



Adoption of Napier Grass [*Cenchrus purpureus* (Schumach.) Morrone] among Livestock Farmers in Botswana: Challenges and Future Prospects

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Authors' contributions

This work was carried out in collaboration among all authors. Author KM designed the study, collected data, performed the statistical analysis and wrote the first draft of the manuscript. Author MK collected data and performed the statistical analysis. Authors KG and MO collected data and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In order to assess the current adoption level of Napier grass [*Cenchrus purpureus* (Schumach.)] in Botswana as well as identify barriers hindering its uptake and effective use, data collection was done through a field survey of purposively selected sample of livestock farmers in North East District and adjacent parts of Central District. Findings of the study indicated that even though farmers' overall perception towards Napier grass was positive, adoption levels were still low. Numerous challenges in Napier grass production included recurrent droughts, non-irrigation, limited access to planting/propagation material, shortage of labor, poor agronomic practices as well as lack of technical knowledge on management and utilization of the fodder grass. Even though adoption levels are still low, opportunities do exist to accelerate future uptake. For example, farmers proposed strategic interventions such as well packaged and targeted education on Napier grass production, subsidized borehole drilling, equipping and water reticulation for irrigation of fodder crops in their farming areas and more technical support from extension officers. Going forward, in order to achieve increased impact with Napier grass, the current extension approach in

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dissemination and adoption can therefore be effectively targeted primarily at farmers likely to accept and use the technology, instead of expecting every farmer within an agro-ecological zone to comprehensively implement the recommended technology disregarding feasibility, profitability and acceptability of such introduced fodder technology to individual farmers.

Keywords: Adoption; Botswana; dis-adoption; extension agents; forages; Napier grass; perception; technology dissemination.

1. INTRODUCTION

Napier or Elephant grass [*Cenchrus purpureus* (Schumach.) Morrone, syn. *Pennisetum purpureum* (Schumach.)] is a tropical perennial C4 grass species native to Africa and spread throughout the world's tropical and subtropical regions. Its potential multiplicity of uses ranging from soil erosion control, use as a trap crop in insect pest management to its contribution towards renewable energy production as a biofuel source [1,2,3] makes it a valuable crop. Not only that, but also its high biomass yield, nutritive value, persistence, drought tolerance and broad adaptation within a wide ecological range [4,5,6] positions Napier grass as a strategic resource for the livestock industry especially in areas experiencing seasonal fluctuations in feed quantity and quality. Napier grass has thus been introduced in semi-arid Botswana to augment existing natural feed resource base which support the livestock economy characterizing the bulk of the country's rural livelihoods. With a population of 1.74 million cattle, 1.21 million goats and 242 000 sheep in 2015, the annual demand for fodder becomes more apparent during the dry season and /or drought years when the quantity and quality of natural rain-fed pastures deteriorate. Fodder production is still gaining traction in the country and constitutes mainly of *Lablab purpureus* cultivation on a small scale. The advent of climate change and recurrent drought episodes however, have laid bare the urgent need to accelerate a comprehensive fodder strategy to support and climate-proof the livestock industry. The country imports most of its fodder from other countries especially the Republic of South Africa, which is then sold at subsidized prices of up to 35% to livestock farmers by the government. Though obtaining exact figures detailing the total demand for each forage type as well as the amount of forage produced locally is challenging due to gross aggregation of data at national level, the country imported approximately 43,957,840 tons of assorted animal feeds and supplements in 2016 worth BWP 219,781,638 while 4,351,000.5 tons of Lucerne (*Medicago sativa*) meal and pellets valued at BWP

7,073,458.2 were imported into the country for the period January 2017 to April 2018. [7], (where 1 USD = 11.65 BWP as at August 2020). There is therefore need to reduce the import bill through development and promotion of utilization of locally-adapted sustainable fodder streams by farmers to improve herd productivity. And one such option is the use of Napier grass. Yields of >15 tons of dry matter per hectare of Napier grass were obtained in south-east Botswana under rain-fed conditions at cutting intervals of 6 to 8 weeks [8] while crude protein (CP) values were still higher than those of indigenous grasses even during the dry season. Other minerals like phosphorus (P), calcium (Ca) and magnesium (Mg) were also still above the requirement for livestock maintenance, even though supplementation especially during early lactation may be necessary for high producing dairy animals. Another study found that cutting Napier grass at a height of 1m and ensiling with various additives increased CP and digestibility values [9]. Even though there are no published local works on comparative economic advantage of growing Napier grass *vis-a-vis* other grass species, the former has potential not only to support beef and small stock production in Botswana but also the emerging dairy industry as a basal diet. That notwithstanding, empirical studies on the level of adoption and utilization of Napier grass by farmers are limited.

Adoption or non-adoption of appropriate agricultural technologies by farmers has been highlighted as one of the factors influencing livestock production levels in Botswana. Adoption is often a complex process. As noted by [10], some farmers may be willing to adopt and able to do so, while others may be willing but unable while at the other end some may be able yet unwilling or both unwilling and unable. Following the diffusion of innovation theory [11], the innovation decision process in the context of Napier grass will consist of five sequential stages; (1) knowledge stage, when farmers become aware of Napier grass technology; (2) persuasion stage, when farmers form favorable or unfavorable attitudes towards Napier grass; (3) decision stage, when farmers engage in

activities that lead to a choice to adopt or reject Napier grass; (4) implementation stage, when farmers plant and utilize Napier grass; and (5) confirmation stage, when farmers seek reinforcement for their decision to use Napier grass but may reverse the decision if exposed to conflicting messages. In addition to looking at the extrinsic factors influencing adoption (such as farmer characteristics, the characteristics of the innovation and the external environment) researchers have started to pay more attention to the internal decision-making process and look beyond the characteristics of the innovation and the household to include psychological and motivational factors in technology uptake [12].

Perceptions on technology-specific attributes are often overlooked when disseminating 'new' or 'improved' innovations to farmers, and this often leads to non-adoption or dis-adoption/discontinuance and subsequent frustration on the part of researchers, extension agents and policy makers alike. Using the traditional top down process of researcher-extension-farmer (transfer-of-technology) approach, farmers who fail to adopt new techniques are termed recalcitrant and irrational as they resist innovations which all evidence clearly suggest that they *should* adopt. Their negative attitudes and their lack of knowledge are often considered to be the main barriers to adoption [13,14], and this professional elitism by researchers and extensionists assumes that farmers have little or nothing to contribute towards the research process. However, farmers do not adopt or dis-adopt technologies haphazardly, but often follow rational decision-making on the appropriateness of the characteristics and the value of the technology. For example, a study among cattle farmers in Botswana found that livestock technologies like the use of *L. purpureus* hay and crop residues were more popular and considered relevant by farmers more than the use of *Cenchrus ciliaris* for rangeland rehabilitation as well as the use of Napier grass among a list of available technologies [15]. If farmers do not positively perceive Napier grass, then they are unlikely to invest capital, land or labor in its production. Perceptions may or may not necessarily be in line with reality, but remain important nonetheless. In this case, it means that for rapid adoption of *C. ciliaris* and Napier grass technologies, there ought to be intensive awareness/education drive. Still, this alone does not guarantee successful uptake thereafter. Indeed, [11] stressed that the new technology should have a relative advantage over existing

ones and should be compatible with farmers' existing systems. Other attributes determining the rate of adoption include complexity, trialability and observability of the new technology. There is therefore need to consider these perceptions when developing technologies and to meaningfully engage end users from the onset as partners.

Empirical studies on the current level of Napier grass adoption in Botswana are lacking. There is a need for baseline data from which future fodder technology dissemination strategies can benchmark. This study therefore set out to assess Napier grass adoption in the North East District of Botswana, as well as farmers' perceptions towards the fodder technology. Outcomes of the study could better inform research and extension approaches towards enhancing adoption of Napier grass and other livestock fodder-related technologies in the region in order to increase overall farm productivity.

2. METHODOLOGY

2.1 Study Area

The survey covered the North East District and adjacent parts of Central District of Botswana. The area is semi-arid with its characteristic highly variable rainfall averaging 430mm annually. Rainfall follows a unimodal pattern, falling mainly between the months of November and April. The area is dominated by major woody plant species particularly *Colophospermum mopane* with other vegetation associations including species like *Acacia tortilis*, *Acacia nigrescens* and *Combretum apiculatum* and grass species like *Panicum maximum*, *Urochloa mosambicensis*, *Aristida congesta*, *Eragrostis rigidior* and *Schmidtia pappophoroides*. The soils are classified as haplic lixisol, a typical sodic type and characterized by clay. The agricultural sector in the region is dominated by smallholder farmers, involving seasonal cultivation of rain-fed crops such as millet (*Pennisetum* spp.), maize (*Zea mays*), sorghum (*Sorghum* spp.), groundnuts (*Arachis hypogaea*) and melons (*Cucumis melo*) as well as keeping of livestock such as cattle, sheep and goats mainly in limited communal rangelands [16,17,18].

2.2 Data Collection

Prior to the survey, willing farmers freely obtained Napier grass cuttings from the government's multiplication center/bulking site at

Impala Research Station (21°08' - 21°11' S, 21°35' - 27°37' E), 7 km East of Francistown, in the North East District of Botswana. Free distribution of Napier grass planting material (stem cuttings), which commenced in earnest in 2016 was done to promote awareness and utilization of the grass species among farmers. Each farmer was given a minimum of fifteen (15) cuttings to plant while records were kept on location of their farms/planting areas. Efforts were made to demonstrate the correct vegetative planting technique of Napier grass to farmers prior to distribution, where short cuttings each consisting of three nodes were to be planted in moist soil vertically, with two nodes below the surface and one above. After 3 seasons, follow up of the same farmers and assessment of performance of the distributed planting material was done in March and April 2019. It was assumed that 3 seasons were adequate to establish and possibly expand the plant stands from the initial allocated cuttings. From the list of all farmers who received free cuttings, initial screening was done to eliminate those who had not planted the cuttings at all (some dried out before planting while some were consumed after being mistaken for sugar cane (*Saccharum officinarum*) or sweet sorghum (*Sorghum bicolor*) etc.). The remaining list formed the sampling frame from which data collection was done using a questionnaire-based survey following purposive sampling. Due to the infancy of fodder production including Napier grass, additional sampling units were incorporated using referrals or the snow ball approach. Site visits also augmented the survey. Consequently, a total of 51 farmers were included in the survey from the following areas; Francistown (10), Tonota (7), Mathangwane (6), Tati Siding (4) Marapong, Matshelagabedi (with 3 each), Borolong, Tsamaya, Makaleng (with 2 each) as well as Maitengwe, Makomoto, Masunga, Mmatshumo, Mosu, Nata, Nshakashogwe, Pole, Semotswane, Siviya, Sowa and Tutume (with 1 each). Data collection included the socio-economic profile of the respondents, farm characteristics, access to agricultural information, farmers' perception towards Napier grass technology as well as the challenges in Napier grass production and possible interventions to enhance rapid adoption in the country.

2.3 Data Analysis

Data were cleaned and captured using Microsoft Excel and later analyzed using SAS. Descriptive statistics were used to show characteristics of

the adopters and non-adopters and their relationships with adoption. Cross-tabulation for categorical variables was used to test for association using Pearson chi-square statistic at $P < .05$.

3. RESULTS AND DISCUSSION

3.1 Socioeconomic Profile of Respondents

The socioeconomic profile of respondents is as reflected in Table 1. The majority were male, middle-aged and had tertiary education. Most farmers were formally employed off-farm and their years in farming ranged from less than 5 years to more than 10 years, with the majority rearing goats and cattle.

Table 2 shows land ownership patterns among respondents as well as sources of Napier grass propagules and water for irrigation. Whilst the majority owned more than 10 ha of farm land, 84.31% allocated less than 5 ha to fodder production, which also highlights the infancy of fodder crop incorporation in farmers' planting plans. *L. purpureus* was the other common fodder species already grown in the study areas.

3.2 Access to Agricultural Information

Neighboring farmers as well as agricultural extension officers in the area were prominent sources of information on Napier grass technology. Moreover, farmers utilized other mass media to access information including internet and television as well as agricultural shows organized by the Ministry of Agricultural Development and Food Security (Table 3). It is at these agricultural shows (or Field Days, Farm Walks, Open Days etc.) where live plant exhibits, planting techniques and Napier grass-based feed formulations are demonstrated to farmers augmented through poster/banner displays and distribution of brochures and pamphlets. However, there was still a large number of farmers (84.31%) who reported lack of training specifically on Napier grass production. Membership of Agricultural Associations was still low, even though these are important in increasing participation and information flow among farmers and other stakeholders.

3.3 Farmers' Perception of Napier Grass Technology

Farmers perception towards Napier grass was characterized by the following variables; Nutritive

value, Pest tolerance, Drought tolerance, Erosion control, Yield, Palatability, Income, Fertilizer needs and Knowledge on Napier grass compared to known local grass varieties. Napier grass was perceived as being more nutritious (66.67%), more drought tolerant (70.59%), more effective in soil erosion control (49.02%), better yielding (78.43%) and more palatable to livestock (56.86%). Less number of farmers perceived the grass to be pest resistant (31.37%) while 45.10% were confident in the knowledge they had on Napier grass production. Information on fertilizer requirements were also largely unknown (62.75%). Only 9.80% of the farmers thought sale of Napier grass (cuttings or fodder) was able to generate income sustainably, while the rest did not know. Overall, there was positive perception towards Napier grass technology compared to existing indigenous grass alternatives – which is a crucial element among the multifaceted factors influencing technology adoption.

3.4 Adopters versus Non-adopters

The total area planted under rain-fed conditions was used to categorize 'Adopters' and 'Non-adopters', where the farmer experimented with

Napier forage technology and subsequently expanded (or not) the area under cultivation using their own resources. The recommended spacing of 2.5m by 1m was used [8]. For the first growing season (September 2016 to March 2017); Assuming on average that 80% of the initial 15 Napier grass stem cuttings survived, then 12 cuttings will have grown into mature plants and formed the 'seed bank' nursery, from which future propagules could be harvested and used for hectare expansion. For the second growing season (September 2017 to March 2018); If the 12 plants from the previous season produce 4 stem cuttings each, then 48 cuttings can be harvested and planted to give rise to 38 new plants. For the third growing season (September 2018 to March 2019); Again following the same assumptions, 50 plants will give 200 cuttings and 80% survival rate will result in a total of 160 new plants. It implies that after 3 seasons the area covered by Napier grass ought to be no less than 131.25m². It should be noted that this is a conservative estimate and does not consider expansion using root splits or additional rooted tillers during the stated period. Using this approach, only 33.33% of farmers adopted Napier grass, while the rest were classified as non-adopters (66.67%) (Table 4).

Table 1. Socioeconomic profile of respondents in the study area

Variable	(n=51) %
1. Gender* (a) Male (b) Female	(a) 84.31 (b) 15.69
2. Age* (a) ≤35yrs (b) 36-50yrs (c) 51-65yrs (d) >65yrs	(a) 3.92 (b) 56.86 (c) 33.33 (d) 5.88
3. Formal education* (a) Primary (b) Secondary (c) Tertiary	(a) 3.92 (b) 19.61 (c) 76.47
4. Main source of income	
Formal employment (off farm)	56.86
Livestock	15.69
Crops	9.80
Pension	9.80
Government Old Age Pension Scheme	1.96
Other	5.88
5. Years in farming (a) <5 (b) 5 to 10 (c) >10	(a) 19.61 (b) 21.57 (c) 58.82
6. Livestock owned? (a) Yes (b) No	(a) 96.08 (b) 3.92
7. Livestock type	
Goats	85.71
Cattle	79.59
Sheep	42.86
Donkeys	10.20
Horses	10.20

*Head of household

Table 2. Land tenure and Napier grass production

Variable	(n=51) %
Land ownership	
(a) Own (b) Family (c) Leased	(a) 76.47 (b) 19.61 (c) 5.88
Total land size (Ha)	
(a) <5 (b) 5 to 10 (c) >10	(a) 15.69 (b) 33.33 (c) 50.98
Total land allotted for fodder (Ha)	
(a) ≤5 (b) >5	(a) 84.31 (b) 15.69
Fodder species grown	
(a) Napier grass (b) <i>L. purpureus</i> (c) Other	(a) 100 (b) 74.51 (c) 21.57
<i>Do you irrigate fodder?</i> (a) Yes (b) No	(a) 41.18 (b) 58.82
Source of irrigation water	
(a) Borehole	(a) 74.07
(b) Well	(b) 14.81
(c) Dam	(c) 7.41
(d) Other	(d) 3.70
Source of Napier grass propagules	
(a) Free cuttings/root splits from Department of Agricultural Research (Impala Station)	(a) 94.11
(b) Purchased cuttings from private retailers	(b) 11.76
(c) Free cuttings from other farmers	(c) 5.88

Table 3. Sources of agricultural information, access to extension and training by respondents in the study area

Variable	%
Source of information on Napier grass	
Other farmers	39.22
Extension Officers	19.61
Agricultural Shows	11.76
Television	11.76
Internet	7.84
Radio	3.92
Other	3.92
Print media	1.96
Ever trained on Napier grass Production?	
(a) No (b) Yes (Demonstrations, Rural Training Centres)	(a) 84.31 (b) 15.69
Distance to Extension Officer	
(a) ≤20km (b) >20km	(a) 86.27 (b) 13.73
Contact with Extension Officer	
Frequent	15.69
Occasional	23.53
Rare	31.37
Never	29.41
Membership of Livestock Association?	
(a) Yes (b) No (c) Used to	(a) 21.57 (b) 72.55 (c) 5.88

3.5 Overall Challenges in Napier Grass Technology Adoption Rate and Use Intensity

The main challenges encountered in dissemination and adoption of Napier grass are reflected in Fig. 1. Some of these factors were related to the

ecological/biophysical environment (e.g., drought, irrigation water shortage, pests, weeds and poor soil fertility) while others were institutional (e.g. limited access to planting/propagation material, lack of technical knowledge on management and utilization) and economic (e.g. limited land, limited access to credit and markets).

The most important challenges were unavailability of water supply for irrigation (72.55%), drought and shortage of labor as well as inadequate Napier grass management knowledge at 29.41% each. These are further discussed next.

3.5.1 Drought and unavailability of irrigation water

An overwhelming majority of respondents (72.55%) cited unavailability of water for irrigation of their Napier grass stands as a serious constraint to improved production. Even though Napier grass can tolerate certain levels of soil moisture deficit, there is still need for moisture especially during the establishment phase. Stem cuttings can easily dry out if soil moisture levels are too low to support bud sprouting and root growth. The newly-established plant should also be given time to build enough carbohydrate reserves before any intense defoliation is attempted. Botswana's rainfall is generally low and highly erratic both in space and time – which is characteristic of the prevailing semi-arid climate inevitably leading to recurrent agricultural droughts [19]. Thus, some kind of irrigation of newly-established plants is required to augment rainfall moisture and sustain seedlings. Unfortunately, not all respondents had access or

means to irrigate their plants during the critical time of establishment, or during extended dry seasons or droughts when high temperatures also result in plant heat stress. Availability of moisture or lack thereof has direct influence on biomass yield. Also, limited soil moisture means only a few mature stem cuttings can be produced by the stressed plant and this will negatively curtail farmers' attempts to further expand total hectareage using stem cuttings planting technique. It should be noted that even though moisture is desirable, Napier grass does not tolerate prolonged flooding or waterlogging. With cuttings done every 6-8 weeks as recommended under Botswana conditions [8], adequate moisture will enable continuous supply of biomass throughout the year unlike depending completely on summer rains only and experiencing feed disruptions during non-rainy periods.

3.5.2 Poor agronomic practices

Another constraint identified by farmers was related to overall dearth of knowledge on Napier grass management practices. These included pests (25.49%), soil fertility requirements (19.61%), weeds infestation (11.76%) and post-harvest handling techniques (13.73%) as well as subsequent livestock feeding regime (13.73%).

Table 4. Characteristics of Napier grass adopter and non-adopter households in the study area

Characteristic	Adopters (n=17)	Non-adopters (n=34)
Gender*		
Male	13 (76.47%)	30 (88.24%)
Female	4 (23.53%)	4 (11.76%)
Age*		
≤35 years	0 (0%)	2 (5.88%)
36-50 years	9 (52.94%)	20 (58.82%)
51-65 years	6 (35.29%)	11 (32.35%)
>65 years	2 (11.76%)	1 (2.94%)
Education level*		
Primary	0 (0%)	2 (5.88%)
Secondary	2 (11.76%)	8 (23.53%)
Tertiary	15 (88.24%)	24 (70.59%)
Contact with extension		
Yes	7 (41.18%)	13 (38.24%)
No	10 (58.82%)	21 (61.76%)
Perception of seasonal feed scarcity as a problem		
Yes	17 (100%)	33 (97.06%)
No	0 (0%)	1 (2.94%)

*Head of household

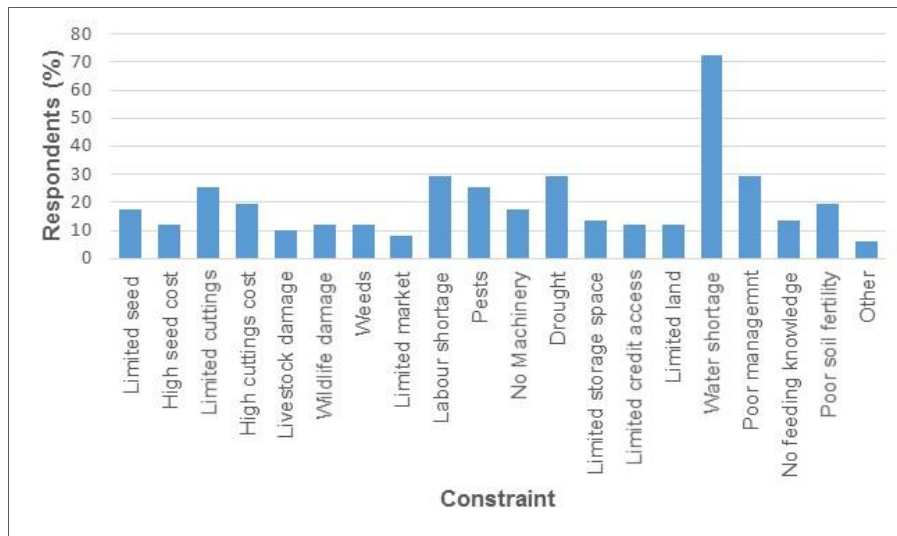


Fig. 1. Main challenges associated with Napier grass production in the study area

Pests identified by farmers were mainly termites particularly during the dry season or drought years, which could lead to reduced production or total loss of plants. Other pests mentioned included small burrowing mammals which used Napier grass clumps for shelter thus damaging the plants' root system as well as birds which tear strips of the monocot leaves to make their nests. For farmers who are still trying to establish their nursery beds or expand their existing stand in the field, these losses may prove significant. Although no diseases of Napier grass were reported locally, in other regions of Africa the Head Smut as well as Stunt Diseases can be of economic importance in Napier grass production [5].

The issue of soil fertility was also raised as a possible constraint to increased Napier grass production. Farmers were generally not knowledgeable on nutrient requirements of the grass, even though a few applied organic manure to the nursery beds (cow dung or chicken manure) on *ad hoc* basis. Most of Botswana's soils generally have poor fertility. The problem may further be compounded by competition from weeds (e.g. *Cynodon dactylon*, *Acanthospermum hispidum* and *Tribulus terrestris*) more so during Napier grass establishment and periods following defoliation. And because of its high biomass yielding ability, Napier grass is itself a heavy miner of soil nutrients particularly nitrogen (N) and phosphorus (P). [20] estimated that Napier grass yielding 15-20 tons of dry matter/ha per year may remove as much as 300 kg N, 50 kg P and 600

kg potassium (K). Thus regular application of fertilizers or manure is required to replenish soil fertility. For example, in Kenya, [5] recommended 20 kg/ha/year of P in the form of either Single or Triple Superphosphates at a rate of 100 kg/ha applied twice a year, or 75 kg/ha of N usually in the form of Calcium Ammonium Nitrate at a rate of 300 kg/ha to be applied in splits after every grass harvest or 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 or dairy cattle slurry (mixture of cow dung, urine and feed leftovers), at a rate of 5.5 tons of DM/ha/year. The use of organic fertilizers like farm yard manure has also been shown to be a low-cost means of increasing quantity and quality of Napier grass fodder [21,22] and this fertility management strategy can be utilized by resource-poor farmers. Another important factor to note is that subsistence farmers with limited land are often reluctant to allocate space to fodder crops, and will first rank staple food crops like maize, sorghum and millet as well as prioritize the latter crops with regard to resource allocation and management practices. Thus it is common to encounter areas where there are well-maintained stands of food crops with weeding and fertilization and total neglect of fodder crops within the same field with the latter often relegated to the periphery.

Some farmers highlighted challenges in proper livestock feeding (13.73%), conservation and storage of harvested Napier grass biomass (13.73%). Only a negligible number of farmers were engaged in sale of either fodder and/or

cuttings (1.96%). Though still largely untapped economically, Napier grass has potential to generate income for rural households through sale of excess forage or non-livestock owners planting the forage specifically to sell to livestock owners in need of fodder. Strong livestock value chains can also be exploited by Napier grass producers in future. Napier grass was commonly fed fresh (86.27%) after manually chopping it to reduce selection of leaves and stems by livestock or to a lesser extent as hay (27.45%). Only 3.92% made silage. For those that attempted to make hay, the differential curing/drying times between the succulent stems and leaves proved a challenge, as stems took longer to dry and risked becoming hard and unpalatable. Though only a few farmers conserved excess forage material as silage, the practice has been shown to be best in retaining the quality of Napier feed and acts as an important nutritional buffer for livestock during the dry season [8]. However, farmers were not yet knowledgeable on the right quantities of Napier grass to feed their different livestock or to use in feed formulation – further demonstrating the lack of adoption intensity or extent of usage.

3.5.3 Shortage of labor

Labor unavailability was cited as a challenge by 29.41% of farmers. Addition of new agricultural technologies to the farmers' field like Napier grass which some deem as labor-intensive needs careful consideration in order to gain acceptance and widespread adoption. Napier grass establishment can be laborious, as planting material has to be planted on well prepared soil either using the conventional method (planting stem cuttings or root splits) or *Tumbukiza* method (planting cuttings or root splits in round or rectangular pits filled with mixture of topsoil and manure in the ratio of 1:2) [5]. The area may also need to be secured (for example using wire fence, wooden posts or branches of *Acacia* spp.) to protect the young seedlings from damage by stray livestock. During the period of establishment, labor may also be needed to replace dead plants or to cut and carry the biomass to feed livestock off the site post-establishment period. Shortage of appropriate machinery that can alleviate manual labor challenges was also reported by some farmers (17.65%). As alluded to earlier, some farmers still prioritize land preparation and other farm operations for food crops, and thus fodder crops may suffer. With an average household size of 4.45±2.05 among surveyed households, there is

possible competition for division of manual labor especially when planting and weeding of Napier grass coincides with seasonal peak periods for planting and weeding of food crops. Thus labor intensive technologies like Napier grass may not be fully taken up in a low input-low output subsistence agricultural system unless farmers envision clear value of expected benefits derived from the use of the introduced technology compared to existing alternatives.

3.5.4 Limited and expensive Napier grass planting material

Non availability of planting materials (seeds, seedlings or cuttings) and their associated high cost was cited as a challenge by a majority of surveyed farmers (74.51%). Propagation by stem cuttings is currently the dominant practice for the distribution of Napier grass propagules and the method assures germplasm stability and quality preservation since the grass produces seeds which are very small, light and of poor quality while spikelets are prone to shattering. As a result of these undesirable traits, the seeds are considered inappropriate for propagation as they produce weak seedlings and, as Napier grass is an open pollinated crop, the seedlings are also highly heterozygous [6,23]. Farmers decried the non-availability of cuttings, or the limited number freely offered by the Department of Agricultural Research. A few farmers who had privately acquired cuttings from other non-government entities paid on average BWP10.00-20.00 per stem cutting with 3 nodes, while those who had bought Napier grass in the past before it became 'popular' paid as little as BWP2.00-5.00 per plant (where 1 USD = 11.65 BWP as at August 2020). Indeed, work done elsewhere has stressed the critical importance of 'putting the germplasm in the hands of farmers' by ensuring availability at reduced cost as well as ease of propagation which will ultimately result in widespread adoption [24,25,26]. Working in the same study area, [16] also noted the challenges related to availability, quality as well as affordability of seeds of the fodder crop *L. purpureus*. In order to avail Napier grass planting material, the government of Botswana has recently included Napier grass seedlings in the Integrated Support Program for Arable Agricultural Development (ISPAAD), a subsidy scheme providing support to farmers with inputs such as seeds and fertilizers, draught power for tillage operations and assistance in land preparation and development in a bid to improve agricultural productivity and increase yields. Under this

program, Napier grass is subsidized at BWP5.00 per seedling and each farmer can be assisted up to 0.5ha only provided they have water for irrigation. While noting the importance of freely availing planting material to farmers, [25] caution against overdoing this practice as it can in the long term stifle farmers' initiatives to use on-farm resources because they expect to continue to be given planting material. Thus farmers ought to be 'weaned' timely to ensure that they become independent or to let other stakeholders like private businesses to fill the niche. Though with huge potential, the local market for fodder is still unorganized and informal with no designated market place and with inadequate quality checks. Quantities produced are still on a small scale such that the forage is completely utilized by the farmer's livestock and never leaves the farm gate, or in the rare event that it does, then it is quickly bought by the road side.

3.6 So what do Farmers Need to Enhance Napier Grass Adoption?

Farmers suggested several interventions which they believe may aid in widespread adoption of Napier grass in the area and possibly beyond. These are reflected in Fig. 2.

3.6.1 Develop Napier grass agronomic practices

The current study highlighted an existing gap in knowledge of management practices among surveyed Napier grass farmers. Indeed, fodder technologies are often information-intensive, therefore access to appropriate technical information, when and where required, is essential [27]. Thus majority of farmers (62.75%) proposed vigorous, well packaged and targeted education on Napier grass production and its associated benefits particularly to livestock farmers whose use of the technology may be compatible with their enterprises. Comprehensive studies on Napier grass are also needed so that local farmers' needs are addressed, ranging from appropriate cultivars to use, soil fertility and irrigation requirements of such fodder all the way to conservation, utilization and the comparative economics of using Napier grass.

3.6.2 Provide water for irrigation

Other farmers (27.45%) proposed subsidized borehole drilling, equipping and water reticulation for irrigation of fodder crops in their farming

areas as a strategic intervention that could enhance Napier grass adoption. To avoid direct competition with other crops and other sectors for the already limited freshwater resources under a changing climate, perhaps the use of treated sewage effluent for fodder irrigation could be a more sustainable option in the long term. With regard to size of farm land, only a few farmers suggested availing more land as a solution in enhancing adoption of Napier grass. Whilst the study area does have limited land for communal use due to dominance of privately owned livestock ranches, Napier grass does not necessarily require vast areas of land if utilized in a cut and carry forage production system. This way, the land use potential is increased as efficiency is emphasized.

3.6.3 Strengthen fodder extension outreach

Even though 86.27% of farmers were ≤ 20 km from the nearest Agricultural Extension Office which could have aided in information dissemination, most farmers first learnt about Napier grass from other farmers. This also underlines the importance of farmer-to-farmer education and linkage in technology dissemination and adoption. Unfortunately, very few farmers had membership to Livestock Associations, which have been shown to increase access to planting material, information and training which leads to higher possibility of adoption [28]. An overwhelming majority of farmers (82.31%) were dissatisfied with frequency of extension visits to their farms to assist with livestock related commodities including Napier fodder production, with officers often citing transport and communication challenges. Farmers therefore called for more contact with extension officers (11.76%), more technology demonstrations where farmers learn through practice (27.45%) and formation of Fodder Associations (1.96%). Studies elsewhere have shown that frequent contact with extension agents results in increased likelihood of technology adoption based on the innovation-diffusion theory [29,30,31]. Whilst extension officers may not be visiting the farmers as desired, it should also be noted that a majority of farmers are employed full-time elsewhere off-farm, and therefore their absence could in a way contribute to non-contact with extension officers. Other studies in southern Botswana have also attributed inefficiency of the agricultural extension system to inadequate input resources, work overload and at times skills gaps among untrained extension staff [32,33,14].

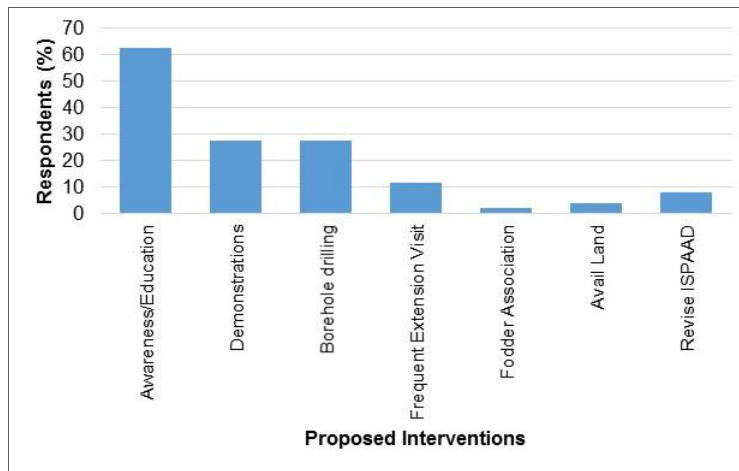


Fig. 2. Farmers' proposed solutions to enhance Napier grass production in the study area

4. CONCLUSION

The study unveiled the current level of Napier grass technology adoption among small scale farmers. Whilst there is overall positive perception towards Napier grass, actual adoption levels are still low, with farmers experiencing a myriad of challenges including unavailability of water for irrigation, shortage of labor and planting material for propagation as well as limited technical knowledge on overall management of Napier grass. This scenario can further delay full adoption of the technology as other prospective Napier grass farmers observe only limited successful uptake by practicing farmers (adopters) while the latter may also reevaluate their decision to incorporate Napier grass in their enterprises which may lead to dis-adoption. To overcome the perceived challenges/barriers, farmers further proposed interventions like provision of irrigation water, enhanced extension-farmer contact and training. Going forward, in order to achieve increased impact with Napier grass, the current extension approach in dissemination and adoption can therefore be effectively targeted primarily at farmers likely to accept and use the technology, instead of expecting every farmer within an agro-ecological zone to comprehensively implement the recommended technology disregarding feasibility, profitability and acceptability of such introduced fodder technology to individual farmers.

CONSENT

As per international standard or university standard guideline participant consent has been collected and preserved by the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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