Kenya Agricultural Research Institute (KARI)

National Animal Husbandry Research Centre, Naivasha

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2. Yield and quality of maize stover harvested at different stages.
3. Effect of chopping on drying rate of Napier grass and lucerne.

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Contents.

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Summary.

To study the effect of harvesting stage on yield and quality of potato vines and maize stover, two experiments were conducted in Naivasha. Potato vines (Cv. Musinya) were harvested at an age of 3 and 6 months during a period of one year. To study the effect of fertilizer nitrogen two treatments, one without, and one with 200 kg N per ha per year were included. Maize stover was harvested at three-weekly intervals from about 3 weeks before the cob was dough ripe to 5 weeks thereafter. The experimental design was a (complete for potato vines) randomized block, with replicates as blocks. There were 3 replicates for potato vines, and 4 for maize stover. In a third, completely different experiment, effect of prior chopping on drying rate of Napier grass and lucerne was studied.

Annual yield of potato vines decreased from 19.1 t DM at a cutting interval of 3 months to 18 t DM per ha at a cutting interval 6 months. Dry matter content increased from 15.2 to 17.4 %. Content of green leaf of potato vines decreased from 46 % at 3 months to 26 % at 6 months, while content of dead leaf increased from 4 to 10 % at the same time. Crude protein content decreased substantially from 11.2 % to 7.7 %. In vitro organic matter digestibility only decreased from 77.3 % at a cutting interval of 3 months to 75.2 % at 6 month. There were only small changes in fiber fractions. The crude protein content of the leaf fraction was much higher than of the stem, (18.0 and 7.4 % respectively at 3 months), whereas the in vitro organic matter digestibility was higher for the stem fraction (70 and 82 % respectively). There were only small effects of nitrogen fertilization on chemical composition and digestibility, except for a higher protein content after nitrogen application.

Yield of maize stover was high at about 18 ton DM per ha, but decreased at the last harvest. About 3 weeks after the maize cob was ripe, all leaf was dead. Crude protein content decreased from 6.3 % at the first harvest to 3.9 % at the last harvest. Sugar content decreased from 10.8 % at the first harvest, to 4.1 % at the last harvest, while in vitro organic matter digestibility decreased from 63.5 % to 59.9 % at the same time. Whereas the leaf digestibility did not change much, digestibility of stem decreased strongly after the first harvest.

Prior chopping increased drying rate of lucerne and Napier grass substantially after the first day, from 1.4 % dry matter per (daytime) hour to 3.7 % per hour for lucerne, and from 1.1 % to 4.4 % per hour for Napier grass.

1. Introduction.

In situations where land availability becomes critical, and during periods of scarcity, byproducts such as maize stover, banana stems and potato vines may become important feed resources (Mcdowell, 1988; Preston et al, 1987). In Kenya maize stover and sweet potato vines are used as a feed to some extent in most districts (Orodho, 1990), maize stover especially in periods after harvest of the grain. Maize stover is grazed in situ, or fed directly after the harvest, but is sometimes cut and stored as hay as well. Potato vines have long been used in Kenya (Abate et al, 1987; Karachi, 1982) e.g. to fatten sheep and calves.

As a supplement to low quality roughage, sweet potato vines improved intake and rate of live weight gain (Meyreles et al, 1978 and 1979; Karachi et al, 1990). For low quality roughage like maize stover, not only the quantity, but also the quality of protein supplementation is important (Preston and Leng, 1987; Smith et al, 1990; Yilala, 1990).

Yields of maize stover and potato vines are variable, and depend on factors like variety (Onim et al, 1985 and 1986; Karachi, 1982; Karachi et al., 1990), soil fertility and climate. Although the quality of maize stover and to a lesser extent of potato vines is rather well known, variation, in particular for maize stover, is rather large (Preston et, 1987). Although later harvest decreased quality of maize stover (Katabange et al, 1989; de Leeuw de et al, 1990) and yield of potato vines (Karachi et al, 1990), effect of harvest stage and quality is not frequently studied. Knowledge of the changes in yield and quality during ageing may be important, when deciding for "reservation" of the standing fodder, or for conservation, if later use of these feed resources is required. Therefore, two rather small experiments were started in Naivasha to investigate the effect of harvest stage on yield and quality of maize stover and potato vines.

For smallholders conservation of fodders as silage is not easy, because of the costs involved and the organisational complexity. Hay making from stemmy fodders like Napier grass, and to a lesser extent from lucerne is risky as well however in humid conditions. To reduce weather risks, the effect of prior chopping on drying rate of Napier grass and lucerne was studied in an experiment in Naivasha.

2. Materials and methods.

2.1. Experimental sites.

All experiments were executed in Naivasha, at the National Animal Husbandry Research Centre. The altitude in Naivasha is about 1900 m. The soil is an imperfectly to poorly drained, very deep, dark greyish to brown, silt loam to clay loam, developed on sediments from volcanic ashes (Jeatzhold and Schmidt, 1982). The soil is slightly alkaline (pH about 8) and chemically fertile. No soil samples were taken however. The experiments on yield and quality of potato vines and maize stover were both situated on a former lucerne field. After about 6 years of lucerne, crop growth indicated good soil fertility, probably because of a relatively high organic matter and N content.

Precipitation and temperature are shown in Annex 1. As the precipitation in Naivasha is rather low, the natural precipitation on the potato vines experiment was supplemented with irrigation. In the first quarter of 1990 the potato vines experiment was irrigated every 2 weeks, thereafter irrigation was less regular, leading to some periods with a water shortage in the second half of the experiment.

2.2 Experimental design and treatments.

2.2.1. Potato vines (Experiment 1).

The experimental design was a randomized complete block with two factors, nitrogen level and cutting interval, each at two levels. Treatments were replicated 3 times (replicates as blocks). The following levels of fertilizer nitrogen and cutting stages were applied respectively:

Levels of fertilizer nitrogen:

N0= 0 kg N per ha per year.

N1= 200 kg N per ha per year.

Age at cutting:

C1= cut every 3 months

C2= cut every 6 months.

The total duration of the experiment was 1 year, from 4th of January 1991 to 4th January 1992. The potato vines were planted about 9 months before the start of the experiment.

Nitrogen fertilizer was applied at the start of the respective cuts in the form of calcium ammonium nitrate (CAN 26% N). In addition to nitrogen fertilizer all treatments received 100 kg P_2O_5 (as triple super phosphate 44% P_2O_5) and 400 kg K_2O (as muriate of potash 60% K_2O). Fertilizer was distributed in equal amounts over all cuts. Before the start of the experiment a clearing cut was executed.

An experimental plot (net plot) consisted of 7 rows of 7 plants with a distance of 50 cm between rows and plants (size of the net plot was 12.25 m^2). The experimental plots were separated from each other by two equal rows, while also two guard rows along the edges of each block were maintained.

2.2.2. Maize stover (Experiment 2).

The experimental design was a randomized complete block, with harvest stage as the experimental factor. Treatments were replicated 4 times (replicates as blocks). The following harvest stages were applied:

Cutting date:

C1 = harvested on 14th August.

C2 = harvested on 4th September.

C2 = harvested on 25th September.

C4 = harvested on 2nd October.

The maize was planted end March 1990, on a former lucerne field, at a row distance of 75 cm and 30 cm between hills. A high yielding variety, H614 was used. Treatments were harvested every 3 weeks, except for the last harvest. Of a row of 15 m length, half was harvested to determine stover and cob yield and chemical composition, the other half was used to separate stover into green leaf, stem (including sheath) and dead leaf. The first harvest was made about 3 weeks before the maize was doughy ripe, about at the moment when maize is roasted for consumption.

2.2.3. Drying of lucerne and Napier grass (Experiment 3).
To investigate to which extent prior chopping of lucerne and Napier grass affected drying rate, both fodders were after cutting subjected to the following treatments:

UC = Napier grass or lucerne were dried **un-chopped** on the site of harvest.

C = Napier grass and lucerne were **chopped** into pieces with a length of about 2 cm after cutting, and thereafter subjected to drying on a PVC type of sheet near the farm buildings.

In both cases moderate quantities of 50 to 100 kg fresh material were dried at a time. The material was dried till the chopped material had reached a dry matter content of about 80 % (hay). The cutting stage was not recorded, but was more or less average. Very old material was not included. The material was regularly sampled to determine dry matter content. In a few cases separate samples of leaf and stem of Napier grass were dried.

2.3. Measurements and sampling.
The experimental plots were cut manually by means of a sickle. The guard rows were cut on the day of harvest or on the day before. Fodders were cut closely to ground level, leaving a stubble height of about 5 cm.
The fresh weight of the fodders was determined by means of a weighing balance (0.2 kg accurately). Sampling for dry matter (DM) and chemical analysis (Experiments 1 and 2 only), was carried out by chopping bulk samples of about 20 kg with a chaff cutter into pieces of about 2.5 cm, after which a grab sample of about 6-8 kgs was taken. This grab sample was spread out on a ridge. Sub-sampling was done by taking two segments of a ridge. For each treatment two samples were taken for DM analysis (dried at 105 ^{0}C) and one for chemical analysis (dried at 70 ^{0}C).
Sampling for the determination of the leave/stem ratio was done by picking at random a number of shoots from the heap of cut fodder. One sample from each experimental plot was taken. The samples were separated into fractions of leaf, stem (including leave sheath) and dead leaf (leaf with a brown color). In most cases these fractions were dried at 105 ^{0}C. A number of samples however was dried for 48 hours at 70 ^{0}C for chemical analysis of these fractions.

2.4. Chemical analysis.
Chemical analysis was done for crude protein and crude ash for all replicates. Besides, samples of 1 or 2 replicates were analysed for crude fiber, neutral detergent fiber, acid detergent fiber and in vitro organic matter digestibility. For a limited number of samples content of Ca, P and K was determined as well. Leaf/stem samples dried at 70 ^{0}C were analysed in the same way, but proximate analysis was done for a limited number of cuts only.
Samples investigated for ash and crude protein only, were analysed at the laboratory of the National Animal Husbandry Research Centre in Naivasha. Samples investigated for in vitro organic matter digestibility, were analysed in the Netherlands at the Institute for Animal Feeding and Nutrition Research in Lelystad. Analysis was done according to standard methods (for

nitrogen with Kjeldahl and for organic matter digestibility with the two stage in vitro; Tilley and Terry, 1963).

2.5. Statistical procedures.

Statistical analysis like analysis of variance was done with help of the statistical package Genstat.

Least significant (square) difference (LSD) is based on the Students T-test ($P<0.05$ from +t to -t; Mead et al 1983). Differences larger than the LSD are significant at the 5 % level. In the tables the LSD for the effect of nitrogen level is normally mentioned first, followed by the LSD for the effect of cutting interval.

3. Results.

3.1. Potato vines (Experiment 1).

3.1.1. Dry matter yield.

Table 1 shows annual dry matter yields.
Nitrogen fertilization and cutting interval had no significant effect on dry matter yield. There was a trend however for a lower yield at older age in the first part of the experiment, and for a higher yield with nitrogen in the second part.
Dry matter content increased significantly with age.

Table 1. Annual yield (t DM per ha) and dry matter content (in % between brackets) for combinations of cutting interval (CI in months) and nitrogen level (N0 to N1 in kg N per ha). Least significant difference (LSD) is shown as well.

CI	N0=0	N1=200	Average
C1=3	19.3 (15.2)	18.9 (15.2)	19.1 (15.2)
C2=6	17.4 (16.3)	18.6 (17.3)	18.0 (17.4)
Average	18.4 (16.3)	18.8 (16.2)	LSD DM=2.8\2.8* LSD DMP=1.0\1.0

* LSD for average yields per nitrogen level and per cutting interval respectively. Differences larger than 2.8 t DM and 2.8 t DM indicate significant effects of nitrogen level and cutting interval respectively. When comparing all possible combinations of N and CI, LSD was 4.0 t DM per ha.

Average dry matter yield at nitrogen levels N0 and N1 amounted to 19.1 and 18.0 t per ha respectively. Average yields at cutting intervals of 3 and 6 months were 18.4, and 18.8 t per ha respectively. Yields were lower in the second half of the experiment.
Dry matter yield (and chemical composition) per cut are shown in Annex 2.

3.1.2. Contents of green leaf,stem and dead leaf.

Table 2 shows contents of green leaf, stem and dead leaf.
Content of green leaf decreased significantly from 46 % at an age of 3 months to 26 % at 6 month, while content of dead leaf increased significantly from 4 to 10 %. Nitrogen had a smaller effect, but decreased leaf content and increased stem content. Ratio of green leaf to dead leaf decreased substantially from 12.3 to 3.1 respectively at 3 and 6 monthly cutting intervals. These results indicate a substantial leaf loss at older age.

3.1.3. Crude protein and ash content.

Table 3 shows the content of crude protein and crude ash.
It shows a small, but significant decrease of the ash content from 14.6 % to 13.0 %, and a decrease of the crude protein content from 11.2 to 7.7 % at an age of 3 and 6 months respectively. Nitrogen fertilization increased crude protein content slightly, but had no effect on ash content.

Table 2. Contents (%) of green leaf (L), stem (S) and dead (D) leaf for combinations of cutting interval (CI in months) and fertilizer nitrogen (N0 to N1 in kg N per ha)*.

CI	N0=0			N1=84			Average		
	L	S	D	L	S	D	L	S	D
C1=3	48	49	3	43	52	5	46	50	4
C2=6	29	59	12	23	69	8	26	64	10
Average	38	54	8	33	61	6	LSD leaf 3.8\3.8		
							LSD stem 5.4\5.4		
							LSD dead 3.3\3.3		

* LSD for combinations of cutting interval and nitrogen was 5.3, 7.7 and 4.7 respectively for leaf, stem and dead leaf.

Table 3. Content of crude protein and ash (% CP and ash) for combinations of cutting interval (CI in months) and fertilizer nitrogen (N0 to N1 in kg N per ha). LSD is shown as well.

CI	N0=0		N1=84		Average	
	ash	%CP	ash	%CP	ash	%CP
C1=3	14.4	10.7	14.9	11.7	14.6	11.2
C2=6	13.4	7.1	12.7	8.3	13.0	7.7
Average	13.9	8.9	13.8	10.0	LSD % ash=1.1\1.1	
					LSD % CP=2.9\2.9*	

3.1.4. Contents of crude, neutral and acid detergent fiber.

Tables 4 shows contents of crude, neutral and acid detergent fiber.

There was a slight increases of crude, neutral and acid detergent fiber contents with age and nitrogen level, but the effects were small. Contents of crude fiber and neutral detergent fiber were relatively low, compared to acid detergent fiber.

Table 4. Content (%) of crude (cf), neutral (ndf) and acid detergent (adf) fiber for combinations of cutting interval (CI in months) and fertilizer nitrogen *.

CI	N0=0			N2=200			Average		
	cf	ndf	adf	cf	ndf	adf	cf	ndf	adf
C1=3	16.8	39.5	30.8	17.8	39.2	31.2	17.3	39.4	31.0
C2=6	17.9	39.8	30.3	19.5	41.2	32.7	18.7	40.5	31.5
Average	17.4	39.6	30.5	18.6	40.2	32.0			

* No LSD (results for 1 replicate only).

3.1.5. Organic matter digestibility and content of digestible organic matter.

Table 5 shows in vitro organic matter digestibility (IVOMD) and content of digestible organic matter (DOM).

There were small negative effects of age and nitrogen on in vitro organic matter digestibility and on content of digestible organic matter. IVOMD and DOM decreased from 77.3 % to 75.2 %, and from 66.6 to 65.1 % respectively at an age of 3 and 6 months.

Table 5. In vitro organic matter digestibility and content of digestible organic matter (IVOMD and DOM in %), for combinations of cutting interval (CI in months) and fertilizer nitrogen (kg N per ha).

CI	N0=0		N1=200		Average	
	IVOMD	DOM	IVOMD	DOM	IVOMD	DOM
C1=3	77.2	66.6	77.4	66.6	77.3	66.6
C2=6	76.6	66.2	73.8	64.0	75.2	65.1
Average	76.9	66.4	75.6	65.3		

* No LSD (1 replicate only).

3.1.6. Fat and mineral contents.

For two replicates during the first half of the experiment, ether extract ("fat content") and mineral content were determined.

Fat content was 1.9 % at 3 months and 2 % at 6 months, without effects of nitrogen.

Contents of phosphorus (P), calcium (Ca), potassium (K) and magnesium (Mg) were respectively 0.27 %, 1.6 %, 3.6 % and 0.31 %. There was no clear effect of age and nitrogen, probably due to minor differences in dry matter yield.

3.1.7. Chemical composition and digestibility of leaves, stem and dead material.

Table 6 shows contents of ash and crude protein for fractions of (green) leaf, stem and dead leaf. Table 7 shows in vitro organic matter digestibility (IVOMD), content of digestible organic matter (DOM) and different fiber fractions for leaf, stem and dead leaf. Ash content was lowest for stem and highest for dead leaf. Effects of fertilizer and age on ash contents were small. The crude protein content of the stem fraction was only 40 % of that of leaf. The crude protein content of leaf in particular was significantly decreased by age. Fertilizer increased content of crude protein (up to 19.7 % at 3 months).

The in vitro organic matter digestibility was always highest for stem fractions and lowest for dead leaf, despite higher contents of crude and acid detergent fiber. Average content of insoluble ash (not shown), was 4.3 % in leaf and 2.3 % in stem (2 samples of leaf and stem each). There was a trend for lower ash contents and for higher crude protein contents at higher nitrogen level, but nitrogen had no clear effect on organic matter digestibility.

Table 6. Average content (%) of ash and crude protein (CP) of leaf, stem and dead leaf at different cutting intervals and fertilizer levels. LSD is shown as well (*).

Code	N0=0		N1=200		Average	
	ash	CP	ash	CP	ash	CP
3 months:						
Leaf	14.7	16.2	13.4	19.7	14.1	18.0
Stem	13.4	5.9	13.2	8.9	13.3	7.4
Dead	19.0	5.3	23.0	5.3	21.0	5.3
6 months:						
Leaf	14.4	13.7	14.0	14.3	14.2	14.0
Stem	11.9	5.1	11.6	5.4	11.7	5.3
Dead	17.1	4.2	22.7	5.1	19.9	4.6
Average						
Leaf	14.5	14.9	13.7	17.0	LSD ash=1.5	CP=3
Stem	12.6	5.5	12.4	7.1	LSD ash=0.9	CP=1.8
Dead	18.0	4.8	22.9	5.2	LSD ash=5.2	CP=0.6

* LSD for cutting interval and fertilizer was the same. No LSD for combinations.

Table 7. In vitro organic matter digestibility (IVOMD) and contents of digestible organic matter (DOM) and crude (pcf), neutral detergent (pndf) and acid detergent (padf) fiber (in %). Results for 1 replicate only.

Code	N0=0					N1=200				
	pcf	pndf	padf	IVOMD	DOM	pcf	pndf	padf	IVOMD	DOM
3 months:										
Leaf	9.8	38.1	28.1	73.4	63.2	10.6	41.0	31.8	70.0	61.5
Stem	20.4	37.9	30.1	83.1	72.4	21.4	39.9	32.6	82.5	71.2
Dead	24.0	38.6	43.8	67.8	54.7	21.5	36.5	43.3	50.2	36.1
6 months:										
Leaf	9.7	35.4	27.3	73.2	62.8	10.5	38.4	31.0	69.8	61.1
Stem	23.2	38.5	30.0	81.0	71.9	24.2	40.4	32.5	80.4	70.7
Dead	24.0	38.6	43.8	67.8	54.7	21.5	36.5	43.3	50.2	36.1

3.1.8. Nitrogen uptake, nitrogen efficiency and nitrogen recovery.

Table 8 shows nitrogen uptake and the nitrogen efficiency and nitrogen recovery. The nitrogen efficiency (NE) can be defined as follows:

$$NE = \frac{\text{DM yield with fertilizer N - DM yield without N}}{\text{N application in kg}}$$

The nitrogen recovery can be expressed as:

$$NR = \frac{\text{N-uptake with fertilizer N - N-uptake without N}}{\text{N application in kg}}$$

The annual nitrogen uptake without fertilizer was rather high at 262 kg N per ha, and decreased significantly with age. The average nitrogen efficiency was only 2 kg DM per kg N. The average recovery was low as well at 18 %. The high nitrogen uptake is probably due residual N mineralisation from the preceding lucerne crop, in particular during the first half of the experiment. This may lead to a low fertilizer requirement and could explain the very low efficiency and rather low recovery. Nitrogen losses due to leaching and denitrification after irrigation (or showers) may have contributed as well. The lower N uptake at 6 months is probably caused by a decreased crude protein content and by leaf loss.

Table 8. Annual nitrogen uptake without fertilizer (N-uptake in kg per ha), nitrogen efficiency (NE in kg DM per kg N) and nitrogen recovery (NR in %) from fertilizer N at different cutting intervals (CI in months).

CI	N-uptake	NE	NR
3 months	330	0	12
6 months	198	6	25
Average	262	2	18

3.2. Maize stover (Experiment 2).

3.2.1. Yield of stover and cobs.

Table 9 shows yield (t DM per ha) of maize stover and maize cobs and dry matter content.

Table 9. Yield (t DM per ha) and dry matter content (in % between brackets) for maize stover and cobs at different harvest dates. Least significant difference (LSD) is shown as well*.

Date	Maize stover		Maize cobs	
14/8	19.1	(22.9)	9.3	(30.3)
4/9	17.3	(29.4)	11.0	(55.5)
25/9	19.1	(63.5)	-	
2/10	13.4	(60.5)	-	
LSD	5.6	(13.1)	2.3	(4.9)

Yields of stover and cobs were very high, and varied from 13.4 to 19.1 t DM per ha for stover and from 9.3 to 11.8 t DM for cob. Yield decreased just significantly at the last harvest. Cob yield was about 50 % of stover yield. The very productive variety H 614, and the fertile former lucerne field probably contributed to the high yields. Dry matter content increased with delay in harvest. The dry matter content of 56 % of the cob at the second harvest, and the high stover dry matter contents at later harvests indicate physiolocical ripeness.

3.2.2. Contents of leaf, stem and dead leaf.
Table 10 shows contents of leaf, stem and dead leaf.
At the last two harvest there was no green leaf anymore. Stem content and content of dead leaf increased at later harvests. The increase in leaf content at the second harvest is probably due to sampling errors.

Table 10. Contents (% dry matter basis) of leaf, stem and dead leaf for maize stover at different harvest dates. Least significant difference (LSD) is shown as well.

Date	Leaf	Stem	Dead
14/8	33	47	20
4/9	44	37	19
25/9	0	61	39
2/10	0	66	34
LSD	6	8	-

3.2.3. Contents of ash and crude protein.
Table 11 shows contents of crude ash and crude protein.

Table 11. Contents (%) of ash and crude protein (CP) at different harvest dates. Least significant difference (LSD) is shown as well*.

Date	ash	CP
14/8	10.7	6.3
4/9	10.7	5.0
25/9	10.4	5.2
2/10	10.1	3.9
LSD	0.7	2.5

Ash content changed only marginally, but there was a trend for lower crude protein contents at later harvests.

3.2.4. Contents of crude, neutral and acid detergent fiber.
Table 12 shows contents of crude, neutral and acid detergent fiber.
Contents of crude fiber and acid detergent fiber increased significantly at later harvests.

Table 12. Contents (%) of crude fiber (cf), fat, sugar, in vitro organic matter digestibility (IVOMD) and content of digestible organic matter (DOM). LSD is shown as well.

Date	cf	ndf	adf
14/8	31.8	61.3	35.7
4/9	35.9	69.8	40.1
25/9	38.6	72.7	44.5
2/10	38.4	71.9	43.1
LSD	1.7	4.6	2.4

3.2.5. Contents of fat, sugar and in vitro organic matter digestibility.

Table 13 shows contents (%) of, fat, sugar, in vitro organic matter digestibility (IVOMD) and content of digestible organic matter (DOM). There was a trend for decreased contents of fat and sugar at later harvests (significantly for sugar on 25th of September). In vitro organic matter digestibility and content of digestible organic matter were significantly lower as well at the third harvest. The results of the last harvest deviate from the trend for unknown reasons.

Table 13. Contents (%) of, fat, sugar, in vitro organic matter digestibility (IVOMD) and content of digestible organic matter (DOM). LSD is shown as well.

Date	fat	sugar	IVOMD	DOM
14/8	1.1	10.8	63.5	56.3
4/9	0.7	5.3	60.9	54.1
25/9	0.7	1.9	56.5	50.3
2/10	0.7	4.1	59.9	53.5
LSD	1.1	7.3	3.4	3.7

3.2.6. Chemical composition and digestibility of leaf, stem and dead leaf.

Table 14 shows contents of ash, crude protein and in vitro organic matter digestibility of fractions of green leaf, stem and dead leaf.

Table 14. Contents of ash, crude protein and in vitro organic matter digestibility of fractions of green leaf, stem and dead leaf.

Date	Leaf			Stem			Dead		
	ash	CP	IVOMD	ash	CP	IVOMD	ash	CP	IVOMD
14/8	12.7	7.0	67.9	9.8	4.4	57.4	15.6	4.9	55.9
4/9	12.5	5.6	60.7	11.4	5.4	34.2	9.3	3.7	65.5
25/9	-	-	-	12.1	6.1	30.9	11.3	5.9	61.6

In vitro organic matter digestibility of leaf and stem decreased with age, but there was no clear trend for dead leaf. The strong decrease of the in vitro digestibility for the stem part of maize stover is not in agreement with the more moderate decrease of the full sample in Table 13. It is possible that sampling errors play a role. Sampling errors may contribute as well to some other deviating results, in particular for the last harvest (Tables 11 to 13).

3.3. Effect of chopping on drying of Napier grass and lucerne.

Table 15 shows the dry matter content of a few batches of un-chopped and chopped Napier grass and lucerne at different times after cutting. Figures 1 and 2 show graphically drying patterns for some other batches of Napier grass and lucerne respectively. Un-chopped grass was field dried, while chopped grass was dried on a (PVC) mat after chopping. Table 15 and Figures 1 and 2 show that long Napier grass and lucerne dried much slower than chopped material. Drying took place only during day time hours. At night some re-wetting was noticed sometimes.

On average, it required a total of 58 hours (26 day time hours) to dry chopped Napier grass to a dry matter content of 83 % (including the effect of a few showers). Un-chopped Napier grass had reached a dry matter content of 51 % at that moment. It required 44 hours (22 day time hours) to dry chopped lucerne to 85 % dry matter. Un-chopped lucerne had reached 61 % dry matter at that time.

Table 15. Dry matter content (in %) of un-chopped (UC) and chopped Napier grass (UC) at different times (T1 to Tn) after cutting (time T in hours). A * marks the first sampling time on a new day.

	Napier 1			Lucerne 2			Napier 2		
Code	T	UC	C	T	UC	C	T	UC	C
T1	0	16.6	16.6	0	25.3	24.6	0	16.4	16.4
T2	4	23.9	24.3	5	39.1	36.9	6	21.8	24.7
T3	7	35.5	48.9	23	48.5	46.8	25	24.7	32.0
T4	24*	38.0	54.6	28	58.0	66.4	28	31.4	53.3
T5	27	41.8	72.7	32	58.3	80.4	50	33.7	67.8
T6	31	47.4	76.8				53	34.0	74.1
T7	48*	51.2	71.3				56	40.0	73.1
T8	51	54.0	84.7				72	48.0	75.7
T9							75	42.5	84.2

Table 16. Increase in dry matter content (% per hour) of un-chopped (UC) and chopped (C) Napier grass and lucerne during day time hours on the first day after cutting and thereafter.

	Napier		Lucerne	
	UC	C	UC	C
Day 1	2.1	3.9	3.6	3.9
Thereafter	1.4	3.7	1.1	4.4

Table 16 shows the difference in drying rate (increase in dry matter content per hour during day time hours, between 8 and 18 o 'clock) between un-chopped and chopped material. The difference was relatively small on the first day after cutting, in particular for lucerne (3.6 and 3.9 % per hour respectively). Thereafter however, chopped material continued to dry at the same rate, while drying rate of un-chopped material was slow. The drying rate of un-chopped material slowed down, once it had reached a dry matter content of 30 to 50 %, in particular for Napier grass. Napier grass contained 50 to 70 % leaf. For a few batches of Napier grass drying rate of leaf, stem and dead material was measured separately as well. The results showed that the un-chopped stem dried very slow, once it had reached a dry matter content of about 25 %.

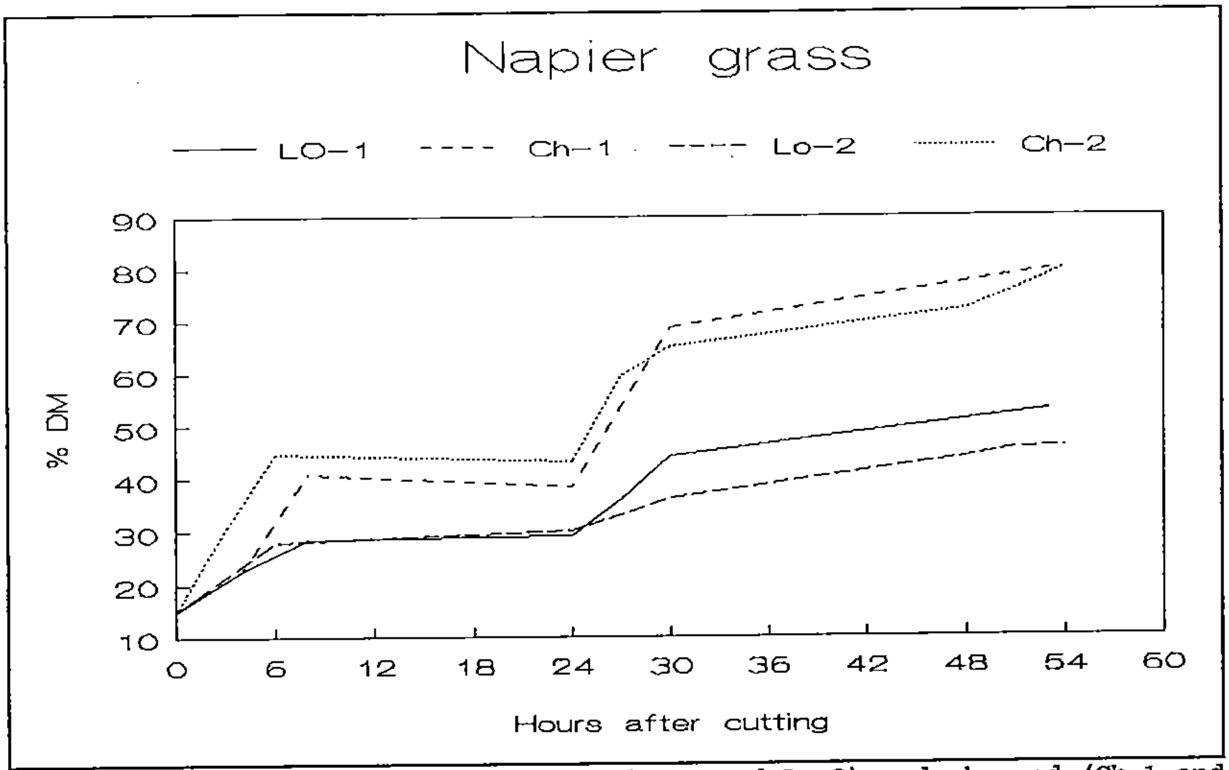

Figure 1. Dry matter % of un-chopped (Lo-1 and Lo-2) and chopped (Ch-1 and Ch-2) Napier grass at different times after cutting.

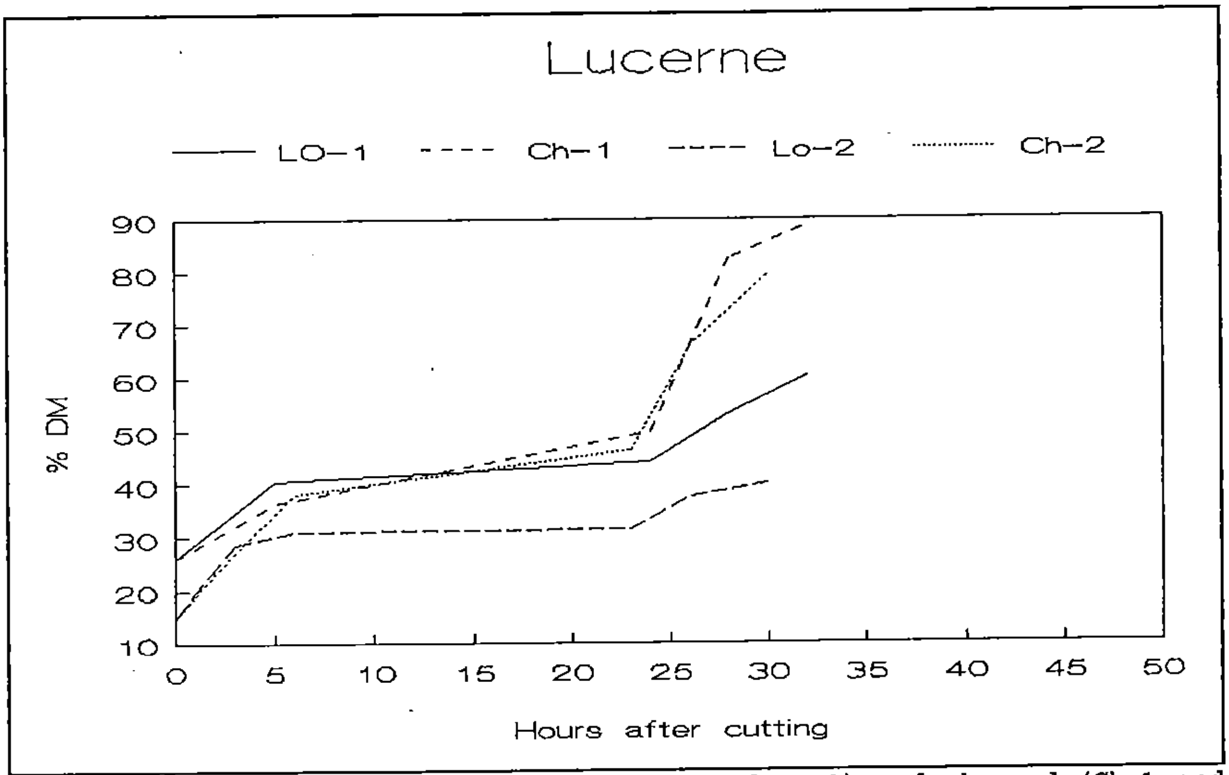

Figure 2. Dry matter % of unchopped (Lo-1 and Lo-2) and chopped (Ch-1 and Ch-2) lucerne at different times after cutting.

Results for drying rate of leaf and stem fractions of Napier grass during the first day after cutting in an earlier experiment in 1989 (Snijders et al, 1990) are shown in Table 17.

Table 17. Dry matter content (%) of leaf and stem of Napier grass at different times after cutting.

Field	Leaf/Stem	After cutting	Evening	Next morning
1	Leaf	20.7	36.5	35.7
1	Stem	9.8	13.2	13.9
2	Leaf	20.2	33.6	35.6
2	Stem	10.1	13.1	13.1
3	Leaf	-	33.1	32.8
3	Stem	-	12.3	12.8
4	Leaf	20.2	33.2	36.7
4	Stem	10.3	13.8	14.2
5	Leaf	21.0	30.5	33.5
5	Stem	10.2	13.0	14.6
Average	Leaf	20.5 ± 0.4	33.4 ± 2.1	34.9 ± 1.6
	Stem	10.2 ± 0.2	13.1 ± 0.5	13.7 ± 0.8

Table 17 shows that average dry matter contents of leaf and stem at the time of cutting were 20.5 % and 10.2 % respectively. The morning thereafter, dry matter content of leaf was 34.9 %, but stem dry matter content had only increased by 3.5 % to 13.7 %.

4. Discussion.

4.1. Potato vines.

The very high dry matter yield of the leafy variety Musinya during the first part of the experiment, was realized in sunny warm weather, with irrigation, and on a fertile soil. The much lower yield during the second part of the experiment is probably due to drought, lower temperatures and tuber initiation (Karachi et al, 1990). The leafy varieties Toilo and Musinya remained very productive under practical conditions of the zerograzing unit in Naivasha, and more or less behaved as a permanent fodder crop during a period of up to 5 years.

High yields of potato vines have been found before in e.g. West Kenya, in particular for leafy varieties (Onim et al, 1986; Abate et al, 1987; Karachi 1982). Although the annual yield tended to be lower if cut at a 6 month cutting interval, the difference was not significant. Lower annual yields of potato vines at an older age have been found by Karachi et al (1982, 1990) for the variety Musinya during the second year of an experiment. Soil fertility may affect the ratio between vine and tuber yields.

Crude protein and ash content decreased with age. In particular the strong decrease in crude protein content, probably due to leaf loss, will affect animal production without proper protein supplementation. Ash content was slightly higher than found by Karachi et al (1990), possibly due to the alkaline soil in Naivasha. Crude protein content at an age of 3 months is comparable with results elsewhere (Karachi, 1982; van Oers, 1976), but lower as found by Onim et al (1985) and Abate et al (1987), possibly due to differences in age and yield.

Crude fiber content is more or less comparable with results reported by Said (1974), Abate (1987) and van Oers (1976). Karachi (1990) mentions higher contents of acid detergent fiber and "cell walls" than found in this experiment. Said (1974) found a higher in vitro than in vivo organic matter digestibility. The very small decrease of the in vitro organic matter digestibility and content of digestible organic matter from an age of 3 to 6 months, shows the potential to reserve sweet potato vines as an energy source. If the protein content of old vines is as low as in this experiment, protein supplementation becomes important however. Dry matter degradability of sweet potato vines was rather high (Santana et al, 1979).

The crude protein content of the leaf fraction of sweet potato vines was much higher than from the stem fraction, but the in vitro organic matter digestibility of the stem fraction was higher, despite higher crude fiber content. This is probably due to the higher insoluble ash (silicium) content of the leaf (Chapter 3.1.7; van Soest, 1990). The crude fiber content of about 10 % in leaf was extremely low.

The very poor reaction to nitrogen fertilization may be due to a fertile soil after about 7 years of lucerne. Broadcasted nitrogen in this experiment (N deposited to far from the plant), and N losses after irrigation may have contributed as well to the low recovery. Karachi (1982) found a very positive

effect of nitrogen on vine yield for some varieties, including Musinya.
The ease of planting, and a possibly positive reaction to fertile soils with a good physical structure, might favor the use of sweet potato vines as a follow crop in a rotation with e.g. legumes like lucerne and Desmodium. The small decrease in digestibility opens the possibility to reserve potato vines for the dry season, in particular if protein rich leaves are fed to the most sensitive animals.

4.2. Maize stover.

The yield of maize stover on a soil formerly planted with lucerne was extremely high, but high forage yields have been found in Kakamega as well (Onim et al, 1985 and 1986). Stover yield decreased at the latest harvest, about 5 weeks after the cob was ripe. At the third harvest, about 3 weeks after maize was ripe, all leaf was dead.
Crude protein content decreased significantly to 3.9 % at the last harvest. This trend is shown as well by others (Fleischer et al,1989; Kabatange 1989; de Leeuw et al, 1990). Crude protein content of leaf of the first harvest was still 7 %, indicating a potentially strong effect of harvest stage on protein intake, if animals are allowed to select on leaf (Zemmelink, 1986). Results for leaf/stem fractions were variable however, probably partly due to problems with sampling.
Sugar content decreased significantly after the first harvest, probably indicating transfer to the ripening cob. In an experiment with bird damage (Wouters, unpublished), sugar content (and digestibility) of the stover remained at a relatively high level. There was a relatively strong increase of fiber fractions from the first to the second harvest. In vitro organic matter digestibility and content of digestible organic matter decreased by about 10 % from the first to the third harvest. Whereas there were only small changes in digestibility of (dead) leaf with time, stem digestibility decreased strongly. Contents of crude fiber and acid detergent fiber at the later harvests were slightly lower than found by Fleischer et al (1989) and Urio (1987). Decrease in digestibility was more or less comparable with the decrease found by de Leeuw (1990), but was in particular at the first harvests, larger than indicated by Kabatanga (1989). Level of digestibility was higher however, but lower as mentioned by Fleischer. Decrease of in particular leaf digestibility is probably very much influenced by weather conditions, as under wet conditions leaves may appear very moldy rather soon after harvest. Weather in Naivasha during the experiment was rather dry (Annex 1).

4.3. Drying of Napier grass and lucerne after prior chopping.

The results of Experiment 3 show the slow drying rate of the un-chopped stem of Napier grass and lucerne. An important effect of leaf content and stem length on drying rate was found by Costa et al (1991).
During more or less dry and sunny weather in Naivasha, un-chopped lucerne will normally be baled (hay stage) 2 to 4 days after cutting. There is a great risk for loss of valuable, crude protein rich leaves, if the lucerne gets too dry. To

prevent leaf loss (and consequent loss of leaf protein and energy), and to decrease risk, a farmer in Naivasha dries large quantities of un-chopped lucerne on elevated wire, under an open roof. Crude protein content and color of lucerne dried in that way is reportedly improved. Drying of small quantities of chopped lucerne (and Napier) on a PVC sheet (one or two batches of about 1 hand made bale per week), as practiced in these experiments probably prevents leaf loss, decreases risk (if the material is covered at night and during showers), but is labor intensive. It will be difficult as well to bale chopped material. It might be stored on a raised bed of netted wire, roofed with e.g. polyethylene sheet with grass or Nyanza mats on top.

4.4. Practical aspects.

As digestibility of potato vines decreased only slowly, but protein content rather fast, proper protein supplementation is important if vines are "reserved" for long periods. Vine leaf however retains a relatively high protein content. In rations with poor roughages, potato vines proved to be a good supplement, in particular if some bypass protein was provided in the form of cottonseed cake (Meyreles, mentioned by Preston et al (1977). Reservation of potato vines, as an alternative for "high cost" options like silage or hay, therefore, probably deserve more attention, in particular as a follow crop after legumes, or planted under maize.

The strong decrease in sugar content of maize stover during ripening of the cob, and the increase in dry matter content indicates that silage making might still be an option for "young stover" , while mature stover is better used as hay, in particular in dry climates (in semi-arid areas, stover is reportedly sometimes dried on top of small flat acacia trees). Silage is probably eaten easier than dry stover (Ndlovu et al, 1989). Losses of maize stover during ensiling were relatively low (Snijders et al, 1990), and it was easily accepted by cows in the zerograzing unit in Naivasha.

Combined planting of early and late maturing varieties of maize may improve the potential for stover utilisation, improving stover quality and quantity. Some farmers in Limuru, with a distinct cold season, plant maize very densely on purpose, partly to increase the availability of thinnings as an animal feed in this season. Also stripping of maize leaves has been studied in Kenya (Abate, personal communication). All these options indicate the potential of maize by-products as an important feed resource, in particular if a potentially higher manure production with use of these byproducts is taken into account as well.

The strong increase in drying rate of chopped material indicates a potential for hay making of Napier grass, if the labor intensity could be overcome. During drying of lucerne for hay, leaf loss is probably lower if small quantities of lucerne are dried on a polythene sheet after prior chopping, with consequent improvement in quality. For smallholders, organisational problems and risk may be lower as well if small quantities are handled at a time. With help of a "contractor", labor intensity might be reduced.

Drying under an open roof deserves further attention, as an option to decrease weather risk of smallholder hay making.

5. Recommendations for research.

1. Decrease in yield and quality of potato vines and maize stover under variable weather conditions have to be further studied.
2. To optimise use of by-products like potato vines, maize stover (and other straws and stovers) and banana stems, other than quantity and quality related aspects have to be studied as well. This includes the potential to plan for timely availability e.g. by choice of variety, crop rotation, the potential for feed reservation and conservation, combinations of byproducts in feed rations and effects on manure production, soil fertility and soil erosion.
3. The potential of prior chopping on drying rate of lucerne and Napier grass, require further study, in particular quality related aspects. Also other methods to reduce weather risk during drying require attention.

6. Conclusions.

1. Annual yield of potato vines decreased slightly from 19.1 t DM to 18 t DM per ha at cutting intervals of 3 and 6 months respectively, but decrease was not significant. Dry matter content increased.
2. Content of green leaf of potato vines decreased with age, whereas content of dead leaf increased. Crude protein content decreased substantially from 11.2 % to 7.7 % at ages of 3 and 6 month respectively.
3. In vitro organic matter digestibility of vines decreased only slightly with age (from 77.3 to 75.2 %), and there were only small changes in fiber fractions.
4. The crude protein content of the leaf fraction of vines was higher than of the stem, whereas the in vitro organic matter digestibility was higher for the stem fraction.
5. There were only small effects of nitrogen fertilization on chemical composition and digestibility of potato vines, except for a higher protein content with nitrogen.
6. Yield of maize stover was extremely high at about 18 ton DM per ha, but decreased at the last harvest.
7. About 3 weeks after the cob was doughy ripe, all leaf was dead. Crude protein content decreased from 6.3 % at the first harvest to 3.9 % at the last harvest.
8. Sugar content of maize stover decreased from 10.8 % at the first harvest, to 4.1 % at the last harvest. At the same time the in vitro organic matter digestibility decreased from 63.5 % to 59.9 %.
9. Whereas the digestibility of the leaf fraction of maize stover did not change much, the digestibility of stem decreased strongly after the first harvest.
10. Prior chopping increased drying rate of lucerne and Napier grass substantially, from the second day after cutting onwards (for lucerne from 1.4 % to 3.7 % increase in dry matter content per daytime hour, and from 1.4 % to 3.7 % per hour for lucerne, and from 1.1 % to 4.4 % per hour for Napier grass).

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Annexes.

Annex 1. Precipitation (P in mm) and normal temperature (T in °C).

	1990	1991	Normal	
	P	P	P	T
Jan	27	17	24	17.6
Feb	96	0	39	17.6
March	133	115	59	18.3
April	165	58	113	18.0
May	88	61	84	17.2
June	18	80	41	16.0
July	47	4	34	15.5
Aug	48	19	44	15.8
Sep	18	40	44	16.2
Oct	71	-	47	17.2
Nov	54	-	59	16.8
Dec	33	-	39	17.0

Annex 2. Yield (t DM per ha), and contents (%) of crude protein (CP) and crude ash (ash) per cut for combinations of cutting intervals (CI in months) and nitrogen level (N0 to N1 in kg N per ha).

CI	N=0			N=200		
	DM	ash	CP	DM	ash	CP
Cut 1:						
CI=3	7.2	14.1	11.9	6.0	14.8	13.2
Cut 2:						
CI=3	6.0	14.9	9.8	6.2	13.9	10.5
CI=6	11.4	13.6	5.7	11.9	12.4	7.5
Cut 3:						
CI=3	1.5	14.6	9.9	1.6	14.7	11.2
Cut 4:						
CI=3	3.1	14.1	10.9	3.4	16.7	12.0
CI=4	6.0	13.0	9.4	6.7	13.3	9.6