# Kenya Agricultural Research Institute (KARI)

National Animal Husbandry Research Centre, Naivasha

1. Yield and quality of a mixture of Napier grass and greenleaf Desmodium at two cutting regimes.
2. Vegetative propagation of greenleaf Desmodium.

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Naivasha, 1992

**Contents.**

Summary.

In 2 experiments in Naivasha, Kenya, cutting management (Experiment 1) and nitrogen fixation (Experiment 2) of a mixture of Napier grass (Pennisetum purpureum, cv. Bana) and greenleaf Desmodium (Desmodium intortum) were investigated. In Experiment 1 pure Napier grass and a mixture of Napier/Desmodium were cut at two stages: at a height of 75 to 90 cm or at 90 to 120 cm. Experiment 2 was a continuation of Experiment 1, but half of the pure Napier plots were fertilized with nitrogen at a rate of 200 kg per ha per year and all treatments were cut at the same stage. In a third experiment (Experiment 3) vegetative propagation of greenleaf Desmodium was studied. All experiments were liberally fertilized with phosphate and potassium.
Experimental design was a randomized complete block with 3 or 4 replicates in all cases.
Five year averages for annual dry matter yield in Experiment 1 were 42 % and 22 % higher for Napier/Desmodium than for pure Napier grass. Actual cutting height of Napier grass was 71 and 94 cm, if cut at younger and older age respectively. Cutting at older age had a small positive effect on the yield of Napier grass, but a small negative effect on yield of Desmodium. Yield for pure Napier was 12.3 t and 13.3 t per ha respectively. If cut at younger and older age, average annual nitrogen uptake was 96 and 94 kg N per ha respectively for pure Napier and 286 and 237 for the mixtures. Nitrogen uptake nearly tripled for the younger cutting stage. Due to declining soil fertility and drought, nitrogen uptake of pure Napier grass decreased with aging of the stand.
Compared to pure Napier grass, crude protein content more than doubled for the mixtures: from 4.9 % to 10.3 % if cut at younger age and from 4.4 % to 9.1 % if cut at older age. In vitro organic matter digestibility was on average 66.5 % for pure Napier grass and 59.1 % for the mixtures of Napier grass and Desmodium. Difference in content of digestible organic matter was only 3 units however.
Desmodium content in the mixture was 51 % and 48 % respectively when Napier was cut at 71 and 94 cm. Yields of Desmodium were higher when Napier was cut younger. Desmodium showed good persistency, with about 50 % Desmodium in the mixture after 5 years.
Recovery of fertilizer nitrogen in Experiment 2 was 44%. Assuming a linear effect of fertilizer nitrogen under the conditions of this experiment, Desmodium in mixture with Napier

grass substituted an annual nitrogen application of 149 and 465 kg N per ha, when based on dry matter and nitrogen yield respectively.
Planting mature stem cuttings of greenleaf Desmodium in Experiment 3 resulted in a regeneration of up to 60 %. After about 4 months full ground cover was achieved.

**Acknowledgements.**
The authors are indebted to the Director of National Animal Husbandry Research Centre (NAHRC) in Naivasha. We gratefully acknowledge the assistance of Kenya Agricultural Research Institute and the National Dairy Development Project.
Thanks are also due to Mrs. F.W. Wekesa and W. Ayako, and staff employed at zerograzing unit at NAHRC for assistance in plot maintenance and sampling. Mr. Njoroge and his staff at the laboratory at NAHRC Naivasha and Mr Steg and staff at the Institute for Animal Feeding and Nutrition Research in Lelystad, the Netherlands are thanked for their assistance in sample analysis. Thanks are due to Aristeriko Omwimbi and Maurice Obiero their help in data entry and drying and handling of samples.
The critical remarks of Mr. J.N. Kariuki to improve the manuscript are very much appreciated.
Mr. Schukking from the Research Station for Cattle Husbandry in Lelystad, the Netherlands regularly consulted.
From 1985 to 1987 experiments were guided by A.P. Wouters, thereafter by P.J.M. Snyders.

## 1. Introduction.

Although Napier grass reacts quite favorable to fertilizer application, (Vicente Chandler 1974; Boonman, 1979), only about 30 % of smallholder zero grazing farmers participating in the National Dairy Development Project (NDDP) in Kenya, applied fertilizer on Napier grass. On farms using fertilizer, on average 125 kg per ha of all types of fertilizer was applied (Valk, 1990). Part of the manure produced by zerograzed animals is often applied to other crops than Napier as well (Valk, 1990). As a potentially high yielding fodder, Napier grass can remove large quantities of minerals. Therefore, after a high production initially, without proper fertilization or manuring, yield and quality of Napier will detoriate (Glover, 1962).
Growing of legumes in association with grasses gives way to another source of nitrogen, through the nitrogen fixing ability of the legume component. Conservative estimates indicate that such associations may fix 100 to 200 kg nitrogen per ha per year (Burt al., 1983), while they improve soil fertility as well (Skerman, 1988; Boonman, 1979). Tropical legumes often have a higher digestible protein content than tropical grasses, (Minson in Skerman,1988), while at the same time protein content decreases less with increasing maturity (Whiteman, 1980). On farm trials in Kenya showed that crude protein content of pure Napier grass is often low (Wouters, 1987).
Desmodium intortum (greenleaf Desmodium) and Desmodium uncinatum (silverleaf Desmodium) have been reported to grow well in association with several grasses, and greenleaf Desmodium grows in Kenya up till altitudes of 2400 m. Greenleaf Desmodium will grow in a wide range of soils with adequate levels of phosphate, potassium, sulphur and molybdenum and with a pH in excess of 5. It is normally propagated by seed, but can be established by stem cuttings as well. In the early stages competition with weeds is poor, but when well established, it will suppress weeds (Skerman,1988). It may establish better when undersown under maize, than when established by itself (Boonman, 1979).
Thairu (1972) and Boonman (1979) describe Desmodium as a species with the greatest promise at the medium altitudes in Kenya (up till 2200 m), and as being more vigorous than Siratro and Glycine wightii. It is sometimes reported that greenleaf Desmodium is more persistent than silverleaf. The opposite has been found as well however (Burt et al, 1983; Jones, 1989). Digestibility of greenleaf Desmodium may be lower than digestibility of some other tropical legumes (Whiteman,1980).

Thairu (1972) studied in Kenya the contribution of silverleaf Desmodium in a mixture with Setaria sphacelata. The mixture outyielded grass in a pure stand, and the effect of Desmodium increased with time. During the fourth year the effect of Desmodium was estimated to be equivalent to a nitrogen fertilization between 134 and 235 kg N per ha per year. On average 6 cuts were made per year. In another four year study (Thairu; 1968,1970), it was found that the yield of Napier grass alone, without fertilizer nitrogen declined from 11.3 tons dry matter (DM) during the first 2 years, to 5.3 tons dry matter per ha per year during the last 2 years. With Desmodium the yield was maintained. No cutting regime was mentioned however.

It is known that frequent cutting (in particular at low height) and overstocking is detrimental to Desmodium and will effect persistency. Also nitrogen fertilization will reduce the Desmodium component in a mixture (Skerman, 1988).

In order to study the yield, quality and persistency of a mixture of Napier grass and greenleaf Desmodium under different cutting regimes, a five year experiment was initiated in Naivasha in 1985. The mixture was compared with pure Napier grass without nitrogen and was cut according to growth stage: at a height of 60 to 90 cm, or at 90 to 120 cm (Experiment 1). To compare fertilized Napier grass with the Napier/Desmodium mixture, in a short follow up experiment of one year, started in 1990, the pure Napier grass of experiment 1, was partly fertilized with nitrogen. Cutting stage was the same for all treatments (Experiment 2).

As seed of greenleaf Desmodium is difficult to obtain in Kenya, vegetative propagation of greenleaf Desmodium was investigated in a small experiment started in 1990, in pure stand as well as in an existing Napier plot (Experiment 3.).

Results are reviewed in this report. Some results of Experiment 1 were already reported before (Wouters, 1987) and are included again.

## 2. Materials and methods.

### 2.1. Experimental site.

Experiment 1 was executed from May 1985 till April 1990, Experiment 2 from April 1990 to July 1991, both at the National Animal Husbandry Research Centre in Naivasha. The experimental site was situated about 40 km south of the Equator at an altitude of about 1900 m. Experiment 2 was a follow up of Experiment 1, at the same site, but a treatment with nitrogen was introduced.

The soil was an imperfectly to poorly drained very deep, dark greyish brown, silt loam to clay soil developed on sediments from volcanic ashes (Jaetzhold and Schmidt, 1982).

Results of soil analysis (Annex 1) show that the soil of Experiment 1 was moderately to strong alkaline (pH 7.5 to 8.9) and had excessive amounts of available sodium, which may be destructive as regards soil structure. The soil was chemically fertile and contained moderately to satisfactorily amounts of organic matter.

Naivasha receives an average precipitation of about 600 mm per year, with a Pan evaporation of about 1850 mm per year (Jeatzhold and Schmidt, 1983). Precipitation during the experiment is shown in Annex 1. As Naivasha is situated in the semi-arid agro-climatical zone 4 ( Anonymus, 1982), natural precipitation was supplemented with irrigation. As much as possible the bimodal precipitation regime of Central Kenya (a precipitation of about 1200 mm) was simulated. Due to serious breakdowns of the irrigation system, from May 1988 onwards, irrigation was not available between May 1988 and March 1989, and from April to October 1990. If available, irrigation was still very irregular. To prevent total desiccation, during the last quarter of 1989, about 150 mm water was applied from a very salty borehole.

### 2.2 Experimental design and treatments.

#### 2.2.1. Experiment 1.

The experimental design for Experiment 1 was a randomized complete block with 4 replicates (blocks as replicates). Following treatments were applied:

N1 = pure Napier grass without nitrogen, cut when reaching a height of 60 to 90 cm.

N2 = pure Napier grass without nitrogen, cut when reaching a height of 90 to 120 cm.

N/D1 = A mixture of Napier grass and Desmodium cut when reaching a height of 60 to 90 cm.

N/D2 = A mixture of Napier grass and Desmodium cut when reaching a height of 90 to 120 cm.

All treatments were randomized within blocks. The experiment continued for a period of 5 years, from 25th of May 1985, up till $10^{th}$ of April 1990.
The Desmodium species used was greenleaf Desmodium (Desmodium intortum, further referred to as Desmodium), obtained via import from Australia. The Desmodium was planted in the experimental plots in November 1984, at a high seed rate of 8 kg per ha (because of disappointing results with establishment at an earlier stage), and at a distance of 45 cm between rows. The seed was inoculated with the Desmodium strain of Rhizobia bacteria, obtained from Mircen at the University of Nairobi. The seedling growth during the first month was slow.
The Napier grass variety used was French Cameroons. Napier was planted in February 1985 by means of rootsplits, in rows of 90 cm apart and 60 cm between plants within rows. In the experimental plots with Desmodium, Napier grass was planted in the rows of Desmodium, leaving one row of Desmodium in between a row of Napier grass interplanted with Desmodium.
An experimental plot (net plot) consisted of 4 Napier rows of 7 plants with a distance of 90 cm between rows and 60 cm between plants within rows (plot size 15.12 $m^2$). 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. This leads to a lay out as shown in Annex 3.
A clearing cut of all experimental plots was made on 25th of May 1985, after which sampling started. Due to circumstances beyond control, the first cut of all treatments was made too late. Also after problems with irrigation started, the proposed cutting regime could not always be maintained.
At the time of establishment, all treatments received 70 kg $P_2O_5$ (as triple super phosphate 46 % $P_2O_5$), later followed by yearly applications of 100 kgs $P_2O_5$. In subsequent years also muriate of potassium was applied, first at a rate of 200 kg $K_2O$ per ha per year, in the last year at a rate of 400 kg (as muriate of potash 60% $K_2O$. Fertilizer was yearly applied in two split applications during the long and the short rains.

**2.2.2. Experiment 2.**

A follow up Experiment 2 continued on the same site as Experiment 1, from 10th of April 1990. All treatments were now cut at the same time however, at a height of about 90 cm. One of the pure Napier plots per replicate in Experiment 1, was now fertilized with nitrogen at a rate of 200 kg N per ha per year (as CAN 26 %). The Napier/Desmodium mixtures N/D1 and N/D2 of Experiment 1 were combined into 1 treatment N/D, with 2*4 replicates. This leads to the following treatments for Experiment 2:

N0 = pure Napier grass without nitrogen, cut at a height of 90 cm.

N200 = pure Napier grass with 200 kg nitrogen per ha per year, cut at a height of 90 cm

N/D = A mixture of Napier grass and Desmodium cut at a height of 90 cm (2*4 replicates).

Nitrogen was equally distributed over 4 cuts, starting from April 1990. No nitrogen was applied in the dry season.

**2.2.3. Experiment 3.**

To study the potential of vegetative propagation of Desmodium by stem cuttings 3 small experiments were executed (Experiments 3a to 3c). Experiments 3a and 3b were planted in October 1990, Experiment 3c in January 1991.

In Experiments 3a and 3b, Desmodium was planted by seed and by stem cuttings, either in a pure stand on a previous fallow plot (Experiment 3a), or in an existing plot old Napier grass (about 8 years old), variety Bana (Experiment 3b). In Experiment 3a Desmodium was planted at row distances of 45 or 90 cm. In the existing plot of Napier grass (Experiment 3b), the rows of Napier grass (row distance 90 cm) were trimmed to create space for planting of Desmodium. After trimming there was 40 to 50 cm open space between the rows of Napier. To study effect of competition from Napier on Desmodium, Napier in Experiment 3b was either cut at a length of 1 to 2 feet or at a length of 2 to 3 feet.

As there was rather large variation in regeneration percentage of stem cuttings in Experiments 3a and 3b, in a third experiment (Experiment 3c), different parts of the overgrown Desmodium stem were used, planted in different ways.

All treatments were fertilized with phosphate and potassium. Desmodium planted by seed was inoculated with an appropriate Rhizobium strain (Mircen, University of Nairobi).

The experimental design was a randomized complete block in all cases with 3 or 4 blocks as replicates. As natural precipitation in this period was limited (see Annex 1), additional water was applied by irrigation, to simulate as much as possible a rainy season. An irrigation schedule of one irrigation per 2 weeks could not be maintained however, and distribution of irrigation water was sometimes irregular.

**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. The grass was cut closely to ground level, leaving a stubble height of 5 cm, the Desmodium was cut slightly higher, at a stubble height of 5 to 10 cm (it was attempted to leave at least some "greenleaf" after cutting, but it occurred that cutting was done too low, with little leaf left).
The height of the Napier was measured before harvesting by means of a measuring stick (in the beginning by lowering a disc). All Napier plants of a net plot were measured.
At the time of harvesting the mixture of Napier/Desmodium, both components were separated by hand. The fresh weights of both were weighed (by means of a weighing balance (0.2 kgs accurate) and sampled.
The sampling of the grass and Desmodium for dry matter (DM) and chemical analysis, was carried out by chopping bulk samples of about 20 kgs with a chaffcutter 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 of Napier and a few samples of Desmodium (in Experiment 2) was done by picking at random a number of shoots from the heap of cut Napier grass or Desmodium. One sample from each experimental plot was taken. The samples were separated into fractions of leaf, stem (including leave sheath) and dead material (material with a brown color). These fractions were dried at 105 $^0$C. For Experiment 2, a few leaf/stem samples of Desmodium were dried for 48 hours at 70 $^0$C, to determine chemical composition.
Germination from seed in Experiment 3 was determined by counting the length of open space in a row (gaps longer than 5 cm) Regeneration from stem cuttings was measured by counting the number of cuttings with some green leaf. Ground cover was estimated 3 to 6 month after germination (ground covered by Desmodium as a percentage of the total area).

**2.4. Chemical analysis.**

Crude protein and crude ash were analyzed for all replicates (N content equals crude protein content divided by 6.25). Only samples of one replicate (replicate 1) were analyzed for in vitro organic matter digestibility. Also a few leaf/stem samples of Desmodium dried at 70 $^0$C were analyzed for crude protein and ash. Samples investigated for ash and crude protein only, were analyzed at the laboratory of the National Animal

Husbandry Research Centre in Naivasha. Samples investigated for in vitro organic matter digestibility as well, were analyzed in the Netherlands at the Institute for Animal Feeding and Nutrition Research at Lelystad. Analysis was done according to standard methods (for nitrogen with Kjeldahl and for organic matter digestibility according to Tilley and Terry, 1963).
Soil analysis was done by the National Agricultural Laboratories (NAL) in Nairobi.

**2.5. Statistical procedures.**
Standard procedures for statistical analysis like analysis of variance were done with help of the statistical package Genstat. Least Significant Difference (LSD) was calculated with help of the T-test ($P<0.05$ for -t to +t; Mead et al, 1983). Differences larger as the Least Significant Difference are significant at the 5 % level.

**3. Results.**

**3.1. Experiment 1.**

**3.1.1. Dry matter yield and Desmodium content.**

Table 1 shows height of Napier grass, annual dry matter (DM) yield and percentage Desmodium in the mixture. Annual DM yields are displayed as well in Figure 1.

Table 1. Height of Napier (H in cm) and average annual DM yield (t DM per ha) for Napier (N) and Desmodium (D) cut at different stages (N1, N2, N/D1 and N/D2). Percentage Desmodium in the mixture (% D) and LSD are shown as well (*).

| Code | H | Napier | Desmodium | Total | % D |
|---|---|---|---|---|---|
| May 1985 to April 1990 (full 5 year experiment): | | | | | |
| N1 | 71 | 12.3 | - | 12.3 | |
| N/D1 | 75 | 8.6 | 8.8 | 17.4 | 51 |
| N2 | 94 | 13.3 | - | 13.3 | |
| N/D2 | 96 | 8.5 | 7.7 | 16.2 | 48 |
| | | | | LSD=2.3 t DM | |
| May 1985 to May/June 1988 (first part): | | | | | |
| N1 | 78 | 14.7 | - | 14.7 | |
| N/D1 | 79 | 9.3 | 10.0 | 19.3 | 52 |
| N2 | 102 | 16.0 | - | 16.0 | |
| N/D2 | 103 | 9.6 | 9.4 | 19.0 | 49 |
| | | | | LSD=2.5 t DM | |
| May/June 1988 to April 1990 (last part): | | | | | |
| N1 | 60 | 8.6 | - | 8.6 | |
| N/D1 | 68 | 7.5 | 7.0 | 14.5 | 48 |
| N2 | 78 | 9.3 | - | 9.3 | |
| N/D2 | 83 | 7.1 | 5.3 | 12.4 | 43 |

(*) Results for 14 cuts for N/D2 only as DM yields for the cut of 6th of February 1990 were lost. Annual yields were calculated by dividing the total yield by the quotient of the number of effective growing days divided by 365. The missing cut may have affected the yield for N/D2 slightly.

Table 1 shows average annual yields of 12.3 t and 17.4 t DM per ha for pure Napier and the mixture of Napier/Desmodium respectively, when cut at a younger stage and 13.3 and 16.2 t DM per ha for cutting at an older stage.

There was a very significant increase of 41 % and 22 % respectively of Napier/Desmodium over pure Napier. Desmodium

yield was highest when cut at a younger stage (8.8 t). Yield of pure Napier was highest when cut at older age. There was no significant effect of cutting management on yield of Napier however. Yields in the second part of the experiment were much lower than in the beginning.
In total 18 cuts were harvested for the shorter cutting interval (N1 and N/D1), and 15 cuts for the longer cutting interval (N2 and N/D2). Average cutting intervals were rather long at 99 and 121 days respectively. This was partly due to

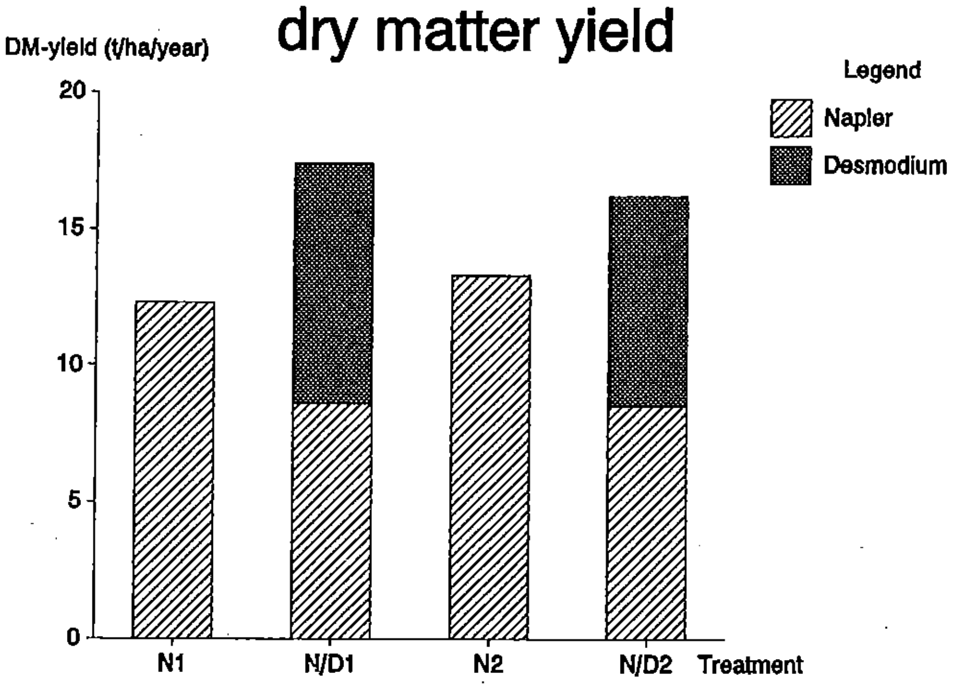


**Figure 1**. Annual dry matter yield of Napier and Desmodium.

long cutting intervals for the first cuts (for reasons beyond control) and partly due to slow growth in the dry season (in particular during the last 2 years when irrigation was problematic). Growth of the pure Napier probably decreased as well during the latter part of the experiment due to detoriating soil fertility. Therefore, to avoid overcutting of pure Napier, cuts were sometimes postponed. Due to drought senescence and consequent loss of leaves occurred sometimes, in particular in case of Desmodium. For reasons mentioned earlier it was not possible to maintain differences in cutting height between both cutting stages always as planned. On average cutting height for pure Napier was 71 cm (from 43 cm to 139 cm) when cut short and 94 cm (from 60 cm to 142 cm) when cut long. In mixture with Desmodium, Napier was slightly taller. During the second part of the experiment growth was slower and heights were rather low compared to the objective.

Percentage Desmodium in the mixture (on DM basis), was 51 % and 48 % when cut at a younger and older stage respectively. In the latter part of the experiment percentage Desmodium was lower, in particular when cut at an older stage (43 %). Annex 4 shows that Desmodium percentages decreased slightly during the period when irrigation was problematic. During the last cuts of the experiment however, percentage Desmodium for the younger cutting stage had again reached about 50 %. During the last part of the experiment, yield of Desmodium was significantly higher if cut at younger age (see also Table 1). In particular at an older age leaf loss occured during dry periods.

Results per cut are shown in Annex 4.

**3.1.2. Chemical composition.**

Table 2 shows the contents of crude ash and crude protein in Napier grass and Desmodium for the different treatments.

Table 2. Content (%) of crude ash and crude protein (CP) for Napier (N) and Desmodium (D) cut at different stages (N1, N/D1, N2, N/D2). LSD is mentioned as well (*).

| Code | Napier | | Desmodium | | Mixture | |
|---|---|---|---|---|---|---|
| | %ash | %CP | %ash | %CP | %ash | %CP |
| May 1985 to April 1990 (5 years): | | | | | | |
| N1 | 17.8 | 4.9 | | | | |
| N/D1 | 17.6 | 6.2 | 11.0 | 14.3 | 14.3 | 10.3 |
| N2 | 16.7 | 4.4 | | | | |
| N/D2 | 16.3 | 5.4 | 10.4 | 13.3 | 13.5 | 9.1 |
| | | | LSD % ash=0.8; LSD % CP=0.8 | | | |
| May 1985 to May/June 1988: | | | | | | |
| N1 | 17.5 | 4.8 | | | | |
| N/D1 | 17.4 | 6.1 | 11.1 | 14.2 | 14.1 | 10.3 |
| N2 | 16.4 | 4.2 | | | | |
| N/D2 | 15.9 | 5.2 | 10.3 | 13.0 | 13.1 | 9.0 |
| | | | LSD % ash=0.9; LSD % CP=0.7 | | | |
| May/June 1988 to April 1990: | | | | | | |
| N1 | 18.4 | 5.2 | | | | |
| N/D1 | 18.1 | 6.5 | 10.8 | 14.6 | 14.6 | 10.4 |
| N2 | 17.8 | 4.9 | | | | |
| N/D2 | 17.3 | 6.2 | 10.8 | 14.0 | 14.5 | 9.5 |
| | | | LSD % ash=1.1; LSD % CP=0.8 | | | |

(*) Results for 14 cuts for N/D2 only as DM yields for the cut of 6th of February 1990 were lost.

Crude protein content averaged 4.9 and 4.4 % for pure Napier (when cut at younger (N1) and older (N2) stage respectively), and 10.3 % and 9.1 % for the mixtures of Napier and Desmodium (N/D1 and N/D2 respectively). Crude protein content for Desmodium averaged 14 % and 13.3 % at D1 and D2 respectively. For D1 crude protein content varied from 11.6 % to 17.3 %. Crude protein content of Napier was significantly higher ($P < 0.01$) in the mixtures with Desmodium, and tended to be lower when cut at older age.
The ash content of Desmodium was much lower compared to Napier. Therefore the content of crude ash in the mixtures was much lower (14.3 % for N/D1) than for pure Napier grass. Ash content of Napier and Desmodium tended to be lower when cut at an older age.

**3.1.3. In vitro organic matter digestibility.**

Table 3 shows the in vitro organic matter digestibility of Napier grass and Desmodium at two growth stages.
On average the in vitro organic matter digestibility was much higher for pure Napier than for Napier/Desmodium (67.2 % versus 60.9 % at the younger stage of cutting). This is due to the much lower organic matter digestibility for Desmodium than for Napier. Cutting at an older growth stage decreased the digestibility of Napier and Desmodium Digestibility of Napier in the mixture was slightly higher as for pure Napier. Probably due to long cutting intervals, digestibilities were rather low, both for Napier as well as for Desmodium. Due to the difference in ash content between Napier and Desmodium, the content of digestible organic matter (not shown) was still 52.2 % for the mixture versus 55.2 % for pure Napier.
Cut at the younger growth stage, the in vitro organic matter digestibility of Desmodium varied from 50 % to 59 % (Annex 4). During the last part of the experiment there was no difference in organic matter digestibility between D1 and D2, probably due to leaf loss because of drought. In a few cases very low organic matter digestibilities were recorded for Desmodium (see Annex 4). This is probably in part due to sampling errors (e.g. samples with a high stem content; 1 replicate only), but senescence of leaves and leaf loss of Desmodium during prolonged dry periods will have contributed as well.
In particular in the second half of 1988 and the beginning of 1989, yield and quality were affected as well by damage due to a rat plague.

Table 3. In vitro organic matter digestibility (IVOMD) for Napier (N) and Desmodium (D) cut at different stages (N1, N/D1, N2, N/D2). LSD is mentioned as well (*).

| Code | Napier | Desmodium | Mixture |
|---|---|---|---|
| May 1985 to April 1990 (5 years): | | | |
| N1 | 67.2 | | |
| N/D1 | 68.7 | 54.1 | 60.9 |
| N2 | 64.9 | | |
| N/D2 | 65.8 | 50.3 | 57.4 |
| May 1985 to May/June 1988: | | | |
| N1 | 66.9 | | |
| N/D1 | 68.8 | 54.7 | 60.8 |
| N2 | 64.6 | | |
| N/D2 | 65.6 | 49.6 | 56.6 |
| May/June 1988 to April 1990: | | | |
| N1 | 68.0 | | |
| N/D1 | 68.5 | 52.3 | 61.1 |
| N2 | 66.0 | | |
| N/D2 | 66.4 | 52.4 | 59.6 |

(*) Results for 14 cuts for N/D2 only as DM yields for the cut of 6th of February 1990 were lost.

**3.1.3. Nitrogen uptake and soil fertility.**

Table 4 shows the annual nitrogen uptake (protein yield divided by 6.25; for Desmodium N uptake refers to N yield!).

Annual nitrogen uptake was 96 and 94 kg N per ha for pure Napier cut at younger and older age respectively. N uptake for the mixtures of Napier/Desmodium was much higher at 286 kg and 237 kg respectively. This represents an increase of 298 % and 252 % over pure Napier. As the nitrogen uptake of Napier in the mixture was slightly lower as for pure Napier, the increase was totally due to Desmodium.

The large contribution of Desmodium is shown as well in Figure 2. The lower Desmodium percentage in N/D2, is reflected in a smaller N uptake.

Assuming that the difference in nitrogen uptake between pure Napier and the mixtures was due to nitrogen fixation (a method with some disadvantages; Danso et al, 1986), Desmodium at N/D1 and N/D2 would have fixed 190 and 143 kg N per ha per year.

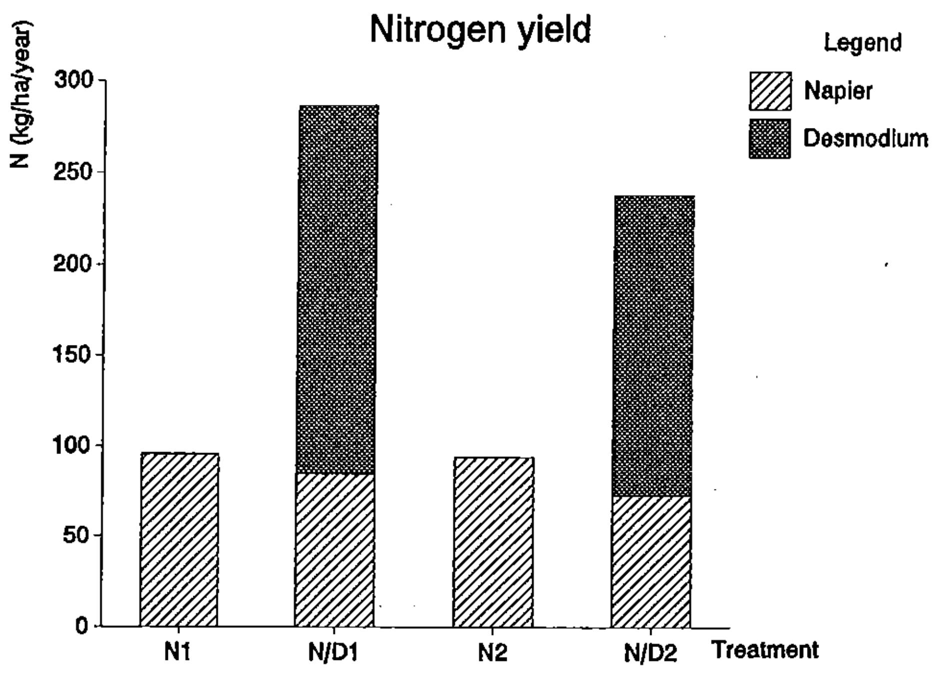


**Figure 2.** Annual nitrogen uptake of Napier and Desmodium.

Table 4. Annual nitrogen uptake (kg N per ha) for Napier (N) and Desmodium (D) cut at different stages (N1, N/D1, N2, N/D2).

| | Napier | Desmodium | Mixture |
|---|---|---|---|
| 1985 to 1990: | | | |
| N1 | 96 | | |
| N/D1 | 85 | 201 | 286 |
| N2 | 94 | | |
| N/D2 | 73 | 164 | 237 |
| 1985 to 1988: | | | |
| N1 | 113 | | |
| N/D1 | 91 | 227 | 318 |
| N2 | 108 | | |
| N/D2 | 80 | 196 | 276 |
| 1988 to 1990: | | | |
| N1 | 72 | | |
| N/D1 | 78 | 163 | 241 |
| N2 | 73 | | |
| N/D2 | 70 | 118 | 188 |

Annual nitrogen uptake from pure Napier was much higher during the first part of the experiment. Averaged over N1 and N2 N uptake was 111 kg from 1985 to 1988 and 73 kg from 1988 to 1990. This represents a decrease of 34 %. During the first year of the experiment (see Annex 4), yield was even 129 kg N per ha per year. The increase in uptake from the Napier/Desmodium mixture was only 126 % in the first year, as compared to an increase of 169 % over the first 3 years (1985 to 1988). For the mixtures of Napier/Desmodium, the decrease in N uptake with time was much lower, probably indicating a fast decrease in soil fertility on the pure Napier plots after the first year. An indication for this is further shown by a tendency for lower soil organic matter contents of the pure Napier plots in 1990, as shown in Annex 1. Carbon (C) contents are 1.33 % and 1.43 % for N1 and N/D1 respectively and 1.41 % and 1.52 % for N2 and N/D2 respectively, indicating at the same time an increase at an older cutting stage. Nitrogen contents of the soils however do not show this tendency very clearly.

## 3.2. Experiment 2.

### 3.2.1. Dry matter yield and chemical composition.

In Table 5 dry matter yields and chemical composition for Experiment 2 are shown. As the difference between the 2 former Desmodium treatments in Experiment 1 was never significant, results are shown as an average of the two (N/D).

Table 5. Average height (H in cm), annual dry matter yield (t DM per ha), and contents (%) of crude ash and crude protein for pure Napier with and without nitrogen (N0 and N200) and for Napier/Desmodium mixtures (N/D)*.

| Code | H | Yield | % ash | % CP |
|---|---|---|---|---|
| N0=0 | 71 | 11.3 | 16.9 | 5.1 |
| N1=200 | 94 | 20.2 | 15.9 | 5.4 |
| N/D (Napier/Desmodium): | | | | |
| Napier | 84 | 8.5 | 17.0 | 5.8 |
| Desmodium | | 11.1 | 11.0 | 14.3 |
| Mixture | | 19.6 | 13.6 | 10.6 |

* Annual yield was calculated by dividing the total yield by the coefficient of the number of effective growing days divided by 365.

Average annual dry matter yield was 11.3 t per ha per year for pure Napier without nitrogen. Nitrogen application increased yield to 20.2 t per ha per year. The dry matter yield for the Napier/Desmodium mixture was 19.6 t per ha. Average cutting interval was 91 days (for all treatments!).

Similar as for Experiment 1, Napier/Desmodium mixtures had a

lower ash, content, and a higher crude protein content.
For a few samples of cut 5 (cut at an age of 84 days), leaves and stems of Desmodium were separated. Leaf (green leaf) and stem content (on dry matter basis) were 42 % and 55 % respectively (3 % dead leaf). Crude protein content of green leaf, stem and dead leaf was 20.4, 5.4 and 7.9 % respectively. This is slightly lower as mentioned by Skerman (1988), whereas the difference between crude protein content of leaf and stem is larger as found by Stobbs et al (1976). Ash content was 9.7 and 9.9 % for leaf and stem respectively.
Desmodium content in the mixtures was 57 % on average. It varied from about 65 % in cut 3, to about 45 % for cut 5 (Annex 5).

**3.2.2. Effect of fertilizer nitrogen and of Desmodium.**

The effect of fertilizer nitrogen can be explained with help of the efficiency and recovery. The nitrogen efficiency (NE) and nitrogen recovery (NR) are defined as follows:

$$NE = \frac{\text{Dry matter yield with N - dry matter yield without N}}{\text{kg applied N}}$$

$$NR = \frac{\text{Nitrogen uptake with N - nitrogen uptake without N}}{\text{kg applied N}}$$

Table 6 shows dry matter yield and nitrogen uptake (for the full experiment), and nitrogen efficiency and nitrogen recovery. Nitrogen uptake is shown as well in Figure 3.

Table 6. Total dry matter and nitrogen uptake (t DM and kg N per ha ) for pure Napier (N0 and N200) and for Napier/Desmodium (N/D). Nitrogen efficiency (NE in kg DM per kg N) and recovery (NR in %) are shown as well.

| Code | N0=0 | N1=200 | N/D |
|---|---|---|---|
| DM yield | 14.1 | 25.2 | 24.4 |
| N uptake | 115 | 218 | 414* |
| | | | |
| NE | | 56 | |
| NR | | 52 | |

* N uptake (yield) was 98 kg for Napier and 316 kg for Desmodium.

Total nitrogen uptake without fertilizer N was 115 kg N per ha (102 kg N per ha per year). With 200 kg fertilizer N, uptake increased to 218 kg N per ha. Figure 3 shows the large

contribution of Desmodium to the N uptake.
The nitrogen efficiency for fertilizer N was on average 56 kg DM per kg applied N. The efficiency was very high for the first cut at 109 kg DM per kg N, but lower, at 37 kg DM per kg N, for following cuts (see Annex 5). The recovery of applied nitrogen was 52 % (without the residual effect after the last application). The increase in the dry matter and nitrogen yield of the Napier/Desmodium mixture over pure Napier was 93 % and 290 % from the effect of fertilizer N respectively. With Napier grass the effect of increasing applications of nitrogen on the recovery is often more or less linear till rather high nitrogen applications (Vicente Chandler et al, 1974; Teitzel et al, 1991). If presuming a linear effect of fertilizer N, yield increase was comparable to an annual nitrogen application of 149 and 465 kg N per ha if based on dry matter and nitrogen yield respectively. The experiment continued for only 15 months however.
The large effect of Desmodium in this experiment (in particular for nitrogen uptake), is probably due to the relatively poor soil after 6 years of Napier grass.

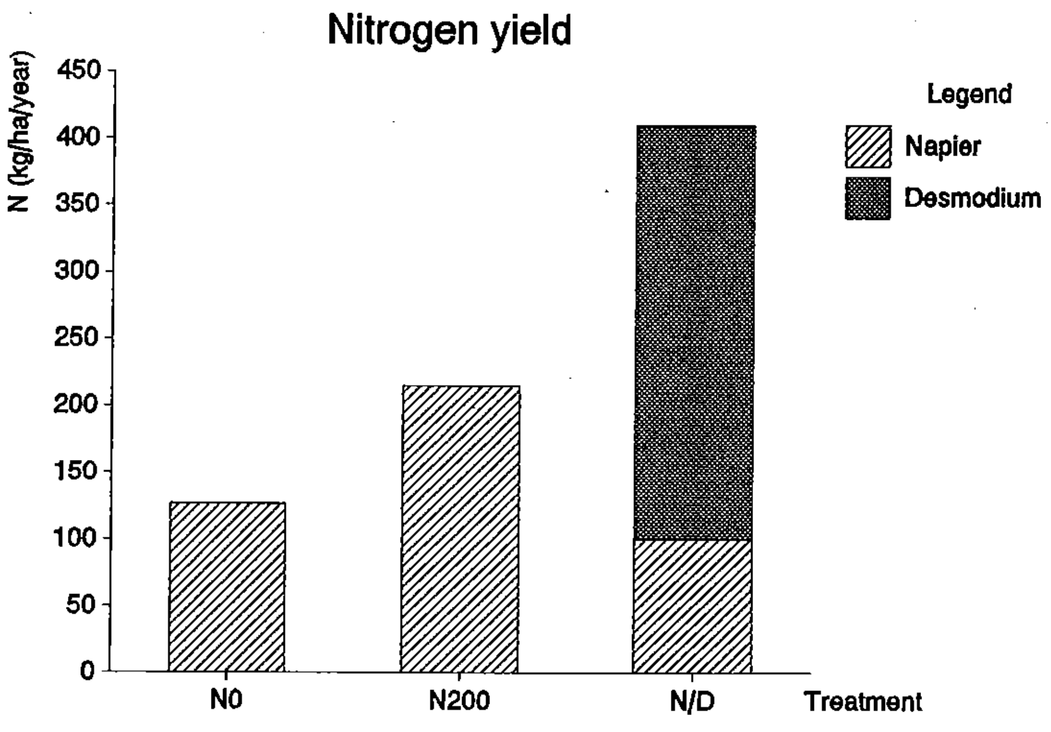


**Figure 3.** Nitrogen yield of Napier and Desmodium in Experiment 2.

### 3.3. Experiment 3.

#### 3.3.1. Experiment 3a.

Germination from seed and regeneration from stem cuttings (5 and 10 weeks after establishment) and percentage ground cover (4 months after establishment) for Experiment 3a are shown in Table 7.

Table 7 shows that germination from seed was much better (88 % at 10 weeks after planting) as regeneration from stem cuttings. For stem cuttings variation between rows was large however, and in some rows stem cuttings reached a regeneration of more than 50 %. Due to water shortage and a high evaporation, growth of seedlings was rather slow. After 4 months ground was not yet fully covered (62 % for seed at 45 cm row distance). After 6 months (results not shown) there was nearly full ground cover, even for establishment by stem cuttings.

Table 7. Germination and regeneration (%) of pure Desmodium planted by seed or by stem cuttings at 5 and 10 weeks after planting, and ground cover (%) at 4 months after establishment*.

| Code. | Seed | Stem cuttings |
|---|---|---|
| Germination and regeneration: | | |
| 5 weeks | 46 (29 to 60) | 18 (0 to 52) |
| 10 weeks | 88 (78 to 99) | 19 (0 to 54) |
| Ground cover: | | |
| Rows at 45 cm | 62 (53 to 75) | 9 (4 to 11) |
| Rows at 90 cm | 34 (31 to 37) | 21 (10 to 32) |

* Between brackets variation between rows (or replicates for ground cover) is shown.

#### 3.3.2. Experiment 3b.

Table 8 shows results for establishment by seed and stem cuttings in existing Napier (Experiment 3b).

The regeneration from stem cuttings was 37 % when Napier was cut at 1 to 2 feet and 57 % for Napier cut at 2 to 3 feet. The regeneration from stem cuttings was much better in existing Napier than for the pure stand (Experiment 3a), in particular if Napier was cut longer. Seeds still showed better germination however (77 to 88 %), and variation for stem cuttings was larger. After 6 months ground cover was still far from complete, in particular for stem cuttings. Growth after germination was slow. In some rows and on the edges, with less

Table 8. Germination and regeneration (in %) of Desmodium planted by seed or stem cuttings in existing Napier (Experiment 3b). Ground cover (%) 4 and 6 months after establishment is shown as well*

| Code. | Seed | Stem cuttings |
|---|---|---|
| Germination and regeneration after 10 weeks: | | |
| Cut at 1 to 2 feet* | 88 (70 to 98) | 37 (7 to 58) |
| Cut at 2 to 3 feet* | 77 (46 to 96) | 57 (44 to 78) |
| Ground cover 4 month after establishment: | | |
| Cut at 1 to 2 feet* | 23 (22 to 24) | 6 (2 to 10) |
| Cut at 2 to 3 feet* | 21 (16 to 25) | 4 (4 to 5) |
| Ground cover 6 month after establishment: | | |
| Cut at 1 to 2 feet* | 22 (12 to 30) | 11 (4 to 18) |
| Cut at 2 to 3 feet* | 30 (24 to 40) | 17 (10 to 28) |

* Napier cut at 1 to 2 feet or at 2 to 3 feet. Variation is shown between brackets.

competition from Napier, later development of stem cuttings was faster. For some time after germination, (too) densely planted seed and some stem cuttings showed a brownish/pinkish color, possibly indicating lack of phosphate due to competition from Napier in the rather narrow open space between Napier rows. Later (after better rooting?), this color disappeared.

### 3.3.3. Experiment 3c.

Table 9 shows results for different methods of planting stem cuttings in a pure stand. Results one month after planting are shown as well in Figure 4. Due to a mistake treatments T1 and T4 were the same.

Table 9. Regeneration (%) 1 and 2 months (M1 and M2) after planting of stem cuttings of pure Desmodium*.

| | M1 | M2 |
|---|---|---|
| T1. Lower part at 5 cm depth. | 52 | 44 |
| T2. Middle part at 5 cm depth. | 56 | 63 |
| T3. Top part at 5 cm depth. | 39 | |
| T4. Lower part at 5 cm depth. | 61 | 34 |
| T5. Lower part at 10 cm depth. | 52 | 60 |
| T6. Lower part at 5 cm; 5 cm stem above soil. | 44 | 55 |
| T7. Lower part at 5 cm; 30 cm stem above soil. | 40 | 51 |
| T8. Lower part; both sides of stem 5 cm above soil. | 12 | 43 |

* Lower, middle or top parts of stem cuttings, placed at different depth.

One month after planting, regeneration for treatments T3 and T8 was only 39 and 12 % respectively (T3: planting the upper part of stems; T8: both sides of the stem 5 cm above soil). For T1, T2, T4 and T5 regeneration was already 50 to 60 %. Two month after planting, regeneration had improved for treatment T8 (both sides of the stem above the soil), while it was lower now for T5 (due to seedling death).
Regeneration was much better than for Experiments 3a and 3b, probably due to more carefully planting and a better water supply. In Experiments 3a and 3b planting material was more variable and had more roots and leaves as well. After 3 months most of the ground was covered, even for treatments where first regeneration was less good.

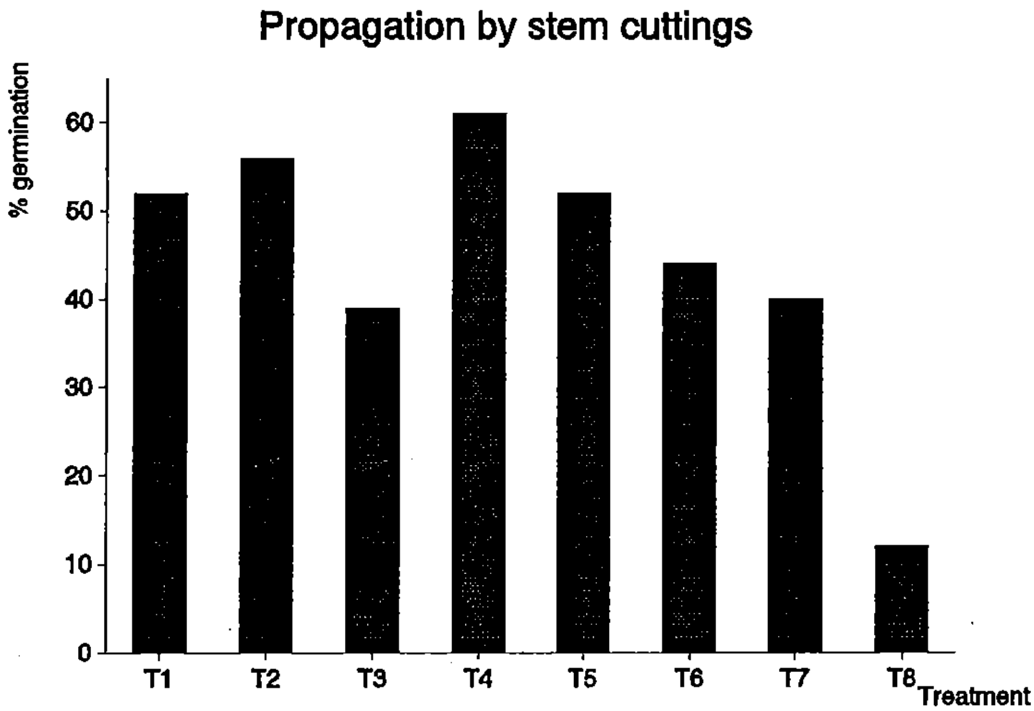


**Figure 4.** Germination of stem cuttings of Desmodium at different methods of planting one month after establishment (see text)

## 4. Discussion.

### 4.1. General.

Experiment 1 showed a small positive effect of age on the yield of pure Napier grass, but Desmodium yield in the mixture tended to decrease if it was cut at older age. Compared to pure Napier, the dry matter yield of Napier/Desmodium was 41 % and 22 % higher, when cut at a younger and older stage respectively (Table 1). Averaged over cutting intervals, crude protein yield increased by 175 % (it nearly tripled for the "short" cutting interval). Yield and Desmodium content in the mixtures were slightly higher at the short cutting interval, probably indicating less competition from Napier under those conditions. Crude protein content of the mixture averaged about 10 %, and doubled compared to pure Napier. As was found in several other investigations, the crude protein content of Napier grass in a mixture with Desmodium was higher compared to pure Napier (e.g. Birch et al, 1967).

Experiment 2 showed the same trends as Experiment 1. There was a very large effect of the first nitrogen application on the yield of pure Napier grass in the first cut, probably due to a "priming effect", leading to extra nitrogen mineralisation (Robbins, 1989).

Substantial effects of Desmodium on dry matter and protein yield of grass/Desmodium mixtures have been found before in Kenya (Thairu, 1972; Keya, 1974), and elsewhere (Whiteman, 1985). It is important that the Desmodium content in the mixture is not too low. Phosphate (and sulphur) application improved Desmodium yield on moderately acid soils (Olsen et al, 1971; Keya et al, 1971; Jones et al, 1984).

In vitro organic matter digestibility was much lower for Desmodium, compared to Napier grass, but due to a much lower ash content in Desmodium, content of digestible organic matter differed only 2 units for the shorter cutting interval. For individual cuts, harvested at younger age, organic matter digestibility of Desmodium was as high as 59 % (Annex 4). Drought stress and long cutting intervals probably decreased digestibility for some cuts (Stobbs et al, 1976). The comparatively low digestibility of Desmodium was found before (Jones, 1969; Stobbs and Imrie, 1976; Kiura, 1992), and is probably caused by tannins in Desmodium (Skerman, 1988). In vivo digestibility of greenleaf Desmodium might be comparatively higher than in vitro digestibility however (Reid et al, 1973). Protein in Napier grass probably degrades faster (v. Eys, 1986: Kiura, 1992). The lower protein degradability of protein in Desmodium may contribute to a relatively higher amount of protein reaching the duodenum (Barry and Manley, 1984; Mangan, 1988; Aii et al, 1980; Kiura, 1992). The optimum content of Desmodium in a ration with Napier grass and the effect of soil fertility and stress on content of condensed tannins in Desmodium require further study however (Barry, 1985).

Mixtures of Napier/Desmodium may therefore give better milk production than expected based on in vitro digestibility (Stobbs, 1976). Positive effects of Desmodium on animal production have been found by Thomas et al (1977) and are described by others (Skerman 1988; Humphreys, 1991; p.127). In the zerograzing unit in Naivasha a change of fodder supply from pure Napier to Napier/Desmodium mixtures, had in general a small positive or no effect on milk production. A more systematic approach to measure the effect of Desmodium on milk yield (per cow and per ha) under zero grazing conditions is however required. Compared to Napier grass, crude protein content of Desmodium probably will decrease less with aging (see Whiteman, 1980). Pure Desmodium and Napier/Desmodium therefore are probably better suited to function as a feed reserve (protein bank).

More than 5 years after establishment, Desmodium content in the mixture was still about 50 %, and there were no indications for a decrease in persistency. In the follow up Experiment 2, Desmodium content even surpassed 60 %. During cutting as much as possible some green leaf of Desmodium was left uncut. Under this management, with annual applications of phosphate and potassium, but without manure application, good persistence was obtained. This is different from grazing situations, where persistence of Desmodium is a problem (Humphries, 1991, p. 16).

The yield of pure Napier grass tended to decrease during the course of the experiment. Reduced yields in ageing stands of Napier grass (Glover et al, 1962), and sown pastures in general have been found by others as well (Myers et al, 1991), and is attributed to a decrease in the nitrogen availability. With grazed pastures far less nitrogen is removed however, compared to zerograzing without return of faeces and urine.

The yield increase from the mixtures in Experiment 2 was comparable to 149 kg N if based on dry matter yield and to 465 kg N when based on crude protein yield. Presuming a nitrogen efficiency of 40 kg dry matter per kg fertilizer N and a nitrogen recovery of 50 %, the extra yield of Napier/Desmodium in Experiment 1 is equivalent to an application of 100 and 333 kg fertilizer N per ha per year if based on dry matter and nitrogen yield respectively (averaged over both cutting

intervals; the effect is higher at younger age).
Based on the results of this experiment and on literature (Thairu, 1972; Skerman, 1988; Burt et al, 1983), it is suggested that in the high potential areas of Kenya a good stand of Napier/Desmodium may substitute a nitrogen fertilization of at least 100 kg N, if based on dry matter yield and up to 300 kg N per ha, if based on crude protein yield (with about 50 % Desmodium in the mixture; on moderate acid soils, low in nitrogen, but with sufficient other minerals). In poor stands the effect of Desmodium may be much less.
A positive effect of Napier/Desmodium on soil fertility was reflected in a tendency for a higher soil organic matter content, in particular at the longer cutting interval (see Annex 1), but did not express itself very clear in an increase in the nitrogen content of the soil. The higher soil organic matter content at higher cutting height can probably be explained by more leaf loss and possibly by a larger root mass. If pure Desmodium is included in a crop rotation (e.g. by under sowing under maize), positive effects may be expected on crop yields due to improved soil fertility (Nnadi et al, 1986, MacColl, 1990). In contrast, in some cases, maize following pure Napier grass in Naivasha has yielded less in the first year, possibly due to nitrogen immobilisation (Robbins, 1989). More information is required however. N losses from surface application of manure may decrease, if animals are fed on tannin containing feeds like Desmodium.
Propagation of Desmodium by mature stem cuttings resulted in a regeneration rate of 40 to 60 % (Experiment 3). Desmodium being a slow starter, covered the ground after 3 months to 6 months (in a pure stand). Desmodium species in Kenya easily established from root splits (Keya et al, 1971). Propagation by mature stem cuttings is easier however. Vegetative propagation of the local Desmodium adscendens showed excellent germination in Uganda (Sabiiti et al, 1987). Establishment by stem cuttings is practiced by some farmers in Kakamega and Taita Taveta (information National Dairy Development Project). Also under grazing conditions vegetative propagation of the trailing legume Desmodium was most important (Jones, 1989).
Although establishment of Desmodium requires full attention for a period of up to half a year, well established Desmodium afterwards smothers weeds (Skerman, 1988). A good stand of Napier and Desmodium used for feeding cows in the zerograzing unit in Naivasha was hardly weeded for more than 4 years.

### 4.2. Practical aspects.

Despite very encouraging results on station, the utilisation of mixtures of Napier and Desmodium on zerograzing farms participating in the National Dairy Development Project, is not yet very successful, although there are some very good examples. According to results from field surveys, Desmodium was included in the ration on about 10 % of zerograzing farms participating in NDDP (Valk, not published). Although chemically less fertile soils compared to Naivasha, may partly explain poorer results on practical farms, improved management systems have to be developed probably. One of the reasons for the slow expansion of Desmodium may be too often a nearly complete removal of all green Desmodium leaf at harvesting, in particular in combination with covered manure application. Also the slow establishment of Desmodium may lead farmers to relax in weeding, expecting failures already.

To increase chances for improved stands of Desmodium, either in a mixture with Napier (which facilitates feeding and reduces weeding of Napier), or in a pure stand, a number of measures are suggested:

1. As a beginning, only small areas of Desmodium should be established during the rainy season, so that proper weeding is possible during the first sensitive period. In particular for greenleaf Desmodium (seed not easily available) establishment of well managed district bulking plots at first, and small farm bulking plots thereafter, will allow for vegetative propagation. Although it has been found that Desmodium sometimes produced well with natural strains of Rhizobium (Wendt, 1970; Haque et al, 1985), proper nodulation with vegetative propagation may be improved by adding a small amount of moist soil from a well established bulking plot during planting of stem cuttings (the soil should be mixed in the planting hole).
2. To use land as intensively as possible and to facilitate weeding, Desmodium could be established under maize (Boonman, 1979; Orodho, personal communication).
3. Desmodium preferably should be established on a suitable site like the far end of the farm, on slopes and possibly on degraded soils. If slurry application could be omitted for Desmodium, establishment on remote sites may save on labor for manure transport later on. On slopes improved erosion control is an extra benefit. Also, due to the risk of run off, application of nitrogen on slopes is probably less feasible. Farmers are probably more willing to plant Desmodium on sites where due to long cultivation soil fertility (and persistency

of Napier grass) has become poor (provided that during establishment on such a site, weeding and fertilization get sufficient attention). Additionally, as Desmodium fixes its own nitrogen, Desmodium will have an competitive advantage over Napier, if Napier growth is slow due to low nitrogen contents in the soil (Humphries, 1991). On soils rich in nitrogen the opposite may be true. In particular if manure is omitted, it is important that other required minerals are sufficiently available for proper establishment of Desmodium.

4. If Napier stands deteriorate and gaps occur, gap filling with stem cuttings of Desmodium is an option (Desmodium probably establishes faster from stem cuttings than from seed, provided regeneration occurs). As Desmodium is a mainly vegetative propagating, trailing legume, relatively few plants may already lead to good ground cover after some time. To decrease competition from existing Napier grass, rows of Napier probably have to be trimmed such that a space of at least 50 to 60 cm is created, if possible with space between plants in rows as well.

5. To control persistent weeds like couch grass or to create space, before "renovation" of Napier with Desmodium, localised , selective use of Glyphosate (e.g. with a rope wick applicator), executed by a specialised "contractor", might be investigated for situations where labor is scarce, and to improve quality of work.

6. When cutting Napier/Desmodium mixtures, it is important to leave sufficient green leaf of Desmodium after cutting, in particular if the Desmodium stand is still weak. This requires specific attention if manure is applied in furrows. Digging of furrows may damage and remove Desmodium plants. After a heavy cut of a pure Desmodium stand in Naivasha (due to age the lower stem had no leaves any more), it took 3 to 4 weeks for the first green leaves to appear.

7. On farms with a shortage of manure it deserves serious consideration to not apply urine (which contains most easy available nitrogen, but also most potassium) or manure as slurry. Competition of Napier will be less in that situation (no nitrogen on Napier), while manure is reserved for the pure Napier without Desmodium (or for other crops). It may be worthwhile as well to investigate the possibility to grow Desmodium between every second row of Napier, and to apply manure in the other row. Compost and solid manure (which contains more phosphorus), could still be applied to Desmodium. Without any manure applied at all, it is important to maintain soil fertility by regular application of small amounts of

phosphate (preferably single superphosphate which contains sulfur as well) and potassium (and if required other minerals) from fertilizer.

8. To facilitate management of Desmodium, on some farms it may be preferred to grow pure plots of Desmodium, in particular if crop rotations are feasible. Crop yields will improve because of improved soil fertility and possibly reduced effects of soil borne diseases and better soil structure. In this situation Desmodium could be fed in periods with relatively low protein content of Napier, or in combination with e.g. maize stover.

**5. Recommendations for research.**

1. Reasons for the still limited success of Desmodium (and other legumes) at farm level should be investigated.

2. Potentially successful strategies for establishment of Desmodium, e.g. gap filling with stem cuttings Desmodium in Napier grass, planting under maize and on slopes, rotation with other crops and planting of small areas of pure Desmodium, should be tested on farm.

4. The possibility of maintaining a mixture of Napier/Desmodium without manure application, reserving manure for pure grass and other crops, should be tested on farm. Also planting Desmodium between every second row of Napier grass, and applying manure only between the two rows of pure grass should be investigated.

5. Multiplication of Desmodium by stem cuttings should be further investigated.

6. In collaboration with the extension service, strategies for a successful introduction of different legumes (forage legumes, grain legumes and fodder trees) have to be established. These strategies should not generalise, but should be site specific, focussing on specific farming systems and farming situations. Help of a "contractor", with potentially better knowledge of establishment of legumes should be considered.

7. There is an urgent need to further test potential for milk production of Desmodium/Napier grass mixtures under zerograzing conditions. Also the optimum Desmodium content in rations with grasses and the content of condensed tannins in Desmodium under variable soil fertility require attention.

8. Because of the relatively large area of pasture, the potential for pasture improvement at altitudes over 2000 m is still considerable. Therefore legumes suitable for use at higher altitudes (tropical legumes like Desmodium and temperate species) should be further investigated.

9. Potential nitrogen losses from slurry produced from rations containing feeds high in tannins should be investigated.

## 6. Conclusions.

1. In Experiment 1 cutting of Napier grass at an older stage had a small positive effect on yield of pure Napier grass, but a small negative effect on the yield of Desmodium.
2. Dry matter yield of the mixtures was 44 % and 22 % higher than the yield of pure Napier grass when Napier was cut at a height 71 cm and 94 cm respectively.
3. Protein yield from the mixtures was 175 % higher than from pure Napier.
4. Five years after establishment, Desmodium content in the mixture was still about 50 %, indicating a good persistency. There was no significant decline in Desmodium content over the years, except for short periods due to drought. Desmodium content was slightly lower if Napier grass was cut older.
5. Crude protein content of the Napier/Desmodium mixture doubled as compared to pure Napier, from 4.7 % to 9.7 %.
6. In vitro organic matter digestibility was on average 66.5 % for pure Napier grass and 59.1 % for Napier/Desmodium. Although the organic matter digestibility of Desmodium was much lower compared to Napier, due to the lower ash content of Desmodium, the difference in the content of digestible organic matter was only 3 units however. Digestibilities were rather low due to old age at cutting.
7. Nitrogen yield of pure Napier decreased as the stand of Napier became older, partly due to drought in later years, but probably as well due to a decline in soil fertility.
8. In Experiment 2 Desmodium substituted 149 kg fertilizer N per ha if based on dry matter yield and 465 kg N if based on yield of crude protein. Based on these experiments it is suggested that in the high potential areas of Kenya, a good mixture of Napier/Desmodium may replace an annual nitrogen application of at least 100 kg N per ha if based on dry matter yield and 300 kg N per ha if based on yield of crude protein.
9. Planting of the lower part of stems of mature Desmodium plants led to regeneration percentages of up to 60 %.

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Annex 1. Results of soil analysis in 1982 and 1990 for pure Napier and Napier/Desmodium mixtures cut at different stages (N1 and N2, N1/D1 and N2/D2 respectively).

| | 1982 | 1990 | | | |
|---|---|---|---|---|---|
| | | Napier | | Napier/Desmodium | |
| | | Y | O | Y | O |
| Ph-$H_2O$ | 8.1 | 7.5 | 7.4 | 7.1 | 7.2 |
| Ca (m.e. %) | 16.3 | 15 | 18 | 19 | 20 |
| K (m.e. %) | 2.6 | 3.1 | 2.5 | 2.0 | 1.9 |
| P (ppm) | | 202 | 227 | 234 | 234 |
| P-Olsen (ppm) | 26 | 44 | 40 | 40 | 28 |
| C (%) | 1.7 | 1.33 | 1.43 | 1.41 | 1.52 |
| N * (%) | 0.17 | 0.19 | 0.16 | 0.17 | 0.21 |
| Ec (mmmhos/cm | 0.65 | 0.4 | 0.5 | 0.3 | 0.4 |
| Mg (m.e. %) | 4.6 | 2.5 | 2.6 | 3.0 | 2.6 |
| Mn (m.e. %) | 0.7 | 0.78 | 0.65 | 0.86 | 0.67 |

Annex 2. Precipitation (P in mm) and normal temperature (T in $^0C$).

| | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | Normal | |
|---|---|---|---|---|---|---|---|---|---|
| | P | P | P | P | P | P | P | P | T |
| Jan | 0 | 10 | 23 | 60 | 55 | 27 | 17 | 24 | 17.6 |
| Feb | 89 | 11 | 6 | 0 | 34 | 96 | 0 | 39 | 17.6 |
| March | 104 | 27 | 57 | 81 | 47 | 133 | 115 | 59 | 18.3 |
| April | 278? | 104 | 37 | 231 | 107 | 165 | 58 | 113 | 18.0 |
| May | 89? | 105 | 107 | 76 | 129 | 88 | 61 | 84 | 17.2 |
| June | 51? | 23 | 150 | 50 | 22 | 18 | 80 | 41 | 16.0 |
| July | 21 | 0 | 53 | 26 | 48 | 47 | 4 | 34 | 15.5 |
| Aug | 14 | 35 | 40 | 81 | 109 | 48 | 19 | 44 | 15.8 |
| Sep | 69 | 24 | 4 | 25 | 53 | 18 | 40 | 44 | 16.2 |
| Oct | 36 | 44 | 16 | 33 | 100 | 71 | | 47 | 17.2 |
| Nov | 31 | 43 | 46 | 37 | 43 | 54 | | 59 | 16.8 |
| Dec | 25 | 40 | 15 | 35 | 128 | 33 | | 39 | 17.0 |
| Total | 807? | 466 | 554 | 735 | 875 | 798 | | | |

Annex 3. Experimental scheme Experiment 1.

< 23.4 m > < >

| 1 | 3 | 5 | 7 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| N1 | N/D1 | N/D2 | N2 | N1 | N/D1 | N2 | N/D2 |
| 2 | 4 | 6 | 8 | 13 | 14 | 15 | 16 |
| N2 | N1 | N/D2 | N/D1 | N/D2 | N/D1 | N2 | N1 |

N1 = Pure Napier cut at 75 to 90 cm.
N2 = Pure Napier cut at 90 to 120 cm.
N/D1 = Napier/Desmodium cut at 75 to 90 cm.
N/D2 = Napier/Desmodium cut at 90 to 120 cm.

Annex 4. Results per cut for Experiment 1 (start 22/5/1985) *.

| | | Napier | | | | | Napier/Desmodium | | | | | %D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | T | H | Yield | %ash | %CP | %omd | H | Yield | %ash | %CP | %omd | |
| 25/9/85 | N1 | 139 | 9425 | 14.5 | 4.4 | 65.5 | 116 | 4878 | 16.2 | 4.9 | 69.0 | |
| Cut 1 | D1 | | | | | | | 4531 | 11.0 | 11.6 | 57.6 | |
| 126 dg | N/D1 | | 9425 | 14.5 | 4.4 | | | 9409 | 13.7 | 8.1 | | 49 |
| 9/10/85 | N2 | 142 | 9786 | 13.9 | 3.9 | 64.9 | 126 | 4207 | 14.0 | 4.5 | 66.0 | |
| Cut 1 | D2 | | | | | | | 4417 | 9.0 | 13.0 | 53.0 | |
| 140 dg | N/D2 | | 9786 | 13.9 | 3.9 | | | 8624 | 11.4 | 8.9 | | 51 |
| 22/1/86 | N1 | 80 | 5494 | 16.6 | 4.3 | 61.8 | 77 | 3422 | 15.3 | 4.7 | 62.5 | |
| Cut 2 | D1 | | | | | | | 3367 | 10.5 | 11.2 | 50.0 | |
| 119 dg | N/D1 | | 5494 | 16.6 | 4.3 | | | 6789 | 12.9 | 7.9 | | 50 |
| 16/4/86 | N2 | 116 | 7565 | 14.4 | 3.6 | 58.0 | 98 | 4156 | 14.6 | 5.2 | 60.8 | |
| Cut 2 | D2 | | | | | | | 4202 | 10.7 | 11.2 | 46.8 | |
| 189 dg | N/D2 | | 7565 | 14.4 | 3.6 | | | 8358 | 12.7 | 8.2 | | 49 |
| 7/5/86 | N1 | 101 | 4133 | 14.6 | 5.0 | 68.2 | 100 | 3494 | 18.3 | 6.0 | 70.3 | |
| Cut 3 | D1 | | | | | | | 2796 | 9.7 | 15.7 | 56.8 | |
| 105 dg | N/D1 | | 4133 | 14.6 | 5.0 | | | 6290 | 14.4 | 10.3 | | 41 |
| 23/7/86 | N2 | 112 | 5622 | 17.4 | 4.9 | 64.9 | 130 | 4683 | 15.7 | 4.6 | 66.0 | |
| Cut 3 | D2 | | | | | | | 3139 | 10.0 | 13.3 | 54.3 | |
| 98 dg | N/D2 | | 5622 | 17.4 | 4.9 | | | 7822 | 13.4 | 8.1 | | 41 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30/7/86 | N1 | 68 | 3503 | 18.9 | 5.3 | 71.1 | 76 | 2119 | 18.4 | 6.8 | 69.7 | |
| Cut 4 | D1 | | | | | | | 2087 | 12.8 | 16.8 | 59.0 | |
| 84 dg | N/D1 | | 3503 | 18.9 | 5.3 | | | 4206 | 15.6 | 11.7 | | 50 |
| 29/10/86 | N1 | 63 | 3446 | 19.6 | 5.6 | 68.7 | 61 | 2161 | 19.3 | 7.0 | 70.0 | |
| Cut 5 | D1 | | | | | | | 2533 | 11.8 | 15.0 | 54.7 | |
| 91 dg | N/D1 | | 3446 | 19.6 | 5.6 | | | 4694 | 15.3 | 11.3 | | 54 |
| 26/11/86 | N2 | 105 | 5293 | 16.4 | 3.7 | 65.7 | 105 | 3470 | 15.5 | 4.4 | 65.5 | |
| Cut 4 | D2 | | | | | | | 3843 | 10.0 | 12.8 | 43.3? | |
| 126 dg | N/D2 | | 5293 | 16.4 | 3.7 | | | 7313 | 12.6 | 8.8 | | 53 |
| 4/2/87 | N1 | 66 | 3145 | 18.3 | 4.3 | 68.8 | 70 | 2183 | 13.7 | 4.3 | 68.0 | |
| Cut 6 | D1 | | | | | | | 2600 | 9.7 | 13.4 | 52.8 | |
| 98 dg | N/D1 | | 3145 | 18.3 | 4.3 | | | 4783 | 11.5 | 9.3 | | 54 |
| 1/4/87 | N2 | 81 | 3836 | 17.4 | 4.5 | 63.2 | 73 | 2202 | 15.7 | 6.0 | 63.6 | |
| Cut 5 | D2 | | | | | | | 2424 | 10.4 | 12.7 | 48.5 | |
| 126 dg | N/D2 | | 3836 | 17.4 | 4.5 | | | 4626 | 12.9 | 9.6 | | 51 |
| 20/5/87 | N1 | 78 | 2948 | 17.4 | 4.8 | 66.0 | 66 | 1630 | 17.6 | 7.9 | 68.0 | |
| Cut 7 | D1 | | | | | | | 1489 | 11.9 | 17.3 | 56.6 | |
| 105 dg | N/D1 | | 2948 | 17.4 | 4.8 | | | 3119 | 14.9 | 12.3 | | 48 |
| 8/7/87 | N2 | 102 | 4523 | 17.9 | 4.4 | 68.3 | 121 | 3775 | 17.0 | 5.4 | 66.9 | |
| Cut 6 | D2 | | | | | | | 3609 | 11.4 | 15.5 | 51.9 | |
| 98 dg | N/D2 | | 4523 | 17.9 | 4.4 | | | 7384 | 14.3 | 10.3 | | 50 |
| 29/7/87 | N1 | 60 | 2245 | 22.3 | 5.7 | 69.4 | 77 | 1658 | 20.2 | 6.6 | 71.6 | |
| Cut 8 | D1 | | | | | | | 2170 | 11.2 | 16.4 | 53.6 | |
| 70 dg | N/D1 | | 2245 | 22.3 | 5.7 | | | 3828 | 15.2 | 12.2 | | 56 |
| 18/11/87 | N2 | 85 | 4621 | 18.3 | 4.3 | 64.7 | 83 | 2627 | 17.4 | 6.4 | 65.6 | |
| Cut 7 | D2 | | | | | | | 3150 | 10.6 | 12.4 | 48.9 | |
| 132 dg | N/D2 | | 4621 | 18.3 | 4.3 | | | 5777 | 13.7 | 9.7 | | 55 |
| 18/11/87 | N1 | 73 | 3742 | 18.0 | 4.5 | 66.9 | 72 | 2278 | 17.4 | 6.8 | 67.9 | |
| Cut 9 | D1 | | | | | | | 2901 | 10.1 | 12.9 | 50.0 | |
| 112 dg | N/D1 | | 3742 | 18.0 | 4.5 | | | 5179 | 13.3 | 10.2 | | 57 |
| 17/2/88 | N1 | 56 | 2298 | 19.7 | 4.3 | 63.9 | 54 | 1397 | 18.8 | 7.5 | 67.9 | |
| Cut 10 | D1 | | | | | | | 2398 | 11.7 | 16.8 | 56.5 | |
| 91 dg | N/D1 | | 2298 | 19.7 | 4.3 | | | 3795 | 14.3 | 13.4 | | 64 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/4/88 | N2 | 96 | 4671 | 16.9 | 3.7 | 64.8 | 81 | 1944 | 16.4 | 5.3 | 70.6 | |
| Cut 8 | D2 | | | | | | | 2096 | 9.8 | 11.4 | 50.2 | |
| 139 dg | N/D2 | | 4671 | 16.9 | 3.7 | | | 4040 | 13.0 | 8.5 | | 51 |
| 3/5/88 | N1 | 85 | 2845 | 20.5 | 5.4 | 70.5 | 100 | 2168 | 18.6 | 7.0 | 74.9 | |
| Cut 11 | D1 | | | | | | | 2639 | 13.3 | 13.9 | 56.1 | |
| 75 dg | N/D1 | | 2845 | 20.5 | 5.4 | | | 4807 | 15.7 | 10.8 | | 55 |
| 8/6/88 | N2 | 83 | 2882 | 19.6 | 5.7 | 72.8 | 108 | 2364 | 18.2 | 5.8 | 70.8 | |
| Cut 9 | D2 | | | | | | | 1687 | 11.7 | 14.8 | 52.6 | |
| 139 dg | N/D2 | | 2882 | 19.6 | 5.7 | | | 4051 | 15.5 | 9.5 | | 42 |
| 7/9/88 | N1 | 68 | 3354 | 17.4 | 3.8 | 66.3 | 69 | 2374 | 16.7 | 5.1 | 67.2 | |
| Cut 12 | D1 | | | | | | | 2785 | 9.9 | 12.8 | 51.4 | |
| 127 dg | N/D1 | | 3354 | 17.4 | 3.8 | | | 5159 | 13.1 | 9.2 | | 54 |
| 14/12/88 | N2 | 100 | 3766 | 13.9 | 3.5 | 61.3 | 86 | 2086 | 12.5 | 4.6 | 64.6 | |
| Cut 10 | D2 | | | | | | | 1469 | 7.8 | 11.7 | 51.3 | |
| 179 dg | N/D2 | | 3766 | 13.9 | 3.5 | | | 3555 | 10.6 | 7.6 | | 41 |
| 26/1/89 | N1 | 57 | 2375 | 17.1 | 5.3 | 69.3 | 56 | 2056 | 18.0 | 7.2 | 74.1 | |
| Cut 13 | D2 | | | | | | | 1377 | 10.7 | 14.5 | 59.0 | |
| 141 dg | N/D1 | | 2375 | 17.1 | 5.3 | | | 3433 | 15.1 | 10.2 | | 40 |
| 21/4/89 | N2 | 82 | 3311 | 17.2 | 4.5 | 67.0 | 73 | 2208 | 17.5 | 6.5 | 68.3 | |
| Cut 11 | D2 | | | | | | | 1333 | 10.5 | 15.5 | 54.0 | |
| 128 dg | N/D2 | | 3311 | 17.2 | 4.5 | | | 3541 | 14.9 | 9.9 | | 38 |
| 5/5/89 | N1 | 66 | 2296 | 18.9 | 4.7 | 66.8 | 65 | 1804 | 18.7 | 6.7 | 68.6 | |
| Cut 14 | D1 | | | | | | | 1250 | 12.0 | 15.7 | 53.6 | |
| 99 dg | N/D1 | | 2296 | 18.9 | 4.7 | | | 3054 | ? | 10.3 | | 40 |
| 14/7/89 | N2 | 70 | 2158 | 19.9 | 5.7 | 68.4 | 75 | 1872 | 19.4 | 5.9 | 68.4 | |
| Cut 12 | D2 | | | | | | | 1364 | 13.2 | 13.9 | 52.8 | |
| 83 dg | N/D2 | | 2158 | 19.9 | 5.7 | | | 3236 | 16.8 | 9.3 | | 40 |
| 25/7/89 | N1 | 43 | 1595 | 19.6 | 6.5 | 70.6 | 41 | 1475 | 18.6 | 7.0 | 67.9 | |
| Cut 15 | D1 | | | | | | | 1482 | 12.2 | 14.8 | 52.0 | |
| 81 dg | N/D1 | | 1595 | 19.6 | 6.5 | | | 2957 | 15.4 | 10.9 | | 49 |
| 1/11/89 | N1 | 60 | 2649 | 19.4 | 5.5 | 68.9 | 78 | 2371 | 17.5 | 6.4 | 67.8 | |
| Cut 16 | D1 | | | | | | | 2485 | 10.1 | 14.3 | 51.9 | |
| 97 dg | N/D1 | | 2649 | 19.4 | 5.5 | | | 4856 | 13.7 | 10.4 | | 51 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/11/89 | N2 | 76 | 3108 | 18.3 | 4.9 | 67.4 | 94 | 2807 | 17.9 | 6.0 | 65.4 | |
| Cut 13 | D2 | | | | | | | 2434 | 9.3 | 13.4 | 52.3 | |
| 110 dg | N/D2 | | 3108 | 18.3 | 4.9 | | | 5241 | 13.9 | 9.5 | | 46 |
| 18/1/90 | N1 | 66 | 2372 | 18.2 | 5.3 | 68.2 | 82 | 2150 | 18.9 | 6.4 | 67.0 | |
| Cut 17 | D1 | | | | | | | 1735 | 9.8 | 14.3 | 51.4 | |
| 77 dg | N/D1 | | 2372 | 18.2 | 5.3 | | | 3885 | 14.9 | 9.9 | | 45 |
| 9/2/90 | N2 | | Yield data lost! | | | | | | | | | |
| Cut 14 | | | | | | | | | | | | |
| 10/4/90 | N1 | 63 | 2104 | 18.9 | 6.4 | 67.2 | 84 | 2300 | 18.3 | 7.1 | 67.9 | |
| Cut 18 | D1 | | | | | | | 2407 | 12.1 | 16.7 | 50.4 | |
| 82 dg | N/D1 | | 2104 | 18.9 | 6.4 | | | 4707 | 15.1 | 12.0 | | 51 |
| 11/4/90 | N2 | 60 | 2303 | 21.5 | 6.8 | 68.2 | 88 | 2285 | 19.0 | 7.5 | 65.8 | |
| Cut 15 | D2 | | | | | | | 1779 | 13.4 | 15.8 | 51.4 | |
| 64 dg | N/D2 | | 2303 | 21.5 | 6.8 | | | 4064 | 16.6 | 11.1 | | 44 |

* T=treatment; H=height; %CP=crude protein content; omd=in vitro organic matter digestibility; cutting interval in days (dg) is shown as well.

Annex 5. Results per cut of Experiment 2 for pure Napier with and without nitrogen (N0 and N200) and for Napier/Desmodium mixtures (coded N/DN1 respectively N/DN2 for Napier, and N/DD1 and N/DD2 for Desmodium). Percentage Desmodium in the mixtures (% D) is mentioned as well (*).

| T | pure Napier | | | T | Napier/Desmodium | | | |
|---|---|---|---|---|---|---|---|---|
| | Yield | %ash | %CP | | Yield | %ash | %CP | %D |
| Cut 1 (10/7/90;CI=91)*: | | | | | | | | |
| N0 | 3128 | 18.8 | 5.3 | N/DN1 | 2014 | 17.4 | 4.6 | |
| | | | | N/DD1 | 1970 | 10.8 | 12.2 | |
| | | | | Total | 3984 | 14.1 | 8.3 | 49 |
| N200 | 8617 | 15.6 | 4.4 | N/DN2 | 2371 | 18.3 | 4.0 | |
| | | | | N/DD2 | 1742 | 10.8 | 14.2 | |
| | | | | Total | 4113 | 14.4 | 8.3 | 52 |
| Cut 2 (30/10/90;CI=112)*: | | | | | | | | |
| N0 | 2623 | 18.1 | 5.0 | N/DN1 | 1626 | 17.1 | 6.7 | |
| | | | | N/DD1 | 2302 | 14.3 | 13.5 | |
| | | | | Total | 3926 | 15.5 | 10.7 | 58 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| N200 | 4075 | 16.4 | 5.6 | N/DN2 | 1685 | 17.4 | 6.9 | |
| | | | | N/DD2 | 2364 | 14.0 | 14.8 | |
| | | | | Total | 4049 | 15.5 | 11.5 | 58 |
| <u>Cut 3 (16/1/91;CI=78)*:</u> | | | | | | | | |
| N0 | 1900 | 18.6 | 5.4 | N/DN1 | 1448 | 17.4 | 6.5 | |
| | | | | N/DD1 | 2772 | 10.1 | 15.5 | |
| | | | | Total | 4220 | 12.6 | 12.3 | 65 |
| N200 | 3670 | 16.6 | 5.2 | N/DN2 | 1698 | 17.3 | 6.5 | |
| | | | | N/DD2 | 3044 | 10.1 | 15.8 | |
| | | | | Total | 4742 | 12.7 | 12.5 | 64 |
| <u>Cut 4 (18/4/91;CI=94):</u> | | | | | | | | |
| N0 | 2683 | 16.3 | 5.0 | N/DN1 | 2184 | 17.9 | 5.7 | |
| | | | | N/DD1 | 4516 | 10.8 | 15.4 | |
| | | | | Total | 6700 | 13.1 | 12.2 | 67 |
| N200 | 2990 | 18.0 | 5.2 | N/DN2 | 2319 | 14.6 | 6.2 | |
| | | | | N/DD2 | 4033 | 11.1 | 12.7 | |
| | | | | Total | 6352 | 12.4 | 10.3 | 64 |
| <u>Cut 5 (11/7/91;CI=84)*</u> | | | | | | | | |
| N0 | 3801 | 14.1 | 4.8 | N/DN1 | 2824 | 15.5 | 6.7 | |
| | | | | N/DD1 | 2476 | 11.4 | 14.4 | |
| | | | | Total | 5300 | 12.6 | 11.8 | 46 |
| N200 | 5830 | 14.1 | 6.9 | N/DN2 | 2996 | 15.0 | 5.7 | |
| | | | | N/DD2 | 2486 | 9.4 | 13.2 | |
| | | | | Total | 5482 | 10.1 | 11.3 | 44 |

* Cut with nitrogen application. Extension 1 and 2 for N/D are for plots which were cut at younger respectively older age in Experiment 1; Extension N and D for N/D are for Napier and Desmodium respectively.