicated that LER above 1.0 showing an advantage to intercropping while numbers below 1.0 showing a disadvantage to intercropping. In LERs, the extra value of higher than 1.0 mean that the yield produced in the total intercrop would have required more land if planted in monoculture system and as illustration the more effect of intercropping system was seen in this study. Hidoto and Loha (2013) showed that intercropping cassava with haricot bean, cowpea, soybean

and mung bean resulted in 82, 49, 48, and 62% greater land use efficiency than for either crop grown alone.

The CP content of cassava foliage of 168 to 187 g kg⁻¹ DM was found in all treatments at interval harvesting and intercropping system. The results were the same with the average of 16.9% CP content was reported by Dung et al. (2005a) when intercropping cassava with Flemingia. A higher value of CP content obtained by Kiyothong and Wanapat (2004) when intercropping cassava with Stylo 184. The CP content depends on different variety, maturity, fertilizer, soil nutrition, interval harvesting time and the variations in CP content can thus be expected. Umeh and Mbah (2010) suggested that the amount of fertilizer recommended for cassava at sole would be reduced if cassava were planted in association with efficient nitrogen fixing legume, such could increase yield of dry matter and crude protein content of cassava. The mean of CP content tend to reduce from 187 g kg⁻¹ DM at 45 days interval harvesting system (I.45) to 168 g kg⁻¹ DM at harvesting at the end (I.0), while increasing with intercropping system compared to monoculture. This comment was also agreed with Khang et al. (2005) that CP content fall down from 20.9 to 19.0% as cutting interval increased from 45 to 285 days. In the interval harvesting system, the estimated protein biomass yield on DM basis of around 1.5 to 1.9 tones ha⁻¹ was found in the present study while there was only 1 to 1.5 tones ha⁻¹ of CP yield was harvested from cassava foliage with five cuts at 45 days interval (Tung et al., 2001; Khang et al., 2005). The intercropping cassava and *Phaseolus calcaratus* legume has a positive effect on total CP foliage yield. According to Rao and Willey (1980) has indicated that an advantage commonly claimed for intercropping system is to give greater yield stability than sole cropping. Intercropping cassava (NR 8230) with soybean (TGX 1894-3E), gave the highest grain yield of Soybean and fresh tuber yield of cassava at 12MAP (Umeh and Mbah, 2010).

With the target of foliage production in this present study, the reduction of 53% of cassava root in interval harvesting (I.45) was found in comparison to harvesting at the end (I.0). But the values of intercropping system were only 25% to 31% compared monoculture were reduced when increasing number of legume row were intercropped. The result was in agreement with the previous studies reported by Ogola et al. (2013) who has shown that the intercropping reduced fresh root yield as compared with sole cropping. Hidoto and Loha (2013) found that intercropping cassava with haricot bean, cowpea, soybean and mung bean, reduced cassava yield by 27, 37, 52 and 50% respectively.

Dung (2002) reported that the root yield of cassava intercropped with two and three rows of peanut compared to cassava in the monoculture system increased by 11.6 to 20%. The difference between the results due to the effect of plant spacing, soil nutritive and different harvesting time between two or more crops in intercropping systems which reduce the competition in the higher densities of crops (Sullivan, 2001). Moreover, there yield increment of fresh tuber from 1.4 to 3.4 % while yield reduction for soybean from 20.4 to 42% was conducted in a field experiment of intercropping cassava with soybean by Mbah et al. (2003).

The rumen degradation characteristic of a feed can be a guide to their nutritive value for ruminants (Mupangwa et al., 2006). The DM and CP degradability of the mixture of cassava and legume foliage was quickly and its characteristics in rumen after 24 hours of incubation. This may be due to different level of nitrogen availability that improved microorganism in rumen and ensure the highly proteolytic population in rumen (Orskov, 1992) and allows an accumulation in the population of cellulytic bacteria (Tessema and Baars, 2004) In this experiment, the CP content of mixture feed was 200.5 g kg⁻¹. This is agreement with Promkot and Wanapat (2003) who has concluded that the nutritive value of protein-rich supplements was improved in term of rumen degradable. The DM and CP loss during time incubation was also affected by the different protein sources. It could be due to the structure and solubility characteristic of protein in the mixture feed of cassava and legume foliage facilitately attacked by microorganisms in rumen. The results of degradability of cassava leaf meal were reported by Khang and Wiktorsson (2000) which were around 60-79 % after 72 hours incubation. The observed results in this study was 70-71% after 24 hours incubation. The difference of these results was due to the interaction between cassava foliage and legume which positively influenced to DM degradability in rumen. The data of DM degradability in rumen of the three tropical forage legume (*Cassia rotundifolia, Lablab purpureus* and *Macroptilium atropurpureum*) were variably around 47.1-63.3% depending on the stage of maturity (Mupangwa et al., 2006). The positively interaction of cassava foliage and legume was seem to have high CP and the fragility of legume cell walls and high proportions of readily digestible thin-walled, non-lignified mesophyll tissues which could have resulted in the maintenance of high degradation rate at the first time of incubation in rumen.

CONCLUSIONS

Phaseolus calcaratus legume was found to be a potential plant for intercropping with cassava (*Maniohot esculenta*). In the frequent harvesting treatment, the intercropping had beneficial effects and improved foliage biomass yield (8.84-9.09 tonnes/ha) and CP yield (1.82-1.98 tonnes/ha), and would be a more sustainable system than planting

in the monoculture.

The *in sacco* DM, CP degradation of the mixture of cassava and legume foliage was high. After 48 h incubation the degradation of mixture cassava and legumes feed was 73% of DM and 83% of CP.

Intercropping between cassava and *Phaseolus calcaratus* legume is a solution to increase both quality and quantity of the biomass, thus contribute to improved cattle production.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

Chu Manh Thang: Writing the manuscript, designing experiments, Data collection, Data analyses.Hans Wiktorsson: Designing experiments, Data analyses, Giving comments and Le Dinh Phung: Designing and Revising the manuscript.

REFERENCES

• AOAC (1990). Official Methods of Analysis of the AOAC.
• Dung NT, I Ledin, NT Mui (2005a). Intercropping cassava (Manihot esculenta Crantz) with Flemingia (Flemingia macrophylla); effect on biomass yield and soil fertility. Livest. Res. Rural Develop. 17: 1-13.
• Dung NT, NT Mui, I Ledin (2005b). Effect of replacing a commercial concentrate with cassava hay (Manihot esculenta Crantz) on the performance of growing goats. Anim. Feed Sci. Technol. 119: 271-281. https://doi.org/10.1016/j.anifeedsci.2004.11.015
• Dung T (2002). FPR trials on cassava intercropping and weed control in Vietnam. In: 7 th Regional Cassava Workshop.
• GSO (2017). Statistical yearbook of Vietnam. 2017. Statistical Publishing House Hanoi (Vietnam).
• Hidoto L, G Loha (2013). Identification of suitable legumes in cassava (Manihot esculenta Crantz)-legumes intercropping. African J. Agric. 8: 2559-2562.
• Hong N, M Wanapat, C Wachirapakorn, P Pakdee, P Rowlinson (2003). Effects of timing of initial cutting and subsequent cutting on yields and chemical compositions of cassava hay and its supplementation on lactating dairy cows. Asian-Australasian J. Anim. Sci. 16: 1763-1769. https://doi.org/10.5713/ajas.2003.1763
• Kiyothong K, M Wanapat (2003). Cassava hay and Stylo 184 hay to replace concentrates in diets for lactating dairy cows. Livestock Research for Rural Develop. 15: 1-8. https://doi.org/10.5713/ajas.2004.670
• Kiyothong K, M Wanapat (2004). Growth, hay yield and chemical composition of cassava and Stylo 184 grown under intercropping. Asian-australasian J. Anim. Sci. 17: 799-807 https://doi.org/10.5713/ajas.2004.799.
• Khang DN, H Wiktorsson (2000). Effects of cassava leaf meal on the rumen environment of local yellow cattle fed urea-

treated paddy straw. Asian-Australasian J. Anim. Sci. 13: 1102-1108. https://doi.org/10.5713/ajas.2000.1102
• Khang DN, H Wiktorsson, TR Preston (2005). Yield and chemical composition of cassava foliage and tuber yield as influenced by harvesting height and cutting interval. Asian-Australasian J. Anim. Sci. 18: 1029-1035. https://doi.org/10.5713/ajas.2005.1029
• Mbah E, C Muoneke, D Okpara (2003). Evaluation of cassava/soybean intercropping system as influenced by cassava genotypes. Nigeria Agric. J. 34: 11-18. https://doi.org/10.4314/naj.v34i1.3164
• Mead R, R Wiley (1980). The concept of "Land Equivalent Ratio" and advantages in yields from intercropping Expt. Agric. https://doi.org/10.1017/S0014479700010978
• Mupangwa J, N Ngongoni, H Hamudikuwanda (2006). The effect of stage of growth and method of drying fresh herbage on chemical composition of three tropical herbaceous forage legumes. Trop. Subtrop. Agroecosyst. 6: 23-30.
• Nguyen HH, VB Pham (2001). Cassava agronomy research and adoption of improved practices in Vietnam. Centro Int. de Agric. Trop. (CIAT).
• Ogola J, C Mathews, S Magongwa (2013). The productivity of cassava-legume intercropping system in a dry environment in Nelspruit, South Africa. In: African Crop Sci. Conf. Proceed. p 61-65.
• Orskov E, FD. Hovell, F Mould (1980). The use of the nylon bag technique for the evaluation of feedstuffs. Trop. Anim. Prod. 5: 195-213.
• Orskov ER (1992). Dynamics of Nitrogen in the rumen. In: U. S. Edition (ed.) Protein Nutrition in Ruminants. p 43-48. Academic Press Limited, San Diego.
• Polthanee A, S Wanapat, M Wanapat, C Wachirapokorn (2001). Cassava-Legumes intercropping: A potential food-feed system for dairy farmers. In: International Workshop on Current Research and Development on Use of Cassava as Animal Feed, Khon Kaen University, Thailand. p 23-24.
• Preston T, L Rodríguez (2004). Production and utilization of cassava foliage for livestock in integrated farming systems. Livest. Res. Rural Develop. 16.
• Promkot C, M Wanapat (2003). Ruminal degradation and intestinal digestion of crude protein of tropical protein resources using nylon bag technique and three-step in vitro procedure in dairy cattle. Livest. Res. Rural Develop. 15: 2003.
• Pypers P, J-M. Sanginga, B Kasereka, M Walangululu, B Vanlauwe (2011). Increased productivity through integrated soil fertility management in cassava–legume intercropping systems in the highlands of Sud-Kivu, DR Congo. Field Crops Res. 120: 76-85. https://doi.org/10.1016/j.fcr.2010.09.004
• Rao M, R Willey (1980). Evaluation of yield stability in intercropping: studies on sorghum/pigeonpea. Exper. Agric. 16: 105-116. https://doi.org/10.1017/S0014479700010796
• Sangkhom I, TR Preston, RA Leng, Le Duc Ngoan, Le Dinh Phung (2017). Rice distillers' byproduct improved growth performance and reduced enteric methane from "Yellow" cattle fed a fattening diet based on cassava root and foliage (Manihot esculenta Cranz). Livest. Res. Rural Develop. 29(7). http://www.lrrd.org/lrrd29/27/sang29131.html.
• Sullivan P (2001). Intercropping principles and production practices: Appropriate technology transfer for rural areas (ATTRA). Fayetteville (AR): USDA Rural Business.
• Tessema Z, R Baars (2004). Chemical composition, in vitro

dry matter digestibility and ruminal degradation of Napier grass (Pennisetum purpureum (L.) Schumach.) mixed with different levels of Sesbania sesban (L.) Merr. Anim. Feed Sci. Technol. 117: 29-41. https://doi.org/10.1016/j.anifeedsci.2004.08.001

• Tung C, J Liang, S. Tan, H Ong, Z Jelan (2001). Fodder productivity and growth persistency of three local cassava varieties. Asian-Australasian J. Anim. Sci. 14: 1253-1259. https://doi.org/10.5713/ajas.2001.1253

• Umeh S, B Mbah (2010). Intercrop performance of different varieties of soybean (Glycine Max.(L) Merril) in a cassava (Manihot esculenta Crantz) based cropping system within the derived savannah zone. African J. Biotechnol. 9: 8636-8642.

• Van Soest P, J Robertson. (1985). A laboratory manual for animal science. Department of Animal Science, Cornell University: Ithaca, NY.

• Wanapat M (2001). Role of cassava hay as animal feed in the tropic In: B. O. a. M. W. T. R. Preston (ed.) International Workshop Current Research and Development on Use of Cassava as Animal Feed, Khon Kean University, Thailand.

• Wanapat M, O Pimpa, A Petlum, U Boontao (1997). Cassava hay: A new strategic feed for ruminants during the dry season. Livest. Res. Rural Develop. 9: 1-5.