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Biodigester effluent versus manure from pigs or cattle as fertilizer for production of cassava foliage (*Manihot esculenta*)

Le Ha Chau

Institute of Agricultural Sciences, Ho Chi Minh City, Vietnam

Abstract

A field experiment was conducted during five months from 1 December 1997 to 30 April 1998) in the University of Tropical Agriculture on the College of Agriculture and Forestry Campus, Thu Duc, Ho Chi Minh City, Vietnam. The experimental soil was grey podzolic. The trial was laid out in a randomized block design, replicated three times with a plot size of 4 x 2.5m and four treatments of organic fertilizer application to cassava grown for forage. The treatments arranged in a 2*2 factorial were:

- Animal species (cows vs pigs)
- Biodigestion (fresh manure vs effluent derived from the same manure after being fermented in a biodigester)

The fresh manure was applied before planting and after the first harvest (at three months). The effluent was applied every three days. Thus the effect of biodigestion was confounded wiith the method of application. Quantities of each source were estimated to provide 200 kg nitrogen/ha/year. The cassava was harvested for forage (cutting height 70 cm above ground level) after 3 months and again 2 months later. The foliage was separated into stem and leaf + petiole and analyzed for dry matter and nitrogen. Soil analysis was done before planting and again 5 months later.

Effluent was significantly better than raw manure in supporting a higher biomass yield and protein content of the foliage. The source of the manure did not affect these parameters. Yields of fresh leaf plus petiole were 6.45 and 5.16 tonnes/ha/harvest for effluent and manure, respectively (SE±0.15; P=0.001). Protein percentages in dry matter of leaf and petiole were: 27.6 and 24.2 (SE±0.165; P=0.001).

There were marked improvements in soil fertility parameters as a result of applying either manure or effluent.

Key words: Cassava, biodigesters, effluent, manure, forage, biomass, fertilizer, integration

Introduction

Cassava is an important food crop occupying a large area in Vietnam. In 1993, the total cassava area was about 284, 600 ha, the average yield 9.1 tonnes per hectare and the total production 2.6 million tonnes (Bien Pham Van and Kim Hoang 1993). The crop is grown in almost every province of the country: in the mountainous area of north Vietnam, the high plateau of central

During the past several years, research has shown clearly that ensiled cassava roots could replace cassava root meal in diets for growing-fattening pigs (Nguyen thi Loc et al 1997); and that cassava leaf meal can partially replace soya bean meal in a diet of cassava root meal (Bui Huy Nguyen Phuc et al 1995). Not only in Vietnam but in many other countries (eg: in parts of Brazil and in Venezuela) cassava is planted in a multi-purpose role. The leaves are sun-dried, ground into a meal and sold for mixing in compounded rations. In North America and Europe, alfalfa meal is the most popular leaf meal used in chicken feeds. It is reported that the feed value of cassava leaf meal for chickens is equal to that of alfalfa meal (Ravindran 1992). In Thailand, Wanapat et al (1997) have reported a system in which the cassava crop is harvested three times for forage, which is made into hay, and finally harvested for the roots. The foliage has yielded 20 tonnes/ha (fresh basis) and the cassava hay contained a high level (25% in dry matter) of crude protein (Wanapat et al 1997).

In Vietnam cassava has been grown predominantly in poor soil on sloping land without fertilizers and its yield has declined due to nutrient depletion and soil erosion. This is one of the most important constraints to its development. Thus cassava is found mainly on soils with very low organic matter or on sandy loam soils in the Central Coastal area, where the pH is usually in the range of 4.0 - 6.0. Due to the drought tolerance of cassava, its root yield is still about 8 - 10 tonnes/ha under these conditions.

Fertilizer use for cassava is very low in Vietnam because of economic reasons: low prices for cassava roots and a high cost of fertilizer. Although cassava-growing soils are poor almost no farmer buys fertilizers for cassava production. Only in some sites, farm yard manure, green manures or ash are applied.Thus, it is very important to find cheaper ways of supplying plant nutrients, such as integrating with use of livestock waste by utilization of biodigester effluent as fertilizer for crop production (Rodriguez and Preston 1996; Moog et al 1997).

The major production problem for cassava is soil erosion, which has resulted in soil degradation and declining soil fertility. A better understanding of the factors that improve the efficiency of applied fertilizers to cassava is therefore necessary. The use of farm yard manure and biodigester effluent is one option to be investigated, in order to develop better cassava growing practices. The advantages of passing manure through a biodigester are many and include gas production for cooking, improved health through elimination of pathogens and no loss of plant nutrients in the process (Bui Xuan An et al 1997). However, an obvious question is: what is the fertilizer and soil enhancement value of the effluent compared with the unprocessed manure?

A study was therefore planned to compare fresh manure and biodigester effluent on yield of cassava leaves and on the maintenance of soil fertility. A comparison of manure and effluent from the two principal livestock species in Vietnam (pigs and cattle) was a secondary aim of the study.

Objectives

These were:

- To determine the effectiveness of different sources of farm manure (from pigs or from cattle) as a fertilizer on biomass yield of cassava leaves.
- To compare manure and the effluent derived from the manure after passing it through a "plug-flow" biodigester.

Hypothesis

It was hypothesized that for increasing yield and nutritive value of cassava leaves and for improving soil fertility:

- Manure from pigs would be better than from cows
- Effluent would be better than the original manure

Materials and methods

Location

The experiment was done at the "Finca Ecologica" on the University of Tropical Agriculture Campus, Thu Duc district, Ho Chi Minh city. The experimental area was located on grey podzolic soils derived from alluvial deposits. The soil contained 72% of sand and was poor in plant nutrients. Organic matter content in the 0-20 cm layer was 0.55%, the pH (KCl) 4.22, N content 0.06%, P_2O_5: 0.03% and K_2O: 0.01% (Source: Department of Soil Science and Fertilizer Research, IAS).

Design and Treatments

The treatments consisted of four kinds of fertilizer:

- Fresh cow manure
- Fresh pig manure
- Effluent from biodigester charged with cow manure
- Effluent from biodigester charged with pig manure

The amounts of each were estimated to supply approximately 200 kg N/ha/year. There were 3 replicates in a completely randomized block design with a total area of 120 m² (10m²/plot) and a plot size of 2.5 x 4m.

The biodigesters

Two experimental biodigesters were constructed following the design, and with similar materials, as described by Bui Xuan An et al (1997). The diameter of the plastic polyethylene tube was 60 cm and the length 2 m. Each biodigester discharged into a hole in the ground lined with plastic to avoid soil contamination of the effluent. The total volume was 560 litres and the liquid phase occupied 420 litres. One biodigester was charged with fresh cow manure collected from an animal consuming urea-treated straw supplemented with cassava root waste. The second biodigester was charged with manure from pigs consuming a mixture of sugar cane juice and cassava root waste supplemented with fresh duckweed (*Lemna minor*). Water was added to each type of manure to give a solids content of 40 g/litre. Approximately 20 litres of each mixture were added daily to the biodigesters to give a liquid retention time of 20 days. The manure (cow and pig) used to fertilize the plots was taken from the same source as used for the biodigester. The effluents (cow and pig) were collected from the discharge pits of the biodigesters every three days for application to the experimental plots.

Management

The experiment was conducted for 5 months during the dry season (15 November 1997 to 15 April 1998). The plots were irrigated throughout the 5 month period. The cassava was planted in rows using stem cuttings with a distance between rows and plants of 50cm. The treatments of fresh manure (cow or pig) were applied to the soil before planting the cassava stems. These treatments were repeated in the same plots after the first harvest of foliage and again after the second harvest. The effluent (cow or pig) was applied after planting and at intervals of three days. Thus the type of fertilizer (fresh manure or biodigester effluent) was confounded with the method of application. While it was technically feasible to have applied the manure at three day intervals, this is not normal practice which is to make the application at the time of planting and at subsequent harvests. Effluent is produced daily by the digester in relatively large quantities (50-100 litres/day from a typical family scale biodigester) and it is neither feasible nor convenient to store it more than 2-3 days. Hence frequent application of effluent to the growing crop is the logical way to use it.

Measurements

Harvesting was done the first time after three months of growth and then two months later. At each harvest the aerial part of the whole plant was removed by cutting the stems at approximately 50-70cm about ground level. The entire harvested plant (stems, petioles and leaves) was weighed after each harvest. Dry matter was determined by using a microwave oven (Undersander et al 1993). The ratio of leaf and petiole to stem was calculated and approximately 100g of each plant fraction (whole plant, stem and leaf plus petiole) for each treatment were retained for analysis. Samples from replicates were pooled and analyzed for nitrogen and crude fibre by AOAC (1990) methods. Samples of soil were taken for analysis before planting and after the final harvest. In each treatment and replicate plot three random soil samples of 0.5 kg were taken to approximately 30cm depth. The replicate samples were pooled and approximately 0.5 kg was kept for analysis. Analyses were made for pH, carbon, nitrogen, P_2O_5 and KCl by standard methods (SSSA 1996).

Statistical analysis

The means of the treatments were compared using the General Linear Model (GML) of Minitab software (Version Release 10.2). The sources of variation in the ANOVA were sources of fertilizer [species: (pig vs cow), processing (manure vs effluent)], interaction [species*processing], harvest (1st or 2nd) and error.

Results and discussion

Composition of the different types of manure used on cassava

Table 1 shows that dry matter and total nitrogen contents of manure and biodigester effluent from pigs are higher than from cows.

Table 1. Dry matter (DM) and Nitrogen (N) content of different types of manure were used on Cassava

Type of manure	Dry matter (%)	Total Nitrogen (% of DM)
Fresh cow dung (CM)	21.42	1.53
Fresh pig dung (PM)	26.53	2.97
Digested cow dung (CF)	2.50	1.72
Digested pig dung (PF)	2.85	2.70

Mean values for biomass and protein yields for individual treatments are given in Table 2. Main effects are compared in Table 3 and illustrated graphically in Figures 1 to 6. There were no interactions for any of the measurements between the source of the manure (cow versus pig) and the effects of processing in the biodigester (manure versus effluent).

Table 2. Effects of manure and effluent from pigs or cows on biomass yield and chemical composition of cassava foliage harvested in the dry season under irrigated condition (means of two harvests)

	Cow effluent	Cow manure	Pig effluent	Pig manure	SEmeans	Probability

Whole plant						
Biomass yield, tonnes/ha	8.89	7.53	8.48	6.83	±0.26	0.005
Plant DM,%	20.98	21.98	21.65	24.42	±0.43	0.006
Protein in DM,%	23.06	18.42	23.75	22.91	±0.54	0.001
Protein yield, tonnes/ha	0.43	0.30	0.43	0.38	±0.02	0.006
Crude fibre in DM,%	23.44	20.62	22.82	23.65	±0.29	0.001
Leaf						
Leaf, % in plant	73.17	71.35	75.52	72.45	±0.74	0.034
Leaves, tonnes/ha	6.50	5.37	6.40	4.95	±0.21	0.004
Leaf DM,%	21.25	22.72	21.50	24.67	±0.23	0.001
Protein in leaf DM,%	27.25	24.25	27.91	24.18	±0.01	0.001
Protein yield of leaf, tonnes/ha	0.38	0.29	0.38	0.30	±0.01	0.002
Crude fibre in leaf DM,%	15.71	15.24	18.35	16.80	±0.22	0.001
Stem						
Stem yield, tonnes/ha	2.40	2.17	2.08	1.88	±0.09	0.034
Stem DM,%	17.85	18.36	20.51	24.30	±0.45	0.001
Protein in stem DM,%	10.39	9.77	12.32	10.23	±0.27	0.002
Protein yield of stem, tonnes/ha	0.05	0.04	0.05	0.05	±0.00	0.211
Crude fibre in stem DM,%	35.19	33.07	37.35	32.82	±0.52	0.003
Plant height, cm	68.63	65.56	65.64	59.83	±1.50	0.031

Table 3. Effects of species of origin (cow vs pig) and type of fertilizer (manure vs effluent) on yield and chemical composition of cassava foliage harvested in the dry season under irrigated conditions (means of two harvests)

	Species		**Fertilizer**			**Probability**	
	Cow	**Pig**	**Manure**	**Effluent**	**SEmeans**	**C vs P**	**M vs E**
Whole plant (leaf + stem)							
Biomass yield, tonnes/ha	8.21	7.65	7.18	8.68	±0.22	0.09	0.001
Plant DM,%	21.5	23.3	23.2	21.3	±0.47	0.03	0.01
Protein in DM,%	20.7	23.3	20.7	23.4	±1.11	0.11	0.10
Protein yield, tonnes/ha	0.363	0.408	0.34	0.43	±0.021	0.14	0.006
Crude fibre in DM,%	22.0	23.2	22.1	23.1	±01.1	0.45	0.53
Leaf (includes petiole)							
Leaf, % in plant	72.3	74.0	71.9	74.3	±0.90	0.19	0.067
Leaves, tonnes/ha	5.93	5.67	5.16	6.45	±0.15	0.25	0.001
Leaf DM,%	22.0	23.1	23.7	21.4	±0.52	0.16	0.005
Protein in leaf DM,%	25.8	26.0	24.2	27.6	±0.17	0.22	0.001
Protein yield of leaf, tonnes/ha	0.335	0.339	0.295	0.379	±0.013	0.82	0.001
Crude fibre in leaf DM,%	15.5	17.6	16.0	17.0	±0.39	0.001	0.078

Effects of manure or effluent on biomass and protein yield of cassava foliage

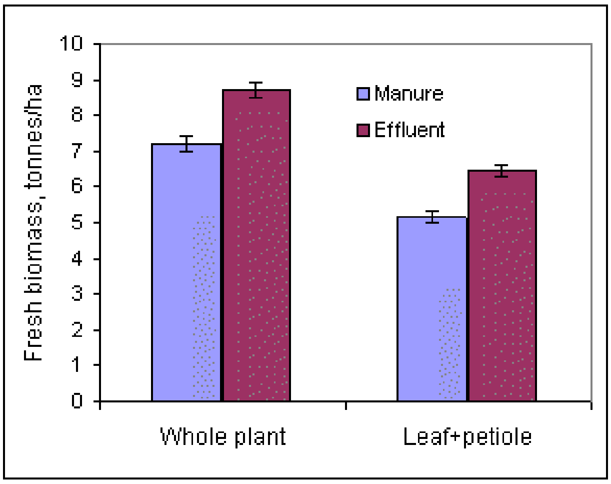

Figure 1: *Yields of fresh biomass of total aerial part and leaf+petiole of cassava fertilized with manure or biodigester effluent from cows and pigs (means for 2 harvests)*

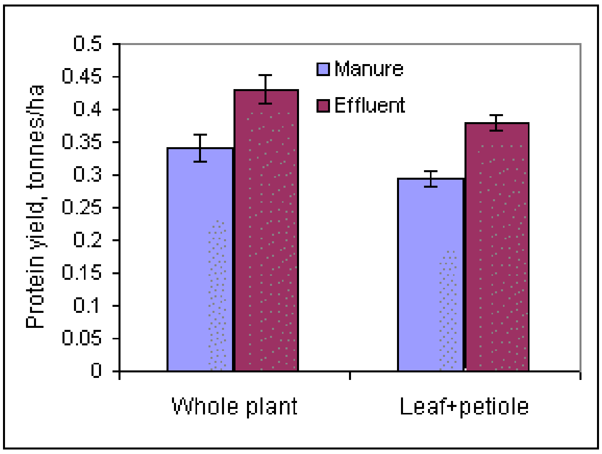

Figure 2: *Yields of protein in total aerial part and leaf+petiole of cassava fertilized with manure or biodigester effluent from cows and pigs (means for 2 harvests)*

The results of the experiment clearly showed the superiority of the biodigester effluent compared with the fresh manure for biomass yield and protein yield of the foliage of the whole (aerial) plant and the leaf and petiole fraction (Table 2 and Figure 1). The average total biomass (aerial part) yields per harvest (two harvests in 5 months growth) were: 8.68 and 7.18 tonnes/ha (SE ± 0.22; P=0.001) for effluent and manure, respectively. Comparable data for the leaf and petiole fraction were: 6.45 and 5.16 tonnes/ha (SE ± 0.15; P=0.001).

There were also significant differences for protein yields which were 0.429 and 0.338 tonnes/ha (SE ±0.012; P=0.001) for whole plant (effluent and manure, respectively) and 0.379 and 0.295 tonnes/ha for the leaf and petiole fraction (SE ± 0.012; P=0.001).

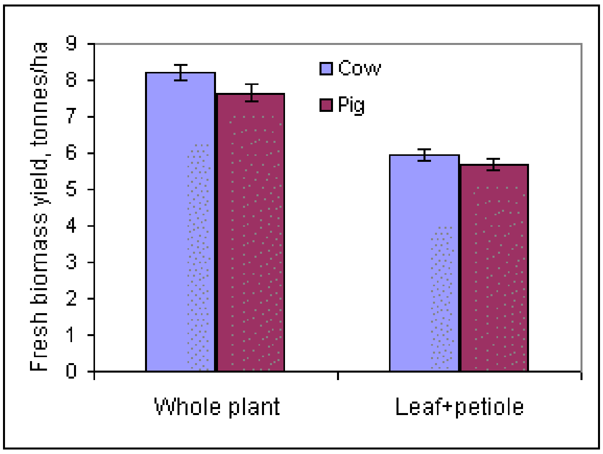

Figure 3: *Yields of fresh biomass of total aerial part and leaf+petiole of cassava fertilized with manure / effluent from cows or pigs (means for 2 harvests)*

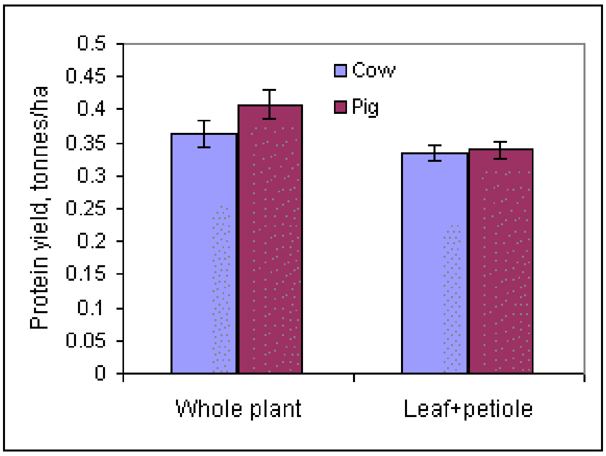

Figure 4: *Yields of protein in aerial part and leaf+petiole of cassava fertilized with manure / effluent from cows or pigs (means for 2 harvests)*

Effect of sources of manure / effluent

There was no effect of source of manure / effluent (cow versus pig) on the yield of biomass or of protein. Main effects are shown in Figures 3 and 4.

Crude protein in dry matter of cassava foliage

The data in Figure 5 show that the crude protein content tended to be higher (SE±1.11; P=0.1) for cassava (aerial part) foliage fertilized with effluent than with manure. The effect was highly significant for the leaf + petiole fraction (SE±0.17; P=0.001). It was observed that the plants on the effluent treatments were higher (Table 2) and had more leaves than those fertilized with manure. Manure and digester effluent derived from pigs (Figure 6) tended to support higher protein content in the foliage (whole plant and leaf+petiole) than when these elements came from cattle (SE±1.11; P=0.12 for whole plant; SE±0.17; P=0.24 for leaf+petiole).

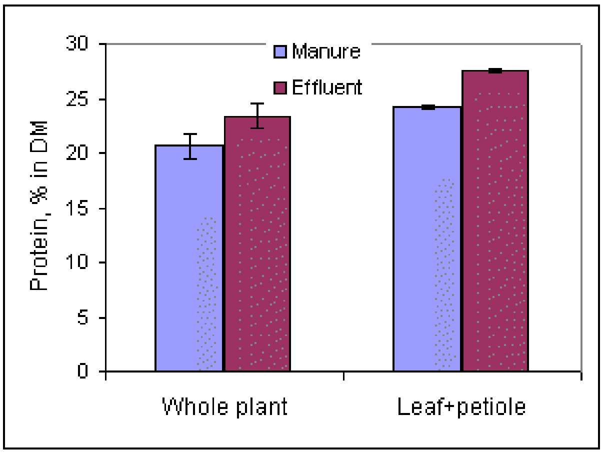

Figure 5: Protein content of total aerial part and of leaf+petiole of cassava fertilized with manure or effluent from cows / pigs (means for 2 harvests)

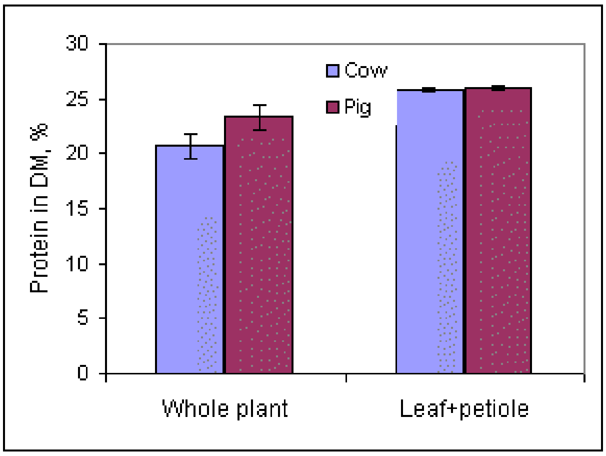

Figure 6: Protein content of total aerial part and of leaf+petiole of cassava fertilized with manure / effluent from cows or pigs (means for 2 harvests)

Effects of different types of fertilizer on soil fertility

The texture of the soil was grey podzolic with poor nitrogen and phosphorus and medium level of potassium. Levels of nitrogen and of carbon were increased (P=0.001) by 68 and 98%, respectively, comparing the soil samples taken before planting with those taken after the second harvest of cassava foliage (a 5 month period) (Table 4). There were no differences between soil samples corresponding to the treatments (cow vs pig and manure vs effluent).

There was confounding between the nature of the organic fertilizer (effluent vs manure) and the method of application. The raw manure was given in two split applications: once at the beginning and a second application 3 months later after the first harvest. By contrast, the effluent was applied every third day throughout the 5 month duration of the study. Thus the positive effects of the effluent on biomass yield and protein content of the cassava foliage may have been due at least partly to the method of application. While it was technically feasible to have applied the manure at three day intervals, this is not normal practice which is to make the application at the time of planting and at subsequent harvests. Effluent is produced daily by the digester in relatively large quantities (50-100 litres/day from a typical family scale biodigester) and it is neither feasible nor convenient to store it more than 2-3 days. Hence frequent application of effluent to the growing crop is the logical way to use it.

Experience with the use of these two contrasting forms of organic manure as fertilizer for aquatic plants, where frequent application of raw manure is feasible, supports the idea of a comparative advantage for biodigester effluent versus raw manure (Chau 1998). The fact that soil fertility status increased during the course of the experiment proves that cassava, when managed with intensive recycling of livestock wastes, can be both highly productive and protective of the soil ecosystem.

Table 4. Effects of manure and effluent from pigs or cow on chemical composition of soil before and at the end of the experiment

Soil	Before planting	At the end of experiment	SEmeans	Probability
Mechanical composition, %				
Sand	71.92	71.02	±0.41	0.176
Mud	9.87	10.79	±0.57	0.295
Clay	18.38	19.17	±0.65	0.421
pH				
H_2O	5.36	5.75	±0.11	0.05
KCl	4.22	4.65	±0.06	0.003
Carbon, %	0.55	1.09	±0.03	0.001
Plant nutrients in soil				
Total, %				
N	0.06	0.10	±0.00	0.001
P_2O_5	0.03	0.05	±0.01	0.016
K_2O	0.01	0.03	±0.00	0.009
Exchangeable, mg/100g				
NH_4	0.00	6.18		
P	56.28	77.73		
K^+	21.38	49.56		

Conclusions and recommendations

The main conclusions are as follows:

- Frequent (every three days) application of biodigester effluent to cassava gave higher yield of leaf biomass with a higher protein content than supplying the same quantity of nitrogen as raw manure in two split applications.
- The effluent and the raw manure were equally effective in improving soil fertility (increased concentrations of N, P, K and carbon) during the 5 month growth cycle despite the high off-take of nutrients in the harvested foliage.

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