The role and importance of Napier grass in the smallholder dairy industry in Kenya

by

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SUMMARY

The high potential agricultural areas of Kenya are very densely populated and holding sizes are very small; natural grazing is no longer available so cattle have to be fed on crop residues, cultivated fodder and some concentrates. Dairy cattle, in very small herds or singly, are now kept under stall feeding and zero grazing and exotic breeds or their crosses with zebu are preferred to better valorize the fodder. Fresh milk is an important and profitable product in many areas and is increasingly being produced as an income source for smallholders. The serious fall in the price of coffee, previously a major cash crop, has led to its being partially replaced by fodder in some areas. The minute farm size precludes grazing so for a long time the emphasis has been on high-yielding fodders for cutting: Napier Grass (*Pennisetum purpureum*) has become by far the most important due to its wide ecological range (from the coast to over 2,000 metres), high yield and ease of propagation and management; sometimes herbaceous legumes or fodder shrubs are associated with the grass but their use is limited and their economics poorly documented. Kenya has a long history of pasture and fodder research and some of the studies and research on Napier Grass in Kenya are described below – these have mainly been on its agronomy with some on feeding value. Most, practically all the cultivars in widespread use are old, at least half a century since their introduction and there is a lack of new cultivars of Napier Grass and of serious studies on other grasses which might supplement it to widen the genetic base of fodders for small-farm use. There are now serious problems of emerging diseases, both fungal and mycoplasmal, which threaten Napier Grass in Eastern Africa and, unless resistant cultivars and alternative fodders are found, the smallholder dairy industry will be in trouble.

INTRODUCTION

Agriculture is the backbone of Kenya's economy, contributing over 25 percent of the gross domestic product as well providing the livelihood of about 80 percent of the country's population and contributing 70 percent of national employment. Many of the poor are smallholder farmers who live in areas of high potential for agriculture and forest production (Smith & Orodho, 2000) with an annual rainfall of more than 750mm, spreading from central Kenya through the central Rift valley to Western Kenya and at the extreme east the coastal strip. By far the greater part of Kenya is outside the lands of high potential and is semi-arid to arid grazing land: livestock and subsistence dairying are important in the semi-arid areas but fodder is not cultivated there and the drylands are not discussed in this paper. Kenya has the most developed smallholder dairy system in sub-Saharan Africa with an estimated dairy herd of 3 million head. Most dairy cattle are crosses of Friesian-Holstein, Ayrshire and other exotic dairy breeds with local zebu. Dairy is important in the livelihoods of many farm households in terms of generating income and employment. Smallholder dairies (mainly family farms of less than 10 hectares and fewer than 10 dairy animals - Anon., 1985, 1987) are concentrated in the crop-dairy systems of the high potential areas, producing about 60 percent of the milk and contributing over 80 percent of the marketed output (Peeler & Omore, 1997; Thorpe *et al.*, 2000). The system is characterized by small crop-livestock farms. An important feature of the system is that milk is a cash crop and the manure produced is used to fertilize food and cash crops which include coffee, tea, sugarcane, wheat, vegetables, pyrethrum, bananas, cut flowers and other horticultural crops. The main food crop is maize but others include, sorghum, millet, beans, sweet and Irish potatoes and vegetables.

Smallholder dairying has increased in recent years because of liberalization in the dairy sub-sector and because low cash crop prices have made dairying an important income earner. However, development of smallholder dairy systems in Kenya's high potential areas has been marked by declining farm sizes, upgrading to dairy breeds and an increasing reliance on purchased feeds both concentrates and forages (Staal *et al.*, 1998, 1999). The major cattle feeds are natural grass and planted fodder, mainly Napier grass (*Pennisetum purpureum*). With the increasing human population, available grazing

is decreasing and planted areas of Napier grass are becoming the main fodder source (Potter, 1987; Orodho, 1990).

Other feeds, which depend on season and region for availability and which are used in smaller quantities include maize crop residues, compound feeds, milling by-products, sugarcane tops, banana pseudostems, as well as other grasses and weeds. Where farms are small, cattle are confined and fed by cut-and-carry, also referred to as zero-grazing (Baltenweck *et al*., 1998; Staal *et al*., 1999). Nutrient cycling through dairy animals and use of manure are key driving forces to dairy adoption and to sustaining smallholdings. The major constraining factors are: lack of adequate and quality feeds particularly in the dry season, animal genetics and disease challenges on livestock and on Napier grass which is the major livestock feed. Emerging diseases, mainly fungal, viral or mycoplasmal are affecting many Napier grass varieties. In fact so great is the threat that loss of Napier grass feed could lead to the collapse of the smallholder dairy industry.

IMPORTANCE OF NAPIER GRASS

The importance of Napier grass (*Pennisetum purpureum*) can be seen from the role it plays as the major livestock feed in smallholder dairy production systems in Kenya. Because of high population pressure farms are small, with an average holding size of 0.9-2.0 ha (Gitau *et al*., 1994); sizes are still decreasing. Animals are therefore confined in stalls and fed mainly on Napier grass under zero grazing. In central Kenya over 80 percent of dairy animals are kept under zero grazing (Staal *et al*., 1998) and Napier grass is the main fodder grown by over 70 percent of smallholder farmers in the region and normally provides over 40 percent of feed (Stots, 1983; Potter, 1987; Bayer, 1990 and Staal *et al.,* 1998). Napier grass has been the most promising and high yielding fodder (Anindo & Potter 1994) giving dry matter yields that surpass most tropical grasses (Humphreys, 1994; Skerman & Riveros, 1990). Reported on-farm dry matter yields from different regions of the country averaged about 16 tonnes/ha/year (Wouters, 1987) with little or no fertilizer, while according to Schreuder *et al.* (1993) yields on research stations vary between 10-40 tonnes dry matter per hectare depending on soil fertility, climate and management factors. These yields surpass those of Rhodes grass (*Chloris gayana*) Setaria (*Setaria sphacelata*) and Kikuyu grass (*Pennisetum clandestinum*) which are popular pasture grasses but which yield between 5 to 15 tonnes of DM per year (Boonman, 1993). High DM yields for Napier grass have been recorded elsewhere in the tropics (Ferraris & Sinclair, 1980: Woodard & Prine, 1991); exceptionally high yields up to 85 tonnes DM/ha have been cited when high rates of fertilizers were applied (Skerman & Riveros, 1990), for example under natural rainfall of 2000 mm per year where 897 kg of N fertilizer were applied per hectare per year and the grass was cut every 90 days the yield was 84, 800 kg DM/year (Vicente-Chandler *et al.,* 1959). Dry matter yield alone, however, is of limited value if it is not closely related to the DM intake of the animals. At farm level, the combination of DM yield and observed DM intake can form the basis for estimating the number of livestock that can be supported by available forage. As Napier grass tolerates frequent defoliation, under good weather conditions it can be cut in Kenya every 6-8 weeks giving up to 8 cuts in a year, depending on fertilizer application, rainfall amount and distribution.

It is the main fodder crop in Central Kenya, and is fed to livestock by cut-and-carry; by 1983 approximately 240,000 ha or 4 percent of the arable land of Kenya was under Napier grass. More was planted as coffee prices fell and farmers took up dairying. About 90 percent of farmers in Central Kenya grow Napier grass and the proportion may be higher now. In spite of the potential for high yields, actual yields are often much lower and variable and have been measured from 2.2 to 26 tonnes DM/ha/year on farms. This wide range in production is mainly caused by management factors such as the application of manure and/or fertilizer, cutting frequency, weed control, etc.

Napier grass can grow in mixture with legumes. Although in Kenya it is generally grown and managed as a pure stand, it can grow as an intercrop within the same row or within alternate rows with legumes such as *Pueraria phaseoloides*, *Centrosema pubescens*, *Neonotonia wightii, Desmodium uncinatum, Desmodium intortum and Stylosanthes guianensis.* When intercropped with herbaceous legumes, cutting or grazing management is adjusted to favour the legumes in order to maintain a satisfactory mixed sward. Napier grass can also be grown as an alley crop with fodder legumes such as leucaena, (*Leucaena leucocephala*), calliandra (*Calliandra calothyrsus*) sesbania (*Sesbania sesban*) and gliricidia (*Gliricidia sepium*). Legumes improve the quality of Napier grass-based feed and also increase the overall yield. Although no longer generally practiced in Kenya, Napier grass can withstand heavy grazing and provide a considerable bulk of feed to livestock, especially if well fertilized and irrigated (Harrison & Snook,

1971) and rotational grazing should not be severe enough to hinder growth (Ware-Austin, 1963). Hay and silage can be made for dry season use. It makes good hay if cut when young but is too coarse if cut late. It is more usually made into silage of high quality without additives. In Taiwan Napier grass is widely used for the production of dehydrated grass pellets used as supplementary stock feed.

ORIGIN AND CHARACTERISTICS OF NAPIER GRASS

Napier grass (Pennisetum purpureum Schumach.) (see images) is also known as "elephant grass". It was named after colonel Napier of Bulawayo in Zimbabwe who early in the last century urged Rhodesia's (now Zimbabwe) Department of Agriculture to explore the possibility of using it for commercial livestock production (Boonman, 1993). Napier grass used to be promoted in Uganda for soil conservation and for mulching coffee. According to Acland (1971) it turned out that very few smallholders mulched their coffee and found it more profitable to sell Napier grass to coffee estates or feed the grass to their livestock. The grass was then promoted as a livestock feed. In recent years the dwarf "Mott" Napier cultivar has been bred in Gainesville (Florida, USA) with a maximum height of about 1.5m (Hanna & Monson,1988) and unlike the tall variety, is leafy and non-flowering. Tall varieties (see Figure 1b) resemble sugarcane in habit. Napier grass is propagated vegetatively because seeds have low genetic stability and viability (Humphreys, 1994). Napier grass which is a robust perennial forage with vigorous root system, sometimes stoloniferous with a creeping rhizome is native to eastern and central Africa and has been introduced to most tropical and sub-tropical countries. Its natural habitat is damp grassland, forest margins and riverbeds. Mature plants normally reach up to 4m in height and have up to 20 nodes (Henderson & Preston, 1977). Boonman (1997) found it growing to a height of 10m in riverbeds and recorded a harvest at Kitale of 29 tonnes/ha DM taken in one cut on a very mature stand (more than 2 years overdue). On the tableland at Walkamin Research Station in Queensland Australia, the author observed Napier grass which had grown to a height of over 10m (Figure 1a). [For a detailed description of *Pennisetum purpureum*, its uses, ecology, yields etc. see]

Figure 1a. Tall Napier grass (over 4m) growing at Walkamin Research Station, DPI, Queensland Australia, during a visit by the author.

Figure 2. Promising tall Kenyan Napier grass varieties being evaluated by the author at KARI's Regional Research Centre Kakamega.

CLIMATE AND SOIL REQUIREMENTS

For optimal growth, Napier grass requires high and well-distributed rainfall (more than 1000 mm per annum) although it can tolerate a moderate dry season (3-4 months) because of its deep root system. At higher altitudes (above 2100 m), growth is slowed by lower temperatures; optimal temperatures for growth are in the range 25 to 40^{o} C with high rainfall (Russell & Webb, 1976). It ceases to grow when temperatures fall below 10^{o}C (Bogdan, 1977) and the tall varieties cannot withstand frost, in contrast to the dwarf type which is frost tolerant (Legal, 1990). However, even though the herbage may be killed by frost, the underground parts remain alive as long as the soil is not frozen. Napier grass can grow in a wide range of soils, performing best in fertile and well drained soils, but cannot tolerate flooding or waterlogging (Bogdan,1977). It establishes well in clay or sandy loam and deep, fertile loam soils produce best growth and yields (Skerman & Riveros, 1990).

NAPIER GRASS VARIETIES, GENETICS AND BREEDING

Napier grass (2*n* = 28) is a robust perennial bunchgrass which can form dense clumps; has large flat leaves that may be 30-90 cm long and up to 3 cm broad. It is a shy breeding grass and seed yields are usually very low - rarely more than 1-2 kg/ha Pure Germinating Seed (PGS) – therefore it is usually established vegetatively from stem cuttings or crown divisions. There are 3,091,410 seeds/kg. It is highly heterozygous giving rise to a very heterogeneous population of seedlings, which are not "true to type". Because the seed has low genetic stability and viability (Humphreys, 1994) research efforts to develop seed were shelved (van Gastel, 1978) and seed is usually not available to farmers. However, seedling progenies offer opportunities for selection and this is how many of the famous Napier grass varieties have emerged. Uganda hairless was developed in Uganda by A.S. Thomas (Tiley, 1959). Cameroon and Gold Coast varieties were developed in South Africa from the seed of West African origin (Kennan 1952), Clone 13 developed from French Cameroon (Wijk,1977); Kakamega 1 and Kakamega 2 were developed from ILRIS accessions No. 16791 and 16 respectively that were improved by the author from ILR1 accession/variety 16791 that had originated from Southern Africa. Napier grass can form a hybrid with bulrush millet (*Pennisetum purpureum* (2n=28) x *P. americanum*(2n=14). Bana grass was formerly thought to be a hybrid with (2n=21) but it was later confirmed that it is just a Napier grass cultivar since it has 2n =28. A Pakistani Napier hybrid, sometimes called bajra Napier hybrid is a cross between Napier grass and bulrush millet. A dwarf Napier grass variety 'Mott' was bred at a research station in Gainesville, Florida (Hanna & Monson, 1988). In Kenya breeding of Napier grass was prompted by the rapid spread of diseases among the few productive Napier cultivars available to farmers and by the complaints about the hairiness and sharp leaf edges which easily pierce or cut human skin and makes handling of Napier grass unpleasant in cut-and-carry systems. Some Napier grasses with stem nodes and leaf sheaths covered with stiff easily breaking hairs or bristles are avoided, especially by calves because of eye damage inflicted by the hairs. In Kenya several Napier grass varieties have been collected locally, introduced from other African countries or improved through selection. Varieties have been screened for high dry matter yield, smooth leaves and resistance to diseases. During the selection process varieties were selected that differed in characteristics such as the number of tillers, plant geometry, plant height, hairiness of leaf and stem, flowering and resistance to fungal disease.

Confusion of varietal names is common because no certification system is operational and varieties are hard to recognize especially when plants are young. Several varieties have been in circulation under more than one name even in official demonstration and testing plots unnoticed by those responsible. A key to identification is long overdue. In Kenya many varieties of Napier grass have been collected locally, introduced from other African countries or developed through improvement and selection breeding programmes. The author has assembled over fifty different Napier grass cultivars which are being evaluated and characterized morphologically and agronomically at various agro-ecological zones in Kenya with the intention of developing a key for identifying the various Napier grass varieties using morphological and agronomic characters (see **Figure 3**).

Figure 3. Napier grass varieties undergoing morphological and agronomic characterization. Note the variability in the heights of the varieties.

As indicated above varieties include collections from different parts of Kenya, Bana grass, French Cameroon, Clone 13, Uganda hairless, Pakistani Napier hybrid, Gold Coast, at least one variety that originated from Congo, Nigeria, Malawi, Uganda and Tanzania, and some cultivars that were introduced from the International Livestock

Research Institute's (ILRI) Napier germplasm collection in Ethiopia through Forage Networks. Bogdan (1977) mentions Capricorn, Cubano, Domira, Ghana, Gold Coast, Merker, Merkeron, Mineiro, Napier, Pungwe, Uganda, and Urukwanu as noteworthy cultivars.

Farmers need meaningful advice on Napier grass cultivars and a practical field key would be useful for their identification. Morphological and agronomic characteristics cannot be used to distinguish all the accessions, whereas molecular markers have the potential to distinguish between closely related individuals. Studies have shown that molecular markers generated by polymeraze chain reaction (PCR) of randomly amplified DNA (RAPDS) have been extremely useful in differentiating different accessions of Napier grass. In a KARI/DFID/ILRI collaborative trial involving eleven Napier grass accessions using RAPDs, it was found that there was enough genetic variation between the 11 cultivars to allow successful separation of all cultivars using RAPDs. The distinct variability has led to the identification of specific markers for potential varieties. Results of this trial confirm that Kakamega 1 which was developed by the author from ILRI material 16791 that had originated from South Africa was different from its parent material 16791 for the two did not cluster together (Jamnadass, 1999). This study also showed that the head smut resistant Kakamega 1 and the head smut susceptible clone 13 clustered separately indicating that they are genotypically different. Since clone 13 is resistant to snow mould fungus *Beniowskia sphaeroidea* but susceptible to another fungal disease, *Ustilago kamerunensis* causing Napier head smut, resistance to each disease is specific. This implies that a Napier grass cultivar resistant to one disease may not necessarily be resistant to another disease even of the same genus.

PESTS AND DISEASES OF NAPIER GRASS

(a) Snow mould fungal disease

In the past Napier grass exhibited few disease and pest incidences of economic importance and therefore few studies addressed pests and diseases. However in the early 1970s a fungus causing white mould attacked the leaves and stems of most Napier grass varieties. The fungus *Beniowskia sphaeroidea* [False mildew *Beniowskia sphaeroidea* (Kalchbr. Cke.) Mason] is a disease of bulrush millet too; it used only to appear at the height of the rains and did little damage for at that season there is plenty of feed and conditions preclude haymaking. Studies in early 1970 focused on developing a variety resistant to the attack. Clone 13 developed from French Cameroon was identified as resistant to the snow mould fungal diseases and it was recommended to be grown by farmers whose Napier have been infected with the fungal disease. Fortunately, although the mould affects most other Napier varieties, it does not affect the vigour of the plants and feeding livestock on the diseased leaves has no adverse effect.

Figure 4. [Left] Snow mould fungal disease *Beniowskia sphaeroidea*; [Right] Napier grass rust

(b) Napier grass head smut in central Kenya

This was first reported in an unpublished paper by Kung'u and Waller in 1992 in Lari Division of Kiambu District. The causal organism of head smut was identified as *Ustilago kamerunensis* (see New Agriculturalist and paper by Farrell *et al*. 1998 and Farrell, 1998) and samples sent to the International Microbiological Institute confirmed the

identification. It was thought to be a systemic smut, hence the precocious flowering of the infected Napier grass. The disease changes the morphology of the plant and is characterized by smutted heads. The infected stems harden and shoot to premature flowering, becoming thin and fibrous rather than normal thick and juicy. Emerging plant stems then become smaller and the total dry matter of the affected crop is drastically reduced (Figure 5a). After 2-3 cuttings, the entire stool dries. The result is a catastrophic decline in biomass which leads to falling milk production. Some farmers have to sell their dairy cows while others have to graze their dairy cattle on sparse communal pastures along the road side, a practice that exposes them to increased risks from East Coast Fever.

By 1994, the disease was present in Lari, Githunguri, Kikuyu, Gatundu, Kangema and Kandara divisions. Consultations with scientists at the regional Research Center, Embu, revealed that the problem was present in Nyeri and Kirinyaga, but not in Embu District. It has also been observed in Molo and Londiani, indicating the widespread nature of the problem which is possibly exacerbated by movement of planting material. It now poses a serious threat to the dairy industry in Kiambu, Murang'a and Nyeri districts. There is a possibility that movement of manure could also spread the disease, as well as wind. Environmental factors, such as temperature, decline in soil fertility and acidity, altitude and rainfall could be predisposing factors resulting in the current increased occurrence, or a more virulent race of the pathogen could have caused the explosion. There is need to investigate whether there are any side effects of feeding smutted heads to the animal apart from the fact that disease could be passed on through manure. Improving soil fertility has beneficial effects but does not eliminate the disease. Cutting frequency could have some effect since it is likely that, as with the head smut of sugarcane, infection is at the tiller bud stage. The effects of crop rotation need to be investigated. Farmers uproot diseased plants (**Figure 5b**) but the disease continues to spread because it is often present in plants not yet showing any symptoms.

Figure 5a. Napier grass head smut

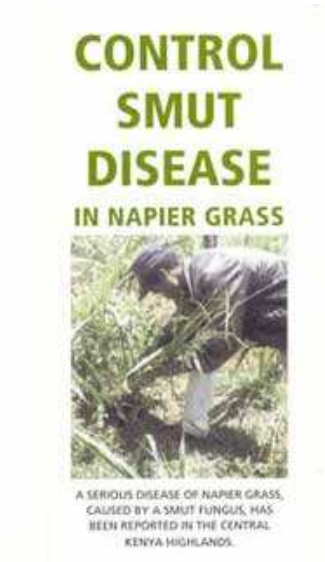

Figure 5b. Farmer uprooting diseased Napier grass

KARI undertook research to identify Napier grass varieties resistant to the disease. A Napier variety known as Kakamega 1, developed by the author, was identified as both high yielding and resistant to head smut. The favourable results obtained in the laboratory were confirmed in farmer's fields. Once word spread other farmers immediately wanted planting material of the new resistant variety; for example, Peter Ndung'u and his fellow farmers from Gatundu division hired a truck and travelled over 100 km to collect Kakamega 1 planting material from the KARI centre at Muguga. Work began immediately to multiply planting material in government institutions and cuttings were distributed to over 10 000 smallholder farmers within the first year. Now, farmers with Napier grass affected by head smut are advised to uproot the diseased Napier grass (**Figure 5b**) and plant the resistant Kakamega 1 variety.

FARMER EXPERIENCE WITH THE DISEASE IN CENTRAL KENYA
[Click here to read farmers views]

(c) Napier grass stunting disease in Western Kenya

Another serious Napier grass disease which has developed in Western Kenya was first reported in Bungoma district bordering Uganda in 1997. Literature shows that a similar stunting disease had been reported in Uganda and the cause of the disease was suspected to be a virus transmitted by insects (Tiley, 1969). It has spread quickly and now covers several districts of Western Kenya causing serious economic loss in the smallholder dairy industry. Most of the Napier grass varieties grown in the area are susceptible to the disease which usually becomes visible in re-growth after cutting or grazing. Affected shoots become pale yellow green in colour and seriously dwarfed. Often the whole stool is affected with complete loss in yield and eventual death. Many smallholders have lost up to 100 percent of their Napier crop and are forced to de-stock or sell off their entire herd because of lack of feed (**Figure 6**).

Figure 6a-c. Napier grass stunting disease on smallholder farms in Western Region

a) Mrs Jane Ngugi who is a District Agricultural Livestock Extension Officer shows her Napier grass field heavily attacked by stunting disease in Kanduyi Division, Bungoma District.

b) The farm manager of Busia Farmers' Training Centre with the author in his Napier grass field heavily affected by the stunting disease.

c) Mr and Mrs Makokha and family in Harambee Division of Butere/Mumias District in their Napier fields heavily affected by grass stunting disease.

Urgent action is needed to identify the cause of the disease and find possible solutions, otherwise it will have a devastating impact on the smallholder dairy industry in Eastern Africa.

The author is collaborating with scientists from KARI and International Research Institutes in studies to learn more about Napier stunting, its cause and mode of transmission. Tests, both at the KARI and CABI laboratories have confirmed that it is caused by a mycoplasma. DNA analysis showed that diseased samples of yellowed leaves from plants with stunted growth were negative for plant viruses but phytoplasma positive. Refracted fragment length polymorphism (RFLP) analysis of amplimers showed a similar pattern for all samples analyzed. Blast analysis showed the phytoplasma to be members of 16SrX1 (Rice yellow dwarf group). Further tests are being carried out to confirm whether the disease is transmitted by insects. Suspected insects have been collected from diseased grass. Scientists are also screening germplasm from over 50 Napier accessions to identify any resistant varieties.

Some farmers suspect that the disease is mechanically spread through harvesting implements, observing that the disease does not spread until after the first cutting. The disease is much more severe and prevalent in poorly managed fields and farmers have noted that in well-weeded and heavily manured fields, disease severity is reduced. However, weeding and heavy fertilization are only temporary measures for reducing the disease level and a more permanent solution such as resistant varieties is needed. Contrary to farmer opinion that nematodes affecting bananas (especially in Bungoma where the disease was first reported) could be transmitting agents, no nematodes were found on affected plant samples analyzed at the Kenya National Agricultural Research Laboratories in Nairobi. Insects were thought to be the transmitting agents of this disease as the pattern of spread in one field is not regular, as would be expected if the disease was being transmitted mechanically through harvest implements. Insects, mainly thrips, aphids and leafhopper are found feeding on the whorls (hearts) of young affected plants collected and analyzed at the Entomology Laboratories and thrips have been most suspect because they were common in all areas/samples collected. Napier grass is normally propagated vegetatively and many farmers transfer planting material from one part of a farm to the other or from farmer to farmer, therefore germplasm transfer through planting material is suspected to be the fastest way the disease could be spreading from one region to another and even across borders.

Orodho & Ajanga (2002) gave a detailed way forward on research needed to be done to solve this disease problem, which include:

- Establish the mode of transmission and spread of the disease including both mechanical / injury to plants using insect vector screening and crushing both the affected plants and the insects feeding on them and comparing their DNA.
- Identify useful insects (natural enemies) to enable development of integrated methods of control.
- Search for resistance and development of Napier grass varieties that are resistant to the diseases by continuing the work started by the author in screening local and introduced Napier grass varieties and develop a resistant variety for farmers in Western Kenya, where the disease is prevalent.
- Survey of other possible alternative plants commonly found in the region affected by the disease; plants including sugarcane, upland rice, bananas and groundnuts (peanuts).

KARI and the Global Plant Clinic recently reported on a short "Going Public" campaign in western Kenya to raise awareness of the problem of Napier Grass Stunt which requires follow up in the form of a sustained and long term programme of extension and research to combat this threat to dairy farmers in East Africa [material used with permission of Prof. Phil Jones, Global Plant Clinic].

[Click to access the file]

IMPROVED TECHNOLOGIES FOR NAPIER PRODUCTION

(a) Napier grass establishment

Conventionally Napier grass is established in well-prepared land (ploughed and harrowed) from root splits, canes with 3 nodes or from whole canes. The material is planted 15-20 cm deep with splits planted upright, three node canes planted at an angle of 30-45^{o} while whole canes are buried in the furrow 60-90 cm apart. The root splits and canes are usually spaced 50 - 60 cm x 50- 60 cm , 50-60cm x 90-100 cm or 90-100 cm x 90-100cm depending on the soil moisture of the area; usually the higher the rainfall the closer the spacing. Root splits generally take more labour (Suttie, 1965) to prepare (uproot) and to plant but result in quicker establishment and earlier and higher forage yields. Once the crop is well-established the original planting material type generally has little effect on dry matter yield although some varieties such as French Cameroon may establish best from canes (NARS, 1979). Whether root splits or canes are used, they should be sufficiently mature to tiller well and produce tall and high yielding forage plants; canes should be from plants 20-28 weeks old. Napier grass can also be established by the "Tumbukiza" method (**Figure 7**) where the planting is done in round or rectangular pits 60-90 cm wide and 60-90 cm deep, filled with a mixture of topsoil and manure in the ratio of 1:2.

Figure 7a Napier grass planted using conventional methods

Figure 7b Napier grass planted using the "Tumbukiza" method.

The Tumbukiza method conserves soil moisture in the pits for longer periods and concentrates fertility at a point of easy use by the Napier grass thus resulting in higher forage production per unit area of the land, even in areas of low rainfall.

(b) Cropping system

Napier grass is usually planted as a sole crop; however, it can also be under sown with other crops such as maize (Wanjala *et al.,* 1983) or intercropped with forage legumes (Kusewa *et al.,* 1980). [Figure 8] When inter-planted with maize, it is planted 12 weeks after sowing maize at a spacing of 75 x 30 cm, as this has been shown to give the best maize yield. However, if the main crop is Napier grass, delayed planting reduces its yield. When Napier grass and maize are planted at the same time, Napier grass yield is increased, without necessarily reducing maize yields. Experience shows that both Napier grass and maize compete for nutrients and it is only under high nutrient management systems that Napier grass and maize can be successfully grown on the same plots. Herbaceous legumes can give high yield when intercropped with Napier grass; those that are compatible and give high yields include: giant vetch (*Vicia dasycarpa*) at higher elevations; silverleaf desmodium (*Desmodium uncinatum*), greenleaf desmodium *(D. intortum),* stylo (S*tylosanthes guianensis*) and glycine (*Neonotonia wightii*) in high and medium altitudes; and Archer axillaris (*Macrotyloma axillare*), centro (*Centrosema pubescens),* siratro (*Macroptilium atropurpureum*), butterfly pea (*Clitoria ternatea*), lablab (*Dolichos lablab*) and stylo in the coastal region. Generally planting Napier grass with herbaceous legumes increases the dry matter yield and crude protein of the forage. The combined dry matter yield is greater than the yield of Napier grass alone. Initial legume establishment is slow with faster growth later, however, Mwangi & Wambugu (2001) reported poor persistence of legumes such as *Desmodium intortum* because insufficient attention was given to the legume when planning row spacing, planting time etc..

Figure 8a. Napier grass intercropped withgreenleaf desmodium

8b. Napier grass intercropped with herbaceous forage and fodder legumes

Fodder trees and shrubs provide useful cattle feed for they remain green and of high quality for most of the dry season, producing ample green matter at a time when there is little available and they re-grow at a fast rate complementing Napier grass forage in a cut-and-carry system. The most useful are those which improve soil fertility by nitrogen

fixation, provide high quality mulch and soil erosion control and which do not compete for nutrients and soil moisture with the adjacent Napier grass on the contours, mainly due to their deeper root system. In addition, some fodder trees and shrubs may provide poles and fuel wood. Fodder shrubs can be successfully grown in mixtures with Napier grass with the fodder trees/shrubs in hedges and the Napier grass planted in alleys between them. Napier grass in the alleys can be intercropped with herbaceous legumes such as desmodium or butterfly pea. Those that have shown promise include: leucaena (*Leucaena leucocephala*), calliandra (*Calliandra calothyrsus*), sesbania (*Sesbania sesban*) and gliricidia (*Gliricidia sepium*). In Kenya, Napier grass has not been found to be suitable for grazing because the preferred varieties show poor persistence under grazing. Also, most dairy farmers in Kenya are smallholders with very small plots of land, which only favour zero grazing. Thus there is little reported work of animal performance on grazed Napier grass. Although the dwarf Napier grass especially bred for grazing purposes (Sollenberger & Jones, 1989; Ruiz *et al*., 1992) has been impressive in south-eastern U.S.A, it has not been adopted by dairy farmers in Kenya due to its relatively low DM yield (Sotomayor *et al*., 1997) and high susceptibility to snow mould fugal disease *Beniowskia sphaeroidea* under Kenyan condition (Boonman, 1997). In Brazil, the author noted that the Napier grass variety used there performed well under specific grazing management, but smallholders in Kenya prefer giant Napier grass suitable for cut-and-carry.

(c) Fertilizer requirement

Because of its rapid growth and high yields Napier grass requires regular application of nitrogen (N) phosphorus (P) and potassium (K) in the form of fertilizers or farm yard manure (FYM). High yields of Napier are obtained/maintained with the following rates of application:

- 20 kg/ha/year of P in the form of either single or triple superphosphates (SSP or TSP) at a rate of 100 kg/ha applied twice a year as a ring application around the stools at the beginning of the long and short rainy season on weeded plots.
- 75 kg/ha/ of N usually in the form of Calcium Ammonium Nitrate (CAN) at a rate of 300 kg/ha to be applied in splits after every grass harvest (except the harvest taken during the dry season, because of low soil moisture) or in three equal doses in a year, during the long rains and short rains.
- 25 kg/ha/year of K usually in the form of Muriate of Potash at a rate of 40 kg/ha/year, to be applied in the same way as phosphate.
- Dairy cattle slurry: this is a mixture of cow dung, urine, and feed left over, available from the zero-grazing stable. The rate of application is 5.5 tons of DM/ha/year or 55 tons of liquid slurry. This should be buried between Napier grass rows to avoid loss of nitrogen by volatilization. The slurry is applied after the onset of long and short rainy seasons.
- Leaving crop residues, feed refusals, mulching, old Napier grass leaves, stalks and other weed trash in the field to cover the soil. An even layer of mulch should be applied between grass rows, ideally after every harvest. The advantages of mulching are: to help conserve moisture and nutrients in the soil, to suppress weed growth and to maintain the soil temperatures for optimal microbial activity.

Phosphorus is required at the time of planting to enable Napier grass to develop a strong root system. Later it requires nitrogen for photosynthesis. Application of N, P and FYM increase DM production but the response may depend on environmental conditions during application and on the soil nutrient status; response may be poor at very dry sites and pronounced when the soil nutrient status is low. The most reliable indicator of fertilizer requirement is through on-site testing: in most Kenyan studies the response to P was more pronounced than to N and in many cases the P&N interaction was significant. N&P responses were found to be greater in ratoons. Old Napier stands generally respond faster to NPK than to FYM. The response of Napier to slurry is better when the slurry is poured into furrows and covered with soil rather than surface application (Snijders *et al*., 1992). Fertilizer requirement may also depend on the feeding system: where Napier grass is cut, carried and fed away from the fields, NPK and Mg application may be required, whereas if grazed then normally only N and P are needed.

Napier grass is a heavy feeder and reduces soil nitrate, K, Ca and Mg status through nutrient uptake. The elements may be returned to the soil and taken up by other crops when Napier grass is used as a mulch. Napier grass is a luxury consumer of K, far above animal requirement (0.44%) and well above the critical level (1- 1.5%).

Table 1. Concentration (%) and removal of minerals in 12.5 tonnes/ha/year of Napier grass

	% in DM		kg removed
	Actual	Animal need*	
Nitrogen (N)	1.20	1.60	150
Potassium (K)	3.00	0.44	375 (450kgK_2O)
Phosphorus (P)	0.25	0.36	30(70kgP_2O_5)
Calcium (Ca)	0.30	0. 43	37
Magnesium (Mg)	0.25	0. 12	31
Sulphur (S)	0.30	0. 10	37

* in edible DM for dairy animals; Source: Boonman (1997)

The improvement of soil fertility as a result of intercropping Napier grass with legumes has been shown in many studies (NARS, 1979b). The best Napier grass-legume intercrop combinations are: Napier grass /*Stylosanthes guianensis* which produced the equivalent of 400 kg/ha/year of N (NARS, 1979b; Kusewa, 1979) and Napier/Desmodium which produced an equivalent of 465 kg/ha/year of N. It can also be used as a fallow to improve soil structure and fertility in general.

(d) Harvesting regime

The first harvest of Napier grass should be when it attains a height of 1-1.2 meters, which is usually three to four months after planting. At this stage Napier grass has high quality and sufficient dry matter. Thereafter the grass should be harvested at intervals of six to eight weeks, when it attains the same height. To some extent this will depend on the Napier grass variety and its ability to grow, weather conditions, soil fertility, management practices and livestock needs. If well managed it can be harvested every month in hot and wet environments like those at the coast while during the dry season it may be harvested after 2 months. Although harvesting at longer intervals produces higher dry matter yields and increased crude fibre, the crude proteins, digestibility, leaf-to stem ratios and ash contents will decline. During harvest a stump (stubble height) of 10 - 15cm is left; this height influences yield quality and life span of the grass. Herbage yields from Napier grass cut too low or too high leaving no stubble or very long stubble tend to decrease over time and the persistence of the stand is also greatly reduced as this interferes with the growing points and weakens the rooting systems resulting in lower production in subsequent harvests. Leaving appropriate stubble height will provide sufficient carbohydrate reserves for subsequent growth and especially the stubble of the last harvest before the long dry period will encourage fast growth after the onset of rains.

(e) Weeding

Weeding of Napier grass will eliminate re-growth of undesirable plants, remove the dry root bound Napier in order to promote fodder re-growth by increasing soil aeration, and provide soil cover from mulching which will improve water infiltration and decrease evaporation of soil water and loss of nutrients. It should be weeded as early as possible after planting and kept weed free throughout growth; it is suggested hand weeding takes place after every harvest. Aggressive weeds such as couch grass (*Digitaria* sp.) are best controlled during the dry season and regular weeding helps to ensure that fertilizer applied after harvest will only be utilized by the forage crop. During establishment, a closer spacing will ensure that the Napier grass quickly forms a closed canopy that suppresses weed growth and planting of forage legumes between and/or within Napier rows will also ensure that the forage legumes suppress other unwanted weeds.

(f) Napier grass conservation

Lack of adequate and high quality feed is a major constraint to production on smallholder farms, particularly in dry periods. In some eastern and coastal regions of Kenya, the prolonged dry season can last up to 6 months (Jatzold & Schmidt, 1982) and during that period dairy cattle could be sustained on conserved Napier grass (Valk, 1990) from the high yields produced during the rainy season, when there is often an excess (Anindo & Potter 1994). Attempts have been made to make hay out of Napier grass (Brown & Chavulimu, 1985; Manyuchi *et al*., 1996) but the succulent stems limit

the rate of drying (Snijders *et al.,* 1992a) and with excess drying the stems may become hard and brittle and less palatable to livestock. The alternative is ensiling the surplus (Cuhna & Silva, 1997) since leaving Napier grass to become too mature may compromise the quality. However, the proportion of farmers ensiling is small (Valk, 1990). Napier grass can be ensiled but the quality of silage obtained depends on fresh grass quality, the ensiling process and use of additives (Yokota & Ohshima, 1997: Ruiz *et al.,* 1992); successful ensiling to maximize nutrient preservation is achieved by harvesting the crop at the proper age, minimizing the activities of plant enzymes and undesirable epiphytic micro-organisms (naturally present in the forage crop) and encouraging the dominance of lactic acid bacteria (Bolsen, 1995). As it has low fermentation sugars, energy sources such as bran and molasses have been found to enhance Napier silage quality (Yokota & Ohshima, 1997; Snijders & Wouters, 1990). Otieno *et al.,* (1990) showed that bana could be successfully ensiled when 1 m tall (101 days after planting) and cut, wilted, chopped and ensiled with molasses additive at 5 percent by weight of material (green matter basis) in a trench silo (Table 2).

Table 2. Mean values of quality parameters for ensiled Napier grass with/without molasses

Napier grass (bana)	% DM	%CP	IVDMO	ADL	ADF	LIGN/ADF	% NDF	pH
Material ensiled	15.90	12.59	68.97	15.71	47.19	0.33	78.44	-
Silage w/out molasses	16.94	10.38	56.28	5.52	40.54	0.14	59.46	5.18
Silage with molasses	19.77	11.94	65.86	9.11	34.61	0.26	56.47	4.18

On the basis of appearance and smell silage with molasses received a higher score for both appearance (brownish/well pickled) and smell (typical silage smell with no foul odour associated with putrefaction) when compared to silage prepared without molasses.

During the prolonged dry season dairy cattle could be sustained on ensiled Napier grass (Valk, 1990) which has an advantage over maize or sorghum because it is a perennial forage and can therefore be harvested over several seasons. Snijders & Wouters (1990) demonstrated that chopped Napier grass wilted for one day and to which molasses (6%) was added produced good silage as evidenced by the level of pH, volatile fatty acids, CP, ammonia nitrogen, and organic matter digestibility (**Table 3**).

Table 3. The quality of silage from chopped Napier grass and added molasses (6%)

	DM loss (%)	pH	AC	BU (%)	NH_3-N (%)	DM(%)	CP(%)	DOM(%)
Fresh Napier	-	-	-	-	-	25.7	9.2	60.5
Napier silage	2	4.9	0.2	0.2	11	24.1	8.5	56.6

DM = dry matter; AC = Acetic acid; BU = Butyric acid; NH_3-N = Ammonia nitrogen, CP = crude protein; DOM = digestible organic matter.
Adapted from Snijders & Wouters (1990)

DRY MATTER YIELD

The dry and wet seasons in East Africa influence the dry matter yield and quality of Napier grass fed to dairy cattle. Water deficit depresses forage yield and has a negative effect on crude protein (CP) concentration (Buxton & Mertens, 1995). Minson & Mcleod (1970) noted that relatively high temperatures during the dry season reduce digestibility. Anindo & Potter (1994) confirmed this and indicated that seasonal variation could cause drastic changes in DM yield and quality characteristics as given in Table 4 below.

Table 4. The effect of season on yield and quality of Napier grass

Components	**Wet Season**	**Dry Season**

DM yield (kg DM/ha/day)	178	25
CP (g/kg DM)	148	82
NDF (g/kg DM)	742	82.9
DM digestibility (%)	72	56
DM intake (kg/100kg BW)	2.7	2.5

Source: Anindo & Potter (1994);
DM = dry matter; CP= crude protein; NDF= neutral detergent fibre, BW=body weight.

The potential DM yield of Napier grass surpasses that of other tropical grasses (Humphreys, 1994; Skerman & Riveros, 1990) which is the reason for its popularity among dairy farmers in Kenya, who need to maximize production per unit area of their land. On farm DM yields of Napier from different regions average about 16 tonnes/ha/year (Wouters, 1987) with little or no fertilizer. In Western Kenya, Mathura *et al.* (1985) reported cumulative dry matter yield of Napier grass of 40 tonnes/ha after 3 cuts in a year with the application of 100kg/ha of NPK (20-20-0) fertilizer. Reported yields within the country vary between 10 to 40 tonnes DM/ha depending on soil fertility, climate and management (Schreuder *et al*., 1993). High yields are achieved in the hot and humid parts of zones II and III. Those DM yields contrast with those of Rhodes grass (*Chloris gayana*) and Kikuyu grass (*Pennisetum clandestinum*), which are popular, and which yield between 5 to 15 tonnes DM/ha (Boonman, 1993). Comparable Napier grass DM yields have been recorded elsewhere in the tropics (Ferraris & Sinclair, 1980) and exceptionally high DM yields up to 85 tons DM/ha here been cited when high rates of fertilizers were applied to Napier grass (Skerman & Riveros, 1990). However the DM yield alone may be of limited utility if it is not closely related to DM intake of animals. Such high yields of Napier grass may consist largely of stems, which may be rejected by animals. Although high yields of 50 tonnes/ha of Napier grass were recorded experimentally in Puerto Rico (Vicente-Chandler *et al.*, 1994), the yields of digestible dry matter were only just above those of other grasses such as Congo signal (*Brachiaria ruziziensis*) common Guinea grass (*Panicum maximum*) and stargrass (*Cynodon nlemfuensis*). It is best to think in terms of yields of edible leaf and to maximize on leaf production especially in the dry season. At farm level, the combination of DM yield and observed DM intake can form the basis for estimating the number of livestock that could be supported by nutrients from the available forage land.

CHEMICAL COMPOSITION, NUTRITIVE VALUE AND DIGESTIBILITY

Serra *et al.* (1996) contrasted the mineral composition of Napier grass with the required dietary concentrations for ruminants and concluded that it is likely to be deficient in most of the minerals considered (Table 5). Inadequate availability of macro elements such as calcium (Ca) phosphorus (P), Sulphur (S), Potassium (K), Sodium (Na), Chlorine (Cl) and Magnesium (Mg) and a range of micro elements may lead to deficiency diseases in ruminants and may limit fibre digestion and microbial protein synthesis (Hanna & Gates, 1990; Durand & Kawashima, 1980). The availability of P for nucleic-acid formation and S for the synthesis of sulphur amino acids is particularly important. Calcium is closely related to P metabolism. Mineral deficiencies for Ca, P, Co, Mo, Zn and Cu have been reported in some parts of Kenya and this has been attributed to low soil fertility (Jumba *et al*., 1995 a,b; Abate, 1994; Mwakatundu, 1977). Dairy cattle should therefore be given a balanced mineral mixture even when being fed on Napier grass.

Table 5. Mineral composition of Napier grass

Minerals	Ca	P	Mg	K	Cu	Zn	Mo	Co	Mn	Fe
	(g/kg DM)					(mg/kg DM)				
Concentration	3.5	2.0	1.7	8.0	7.1	50.4	14.4	2.0	33	40.4
Critical level	3.0	2.5	2.0	0.7	10.0	30.0	6.0	0.1	35	30.0

Source: Sierra *et al.* (1996)

Chemical composition of the forage is a major determinant in animal production (Skerman & Riveros, 1990; Minson, 1990). As Napier grass matures, the leaf to stem

ratio declines (Kariuki, 1989; Karanja, 1984) causing changes in the chemical composition and a concomitant reduction in feed value (Minson, 1990). Feed quality may affect voluntary feed intake and animal performance in terms of milk yield or body weight gain. Grass maturity is usually negatively related to CP content (Minson, 1970; Norton 1981) and the results summarized by Skerman & Riveros (1990), Woodard & Prine (1991) and Williams & Hanna (1995) confirm this for Napier grass with the rate of decline in CP content more rapid in stems than leaves (Brown & Chavulimu, 1985). The cell wall, composed primarily of the structural carbohydrates cellulose and hemicellulose, is the most important factor affecting forage utilization (Van Soest, 1994) as it comprises the major fraction of forage DM and its extent of degradation by the microflora has important implications on forage digestibility and intake (Paterson *et al*., 1994). The cell wall content in Napier grass increases less prominently with age compared with other tropical grasses such as Kikuyu and Pangola grass (Minson & Mcleod, 1990) and ranges between 650 to 750g/kg DM. Whereas other tropical grasses showed a daily decline of 0.30 to 0.50 units of DM digestibility, Napier grass only declined by 0.20 units per day (Reid *et al*., 1973) which was lower than the mean of 0.26 units per day for tropical forages (Minson, 1990). This makes Napier an attractive feed since it can retain a given level of digestibility for a slightly longer period compared with other tropical grasses. Stobbs & Thompson (1975) reported that OM digestibility of most tropical grasses ranged from 50 to 60% which is consistent with observations by Minson (1990). The data summarized in Table 6 confirm this. However in well fertilized fields, Chaparro & Sollenberger (1997) recorded a range of 65 to 79 % in *vitro* DM digestibility for dwarf Napier grass so it is important to bear in mind that climate, soil fertility, cutting interval, variety and management practices may have an important influence on chemical composition and digestibility of Napier grass.

At farm level, the CP content does not always satisfy the 60 to 80g/kg DM which is considered the minimum requirement for optimum rumen microbial activity (Minson & Milford, 1976). A study covering all main Napier grass growing areas in Kenya showed that the mean CP level on farms was 76g/kg DM (Wouters, 1987). Results from other parts of the world as summarized by Gohl (1981) and from Kenya as reviewed by Schreuder *et al.* (1993) indicate that the CP values commonly recorded for Napier grass lie between 50 and 90 g/kg DM. Observations from more recent studies are generally in agreement, as shown in Table 6. These results contrast with those for dwarf Napier grass whose CP content has been reported to range between 80 and 150 g/kg (Chaparro & Sollenberger, 1997; Flores *et al.,* 1993, Sollenberger & Jones, 1989) under good management and high fertilizer application.

Table 6. Chemical composition (g/kg DM) and digestible organic matter (g/kg DM) of Napier grass

References	CP	NDF	ADF	ADL	DOM
Serra *et al*., 1996	106	668	397	18	-
Devasena *et al*., 1993	82	714	-	-	550
Abate & Abate, 1991	90	706	436	58	-
Van Eys *et al.,* 1986	119	733	441	69	505
Muinga *et al.,* 1993	72	-	-	-	504
Anindo & Potter 1994	110	705	-	63	560
Muinga *et al.,* 1995	64	690	-	-	515
Kariuki *et al*., 1998	118	587	301	47	517
Abdulrazak *et al.,* 1996	79	680	-	-	554
Anindo & Potter, 1986	86	-	413	39	-
Grant *et al*., 1974	60	658	450	70	543
Ibrahim *et al*., 1995	86	647	364	32	634

DM= dry matter; OM = Organic matter, CP= Crude Protein; NDF= neutral detergent fibre; ADF acid detergent fibre; ADL=Acid detergent lignin, DOM= digestible organic matter.

Nutritive value has been defined as the amount of feed ingested and the efficiency with which nutrients are extracted from a given feed (Norton & Poppi, 1995). From this perspective, little information is available on the nutritive value of Napier grass as the

bulk of the available literature deals with its agronomy. Previous studies on Napier grass in Eastern Africa have concentrated on aspects such as effects of climate, fertilizer and cutting interval on DM yield, and to a lesser extent on leaf stem ratio, proximate composition and in vitro digestibility (Anindo & Potter, 1994; Wouters, 1987; Karanja, 1984; Reid *et al*., 1973). Similar studies have been reported from other parts of the world (Chaparro & Sollenberger, 1997; Mislevy *et al*., 1989). Compared to other well known tropical pasture grasses such as *Digitaria decumbens, Chloris gayana,* Kikuyu grass (*Pennisetum clandestinum)* and *Panicum maximum*, relatively few data are available on the effects of feeding Napier grass on animal performance (Minson, 1990, Minson & McLeod, 1970).

The nutritive value of forage is mainly determined by voluntary intake, crude protein and structural carbohydrates and forage intake is influenced by digestible DM and CP content and the extent of degradation (Minson, 1990). The structural polysaccharides composed primarily of cellulose and hemicelluloses are primary restrictive determinants of nutrient intake.The digestibility of forage in the rumen is related to the proportion and extent of lignification (Van Soest, 1994). Chemical composition and digestible DM may be poor indicators of the nutritive value of Napier grass because the farmer fails to take into account nutrient availability whilst the latter does not provide the profile of absorbed nutrients. Therefore, if nutrient value is to be of practical importance, the ultimate measure should be animal performance. It has been well documented that animal performance is closely associated with the capacity of a feed to promote effective microbial fermentation in the rumen and to supply the quantities and balances of nutrients required for different productive status (Beever, 1997; Sniffen *et al.,* 1992; AFRC, 1992); thus milk yield or weight gain should be closely related to intake, forage composition and digestibility. In ruminants, the use of CP or digestible CP to determine nitrogen value is regarded as inadequate because they ignore the role of rumen microbes (AFRC, 1992; Tamminga *et al*., 1994), yet in all forage diets, protein quality of each dietary component is important in evaluating response to supplementation. Current protein evaluation systems partition feed nitrogen into the amount degraded in the rumen and that which escapes rumen degradation (Hvelplund, 1985; INRA, 1988; ARC, 1980; AFRC 1992; Tamminga *et al*., 1994). The system is based on the concept that the nitrogen (N) requirement of rumen microbes is distinct from the requirements of the host animal, which is met by the protein escaping the rumen along with the microbial protein. Thus, determining rumen degradation of dietary protein and the amount that passes through the rumen and subsequently becomes available for digestion by the host animal is important. This information is lacking for Napier grass and other Kenya forages.

DAIRY ANIMAL PERFORMANCE ON NAPIER GRASS-BASED DIETS

Within the smallholder dairy system, the recommended weaning weight for a dairy heifer is 70kg weight with a target of 300kg to be attained by 18 months of age at the first service (MLD, 1991). This recommendation assumes that heifers gain at least 0.5kg/day but in practice less than 0.25kg is observed on small farms (Gitau *et al*., 1994) and therefore puberty is not achieved until after 24 months. This is attributed to the low quality of Napier grass fed on the farms and the absence of concentrate feeds (Wouters, 1987). The potential of Napier grass for weight gain in cattle has been investigated with or without energy or protein supplements. Results seem to differ widely depending on grass quality, cattle species and the level and the type of supplement used. Friesian heifers gained between 0.13 and 0.8 kg/day when fed on Napier grass varying in maturity from flowering to early vegetative stage (CP 63 to 96 g/kg DM) and achieved a daily DM intake of 2.1 to 3.1 kg per 100kg body weight (Arias, 1980). Dixon (1984) obtained a weight gain of 0.72 +/- 0.21kg/day from Holstein heifers fed 60 to 85 day old Napier grass of unspecified CP content supplement with 0.2, 0.4 and 0.8 percent molasses on body weight basis. The author noted no significant influence of molasses on weight gain, FE and DM intake. The mean milk yield on small farms in Kenya is less than 2000 kg/cow/year (Abate & Abate, 1991) and although it has been established that commercial concentrates could boost milk yield by about 50 percent (Anindo & Potter, 1986) their widespread use is limited by the high cost (Valk, 1990).

Muinga *et al*. (1995) demonstrated that supplementing *Bos indicus* x *Bos taurus* cows fed Napier grass *ad libitum* (CP 64 g/kg DM) with varying levels of Leucaena improved milk production by about 28 percent (Table 7).

Table 7. Effect of leucaena supplementation on dry matter intake and milk yield

	Leucaena level (kg fresh/day)

	0	4	8	8*
DM intake (kg day^{-1})				
Napier grass	6.3	6.6	5.9	5.7
Total	6.3	7.6	7.9	8.7
DMlg kg $^{0.75}$	75	82	92	102
Milk yield (kg/day)	5.1	5.4	5.5	6.5

Adapted from Muinga *et al.* (1995);
DM = dry matter intake, *1.2 kg maize bran offered (CP 95g/kg DM; DOM = 75%).

Protein - rich forages (PRF), which can be used in combination with Napier grass, are endowed with the important attribute of high protein content, palatability and digestibility relative to grasses. For example while the mean protein content of tropical grass has been reported as 75 g/kg DM, that for tropical forage legumes averaged 170 g/kg DM (D' Mello & Devendra, 1995).

Several species has been documented as useful supplements to Napier grass: Desmodium spp. (Snijders *et al.*, 1992b), *Calliandra calothyrsus* (Kaitho *et al.*, 1993) and *Leucaena leucocephala* (Mureithi *et al*., 1995); others include: *Ipomoea batatas* (vines), *Medicago sativa*, *Musa sapientum* (leaves/stems), *Trifolium semipilosum* and *Canna edulis* (Boonman, 1993; Karachi, 1982). However, few studies have been conducted in which Napier grass is fed to cattle in combination with PRF. Nevertheless, an ideal forage supplement should increase or at least maintain intake of basal roughage rather than substitute for it (McMeniman *et al.,* 1988). The PRF overcome protein deficiency in tropical grasses (Minson, 1990), by providing ruminally degradable and by-pass protein (Norton & Poppi, 1995; Brandt & Klopfenstein, 1986). In a study where gliricidia and leucaena were used to supplement two groups of zebu steers (mean body weight 173 and 208 kg) offered napier grass *ad libitum*, significant differences were observed in weight gain and DM intake across similar levels of supplementation (Abdulrazak *et al*., 1996) as summarized in **Table 8**. These considerable differences in response between gliricidia and leucaena suggest that the variations depend partly upon factors intrinsic to the supplement and partly to the quality of grass fed. Studies conducted using sheep and goats have shown that intake, digestion and weight gains improved when energy and protein supplement were included in Napier grass diets (Yates & Pangabean, 1988: van Eys *et al*., 1986.

Table 8. Influence of Gliricidia and Leucaena on DM intake and weight gain of zebu steers fed on Napier grass

Experiment 1	Level of Supplementation (g/kg $^{0.75}$)				
DMi (kg/day)	0	7.5	15	22.5	30
Napier (CP=76)	5.2	4.7	4.5	4.3	4.2
Gliricidia (CP = 210)	0	0.4	0.7	1.1	1.5
Total	5.2	5.1	5.2	5.4	5.7
Gain (kg/day)	0.31	0.36	0.43	0.37	0.48
Experiment 2					
DMi (kg/day)					
Napier (CP = 79)	5.2	5.3	5.3	5.3	5.1
Leucaena (CP = 220)	0	0.5	0.9	1.3	1.7
Total	5.2	5.8	6.2	6.6	6.8
Gain (kg/day)	0.54	0.71	0.72	0.79	0.85

Source: Abdulrazak *et al*., 1996; DMi = dry matter intake;
CP = Crude protein (g/kg DM).

In a study using dairy goats, supplementation of Napier grass with *Erythrina* spp. foliage enhanced milk production (Benavides, 1986).

Feeding of Napier grass to dairy cows - some examples of fodder rations

Scenario 1. Crossbred cows (Ayrshire /Brown Swiss x Sahiwal) when fed on Napier grass only will consume about 2.2 kg dry matter of Napier grass per 100 kg body weight. This will provide enough nutrients for their maintenance and about 5kg of milk.

Scenario 2. Cows fed on Napier grass and supplemented with about 8kg of fresh leucaena (2kg dry matter) will consume about 2.8kg of dry matter per 100kg. body weight.

This fodder mixture will provide enough nutrients for maintenance and about 10kg of milk daily.

Scenario 3. A crossbred cow weighing about 400kg at peak milk production should be offered about 12kg of dry matter per day. For the cow to produce 15 kg of milk per day it should have available feed at all times.

FARMERS EXPERIENCE WITH NAPIER

FARMER 1
John Khwalwale and his wife Agnes M'mboga Khwalwale are smallholder dairy farmers in Mbihi sub-location in the densely populated Vihiga District of Western Kenya. They have 8 children (5 daughters, 3 sons) and 12 grandchildren. They own 0.6ha of land of which they have already apportioned 0.2 ha to their eldest married son John Akidiva who is also a smallholder dairy farmer. Mr and Mrs Khwalwale have 4 dairy cattle while their son has two. They have been dairy farmers since 1982 when Mr Khalwale attended a Farmer's Training Seminar at Mabanga Farmer Training Centre, Bungoma. They were previously crop (maize/beans) farmers producing only 5–6 bags of maize and 1-2 bags of beans. In 1982 they decided to concentrate on dairy and to grow only Napier grass on most of the farm and to keep grade animals. The grass they established in 1982 is still healthy and productive after more than 20 years and they indicate that if well managed, it can stay for many years. "We have had no problem with our Napier grass for the last 20 years. We have supplied a lot of materials to other farmers around us and manage our Napier well so that we get enough livestock feed for our dairy animals. We get much more regular income from our farm than we used to get from crop farming; then with maize and beans we could hardly get enough to feed our family for the whole year, but with dairy farming we get regular resources to feed, clothe, educate and give Medicare to our family". When asked how they have been able to keep their Napier grass productive and good looking for so many years they said. "We planted this Napier grass from planting materials we got from the Research Station and according to the advice given to us by both the Research staff and Ministry of Agriculture Extension personnel. We cut the Napier grass when it reaches the height of about 1 metre when it is green and nutritious. We have a rod, which we received, from the Research Station, which is painted with various colours indicating the possible state and nutrition of Napier grass: black indicating that Napier grass is still very young, deep green to green indicating that it is nutritious and should be harvested when it reaches the correct height of about 1 metre; pale green indicates that the quality has started declining, yellow to red colour indicating that the quality has declined either because it is too mature or because of poor fertility.

Figure 9. Mr Khwalwale standing in his Napier grass farm with the rod he uses to check the quality of the grass

We only cut and feed our Napier grass when it is green and we know that when it becomes pale green, yellow or red its nutrition is low. It is also not good to feed the young grass because although the quality is high a lot of material would be harvested from a bigger area of land to get enough feeding material for our dairy animals."

Mr Khwalwale mentioned that he carries his rod even when he goes to visit other farmers to advise them on the right stage of harvesting Napier grass. Occasionally he purchases extra Napier grass from farmers who have no dairy animals but who grow Napier for income. He uses his rod to select the most nutritious grass to buy. On Napier grass management, Mr and Mrs Khwalwale stated that "we cut the Napier grass leaving a stubble height of 10 – 15 cm from the ground. We weed our Napier grass field after every Napier harvest making sure that we dig deep enough to enable roots of Napier grass to have adequate aeration and to allow rain water to infiltrate deep to the rooting system. We remove any dead stumps in the rootstock ensuring that there is adequate space separating the stools, removing undesirable weeds and leaving only healthy stumps that are ready to make rapid re-growth. We them apply adequate farm yard manure, which we spread in the field, and slurry, which we pour in furrows and cover. We apply the slurry only in the early morning or late in the evening to avoid loss through evaporation. With this management of Napier grass we are able to obtain enough forage to maintain our 4 dairy cows throughout the year". The photograph in Figure 9 was taken in late January at the peak of the dry season and yet they still had good looking Napier grass.

On dairy management and milk production they indicated that "we only keep 4 mature dairy animals most of the time. We slaughter any bull calves when they reach two weeks old. We also sell our heifer calves as early as possible to reduce pressure on feeding material and loss of milk to calves. Our best dairy cow called "Kadembechi" produces 48 "treetop" bottles full of milk per day while the other three produce 28, 24 and 20 bottles respectively" [A "treetop" bottle is 0.75 of a litre costing about 20 Kenya shillings]. On feeding regime they explained that "we cut-and-carry our Napier grass, chop it together with some herbaceous or fodder legumes which we have planted within the farm. We have calliandra, sesbania and leucaena planted as hedgerows along the farm and we also have some desmodium. We make sure that there is adequate feeding material in the cattle troughs and enough water for drinking. We also use two tons of brewers' waste (*machicha*) which we collect every month from Kisumu. Every day each animal gets 1 *karai* full of brewers waste which we mix with 40 litres of water in a drum before we feed to the dairy animal. [1 *karai* is equivalent to a tin of about 5 – 6 litres]".

They indicated that they have no problems marketing their milk because there is a high demand from the population around the farm, which is close to Mbale township which is the Headquarters of Vihiga District and Kakamega and Kisumu towns are also not very far away. Milk is sold to neighbours, to residents of Vihiga Township, to Vihiga Dairy Co-operative Society and to the Asian community from Kisumu which comes to collect milk.

Mr. and Mrs Khwalwale have been very useful in extending Napier grass and dairy technology to other farmers. They often educate other farmers through National Broadcasting Media by participating in Farmers Education Radio Broadcasting Forums such as "Chakula kwa taifa"- Food for the Nation. Many farmers and scholars have visited and have been able to learn much from them. They have also participated in the Kenya Agricultural Shows where they have taken their animals for display and used their animals to discuss various livestock technologies including Napier grass management. Figure 10 shows Mr. Khwalwale (farmer in a cap) displaying one of his Friesian dairy animals in the Western Region Agricultural Show, which was attended by the former Head of State, President Daniel Arap Moi (in blue suit) as the president was being taken around by the author (in white overall) to inspect the livestock parade in the show ground.

Figure 10. Mr. Khwalwale displaying his well-fed Friesian dairy cow (judged as champion) at the Agricultural Society of Kenya livestock parade inspected by the former President of Kenya.

Mr. Khwalwale's son John Akidiva has been keenly leaning from his parents and has two dairy cattle producing a total of 25 litres of milk per day from his 0.2 ha of Napier grass.

FARMER 2

Mrs Okido Ratemo lives in Sunuka division of Kisii District on a farm of one third of an hectare. The farm is zero-grazed with seven head of dairy cattle (5 milking cows and 2 heifers). There are also many dairy goats most of which are in milk and are also kept under zero grazing (**Figure 11**). They also grow horticultural crops mainly vegetables and bananas, plus some fodder trees such as calliandra and mulberry which are used as feed for the dairy animals.

Figure 11. Dairy cattle and goats feeding on chopped Napier grass and resting in a zero grazing unit

Mrs Okido Ratemo indicates that "we have another separate parcel of land, which we

bought later, which is about 0.8 ha where we grow Napier grass, which is the main feed for our dairy animals. We cut the Napier grass when it is about 1 metre high, chop it together with the fodder trees and feed our dairy animals. We supplement this with other grasses, weeds, banana pseudostems and other farm by-products, particularly during the dry season. During milking, we use dairy meal, which we purchase from shops. We also make our own homemade concentrates from maize meal, cotton seed cake, sunflower and salt. The slurry and dung from our zero-grazing unit is channelled to our biogas unit where it is digested to produce methane gas for our domestic use (lighting and cooking) (**Figure 12**). The slurry from the bio-digester is collected in drums and other containers and taken to fertilize our Napier grass fields and also some is left to flow by gradient to the horticultural garden and to the crops grown within the homestead".

Figure12. Mrs Okido shows her biogas unit that produces methane for her cooking and lighting and slurry for fertilizing crops

"We strongly believe that there is no fodder crop better than Napier grass, which can be used as livestock feed. Napier grass is important to us because it produces a lot of herbage for our dairy animals. Depending on the way Napier grass is planted and managed, it can be more productive for it has potential to increase in yield with increased doses of commercial fertilizer and manure. We used to grow Napier grass using the "conventional" method but nowadays we prefer growing it using the "Tumbukiza" method because this is much more productive and higher yielding than the conventional method. When grown in trenches (furrows) using the tumbukiza method it produce more than double the amount of herbage. We have also compared the yield of Napier grass planted in Tumbukiza pits with the yield in Tumbukiza trenches and found that trenches are more productive and yield higher than pits (**Figure 13**). Also, growing it in trenches is better than growing it in pits, because cutting and harvesting are cumbersome and difficult in pits compared with trenches".

Figure 13. Mrs Okido discusses the various methods of Napier grass establishment and compares yields when grown by conventional method (left) and by the Tumbukiza methods in pits and in trenches (right).

"Also, fertilizing Napier grass after harvesting is easier when it is grown in trenches than in pits. Slurry is poured continuously in the trench and this is easier than pouring slurry in every Tumbukiza pit. We also found out that there is less wastage of land when grass is planted continuously in trenches than when it is planted in pits. Harvesting from one

continuous trench produces forage to fill one pick up, but to get a similar amount from pits we would to harvest grass from several pits covering a wider area of land. It was also noted that during prolonged periods of drought, moisture conservation was better in trenches than in pits and the Napier grass in trenches remained greener and healthier for longer periods; in general grass grown using the conventional method was much more stressed with prolonged drought than when grown by the Tumbukiza method. It was also evident to us that damage to the grass by moles is much less in tumbukiza than in conventional plots.

Before planting, we ploughed the fields and removing all the couch grass and then using the conventional method we planted one Napier grass stem cutting in every hole dug 15-20cm deep at a spacing of one metre between rows and a half a metre within rows; a handful of farmyard manure was placed in each hole when planting. When using Tumbukiza methods, we first ploughed the fields then dug the pits and trenches; pits were about 60cm deep, 60cm in diameter with a spacing of 60cm separating each pit and 1 metre inter row spacing. We also dug trenches, which were also 60cm deep, 60cm wide, and with 90 cm separating one trench from the other; the trenches were dug the whole length of our farm. We separated topsoil from subsoil from both pits and trenches and used the topsoil to mix with farmyard manure at a ratio of 1:2 topsoil: manure, filling the pits and trenches 3/4 full with the topsoil-manure mixture and left them to settle until the onset of the rainy season when we planted several Napier grass cuttings (5-10) in each pit or at every ½ metre in the trench. We also planted sweet potatoes on the bench terraces of the Tumbukiza holes or trenches particularly during the initial Napier grass establishment. Whenever we harvest Napier grass we weed the plot and apply slurry to fertilize the re-growth. At cutting we leave a stubble height of 10-15cm (from the soil surface).

During a prolonged dry season we normally have a feed shortage and have to buy additional Napier grass from our neighbouring smallholder farmers who grow purely for sale. Also, some farmers grow Napier grass as a soil conservation measure on the terraces of their hilly and sloping farms and sell the grown grass to livestock farmers. During the rainy season, we normally have some excess of Napier grass which could be conserved in the form of silage for dry season feeding, however, although we presently don't conserve feed we are aware of the technology and we plan to try it in future".

FARMER 3

Purity and Stanley Gachogo of Ngindo Division in Embu District are a wife and husband who depend on dairy farming to feed their family. They have a 1.6 ha farm on which about 0.6 ha are Napier grass for their livestock. "We have six mature dairy cows in milk, two heifers and many dairy goats that mainly depend on Napier grass as livestock feed. We have three equal portions of Napier grass of about 0.2 ha each; the first portion was planted in 1990 and the latest in 1997. Napier grass is able to remain productive for a long time depending on the way it is managed. We never apply commercial fertilizers like DAP or CAN to our Napier grass but instead we use slurry, which is a mixture of cattle faeces and urine from the zero-grazing unit; there is a channel, which leads cows' urine into a covered pit and before we use the slurry in the pit we stir it and then carry it to the Napier grass field (Figure 14).


Figure 14. (left) Purity stirs slurry in the collecting pit of the zero grazing units while (left and right) Stanley collects slurry from the pit into buckets ready to transport it to the farm.

After every Napier grass harvest, we weed the plots, make furrows between the grass rows and pour the slurry and cover it (**Figure 15**); the nutrients from the slurry are then easily absorbed by the grass roots and it grows faster, greener and is more productive".


Figure 15. (left) Purity weeds the Napier and makes furrows while (right) Stanley pours slurry in the furrows as Purity watches and will then coverthe slurry in the furrows with soil.

"The portion of Napier grass that we planted in 1990 is still highly productive and is as productive as the ones planted in 1997. Normally as we weed the Napier grass and make furrows between the plots for the slurry, we remove any dead Napier grass stumps and those that have spread to cover the inter-rows. We only leave the healthy plants in the stumps to maintain the original row spacing; with this and with regular fertilization, the grass remains healthy and productive for many years. We have also planted many species of fodder trees and shrubs and other herbaceous legumes along the terraces, along the boundary fence of our farm, along the fences separating paddocks and along the pathways leading to and separating our homestead (**Figure 16**). All these fodder and herbaceous leguminous species are cut and chopped together with Napier grass and fed to the dairy animals. We have several species of *Leucaena, Calliandra, Sesbania, Gliricidia,* Mulberry and D*esmodium* planted to provide additional feed for our livestock.

Figure 16. Leguminous fodder trees and shrubs grown along the farm fences being harvested for animal feed.

Mulberry leaves are good for livestock digestion and when we feed our dairy animals with fodder trees, we add mulberry leaves to the feed. Normally fodder trees are not totally digestible because they have tannins, but we believe that mulberry leaves reduces tannin content and thus makes fodder trees to be easily and 100 percent digestible. We have planted the following species of *leucaena* namely *L. pallida, L. trichandra, L. leucocephala* and *L. collinsii*. Of all the species of *leucaena* and indeed all other fodder trees, *L. leucocephala* is the most popular fodder tree; the major and unfortunate problem is that this species of fodder tree is attacked by *leucaena psyllids*, which has wiped out most of the trees in this farm and in other farmers fields. There are small insects which fly from tree to tree sucking sap from *Leucaena leucocephala* leaves causing the trees to dry and die. Although Napier grass is the main crop in the farm (**Figure 17**), we also have some coffee, medicinal trees, bananas and other horticultural crops planted in the farm".

Figure 17. Purity and Stanley show the various portions of their land occupied by Napier grass and fodder trees and shrubs that will be harvested for dairy feed.

"The three portions of the field each provide feed for one month for our animals. We rotate so that after one month of feeding on one portion, we move to the second portion of the field and then to the third portion. This rotation ensures that we have adequate Napier grass to last for 10 months of the year during the normal rainy season. During the two driest months of the year, January and February, we normally experience a shortage of grass, so we purchase Napier grass from neighbouring farmers. Most farmers in Embu grow Napier grass and some grow it purely for sale. Also farmers who own land on slopes grow Napier grass along the terraces for soil conservation and erosion control and the grass is sold to livestock farmers. Grass may be sold in terms of "back loads" or in terms of area, which is negotiated and agreed with the owner. A back load is a heap of Napier grass cut and tied together, which can be carried by a strong person (mainly women) or using a bicycle (**Figure 18**). We normally pay 15-20 Ksh for each back load and we would purchase 6 back loads (equivalent to 3 ½ large

wheelbarrows full) of Napier grass per day to feed our dairy animals. We also go round to identify farmers with good Napier grass for sale and then hire the Napier grass from the farmers. We assess the quantity and quality of the Napier grass in the field before hiring it, if the Napier grass is able to feed all our dairy animals for three weeks or one month, we normally pay about two to three thousand Kenya shillings for the harvest.

Normally the quality of Napier grass during the peak of the dry season is not high so we argue with owners of the field to reduce the cost accordingly and then make our own arrangements for cutting and transporting the grass on a daily basis".

Figure 18. Farmer carrying purchased Napier grass on a bicycle

"Napier grass is much more profitable than growing food crops such as maize or cash crops like coffee. Prior to planting Napier grass in 1997 we used to grow maize on this land and we would harvest about 4-5 bags of 90kg of shelled maize during the main growing season lasting 5-6 months. We also grew a short rains crop and harvested two additional bags. So in the whole year we would harvest six to seven bags of maize which were worth seven thousand Kenya shillings at a rate of one thousand per bag, so this portion of land would produce about seven thousand shillings per year when grown with maize. This same portion of land is producing much more when planted with Napier grass: we are able to harvest Napier grass every 6-8 weeks during the rainy season which means that in one year we are able to get 6-8 harvests from this plot; as the harvested grass can feed all of our dairy animals for one month and during our highest peak production of milk one animal can produce milk worth three thousand Kenya Shillings per week, then for the one month we feed the animals on this portion of land we are able to receive twelve thousand (12,000/=) Kenya Shillings from that one animal. If we have three animals producing well we are able to get thirty-six thousand Kenya Shillings from milk for that one month in a single harvest of this Napier grass. Considering the number of harvests we make in a year from this portion of land then if we harvest every third month, we can make a conservative four harvests per year which would earn us over Kshs.100, 000 in milk as compared to Kshs. 7,000 for maize. So you can see that we are convinced that Napier grass is much more profitable than planting maize. We also note that apart from getting money from milk, there is additional value from dung and from the calves that are born and raised as heifers and we also get slurry for fertilizing our crops and can make rich compost manure mainly from the dung and the remains of Napier grass and legumes collected from the zero grazing unit.

Napier grass is even much more profitable than coffee which is normally considered as the main cash crop in this region. We used to have 630 trees of coffee but when we learned about dairy farming we had to uproot some of them and use the land to grow Napier grass. Previously we had purchased Napier grass on a daily basis to feed our one cow. We then compared the amount of money we used to get from milk from that cow and then deducted the amount of money we used to pay for the Napier grass feed. We realized that the area of Napier grass we used to cut from our neighbour to feed our one dairy cow was equivalent to the area on which we planted ten stems of coffee which produced comparatively less money. So we decided to uproot the coffee stems to plant our own Napier grass and save money on feed; also we soon realized that the amount of money we received from coffee was so little and in most cases we received no money because of the lack of a foreign market for coffee. Planting Napier grass is the answer to that problem because there is a high milk demand in this district and in Kenya as a whole. Coffee prices went so low that we would get only as much as Kshs. Fifty (shs.50/=) for every coffee plant picked. When comparing the production of one coffee

tree with a stump of Napier grass, we find that on average one stump of Napier grass planted using convectional method when cut and fed to a high yielding dairy cow can produce three bottles of milk per day (a bottle of milk is 0.75litres). Each bottle of milk costs a minimum of ten Kenya shillings (10/=) which means that every stump of Napier grass produces thirty Kenya shillings (30/=); so in a year when this stump is cut about six times, it can produce one hundred and eighty Kenya shillings (180/=) which is much more than the fifty Kenya shillings, we would get from each coffee tree. Besides, the land area occupied by one Napier grass stump at the normal spacing of 1m x 0.5m spacing is much less that the land space occupied by one coffee tree.

On average we harvest about 60 stumps from an area of about $25m^2$ for feed for one day for our dairy herd of six mature animals and wo heifers (8 cattle + some goats). On average one stump of Napier grass harvested at the correct height of growth weighs five-kilogram fresh weight; so on average we harvest about 300kg daily fresh weight. We also harvest fodder trees which we add to the Napier grass in the ratio of 1:3 fodder tree to Napier grass i.e. we harvest about 100 kg of fodder tree per day. The total fresh weight feed used by our dairy animals is approximately 400kg, which works out to be approximately 55-60kg of fresh material per mature dairy animal per day. The fresh weight could be a bit lower during the dry season and higher during the wet season because of variation in the moisture content of the material. We chop the grass/fodder shrubs mixture using a kerosene driven chaff cutter (**Figure 19**) and this high quality feed is offered to the animals *ad libitum* and in addition the animals may be given some other feeds such as banana psendostems and other farm by-products. The Napier grass and fodder tree mixture is also fed to our dairy goats, which produce about 3-5 litres of milk per day.

Figure 19. (left) Purity feeds Napier grass/forage legume mixture into the motorized chaff cutter while (right) the author inspects the finely chopped forage material which is ready for use

We do not purchase concentrates like dairy meal from the shops but instead we use our own home made concentrates as supplementary feeds for our milking animals. We mainly use *calliandra* leaves, which we dry in the shade and store at room temperature; then we mix 1½ kg of dried *calliandra* with 45kg of wheat bran and add 1kg of fish meal and 1kg of cotton seed cake and offer 3kg of this concentrate per milking cow during every milking. We also offer this concentrate to cows which are about to calve".

FARMER 4

Mr and Mrs Muriuki Tera live in Gatituri in the central division of Meru district with their family on a 1.2 ha mixed farm, in which they have planted coffee, Napier grass, fodder trees and shrubs, and horticultural crops such as bananas and chillies. "The farm is on the slopes running down to the river and we planted some Napier grass and fodder trees, mostly *calliandra,* on terraces across the slopes, both for feed and soil conservation. The grass we planted in 1989 using conventional methods on about 0.1 ha is now 15 years old; we also have grass on four bench terraces covering another 0.1 ha which was planted in 1994; so altogether we have 0.2 ha of Napier grass. Most of the

farm is under coffee and we used to be one of the best coffee farms in this region when coffee farming was famous and paying well. However, Kenya coffee farming has now declined to a level where we no longer have any income from our coffee. In addition we kept dairy cattle in a zero-grazing unit from which we got a good amount of money from milk, which complemented money from coffee in paying school fees and for our family subsistence and maintenance. Since we put the zero grazing unit at the upper section our farm next to our homestead, we made channels that led slurry to the Napier grass field downslope to fertilize the Napier grass field where production was very high, much higher than what we have currently because we do not use any form of fertilization on the Napier grass. The Napier grass is still doing well due to the residual fertilizers and also because it is located down slope receiving fertility from the nutrients being washed down from the upper part of the farm.

When we could get no income from our coffee plants and had to depend on dairy farming entirely, we reached a point where we could not pay for the increased school fees from the milk revenue. Therefore we had to sell our dairy cows to pay for school fees and to maintain the family. We continue to sell Napier grass and fodder legumes in order to continue raising school fees and to maintain our family. Most of our children have now gone through school except the last born who is finishing high school this year. We sell Napier grass to a livestock farmer on contract and he pays us five thousand Ksh. for every harvest he makes of the whole amount of Napier grass (about 0.2 ha) and fodder shrubs planted on the terraces. He cuts four times in a year and the income from the Napier grass has been able to sustain the family in food and pay for school fees. At the moment I prefer selling Napier grass on contract to farmers who have a large number of dairy cows because such livestock farmers are able to harvest the whole Napier grass farm within a short time to give the Napier grass time to re-grow for the next harvest. Some other farmers sell their Napier grass on the basis of heaps or back loads or in terms of pick up loads. One ton pick up load of Napier grass may be sold for five hundred Kenya shillings (Ksh. 500/=). We plan that when we finish paying for the third term's school fees for our last born child, we shall start saving and by early next year we shall be able to buy a dairy cow. We also plan to uproot most of our coffee trees and replace them with both Napier grass and some bananas. This will enable us to develop our dairy production. We like dairying because it pays better than crops, particularly coffee or maize. We used to grow maize on the 0.1 ha currently under Napier grass and harvested one bag of maize during the main maize growing season and hardly a bag during the short growing season. A 90 kg bag of shelled maize gave us one thousand Kenya shillings. From the four Napier grass harvests which we get without using any fertilizer, we are able to earn ten (10) thousand Kenya shillings per year from the 0.1 ha which we had grown by conventional methods. We are therefore able to buy five bags of maize and keep it for our family use for most of the year from the grass harvests. In addition the role of Napier grass as a soil conservation measure along the terraces is very important to us (Figure 20). Before we planted the Napier grass on the sloping farm, most of the soil used to be eroded, but now with the Napier grass forming barriers along the slopes there is no soil erosion and we are able to plant other crops such as chillies which earn us additional funds for family needs".

Figure 20. Mr Muriuki discusses the importance of Napier grass as a cash crop and as a soil conservation measure. He has grown Napier grass along the slopes to form protecting belts with chillies as the main crop on the bench terraces.

FARMER 5

Katana Mashia farm is located in Bomani, Kikambala division of Kilifi District of the coast province it is a 4.8 ha family farm for Katana Mashia and the families of his three sons. Although most of the farm is under coconuts, 2.8 ha are under livestock and fodder production with the rest under both food and cash crops. Napier grass is planted in various fields so that during the rainy season there is always grass ready to be harvested; under coconuts the grass is in alleys between the 10 metres apart coconut rows and where there are no coconuts the grass is planted in alleys between Leucaena and/or Gliricidia hedges which are 5 metres apart. The wide coconut and fodder tree row spacings allow for easy land preparation using a tractor or ox plough and planting Napier grass using the conventional method with manure or slurry and in places intercropping with the herbaceous legume butterfly pea, which produces a fodder high in protein and energy. The legume also acts as a cover crop to maintain soil moisture, recycles nitrogen through fixation and thus improves soil fertility, results in fewer gaps in the Napier grass and produces more forage than when the grass is grown alone. Establishing the grass in alleys between fodder tree hedgerows has the advantage that both can be harvested together and fed to the dairy animals. In most cases fodder trees are cut at a height of half a metre and will re-grow vigorously; however, some are left so that they can provide poles and firewood. Napier grass is the main fodder and is cut when about 1 metre tall, leaving a stubble of 10cm, after which the fields are weeded and slurry and manure applied in furrows, which are made between grass rows and covered after the slurry application. During the hot rainy season grass production is high and can be cut almost monthly, but during the dry season is cut after every two months or even longer.

Unlike many farmers, Katana Mashia harvests excess grass during the rainy season and makes silage (especially when the long rainy season is almost over): the grass is either chopped using a chaff cutter or laid in sheaves in a large slanting pit (silo) dug into the sandy soil, mixed with crushed sugarcane or molasses from a sugar factory, tightly compacted and covered with polythene sheet to make silage or "grass gem" as they call it; this provides a good fodder supplement during the dry season. The silage made can be kept for 3 months or more before it is used during dry periods; in fact well-made silage can be kept for even 2-3 years.

The farmer has 10 mature dairy milking cows and two heifers that are mainly Friesian, Ayrshire or Guernsey breeds and crosses, under zero-grazing. Each mature animal needs approximately 50 kg of freshly cut Napier grass per day mixed with about 1/3 weight of legumes and then finely chopped with a chaff cutter; this is supplemented with other feeds such as mineral salts, maize germ which is bought and fed at a rate of 4 kg per animal when milking, crop by-products (including maize cobs, maize stalk, bean husks and banana pseudostems), and green grass [mainly Rhodes (*Chloris gayana*)] and natural pastures [mainly *Panicum* spp.] harvested from neighbouring farms particularly during dry seasons. Occasionally the farm experiences an exceptionally prolonged dry season of over 4 months when Napier grass completely dries up particularly on sandy soils that have not been improved with cattle manure and slurry and then he uses his silage and also improved and natural pastures from his farm or which he purchases from neighbouring farms; natural pastures can be purchased for thirty (30/=) Kenya shillings per full oxen-cart and he needs 4 cart loads per day (see Figure 21c). The fodder legumes/trees normally better tolerate the dry periods because of their deeper rooting systems. Any left over feed is composted.

Cows produce on average 15 litres of milk per day and with his 10 milking cows he is able to employ many people around the farm; jobs include: attending to and feeding the cattle, cutting grass and cleaning out and spreading manure (on the grass and other cash and food crops), as well as three young men taking care of the milk sales. The farm produces almost 100 litres of milk to spare each day once the four families on the farm have had their share. Some of the milk is sold at twenty-five shillings (25/=) per litre to milk vendors who then sell it for up to forty shillings (40/=) per litre in urban centres. The rest of the milk is loaded into churns and taken by bicycle to sell door to door to families near the highway and in the nearby Mtwapa township. In spite of what farmers regard as interference in milk marketing by large commercial businessmen who import cheap powdered milk and flood the market with milk, smallholder dairying is still very profitable since most people still prefer fresh milk and the demand remains high. Katana Mashia reckons that there is more money to be made by selling milk this way rather than selling it to the dairy co-operatives who pay approximately 60 cents per litre less. Even after the herdsmen, the foremen, the stable boys, the day labourers and milk boys have been paid, the farm still shows a profit. So the farm is doing well, the farmer is able to service his initial loan used to purchase the dairy animals, and has gone one to expand his dairy herd without having to use outside capital. He makes much more money from dairy cattle than from either cash or food crops. His major cash crops are

cashew nuts, mangoes and coconuts while his major food crops are maize, cassava, beans and horticultural crops.

Mr Katana Mashia's farm has been used as a demonstration farm to extend Napier grass technology to other farmers in the Coast province. Even scientists have been keen on visiting this farm to see how technologies developed are adapted by farmers. It is particularly useful as a reference farm for "Dairy cows under coconuts".

Figure 21a-d. Various activities on Katana Mashia's farm

(a) Napier grass being chopped

(b) Chopped Napier grass being fed to livestock

(c) Napier grass collected during prolonged period of drought

(d) Livestock feeding on dry natural grass during severe drought

FARMER 6

Mr Mukhwana Obbuyi and Mrs Majuma Mukhwana Obbuyi are smallholder mixed dairy and crop farmers living in Mtepeni, Kisingitini in Mtwapa, Kilifi district of Coast Province. They have three dairy cattle and goats that depend on Napier grass grown on their farm. They also grow beans, green grams, cassava, vegetables and maize, as well as cash crops such as coconut, cashew nuts, mango, lemons and bananas. "Napier grass is the most important fodder which we grow using conventional methods; it performs very well during the rainy season and we depend on it as the major dairy feed, mixing it with leaves from Leucaena and Gliricidia trees and shrubs. When well established and managed it remains productive for many years, but does not persist well under prolonged drought of more than 5 months such as we experienced this year. We are now in mid May 2004 and yet we have no rains since late last year; even then we had much below average rainfall last year. This has resulted in most of our Napier grass drying up except for those growing in deep fertile soils with better water retention ability; we plan to re-establish our Napier grass fields as soon as the rains come, but we were expecting the long rains by mid March and to-date we are still hopeful they will come. Such prolonged droughts are not common, but they are expected once every ten years in the Kenya Coastal region. We now depend on dry natural grasses growing on isolated areas with fertile soil and better water retention; we collect the grass or graze our animals on these natural grasses to sustain our dairy animals in a semi-zero grazing system, but also feed Leucaena and Gliricidia that we have grown as well as maize bran, chicken mash and any other concentrates that we are able to purchase.

Dairy production is much more profitable than food or cash crops in our farm; cash crops like coconuts, cashew nuts, lemons and mango trees take a long time to mature and become productive, but even when they are mature they bear fruits seasonally and what we get annually from them cannot compare with what we get cumulatively from the milk yields. Milk from this one dairy animal (Figure 22) has been used to pay school fees for our children through primary and secondary school and college and has also provided cash to purchase our daily needs. Even during the drought period when the crops are barren, we still get some milk from our animals. We depend on dairy since we are both retired civil servants and even when we were still in service, money received on a daily basis from our dairy animals used to keep us until the end of the month before we got our salaries.

Figure 22. Mr and Mrs Mukhwana Obbuyi with one of their dairy animals under semi-zero grazing management

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