*Tropical and Subtropical Agroecosystems*

SHORT NOTE [NOTA CORTA]

# EFFECTS OF DIFFERENT FERTILISERS AND HARVEST FREQUENCIES ON FOLIAGE AND TUBER YIELD AND CHEMICAL COMPOSITION OF FOLIAGE FROM TWO CASSAVA (*Manihot esculenta*, Crantz) VARIETIES

# [EFECTO DE DIFERENTES FERTILIZANTES Y FRECUENCIAS DE COSECHA SOBRE LA COMPOSICIÓN QUÍMICA Y PRODUCCIÓN DE FOLLAJE Y TUBÉRCULOS DE DOS VARIEDADES DE YUCA (*Manihot esculenta*, CRANTZ)]

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## SUMMARY

The effect of type of fertiliser and harvest frequency on foliage and tuber yield of cassava was studied in two experiments in Laos. In experiment 1 one local and one improved cassava variety were tested with four different fertilisers, control (no fertiliser), inter-cropped legume, chicken manure and urea. The foliages were harvested three times during the experimental period. Dry matter (DM) yields were recorded and chemical composition of the foliage analysed. Fertilisers significantly influenced DM yield and crude protein (CP) content in foliages of both cassava varieties**.** Mean total DM foliage yields of the local variety were 2.6, 3.6, 4.1, and 3.8 tons ha$^{-1}$ for the local variety and 2.3, 3.4, 3.7 and 3.7 tons ha$^{-1}$ for the improved variety for control, inter-cropped legume, chicken manure and urea fertiliser, respectively. CP content in the foliage was similar for the two varieties but significantly higher for the different fertilisers than for the control. The content of cyanide (HCN) and total tannins increased with all types of fertiliser application compared to the control treatment. In experiment 2, the foliage and tuber yields of the same two cassava varieties were tested with three different times of foliage harvest during the experimental period. The fresh and DM tuber yield in the control treatment was 16.7 and 5.8 tons ha$^{-1}$ and 24.5 and 8.4 tons ha$^{-1}$ for the local and improved variety, respectively. There was significantly increasing DM yields of foliage up to 4.1 and 3.4 tons ha$^{-1}$ for the local and improved variety, respectively, when the foliage was harvested 3 times during the growing period. While increased harvesting frequency increased the total foliage yield the effect on the tuber yields was negative. The tuber yield of the local variety was reduced by 11, 48 and 72% and the improved variety by 7, 47 and 71% at 1, 2 or 3 foliage harvests, respectively.

**Key words:** Cassava, variety, foliage yield, tuber yield, harvesting frequencies, fertilisers, chemical composition.

## RESUMEN

En dos experimentos realizados en Laos, se estudió el efecto de diferentes tipos de fertilizantes y frecuencias de cosecha sobre la producción de follaje y tubérculos de yuca. En el experimento 1, dos variedades de yuca (una local y una mejorada) fueron evaluadas con 4 tipos de tratamientos, control (sin fertilización), asociada con leguminosa, pollinaza y urea. Se midió la producción de Materia Seca (MS) y se analizó la composicion química del follaje. La produccion de MS y el contenido de proteína cruda (PC) del follaje en ambas variedades de yuca fueron influenciadas significativamente por los tipos de fertilizantes. Los rendimientos promedios de follaje en base seca fueron 2.6, 3.6, 4.1 y 3.8 ton ha$^{-1}$ para la variedad local y 2.3, 3.4, 3.7 y 3.7 ton ha$^{-1}$ para la variedad mejorada sin fertilizacion (control), asociada con leguminosa, pollinaza y urea, respectivamente. El contenido de PC del follaje fue similar en ambas variedades, aunque significativamente mayor en los tratamientos con fertilizantes que en el tratamiento control. Los contenidos de ácido cianhídrico (HCN) y taninos totales aumentaron con relación al control, cuando se aplicó los diferentes tipos de fertilizantes. En el experimento 2, la producción de follaje y tubérculos de las dos variedades de yuca fueron evaluadas bajo tres diferentes frecuencias de cosecha. La producción de tubérculos (fresco y seco) en el tratamiento control fue 16.7 y 5.8 ton $ha^{-1}$ y 24.5 y 8.4 ton $ha^{-1}$ para la variedad local y la variedad mejorada, respectivamente. Se observó un incremento significativo de la producción de MS de follaje de 4.1 y 3.4 ton $ha^{-1}$ para las variedades local y mejorada, respectivamente, cuando el follaje fue cosechado 3 veces durante el período de crecimiento. Aunque al incrementar la frecuencia de corte aumenta la producción total de follaje, el efecto sobre la producción de tubérculos fue negativa. La produccion de tubérculos disminuye 11, 48 y 72% en la variedad local y 7, 47 y 71% en la variedad mejorada, cuando se realizaron 1, 2 o 3 cosechas de follaje, respectivamente.

**Palabras clave**: Yuca, variedades, producción de follaje y tubérculos, frecuencias de cosecha, tipos de fertilizantes, composicion química.

## INTRODUCTION

The intensification of the agricultural production in most developing countries in the last decade has relied mainly on the expansion of cultivated land and increased agricultural inputs in order to maximise total production. The cultivation of fragile lands for crop and forage production and the increase in use of chemical fertilisers and pesticides for agricultural production has resulted in unsustainable production and negative environmental effects. Many developing countries are faced with the challenge of rapidly increasing agricultural productivity to meet their growing populations without depleting the natural resource base.

With the increasing use of cereal grains for human food, cassava (*Manihot esculenta,* Crantz) has been identified as a possible replacement for grain in the diet of animals, if properly supplemented with protein, minerals, and, in some cases, essential vitamins. The crop has multiple advantages including good yield, tolerance of poor soils, drought resistance, and can be left in the ground, thus permitting staggered harvests. Roots or tubers can be harvested between 7 and 18 months, depending on variety. The potential use of cassava foliage as an animal feed has recently been studied and described by several authors. Phuc et al. (2001) investigated the use of cassava foliage as a feed for pigs and poultry. Van et al. (2001) and Khang (2004) described the foliage of cassava as a protein source for small ruminants and cattle. The tubers are rich in energy and the foliages or leaves have high protein content, and can yield as much as 4 t/ha annually (Preston, 2001). Protein content in cassava leaves ranges between 160 g to 250 g/kg dry matter (DM), and with almost 85% of the crude protein (CP) fraction as true protein (Ravindran, 1993).

Although cassava can grow in infertile soils, maintaining or improving soil productivity is an important factor that contributes to a good crop yield. The application of nutrients for the cassava crop can be in the form of inorganic or organic fertiliser or through the use of legumes for biological N fixation (Plaza et al., 2002).

Some research has been done to investigate promising technologies for processing cassava products of high quality to be used for livestock feeding (Preston, 2001). Most research on cassava agronomy has, however, been done on breeding and selection of cassava varieties and crop management to obtain a high yield of tuber and starch production. There are few published reports that focus on agronomic management or cultivation practices for optimising cassava foliage together with tuber production. The objectives of the present two experiments were to investigate the effect of different fertilisers on foliage yield and chemical composition of two cassava varieties, one local and one improved, and to determine the effect of foliage harvest frequencies on foliage and tuber yield of the same varieties.

## MATERIAL AND METHODS

### Location and climate

The experiments were carried out at the Livestock Research Centre, Nam Souang about 40 km north of Vientiane, Laos. The first experiment, Exp. 1 was conducted during early June to December 2002 to study the effect of different fertilisers on foliage yield and chemical composition of foliage from one local and one improved cassava variety. The second experiment, Exp. 2, was carried out at the same location during the following season in May 2003 to February 2004 to study the effect of different foliage harvesting frequencies on foliage and tuber yield of the same varieties.

The climate in the area of the experimental site is tropical monsoon, with a dry season from November to April and a wet season from May to October. The average annual rainfall is about 1765 mm, ranging from 1500 mm to more than 2000 mm. The highest rainfall occurs in June to August. The maximum temperature ranges from 35$^{o}$C to 42$^{o}$C in March to May and the minimum temperature from 18$^{o}$C to 22$^{o}$C in December to February. The soils in the area are generally sandy loams classified as Vientiane plain

(National Soil Classification) with low fertility and an average pH of 4.5.

## Experimental design

A completely randomised 2*4 factorial block design was used for both experiments. All treatments were randomly assigned to the four blocks.

In Exp. 1 two cassava varieties were tested with four different methods of fertilisation. A compound fertiliser was applied to all plots at planting and the treatments were (1) no further fertilisation (control), (2) chicken manure, (3) chemical fertiliser (urea) and (4) a forage legume *Arachis pintoi* inter-cropped with cassava. The size of each subplot was 4 x 5 m.

In Exp. 2 the same two cassava varieties were tested with 1, 2 or 3 foliage harvests during the experimental period. The size of the plots was 4 x 7 m

According to Khang (2004) and Khieu Borin (2005) these plot sizes were adequate.

## Plant material

In Exp. 1 the two varieties of cassava used in the experiment were a local variety called red cassava, due to the red colour of the petiole, and an improved variety recently introduced from Thailand, Kasetsart 50 (KS50). The mature stem cuttings of the local variety were collected from fields belonging to farmers near the experimental site, and in total 800 cuttings with a length of about 20 to 25 cm were used as plant material. Another 800 stem cuttings of the improved variety were collected from the National Agriculture Research Centre about 60 km from the experimental site.

In Exp. 2 altogether 1280 stem cuttings of the same two cassava varieties from the first experiment were used.

## Planting and management

Exp. 1 was established in a field of 1000 m$^2$ of which 640 m$^2$ were allocated for planting cassava and another 360 m$^2$ were the border area between the plots and blocks. The land of the experimental area was previously used as a pasture for cattle grazing. Twelve soil sub samples of three different profiles (0 to 20 cm, 20 to 40 cm and 40 to 60 cm) were collected from four locations within the experimental area for soil property identification and chemical analysis prior to the land preparation and planting. The soil was a sandy loam with pH 4.50 and low P and N content. The result of the soil analysis is presented in Table 1.

The land was ploughed by a tractor with a 7-disc plough to about 15 to 20 cm depth at the end of April 2002 and was then left to dry for 14 days to control weeds. The land was harrowed with a disc harrow, resulting in clods of 3 to 5 cm in diameter. The experimental plots were demarcated and finally prepared by hand, using hoes to break or refine big soil particles before planting.

Each plot was planted manually with one stem cutting (25-30 cm) per hole in an upright position and the bottom end was covered with soil to about 15 cm depth on June 1$^{st}$ 2002. The distance between plants and the row spacing was 50 x 100 cm. In each plot, a total of 50 stem cuttings were planted into 5 rows with 10 plants in each row, giving a population of 25.000 plants ha$^{-1}$ and the survival rate was 100% during the experimental period.

Table 1. Soil texture and chemical characterisation of the soil at the experimental site (means and standard deviation).

| Texture and chemical composition | Soil depth (cm) 0-20 | 20-40 | 40-60 |
|---|---|---|---|
| pH in water (soil 1: liquid 2.5) | 4.55 (0.12) | 4.51 (0.08) | 4.50 (0.12) |
| Organic matter, % | 1.37 (0.12) | 0.92 (0.08) | 0.73 (0.12) |
| Nitrogen, % | 0.07 (0.01) | 0.06 (0.02) | 0.05 (0.01) |
| $NH_4$ ppm | 12.60 (2.85) | 9.10 (0.11) | 5.60 (0.15) |
| $NO_3$ ppm | 8.22 (3.35) | 7.35 (2.02) | 6.47 (1.75) |
| $P_2O_5$ % (P total) | 0.020 (0.004) | 0.017 (0.001) | 0.016 (0.002) |
| P ppm (P available) | 4.30 (0.83) | 2.13 (1.22) | 1.68 (0.74) |
| $K_2O$ % (K total) | 0.032 (0.003) | 0.037 (0.006) | 0.038 (0.005) |
| $K_2O$ mg/100g (K available) | 5.90 (1.24) | 4.10 (1.83) | 3.70 (2.35) |
| Fine sand, % | 54.4 (1.92) | 52.4 (1.92) | 50.9 (1.53) |
| Silt, % | 24.6 (1.15) | 22.6 (2.58) | 22.6 (1.16) |
| Clay, % | 20.9 (1.25) | 24.9 (2.10) | 26.4 (1.53) |
| Number of samples | 4 | 4 | 4 |

Vegetative stem cuttings, 20 to 25 cm long, of the forage legume *Arachis pintoi* were collected from farms in Luang Prabang province about 300 km north of the experimental site, and used as plant material. In each plot with inter-cropped legume, a total of 320 cutting stems were planted inter four rows of cassava. The cuttings of legume were planted manually with 2 to 3 cuttings per hole, one week after planting the cassava. The plant and row spacing was 25 x 25 cm. A compound fertiliser (NPK 15:15:15) was broadcasted initially as a basal fertilisation for all experimental plots at the rate of 100 kg $ha^{-1}$ at the same time as the planting of cassava. Additional fertiliser was applied one month after planting and then after each foliage harvest according to treatment. Urea fertiliser containing 46% N was applied as top dressing to the urea fertiliser treatment plots at the rate of 30 kg $ha^{-1}$ one month after planting and at the rate of 35 kg at the first and second foliage harvest, respectively. The total rate of urea fertiliser was 100 kg $ha^{-1}$. Dry chicken manure containing 880 g DM and 17.8 g N, 31.7 g total $P_2O_5$ and 1.3 g total $K_2O$ per kg was also applied as top dressing in the amount of 5.20 kg per plot of 20 $m^2$, equal to 2.6 t/ha. The total amount of animal manure was divided equally into three lots, which were applied one month after planting and after the first and second foliage harvest, respectively.

The top biomass of the inter-cropped forage legume was cut about 10 to 15 cm above the ground at the same time as the cassava foliage harvests. The biomass of the legume harvested from each plot was weighed and sampled and the remaining biomass from each sub plot was spread along the rows of cassava as green manure in the same sub plot. The total fresh biomass yield of legume harvested twice in each plot (20 $m^2$), was approximately 9.60 kg equal to about 4800 kg fresh biomass/ha. The average DM and N content of the legume was 156 g and 41 g/kg DM, respectively. The N applications from the different treatments were estimated to be equivalent to 40.7 kg $ha^{-1}$ for chicken manure, 46.0 kg $ha^{-1}$ for urea and 30.7 kg $ha^{-1}$ for the inter-cropped legume. Manual weeding was undertaken twice during the first three months of the experimental period, three weeks and 11 weeks after planting. Weed slashing with a bush knife and a slashing machine along the walk-way or border of the experimental plots was performed every month during the growing season.

Exp. 2 was conducted close to the site of the first experiment. The soil type was similar, a sandy loam. Land preparation was performed in the same manner as for the first experiment, but two weeks earlier (mid April 2003) than the previous experiment, due to early rain and sufficient soil moisture for land preparation. Before planting, the experimental area was demarcated and divided equally into four main plots. Each main plot was subdivided into 8 subplots where two cassava varieties were assigned randomly to four times of foliage harvest, 0, 1, 2 or 3. The total area of the experiment was 1260 $m^2$, out of this 896 $m^2$ was allocated for the experiment plots and the rest was the walk-way and border between the plots and blocks. Planting was performed as in the previous experiment, but the distance between the plants and the row spacing was 1 x 1 m. A total of 40 stem cuttings of each cassava variety were planted individually in each subplot on May 3rd 2003, giving a population of about 14.285 plants $ha^{-1}$. The survival rate was 98% due to the fact that some plants in the border row were damaged by rats. However, this did not affect the results since the border row was not included in the measurements.

Fertiliser was applied using a compound fertiliser (NPK 15:15:15) as broadcast at the same rate of 100 kg/ha for all treatments at the same time of planting. An additional urea fertiliser containing 46% N was applied at the rate of 50 kg/ha by top dressing all subplots one month after planting, and again after the first and second foliage harvest. The total amount of urea fertiliser applied for the whole cropping season was 150 kg/ha. Weeding was undertaken manually three times during the experimental period, three weeks and 7 weeks after planting, and the last weeding was performed by light slashing with bush knife where the weed was present. Weed control along the walk-way or border of the experimental plots was performed as in the previous experiment. Disease and pest outbreak was observed during the experimental period. There was no evidence of disease, but a few cassava plants in the border rows of the experimental plot were damaged by mice or rats eating the roots.

**Data collection and plant harvesting**

In Exp. 1 the cassava foliage was harvested three times during the experimental period. The first harvest was 3 months after planting; the second and the third harvest every two months thereafter. All experimental subplots were harvested on the same day from 08:00 h to 10:00 h to avoid differences in moisture content. All records of cassava foliage yield were taken only from the inner 2x3 m area of each subplot to minimise the effect of border row. The cassava foliage was harvested by hand by breaking or cutting the foliage at approximately 30 to 40 cm from the top of the plant. All foliages harvested in each subplot were pooled and weighed to determine the fresh biomass yield, and a sub-sample of 3 kg was taken from each subplot for DM determination and chemical analyses. The foliage of *Arachis pintoi* planted in the respective treatment of forage legume intercropping with cassava was also harvested at the same time of harvesting cassava foliage. The legume foliage was cut about 15 cm above the ground level and the biomass harvested in each individual plot was weighed to determine the fresh biomass yield, and a sub-sample of 1 kg was taken to determine DM and N content.

The measurement of cassava foliage yield in the second experiment was performed in the same manner as for the first experiment. Foliage harvest was also undertaken three times: the first foliage harvest was 3 months after planting, followed by harvesting every two months thereafter. The foliage yield in each subplot was recorded from the inner 2x5 m area of the subplot. The cassava foliage harvested was weighed fresh and a sub-sample of 3 kg was taken for DM determination. All experimental subplots were harvested on the same day from 8:00 h to 10:00 h. Roots or tubers were harvested manually once at the end of the experiment on February 3rd 2004. The tubers harvested from each treatment subplot were weighed to determine fresh tuber yield, and a sub-sample of 2 kg was taken for DM analysis.

**Chemical analysis**

All foliage samples from the different harvests, and treatment subplots were chopped into small pieces and dried in a forced air-oven (60°C) for 48 hours to determine field DM. The samples were ground in a Wiley mill to pass a 2 mm screen for further chemical analyses. The samples from Exp. 1 were analysed for CP, neutral detergent fibre (NDF), acid detergent fibre (ADF), ash and total tannins. CP and ash were analysed according to the standard methods of AOAC (1990). NDF and ADF were determined according to the procedure of Van Soest et al. (1991). Total tannins were analysed according to AOAC (1975) and were expressed in % of DM. The HCN content was determined by the alkaline titration method (AOAC, 1990). Soil pH was determined in distilled water (soil 1: liquid 2.5) using a pH meter. Chemical composition of the soil and chicken manure were analysed by the following methods: the organic matter (OM) was determined by Tyurin's method (Tyurin, 1931) and total N content by micro-Kjeldahl. The total P was measured by the molybdenum-blue colorimetric method (Grimshaw et al., 1989) and available P by the Bray method (Bray and Kurtz, 1945). Total K and available K were measured by an extraction method, as described by Mehlich (1984).

**Statistical analysis**

The data was analysed by analysis of variance using the General Linear Model (GLM) procedure of Minitab Statistical Software (Minitab, 1998). When the differences between treatment means were significant at the probability level of $P<0.05$, the means were compared using Tukey's pairwise comparison test. The yields of DM and CP in kg/ha are the sum of all harvests. The statistical model used in the first experiment was: $Y_{ijk} = \mu + T_i + B_j + V_k + e_{ijk.}$ where $Y_{ijk}$:foliage yield or nutritive value, $\mu$:general mean, $T_i$:treatment effect, $B_j$:block effect, $V_k$:variety effect, and $e_{ijk}$:experimental error. The statistical model used in the second experiment was: $Y_{ijk} = \mu + T_i + B_j + V_k + e_{ijk.}$ where $Y_{ijk}$:Cassava tuber yield, $\mu$:general mean, $T_i$:treatment effect, $B_j$:block effect, $V_k$:variety effect, and $e_{ijk}$:experimental error. The relationship between DM yield and harvest frequency was expressed as regressions, on which linearity tests were performed.

## RESULTS

**Effects of variety and different fertilisers on fresh and dry weight of foliage**

Fresh and DM foliage yield of the two varieties treated with different fertilisers are presented in Table 2. There were significant differences in foliage yield between varieties and fertilisers. The local variety had a significantly higher total fresh and DM foliage yield than the improved variety, and had a high response to all types of fertiliser. There was no interaction between variety and fertiliser. The total fresh and DM foliage yield of the local variety fertilised with chicken manure was higher than the yield of the plots fertilised with urea or inter-cropped with legume, while there were no significant differences between plots with urea fertiliser and inter-cropped legume. For the improved cassava variety fertilising with chicken manure and urea resulted in the highest fresh and DM foliage yield, but there were no significant differences between the three types of fertiliser.

**Effects of harvest frequencies on yield of foliage and tubers**

Data from Exp. 2 on foliage and tuber yields of the local and improved cassava variety for the whole growing period are summarised in Table 3. The harvesting frequencies had significant effects on foliage and tuber yield of the two cassava varieties. The control treatment, with the only foliage harvest at the same time as when the tubers were harvested (harvest frequency 0) had a significantly lower foliage yield than the other treatments, of 1.03 and 0.88 tons $ha^{-1}$, from local and improved variety, respectively. The DM foliage yield of the local variety was 1.37, 3.10 and 4.14 tons $ha^{-1}$ and of the improved variety 1.26, 2.37 and 3.38 tons $ha^{-1}$, for harvesting 1, 2 and 3 times, respectively. The local variety had significantly higher DM foliage yield than the improved variety and increasing the number of harvests increased the foliage yield ($P<0.001$). The interaction between variety and harvest frequency was significant ($P<0.001$).

Harvesting foliage during the growth period had a significantly negative effect on the tuber yield of both cassava varieties (Table 3). The most extreme effect was for foliage harvesting 3 times during the growing period, which reduced the tuber yield of the local variety by 72.2% and the improved variety by 71.2%. Harvesting 2 and 1 times reduced the tuber DM yield of the local variety by 48.0% and 10.7%, and of the improved variety by 46.6% and 7.4%, respectively. There was a linear decrease in DM cassava tuber yields with increasing harvest frequencies for both varieties. The regression equations, $r^2$ values and probabilities for the equations can be found in Fig. 1. The maximum yield for tuber and foliage together was obtained at 2 harvests for the local variety and close to 3 harvests for the improved variety.

Table 2. Exp.1: Fresh and DM cassava foliage yield of two varieties and with different fertilizers (t/ha).

| | 1st harvest | | 2nd harvest | | 3rd harvest | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Fresh | DM | Fresh | DM | Fresh | DM | Fresh | DM |
| *Local variety* | | | | | | | | |
| Control | $4.05^b$ | $0.88^b$ | $4.97^c$ | $1.10^c$ | $2.35^b$ | $0.58^c$ | $11.37^b$ | $2.56^b$ |
| Legume inter-cropping | $4.90^b$ | $0.99^b$ | $6.31^b$ | $1.39^b$ | $4.93^a$ | $1.18^a$ | $16.14^b$ | $3.56^b$ |
| Chicken manure | $7.20^a$ | $1.60^a$ | $7.94^a$ | $1.68^a$ | $3.65^a$ | $0.88^b$ | $18.79^a$ | $4.16^a$ |
| Urea | $6.50^a$ | $1.32^a$ | $7.56^{ab}$ | $1.60^a$ | $3.59^a$ | $0.86^b$ | $17.65^{ab}$ | $3.78^b$ |
| *Improved variety(KS50)* | | | | | | | | |
| Control | $4.11^b$ | $0.89^b$ | $3.81^b$ | $0.85^b$ | $2.33^b$ | $0.58^c$ | $10.25^c$ | $2.32^b$ |
| Legume inter-cropping | $4.53^b$ | $0.93^b$ | $5.98^a$ | $1.33^a$ | $4.81^a$ | $1.16^a$ | $15.32^b$ | $3.42^a$ |
| Chicken manure | $6.67^a$ | $1.35^a$ | $6.65^a$ | $1.43^a$ | $3.63^a$ | $0.88^b$ | $16.95^a$ | $3.66^a$ |
| Urea | $6.23^a$ | $1.26^a$ | $6.85^a$ | $1.50^a$ | $3.87^a$ | $0.92^b$ | $16.95^a$ | $3.68^a$ |
| *SE* | *0.231* | *0.050* | *0.264* | *0.056* | *0.066* | *0.016* | *0.336* | *0.070* |
| *Significance level* | | | | | | | | |
| Variety | ** | ** | *** | *** | ns | ns | *** | *** |
| Fertiliser | *** | *** | *** | *** | *** | *** | *** | *** |
| Variety x Fertiliser | ns | ns | ns | ns | ** | ns | ns | ns |

[a, b, c] Means with different superscripts within column and variety are significantly different (P<0.05); ns=non significant; ** P<0.01;*** P< 0.001

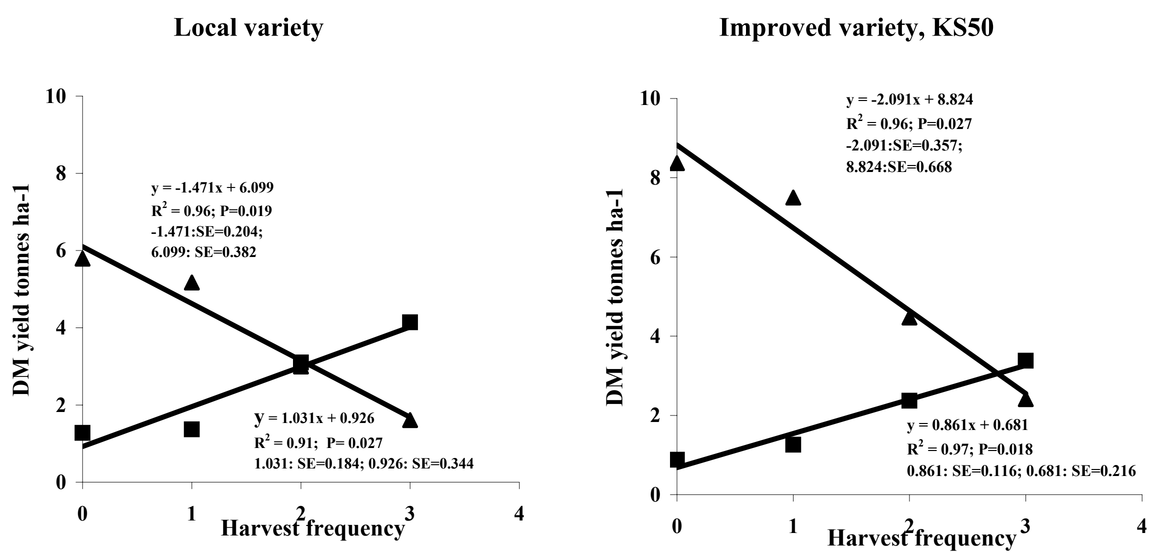


Figure 1. The relationship between DM foliage and tuber yield of two cassava varieties at different foliage harvest frequencies (Exp. 2.). ▲=Tuber yield; ■ =Foliage yield

**Effects of variety and type of fertiliser on chemical composition of foliage**

The chemical analyses (Table 4) show that CP content in foliages of both the local and the improved variety was not significantly different; however, the CP content in the foliage was influenced by the fertiliser. The CP content in foliage of the local variety fertilised with chicken manure was 218 g, with urea 217 g, with legume 201 g and for the control 180g/kg DM, while CP content of the foliage of the improved variety (KS50) fertilised with urea was 218 g, with chicken manure, 217 g, with legume, 201 g and for the control 178 g/kg DM. However, there were no significant differences between chicken manure, urea and legume inter-cropping. Total DM yield of CP of both varieties followed the same pattern as for CP content, which was influenced by the different fertilisers. The local cassava variety fertilised with chicken manure had a high CP yield, 0.90 tons ha$^{-1}$, while fertilising with urea, legume and control fertiliser resulted in yields of 0.82, 0.72 and 0.46 tons ha$^{-1}$, respectively. The improved variety fertilised with urea had the highest protein yield, 0.80 tons ha$^{-1}$, compared to chicken manure 0.79, inter-cropped legume 0.69 and control 0.14 tons ha$^{-1}$, respectively, and there was no significant difference between chicken manure and urea treatment. The NDF and ADF content in foliage of both cassava varieties was affected by the different types of fertiliser. In the control treatment, the NDF and ADF content of the local variety was 420 and 343, inter-cropped with legume 407 and 311, with chicken manure 380 and 307 and with urea 387 and 294 g/kg DM, respectively. In the control treatment the NDF and ADF content of the improved variety was 424 and 345, inter-cropped with legume 409 and 312, with chicken manure 384 and 310 and with urea 389 and 292 g/kg DM, respectively.

The mean HCN content of the fresh foliage varied with the different fertilisers. The highest HCN content in both varieties was obtained with urea fertiliser, although there were no significant differences between the control, inter-cropped with legume and chicken manure. In both varieties there were differences in the content of tannin due to treatment Tannin content in the foliage of the local and the improved variety with urea fertiliser being highest (26 g and 38 g/kg DM, respectively).

## DISCUSSION

### Varieties and fertiliser

Total fresh and DM foliage yield of the local and the improved cassava variety was significantly different, probably due to the selection for high root yield in the improved variety (Gomez and Valdivieso, 1984; Simwambana et al., 1992). Cassava variety and fertiliser had a significant effect on total foliage yield. The total DM foliage yield of both cassava varieties from three foliage harvests in each treatment (2.32 to 4.16 tons ha$^{-1}$) was much lower than the figures reported by Tung et al. (2001) in an experiment with different varieties and 5 harvests at 45 days interval (4.3 to 5.9 tons ha$^{-1}$). Differences in DM foliage yield could be due to the differences in variety (Gomez and Valdivieso, 1984; Simwambana et al., 1992) and harvest frequencies. DM foliage yield was reduced in all treatments in the last harvest, most likely due to the onset of the dry season.

Table 3. Exp.2: Yield of foliage and tuber of the two varieties at different harvest frequencies (t/ha).

| Variety | Harvest frequency | Foliage yield | | Tuber yield | |
|---|---|---|---|---|---|
| | | Fresh | DM | Fresh | DM |
| Local | 0 | 4.17$^{d}$ | 1.03$^{d}$ | 16.7$^{a}$ | 5.79$^{a}$ |
| | 1 | 6.59$^{c}$ | 1.37$^{c}$ | 14.26$^{b}$ | 5.17$^{b}$ |
| | 2 | 15.29$^{b}$ | 3.10$^{b}$ | 8.37$^{c}$ | 3.01$^{c}$ |
| | 3 | 19.92$^{a}$ | 4.13$^{a}$ | 4.28$^{d}$ | 1.61$^{d}$ |
| Improved | 0 | 3.65$^{d}$ | 0.88$^{d}$ | 24.53$^{a}$ | 8.37$^{a}$ |
| (KS50) | 1 | 6.12$^{c}$ | 1.26$^{c}$ | 19.92$^{b}$ | 7.75$^{b}$ |
| | 2 | 11.69$^{b}$ | 2.37$^{b}$ | 11.95$^{c}$ | 4.47$^{c}$ |
| | 3 | 16.26$^{a}$ | 3.38$^{a}$ | 6.47$^{d}$ | 2.4$^{d}$ |
| *SE* | | *0.122* | *0.028* | *0.049* | *0.034* |
| *Significance level* | | | | | |
| Variety | | *** | *** | *** | *** |
| Harvest frequency | | *** | *** | *** | *** |
| Variety x Harvest frequency | | *** | *** | *** | *** |

$^{a, b, c, d}$ Means with different superscripts within column and variety are significantly different (P<0.05); ns=non significant; *** P< 0.001; Harvest frequency 0=harvest only at the time of harvesting the tubers.

Table 4. Exp.1: Chemical composition and total CP yield of cassava foliage of two varieties and with different fertilisers.

| Variety | Parameter | Fertiliser | | | | |
|---|---|---|---|---|---|---|
| | | Control | Legume | Chicken man. | Urea | SE |
| Local | DM, g/kg | 228 | 221 | 218 | 218 | 4.6 |
| | *In g/kg DM* | | | | | |
| | CP | $180^{b}$ | $201^{ab}$ | $218^{a}$ | $217^{a}$ | 7.9 |
| | NDF | $420^{a}$ | $407^{ab}$ | $380^{c}$ | $387^{bc}$ | 5.6 |
| | ADF | $343^{a}$ | $311^{ab}$ | $307^{b}$ | $294^{b}$ | 8.0 |
| | Ash | $47^{b}$ | $48^{b}$ | $51^{a}$ | $52^{a}$ | 0.6 |
| | Total tannins | $18^{d}$ | $19^{c}$ | $23^{b}$ | $26^{a}$ | 0.2 |
| | HCN, mg/kg$^{-}$ | $338^{b}$ | $364^{b}$ | $377^{b}$ | $463^{a}$ | 10.7 |
| | Total CP yield, t/ha | $0.46^{d}$ | $0.72^{c}$ | $0.90^{a}$ | $0.82^{b}$ | 0.014 |
| Improved KS50 | DM, g/kg | 228 | 223 | 219 | 220 | 4.6 |
| | *In g/kg DM* | | | | | |
| | CP | $178^{b}$ | $201^{ab}$ | $217^{a}$ | $218^{a}$ | 7.7 |
| | NDF | $424^{a}$ | $409^{ab}$ | $384^{c}$ | $389^{bc}$ | 5.6 |
| | ADF | $345^{a}$ | $312^{ab}$ | $310^{b}$ | $292^{b}$ | 8.0 |
| | Ash | $48^{b}$ | $48^{b}$ | $52^{a}$ | $51^{a}$ | 0.6 |
| | Total tannins | $18^{d}$ | $19^{c}$ | $21^{b}$ | $38^{a}$ | 0.2 |
| | HCN, mg/kg | $348^{b}$ | $375^{b}$ | $384^{b}$ | $478^{a}$ | 10.7 |
| | Total CP yield, t/ha | $0.41^{c}$ | $0.69^{b}$ | $0.79^{a}$ | $0.80^{a}$ | 0.014 |

$^{a, b, c}$ Means with different superscripts within rows are significantly different (P<0.05)

**Inter-cropping and animal manure**

When the cassava crop is intercropped with grain legumes, the crop residues from the legumes can be incorporated into the soil to maintain soil fertility after harvest. This cultural practice can result in better productivity and reduce the risk for crop failure due to diseases, which is common in monocultures (Leihner, 1999; Polthanee et al., 2001). In addition, the use of green manure to maintain soil fertility by either incorporating forage or grain legumes as green manure before planting cassava, or planting shrub legumes in alley cropping systems, have been shown to successfully improve the soil fertility (Plaza et al., 2002; Tien et al., 2001). In the present study, the forage legume was inter-cropped with the cassava and the legume foliage was cut as green manure The nutrients in the foliage of the legume were returned to the soil, and thus the yield of the cassava foliage of both varieties was significantly higher than of the control treatment. However, data of fresh and DM yield of foliage of both cassava varieties (Table 3) indicate that there was no immediate effect of legume on cassava foliage yield when cassava foliages were harvested in the first cut, but in the second and the third cut the foliage yields were significantly improved.

The results of the chemical analysis of the dry chicken manure showed that the nutrient content was slightly higher than the nutrient content in cow manure, which has been reported to be 3 g to 8 g of N, 3 g to 5 g of $P_2O_5$ and 2 g to 5 g of $K_2O$ on a DM basis by Tawil (1997). The practice of using animal manure as fertiliser is a way of efficiently recycling nutrients within the farm system and can improve soil fertility. In Table 3, fresh and DM cassava yield of the two varieties and with different fertilisers (t/ha), showed that although there were no significant differences between chicken manure and urea fertiliser in total fresh and DM foliage yield of the improved cassava variety, the DM yield of the local variety fertilised with chicken manure was significantly higher than when fertilised with urea. The total DM yield of the local and the improved variety with chicken manure in the present study was 4.1 and 3.7 tons $ha^{-1}$, respectively, which was similar to the result reported by Poungchompu et al. (2001) of 4.2 tons $ha^{-1}$ when fertilising cassava managed for forage production with fresh cow manure (1,250 kg/ha). When cassava was managed as forage in Cambodia (Preston, 2001) high yields of 50 to 60 ton fresh foliage (from 10 to 12 ton DM $ha^{-1}$) over a 12 month growing cycle were obtained. However, fertilisation was at a high level, with the equivalent of around 600 kg N $ha^{-1}$ and year applied as bio-digester effluent.

**DM yield and harvest frequency**

The potential yield of cassava leaves or foliages varies considerably, depending on variety, age of plants, plant density, soil fertility, harvesting frequency and climate (Lutaladio and Ezumah, 1981;Gomez and Valdivieso, 1984; Lockard et.al., 1985; Khang, 2004). If cassava is cultivated primarily for its roots it is imperative that leaf harvesting should not greatly reduce root yield. In the present study the foliage DM yields were lower when cassava leaves were obtained as a by-product at root harvest. DM yield of cassava foliage of the local and improved variety was only 1.3 and 0.9 tons $ha^{-1}$, respectively, when foliage harvest was undertaken only once at the same time as the root harvest, while some studies have reported yields of leaf DM at root maturity of from 1.2 (Gomez and Valdivieso, 1984) to 4.64 tons $ha^{-1}$ (Ravindran and Rajaguru, 1988). The amount of forage available at root harvest is equivalent to about 30% of the root yield. The present study showed that there was a significant increase in the DM yields of foliage of the local and the improved cassava variety when the foliage harvest was undertaken 3 times during the growing period. Tuber yield was strongly affected by frequent harvests, with a reduction in tuber yields of the local and improved variety of 72.2% and 71.2%, respectively, when the foliage harvest was performed 3 times during the growth period. In contrast, the tuber yield was reduced by only 10.7% and 7.4%, respectively, when the foliages of local or improved varieties were harvested only one time. Similarly, Ravindran and Rajaguru (1988) reported that when defoliation was done once at 7 months of growth 86% of the normal yield of roots was obtained. Dahniya et al (1981) recommended a harvesting frequency of 2 to 3 months, starting from 4 months, for maximum all-round yields of roots and leaves in 12 months cultivars. However, the variation that appears to exist among cultivars in their tolerance to defoliation needs to be taken into consideration before making any recommendation of harvesting frequency.

**Chemical composition**

The difference in CP content in the foliage of both cassava varieties among the three types of fertilisation (legume inter-cropping, chicken manure and urea fertiliser) was not statistically significant (Table 5). However, CP content in the foliages was influenced by fertilisation. In the local variety, fertilisation with chicken manure resulted in the highest CP content, while urea fertiliser gave the highest CP yield in the improved variety, although, there was no significant difference between chicken manure and urea fertiliser. The present result is similar to the figure of 228 g/kg DM reported by Khang and Wiktorsson (2000), and 188 g/kg DM by Man and Wiktorsson (2001). Fibre components of cassava foliage were influenced by fertilisation, and there was a significant difference among fertilisers, but also between cassava varieties. In both cassava varieties, the values of NDF and ADF were highest in the control and relatively low in chicken manure. The content of NDF and ADF found in the present study was similar to those reported by Hong et al. (2003) and Man and Wiktorsson (2001), but lower than values reported by Khang (2004). The differences were probably due to cassava variety, cutting interval, study site, fertilisation or seasonal conditions.

In contrast to the fibre components, the level of cyanide (HCN) and total tannins was increased by fertilisation. Fertilisation with urea fertiliser resulted in the highest values of HCN, while there were no significant differences between control, inter-cropped legume or chicken manure. However, the HCN levels in all treatments were lower than those reported by Khang (2004). The differences were probably due to different varieties and crop management practices, e.g. type of fertiliser.

## CONCLUSIONS

The local variety had higher foliage yield than the improved variety, but lower tuber production. Fertilising cassava managed for forage production with animal manure and an inter-cropped legume tended to increase the combined yield of foliage from the first to the third harvests, but there was no effect on the CP content when comparing with a chemical fertiliser in the form of urea. Harvesting frequencies influenced the yield of cassava foliage and tubers of both cassava varieties during the growth period. The present study showed that it is possible to harvest cassava leaves at least two times (once during the growing period and at the end when the root is harvested) while maintaining acceptable yields of root. However, if the cultivation of cassava is exclusively aimed towards leaf production, the optimum plant density needs to be studied and the harvesting frequency can probably be shorter. Whether the aim of cassava cultivation under a given situation should be root, leaves or both would depend upon the relative prices of cassava roots and the need of fodder for animals.

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