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Economic Importance and Production Constraints of Napier (*Cenchrus purpureus)* Grass in Africa (Review)

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Abstract **– Napier grass, scientifically known as Cenchrus purpureus and commonly referred to as elephant grass, plays a significant role in the agricultural and industrial sectors in Africa. This review provides an overview of the economic importance of Napier grass and highlights its various applications, including its use as a fodder crop in smallholder farming systems, a raw material in the pulp and paper industry, a source of biofuel for renewable energy production, and as a phytoremediator plant for combating environmental pollution, particularly heavy metals. Additionally, the grass is utilized in 'pull-push' insect pest management strategies. Despite its invasive characteristics impacting native flora, Napier grass also serves as a natural barrier against soil erosion. However, the production of Napier grass faces certain constraints, such as the prevalence of diseases like Napier grass head smut and stunt diseases. This review aims to provide a comprehensive understanding of the multifaceted uses of Napier grass and shed light on the challenges associated with its cultivation.**

Keywords **– Elephant Grass, Forage, Phytoremediation, Head Smut, Abiotic Stress.**

I. Introduction

Napier grass (Cenchrus purpureus (Schumach) Morrone syn. Pennisetum purpureus Schumach.) is a monocotyledonous, perennial, C4 grass [1, 2] that originated in sub-Saharan Africa and is now widely cultivated across tropical and subtropical regions of the world [3]. It is a summer growing flexible plant species that can survive and grow in broad range of environmental conditions from sea level up to an altitude of 2500m. Although it produces numerous seeds with good germination capacity, its reproduction behavior as an allogamous plant makes seed propagation not recommended. Instead, it is mostly propagated vegetatively by stem cuttings with at least three nodes, two of which are buried in soil [4].

Even though, it has a lot of economic importance it is widely cultivated as forage crop for its ease of establishment and management system, high palatability, high crude protein content, high tillering, and significant dry matter yield that reach up to 78 tons of dry matter/ha/year [1, 2, 5]. Because of its high cellulose content, Napier grass has the potential to produce biofuels such as alcohols, enthan, butanol, and methane [6, 7]. Furthermore, it is regarded as a potential phytoremediator plant for dealing with heavy metal and chemical environmental pollutions [8].

Further to that, some Napier grass cultivars were identified as potential plants in a "pull-push repulsive insect pest management strategy" to trap the African stem borer, *Busseola fusca Fuller* (*Lepidoptera: Noctuidae*), an insect that causes maize and sorghum production loss [9]. Moreover, it aids in the prevention of soil erosion and degradation [10]. Napier grass also used as a feedstock in pulp and paper production sectors [11, 12]. Napier grasses improve soil fertility, and protect arid land from soil erosion [13]. In addition, to these Napier grass can be used as a firebreak to prevent the spread of wildfires, and it can also be used as a Windbreak to protect crops and other vegetation from wind damage [14].

Despite its many benefits, Napier grass faces several production constraints that can impact its use in various sectors. However, through the development and implementation of effective management strategies, these constraints can be addressed, and the full potential of Napier grass can be realized [15].

II. Economical Values of Napier Grass

2.1. *Napier Grass as Froge Crop*

2.1.1. *AS Fresh/Cut and Carry*

Napier grass holds significant value as a forage crop, particularly within smallholder farming communities in Eastern and Central Africa. It is commonly utilized in a fresh form through a cut-and-carry system [1, 16, 17]. To minimize the animal's selective feeding on leaves and stems, the grass can be manually or mechanically chopped prior to feeding. An additional step that proves beneficial is wilting the chopped grass in the sun for several hours. This process reduces moisture content, stimulates the animal's appetite, encourages rumination, and ultimately enhances the utilization of the forage [18].

According to Orodho [19], the first harvest of Napier grass in a cut and carry feeding system should occur when it reaches a height of 1-1.2 meters, typically three to four months after planting. This stage is characterized by high-quality grass with adequate dry matter content.

Subsequent harvests should be scheduled when the grass reaches the same height every six to eight weeks. However, the frequency of harvesting depends on various factors, including the grass variety, growth capacity, weather conditions, soil fertility, management practices, and livestock requirements, all of which play a significant role [19].

In hot and humid environments, such as the coast, it is recommended to harvest the grass every month if well managed. Conversely, during the dry season, a harvest interval of every two months is advised [19].

2.1.2. *Pasture*

According to Mureithi *et al.* [15], for optimal utilization of elephant grass as pasture, it is recommended to practice heavy grazing. This ensures that the majority of the young leaves and shoots, which possess the highest nutritive value, are made available to ruminants. Grazing should be carried out every 6-9 weeks, maintaining a height of approximately 90 cm, as this has been shown to result in improved grass utilization.

In regions with high rainfall, it is advisable to apply nitrogen after each grazing or cutting to enhance grass productivity [20]. Additionally, it is recommended to mow grassy, leafless stems to maintain the quality of the pasture.

2.1.3. *Hay and Dry Grass*

Napier grass holds great potential as a highly productive forage crop for hay and dry grass production. To ensure optimal hay quality, it is recommended to cut elephant grass at an early stage of maturity, typically when it reaches a height of 1.5-2 meters and has 4-6 leaves [15]. At this stage, the stems are still tender, and the leaves are abundant in nutrients. Delaying the cutting process can result in coarse and fibrous stems, which adversely a-

-ffects the overall hay quality.

Once the grass is harvested, it can be dried using either natural sun drying or mechanical dryers. In some regions, such as Taiwan, Napier grass is processed into dehydrated grass pellets, which serve as supplementary stock feed [20]. It is important to carefully manage the drying process to avoid over-drying or under-drying, as these conditions can compromise the nutritional value and palatability of the hay.

2.1.4. *Silage*

When harvested at its peak water-soluble carbohydrate (WSC) concentration, elephant grass can be processed into silage of high quality [20]. However, the ensiling process of elephant grass is hindered by its high cell wall content and low WSC concentration, leading to undesirable fermentation and significant nutrient losses [21]. Nevertheless, recent research has indicated successful silage production of specific cultivars of elephant grass, such as BRS Capiacu, in various regions of Brazil [22]. This particular cultivar has been specifically bred to address the challenges associated with ensiling elephant grass. It exhibits an elevated WSC concentration and reduced cell wall content, resulting in improved fermentation and better retention of nutrients.

Therefore, although the high moisture content of elephant grass may present obstacles to its use as silage, the development of new cultivars and the implementation of improved management practices offer potential solutions to overcome these challenges and maximize the nutritional value of elephant grass silage.

2.2. *Napier Grass as Second Generation Energy Crop*

2.2.1. *Ethanol Production from Napier Grass: Cultivars and Bioconversion Processes*

Ethanol, one of the world's most widely used liquid biofuels, has gained significant interest in recent years. The transition from sugar-based to second-generation, lignocellulosic-based production has been driven by the abundance of non-edible raw materials. Napier grass, a tropical fodder, has emerged as a promising energy crop for ethanol production due to its high cellulose concentration [23]. This article aims to provide a comprehensive overview of ethanol production from Napier grass, focusing on cultivars suitable for ethanol production and the bioconversion processes involved.

Napier Grass Cultivars for Ethanol Production:

Several Napier grass cultivars have shown promise for ethanol production. These cultivars possess desirable traits such as high biomass yield, high cellulose and hemicellulose content, good sugar content, fermentability, and resistance to pests and diseases. Notable cultivars include:

Pusa Giant: This cultivar is known for its high biomass yield and cellulose content, making it a suitable candidate for bioethanol production. It also exhibits high sugar content and good fermentability [24, 25].

Bana grass: With its high cellulose and hemicellulose content, along with good fermentability, Bana grass holds promise as a feedstock for bioethanol production [25].

Kakamega 1: This cultivar demonstrates high biomass yield and good sugar content, which can be easily converted to ethanol. Additionally, it exhibits resistance to pests and diseases, contributing to improved sustainability [26].

Clone 13: This Napier grass clone exhibits high cellulose and hemicellulose content, as well as good ferment-

-ability, making it a potential feedstock for bioethanol production [25].

In addition to these specific cultivars, desirable traits for Napier grass intended for ethanol production include high cellulose and hemicellulose content, high sugar content, and ease of hydrolysis. These traits significantly impact the efficiency of the bioconversion process and the yield of bioethanol. Therefore, selecting cultivars with these traits can enhance the overall efficiency and sustainability of bioethanol production from Napier grass.

Bioconversion Processes:

The production of bioethanol from Napier grass involves two main processes: hydrolysis and fermentation. Various methods have been employed for hydrolysis, including enzymatic, acid, and base hydrolysis. Researchers have explored different pretreatment methods and ethanol production processes with specific yeast strains to achieve optimal ethanol yields. For instance, Kongkeitkajorn, Sae-Kuay, and Reungsang [23] obtained high ethanol yields by utilizing various pretreatment methods and ethanol production processes with Saccharomyces cerevisiae and Scheffersomyces shehatae, a xylose-fermenting yeast. On other hand, Tsai *et al*. [27] found that Napier grass has the potential to be transformed into ethanol through a process known as simultaneous saccharification and fermentation (SSF). This process involves the utilization of dried yeast (*S. cerevisiae*) and cellulase (CTec2) to convert the Napier grass into ethanol after undergoing pretreatment with an alkaline solution.

2.2.2. *Napier Grass: Feedstock for Biogas and Methane Production*

Napier grass, in addition to its potential for ethanol production, holds promise as a feedstock for biogas and methane production. Biogas, a renewable energy source, is produced through the anaerobic digestion of organic materials. Napier grass exhibits several characteristics that make it suitable for biogas production, including its high biomass yield, nutrient content, and compatibility with cow dung from cattle fed on Napier grass [23]. Napier grass has a high biomass yield, making it an abundant and readily available source of organic material for biogas production [23]. Its rapid growth and ability to regenerate quickly contribute to its suitability as a feedstock. Moreover, Napier grass has a favorable nutrient composition, containing significant amounts of cellulose and hemicellulose. These components can be efficiently converted into biogas during the anaerobic digestion process [23]. One unique advantage of Napier grass is its compatibility with cow dung from cattle fed on Napier grass. Combining Napier grass with cow dung as a co-substrate for biogas production enhances the nutrient content and overall biogas yield. The fibrous nature of Napier grass complements the high nitrogen content of cow dung, creating an optimal substrate for biogas production [23].

The utilization of Napier grass for biogas production offers environmental benefits as well. By diverting organic waste, such as cow dung and agricultural residues, from landfills and utilizing them as feedstock for biogas production, greenhouse gas emissions can be reduced. Biogas production also helps mitigate odor issues associated with organic waste disposal [23].

Furthermore, Napier grass, as a lignocellulosic biomass, is a valuable renewable raw material for bioenergy production. It contains sugars like pentose (C5) and hexose (C6) that can be converted into liquid or gas fuels [28]. Napier grass has a high potential for biogas production due to its low cost and abundance [28]. The grass is composed of cellulose, hemicellulose, and lignin, with cellulose and hemicellulose being fermentable sugars th-

-at can generate renewable energy through microbial processes.

Various pretreatment methods have been used to increase methane yields from Napier grass by decomposing lignin and facilitating the processing of cellulose and hemicellulose. One effective pretreatment method is microwave acid pretreatment, which offers simplicity, speed, economy, and efficiency [29]. This method degrades lignin and hemicellulose in Napier grass, resulting in a cellulose-rich solid fraction that can be hydrolyzed to glucose and converted to methane through anaerobic digestion [29].

Studies have shown that the highest methane yield can be obtained from the hydrolysate and solid fraction of microwave acid-pretreated Napier grass co-digested with swine manure [30]. This highlights the potential of Napier grass as a co-substrate for biogas production in combination with other organic waste materials.

Generally, Napier grass exhibits several characteristics that make it a versatile feedstock for biogas and methane production. Its high biomass yield, favorable nutrient content, and compatibility with cow dung contribute to its potential as a valuable resource for renewable energy generation. By harnessing the energy potential of Napier grass through biogas production, we can not only obtain a sustainable energy source but also reduce waste and mitigate greenhouse gas emissions.

2.3. *Napier Grass in Pulp and Paper Industry*

The scarcity of conventional raw materials for pulp and paper products, coupled with the increasing global demand for paper, has renewed interest in non-wood fibers [31]. Among the biomass crops evaluated for their pulp production potential, Elephant grass and hybrid pennisetum (Cenchrus purpureus Schum. cv. SDPN3) as well as switchgrass (Panicum virgatum L.) have shown promise [32].

Studies have revealed the chemical composition and pulp characteristics of Elephant grass and switchgrass. Elephant grass possesses 45.6 percent cellulose and 17.7 percent Klasson lignin, while Switchgrass exhibits values of 41.2 percent cellulose and 23.89 percent lignin [11]. Both Elephant grass and switchgrass demonstrate suitable pulp yields after a mild kraft process, with associated kappa values and fiber lengths varying between the two [11]. Elephant grass has higher pulp freeness and burst index compared to switchgrass, making it suitable for pulp production [11].

Napier grass, has gained attention in the pulp and paper industry as a potential raw material due to its desirable properties [34]. Several cultivars of Napier grass have been identified for their suitability in pulp and paper production. One notable cultivar is Bana grass (Pennisetum purpureus cv. Bana grass), which is recognized for its high biomass production and excellent fiber quality. Bana grass exhibits a high cellulose content and favorable fiber length and strength properties [12]. Another Napier grass cultivar, Merkeron grass, is valued for its high lignocellulosic content and favorable fiber characteristics. It has been found to have high cellulose and lignin content, making it suitable for pulp production [36]. Cultivar Kakamega, also shows potential for pulp and paper production. It possesses a high cellulose content and favorable fiber properties, contributing to good pulp yield and quality [36]. These selected Napier grass cultivars offer promising characteristics for the pulp and paper industry, such as high cellulose content, favorable fiber properties, and good pulp yield. They provide a sustainable alternative to conventional raw materials [34].

Furthermore, Elephant grass has been evaluated for its potential as a raw material for paper pulp production. It exhibits a high ash content and total extractives content, demonstrating its potential for pulp production [37].

The kraft process at specific kappa numbers has shown favorable results in terms of screened yield, bleachability, and viscosity for Elephant grass pulp [37].

Considering these findings, Napier grass, including cultivars such as Bana grass, Merkeron grass, and Kakamega grass, offer promising properties for the pulp and paper industry. Their favorable characteristics make them suitable alternatives to conventional raw materials, thereby contributing to sustainable pulp and paper production [34]. The increasing global demand for paper and the scarcity of conventional raw materials make the cultivation and utilization of Napier grass cultivars a viable solution for the industry [31].

2.4. *Phaytoremediation of Environmental Pollution*

Napier grass has several advantages as a phytoremediation plant, such as high biomass yield, fast growth rate, easy propagation, and tolerance to drought and salinity [2]. Napier grass can also absorb, bind, and stabilize heavy metals and other toxic elements in its tissues through phytoextraction, reducing the environmental risks of soil and water contamination [38].

Several studies have demonstrated the potential of Napier grass for phytoremediation of different heavy metals, such as Cd, Zn, Cr, Pb, and Cs. For example, Yang *et al.*, [39] evaluated the effect of three Napier grass varieties on phytoextraction of Cd- and Zn-contaminated cultivated soil under mowing and found that one variety (PG) removed up to 197.5 g ha-1 of Cd and 5023.9 g ha-1 of Zn in 180 days, which was comparable to hyperaccumulators. Mowing increased the biomass and metal uptake of Napier grass, and liquid extraction reduced the Cd and Zn contents in the stem and leaf below the limit for animal feed. Kang *et al.*, [40] suggested that Napier grass had a high potential for phytoremediation of Cs-137 from Cs-contaminated soil in Fukushima Prefecture, Japan, based on its high Cs uptake and translocation factor. Dey and Kumar [41] assessed the phytoremediation potential of Napier grass and Indian mustard (Brassica juncea) in tannery sludge and found that both plants accumulated heavy metals in the order Cr>Zn>Cu>Pb in different parts of their tissues. They also reported that Napier grass had the highest Zn uptake and a high Cr accumulating capacity.

Napier grass can also be used for phytostabilization and phytofiltration of contaminated soils and waters. Phytostabilization is the use of plants to immobilize contaminants in the soil or water by reducing their mobility or bioavailability. Phytofiltration is the use of plants to filter contaminants from water by adsorption or precipitation on plant surfaces or in plant tissues. For example, Mohammed et al. [42] investigated the effectiveness of Napier grass as a phytoremediator plant for lead-contaminated soil and found that it reduced the lead concentration in soil by 67% after six months. They also observed that Napier grass increased the organic matter, nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, zinc, copper, and boron contents in soil. Juel *et al.* [38] studied the phytoremediation potential of three varieties of rice (Oryza sativa) and Napier grass for phenol removal under hydroponic conditions with artificial wastewater and found that Napier grass removed 99% of phenol within 24 hours.

Therefore, Napier grass is a promising candidate for phytoremediation of various environmental pollutants due to its high productivity, adaptability, and metal accumulation capacity. However, more research is needed to identify the optimal varieties, cultivation practices, and harvesting methods for different contaminants and conditions.

2.5. *Environmental Impact of Napier Grass*

2.5.1. *Weed and Soil Erosion Control*

Elephant grass is a pioneer species that outcompetes weeds very effectively [20]. It has been used to control Imperata cylindrica in the Philippines [43, 44]. Elephant grass has been used as mulch (25 cm layer) in Nigeria for weed control, water storage, and reducing soil losses on slopes [45, 46]. Elephant grass grows a robust root system that may aid in the prevention of river bank erosion. It provides effective windbreaks for crops and houses when planted as hedgerows. It is used in agroforestry alley-cropping systems for erosion control and forage production [47].

2.5.2. *Biological Control Agent of Pests*

A 'push-pull' strategy is a cropping system that involves the cultivation of specific companion plants alongside the main crop. These companion plants release semiochemicals that repel insect pests from the main crop (the 'push' component) and attract them towards a trap crop (the 'pull' component) [48]. Implementing this system requires a comprehensive understanding of the chemical ecology of plant-insect interactions and the evaluation of candidate crops through field trials.

In the context of smallholder maize production in Kenya, the development of a push-pull system aimed at controlling cereal stemborers led to the discovery of certain intercrops that also suppressed Striga weed [9]. Lepidopteran stemborers and parasitic weeds like Striga pose significant challenges to cereal production in Africa, particularly for resource-constrained smallholder farmers who cannot afford expensive chemical control methods. The push-pull approach offers an integrated pest and weed management strategy that addresses these issues.

Plants emitting semiochemicals attractive to stemborer pests were selected as trap crops to divert pests away from the main crop. Napier grass was found to be highly attractive for egg-laying by stemborer pests, but it supported minimal survival of the pests' immature stages. On the other hand, intercrops like molasses grass (*Melinis minutiflora*) and forage legumes in the Desmodium genus exhibited repellent properties against stemborer pests [49]. Desmodium intercrops also suppressed *Striga hermonthica* through allelopathic mechanisms, as their root exudates contained flavonoid compounds that stimulated suicidal germination of Striga seeds and inhibited their attachment to host roots.

The companion crops not only provide valuable forage for livestock but also contribute to soil fertility and moisture retention. The push-pull system is advantageous as it utilizes locally available plants without relying on expensive external inputs, aligning well with traditional mixed cropping systems in Africa. This approach has been widely adopted by more than 30,000 smallholder farmers in East Africa, resulting in significant maize yield increases from 1 ton per hectare to 3.5 tons per hectare [9, 49].

Furthermore, Elephant grass, when combined with molasses grass or Desmodium spp., has shown potential as an effective biological control agent against the maize stemborer moth. The moth lays eggs on elephant grass after being pushed out of the field by molasses grass or Desmodium. When the larvae bore into the elephant grass, the plant produces a sticky liquid that kills most of the larvae. The surviving larvae are then attacked by Cotesia sesamiae, a parasitoid wasp [49].

In summary, the use of a push-pull strategy with companion crops like Napier grass, molasses grass, and Desmodium has demonstrated its effectiveness in controlling pests and suppressing weeds while providing addi-

-itional benefits such as forage, improved soil fertility, and increased crop yields.

Table .1. Summary of Diverse Applications of Napier grass in different sectors.

Usage	Cultivars	References
Forage for livestock	Napier grass	[15, 50]
Soil conservation and land use management	Bana grass, King grass	[15, 51, 52]
Biogas production	Napier grass	[53, 54, 55, 56]
Ethanol production	Pusa Giant, Bana grass, Kakamega 1, Clone 13	[23, 25, 26, 27]
Phytoremediation	Bana grass, Napier grass	[33, 35, 55, 56, 57, 58]
Pulp and Paper	Napier grass	[31, 32]
Insect pest management	Napier grass	[48, 59]

2.5.3. *Invasiveness*

Napier grass has been widely introduced to the world for forage and bioenergy production. However, it can also become an invasive weed in some areas, particularly in tropical and subtropical regions. Napier grass has the ability to outcompete other plants and reduce biodiversity and ecosystem functions. For example, in Hawaii, it has been identified as a threat to native forest ecosystems and endangered species habitats [60]. In the Philippines, it has been reported to invade natural forests and grasslands, causing significant ecological and economic impacts [61]. In some parts of the world, such as the Galapagos Islands and Florida, Napier grass is considered a noxious weed [46, 62]. Therefore, there is a need for effective management strategies to prevent or control its spread as a weed.

To prevent the invasiveness of Napier grass, it is important to carefully manage its cultivation and prevent its spread into natural areas. This can be done through the use of sterile cultivars, careful monitoring of seed and plant material, and strict regulations on its cultivation and transport.

3. *Production Constraints of Napier Grass*

Napier grass is a popular forage crop due to its high yield potential and tolerance to a wide range of environmental conditions. However, Napier grass production can be constrained by various factors, including diseases, lack of skills and management by producers, and abiotic conditions such as drought and soil acidity [63]. One of the biggest challenges in improving Napier grass production is the lack of viable and true-to-type seeds [15]. Unlike other grasses that can be easily improved through breeding, Napier grass does not produce seeds that are reliable for propagation. This means that farmers must rely on vegetative propagation methods such as stem cuttings, which can be time-consuming and labor-intensive.

In addition to seed constraints, Napier grass production can also be impacted by diseases such as Napier grass stunt disease and smut disease. These diseases can cause significant yield losses and reduce the quality of the forage [64].

Furthermore, Napier grass production can be limited by a lack of skills and management by producers. This includes inadequate soil preparation, poor pest and disease management, and insufficient nutrient management. Lack of access to credit, markets, and extension services can also limit the potential for Napier grass production

[65].

Overall, addressing the production constraints of Napier grass will require a multi-faceted approach that includes improved breeding techniques, disease management strategies, and capacity building for farmers.

3.1. *Napier Grass Pests and Diseases*

Napier grass is a popular forage crop for livestock in many parts of Africa, due to its high yields and nutritional value. However, like any crop, it is susceptible to a range of pests and diseases that can cause significant damage and reduce yields. In this article, we'll take a look at some of the most common pests and diseases that affect Napier grass in Africa, and what can be done to prevent or manage them.

3.1.1. *Pests Affecting Napier Grass*

Stem borers: These are the most common pests of Napier grass in Africa, and can cause significant damage to the stems and leaves. The most common species of stem borers that affect Napier grass in Africa are Chilo partellus and Eldana saccharina. They tunnel into the stems of the grass, which weakens them and can cause the plants to break or topple over. Infested plants also show stunted growth, reduced yields, and yellowing of the leaves [66]. Stem borers can be managed by using resistant varieties, planting early in the season, and using appropriate insecticides.

Armyworms: These are another common pest of Napier grass in Africa, and can cause significant damage to the leaves and stems. The most common species of armyworms that affect Napier grass in Africa are Spodoptera exempta and Spodoptera frugiperda. They feed on the leaves of the grass, which can cause defoliation and reduce yields. Armyworms can be managed by using appropriate insecticides, planting early in the season, and practicing good crop management practices [66].

Aphids: These are small insects that feed on the sap of the grass, and can cause yellowing and stunted growth of the leaves. The most common species of aphids that affect Napier grass in Africa are Aphis craccivora and Rhopalosiphum maidis. They can be managed by using appropriate insecticides, planting early in the season, and practicing good crop management practices [66].

3.1.2. *Common Diseases in Napier Grass*

Head smut: This is a fungal disease that affects the inflorescence of the grass, and can cause reduced yields and poor quality forage. The most common species of head smut that affect Napier grass in Africa are Ustilago kamerunensis and Ustilago trichophora. It is a serious problem in central and eastern Kenya but has also been reported in Tanzania, Uganda, Rwanda and Congo [67]. It spread rapidly by wind and infected plant material and Infected plants show black powdery masses on the inflorescence, which can easily spread to other plants; Early flowering with smutted heads, stunted plant with thin leaves and lots stems, these lead eventually to tillers dying. Symptoms start on some tillers and eventually affect the whole plant. Infected stems are smaller, thinner and shorter, with few, small and sometimes distorted leaves. Re-growth of infected plants is slow after cutting. The total dry matter reduced, after 2-3 cuttings, the entire stool dries. It can be managed by using resistant varieties such as Kakamega 1 which is resistant to head smut (Sphacelotheca cruenta) [68], planting early in the season, and using appropriate fungicides [69].

Leaf spot: This is a fungal disease that affects the leaves of the grass and can cause yellowing and defoliation.

The most common species of leaf spot that affect Napier grass in Africa are Cercospora fusimaculans and Helminthosporium sacchari [70]. Infected plants show circular or oval lesions on the leaves, which can coalesce and cause defoliation. Leaf spot can be managed by using resistant varieties, planting early in the season, and using appropriate fungicides [69].

Rust: This is a fungal disease that affects the leaves of the grass, and can cause yellowing and defoliation. The most common species of rust that affect Napier grass in Africa are Puccinia purpurea and Puccinia substriata [71]. Infected plants show orange or brown pustules on the leaves, which can easily spread to other plants. Rust can be managed by using resistant varieties, planting early in the season, and using appropriate fungicides [72].

Stunt: a serious problem that affects Napier grass production in Africa. According to O'Neill and Clark [73], the disease is caused by a phytoplasma, which is a type of bacteria that infects plant cells. The disease is characterized by stunted growth, curling/twisting of leaf tips, yellowing and reddening of leaves, and reduced yield. Infected plants also produce fewer tillers and have shorter internodes, which can make them less suitable for forage or silage production [68].

According to a study by Orodho et al. [68], Napier grass stunt disease is prevalent in many areas of East Africa, and can cause yield losses of up to 70%. The disease is spread by insect vectors, such as leafhoppers, which feed on infected plants and then transmit the phytoplasma to healthy plants.

To address the problem of Napier grass stunt disease, researchers have been working to identify cultivars that are more resistant to the disease. A study by Orodho et al. [68] evaluated 20 Napier grass cultivars for their resistance to the disease and found that some cultivars, such as Kakamega 1 and Kakamega 9, were more resistant than others. However, no cultivars were completely resistant. This means that while resistant cultivars can help to reduce the impact of the disease, they are not a complete solution.

In addition to identifying resistant cultivars, other approaches to managing Napier grass stunt disease include using disease-free planting material, controlling insect vectors that spread the disease, and practicing good crop management techniques to minimize stress on the plants. By using a combination of these approaches, it may be possible to reduce the impact of Napier grass stunt disease and improve the productivity of Napier grass.

3.2. *Abiotic Stress Influencing Napier Grass*

Drought tolerance: Napier grass has a deep root system that can access water from deeper soil layers, allowing it to tolerate drought conditions. In addition, some Napier grass cultivars, such as Bana grass, [70,74] , Kakamega 1 and 2 [68] have been developed specifically for their drought tolerance.

Salinity tolerance: Napier grass has been shown to tolerate high levels of soil salinity, making it a potential forage crop for saline areas. This tolerance is due in part to the plant's ability to exclude salt from its tissues and compartmentalize it in older leaves. [75] varieties such as Kakamega 1 and 2 were also identified [68].

Heat tolerance: Napier grass can tolerate high temperatures and is commonly grown in tropical and subtropical regions. Some cultivars, such as Kakamega 1 and 2, KAT R1 (KARI Improved Tana River 1), have been specifically developed for their heat tolerance. [68, 76].

Acid soil tolerance: Napier grass can grow in acidic soils with pH as low as 4.0. This tolerance is due in part to the plant’s ability to absorb and utilize aluminum, which is toxic to many other plants (Brouwer et al., 1985).

Some cultivars, such as Kakamega 1 and 2, were also identified as tolerant [68].

IV. Conclusion

Napier grass is an important feed resource for smallholder farmers in East and Central Africa, where it is used to feed dairy cattle and other livestock in cut-and-carry systems. Napier grass has many advantages, such as high biomass yield, adaptability to different agro-ecological zones, drought tolerance, soil conservation, and pest and weed control. Napier grass can also be used as a source of biofuel and biogas. However, Napier grass also faces some production constraints, such as: Napier stunt disease, which is caused by a phytoplasma and transmitted by leafhoppers. This disease reduces the yield and quality of Napier grass and has spread to several countries in the region. Napier head smut, which is caused by a fungus and affects the inflorescence of Napier grass. This disease reduces the seed production and vegetative propagation of Napier grass and has been reported in Kenya and Tanzania. Low soil fertility, which limits the growth and productivity of Napier grass. Napier grass requires adequate nitrogen, phosphorus, potassium, and other nutrients for optimal performance. Inadequate management practices, such as irregular cutting, overgrazing, poor weed control, lack of irrigation, and insufficient use of improved varieties. These practices affect the quantity and quality of Napier grass and reduce its resilience to biotic and abiotic stresses.

Some recommendations for improving Napier grass production are:

- Use of resistant or tolerant varieties that can cope with diseases, drought, pests, and weeds. For example, some varieties of Napier grass have been developed by conventional breeding or genetic engineering to resist Napier stunt disease or head smut.
- Use of integrated pest management (IPM) strategies that combine cultural, biological, and chemical methods to control diseases and pests. For example, some strategies include crop rotation, intercropping, use of trap crops, use of natural enemies, and use of selective pesticides.
- Use of soil fertility management practices that enhance the nutrient availability and uptake by Napier grass. For example, some practices include application of organic or inorganic fertilizers, use of legume intercrops or cover crops, mulching, and liming.
- Use of good agronomic practices that optimize the growth and yield of Napier grass. For example, some practices include proper land preparation, planting density, cutting frequency and height, irrigation, weed control, and conservation methods.

Napier grass has a great potential to contribute to the food security and income generation of smallholder farmers in East and Central Africa. However, it requires more research and development efforts to overcome the production constraints and enhance its economic importance.

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