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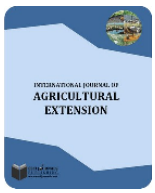

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PARTICIPATORY SURVEY ON THE PERFORMANCES OF SOME FORAGE SPECIES PERCEIVED BY SMALLHOLDER DAIRY FARMERS IN RWANDA: CASE STUDY OF NGOMA AND BUGESERA DISTRICTS

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ABSTRACT

Farmers in semi-arid areas of Ngoma and Bugesera districts used to cultivate exclusively *Penissetum purpureum* var French Cameroon which was susceptible to Napier Stunt Disease, a real cause of loss of forage biomass. To remedy the problem, a pilot experiment with the introduction of improved forage species was carried out in conjoint participation with the farmers for three months. Using a participatory approach, this survey assessed farmers' perception and criteria for selecting forage species on seven improved forages. Using pair-wise comparison, results in both Bugesera and Ngoma" showed that palatability ranked first against all criteria while drought tolerance and leaf/stem ratio ranked second and third respectively. In both districts, the palatability criterion was preferred by farmers due to high intake when feeding dairy cattle. Forage color was ranked last by farmers and the trait was considered less important for future forage improvement in both districts. According to farmer's perception, *Brachiaria brizantha cv. Xaraes, Brachiaria decumbens cv. Basilisk, Penissetum purpureum var Kakamega* 1 and *Brachiaria brizantha cv*. Piata was selected first for capacity to mitigate soil erosion, weed control, improve soil fertility as well as carbon sequestration. *Brachiaria cultivars cv. Basilisk, Piata and Xaraes and Penissetum purpureum cv. Kakamega* 1 showed higher perception performance for soil coverage and drought tolerance across all sites. Findings suggest that palatability, leaf/stem ratio and drought tolerance were more important in evaluating forage as livestock feeds for Bugesera and Ngoma districts. *Brachiaria brizantha cvs. Xaraes, Piata, Penissetum purpureum cv. Kakamega* 1 and *Desmodium distortum* were viewed as a breakthrough for increasing milk yield for dairy animals. In addition, *Brachiaria* cultivars could contribute to climate change mitigation through carbon sequestration, soil cover and soil erosion control.

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INTRODUCTION

Crop-livestock production is an integral part of the mixed farming systems in Rwanda and characterised by small-scale subsistence farming to producing food for meeting daily household dietary requirements. However, forage productivity is quite low in Bugesera and Ngoma districts due to land scarcity, severe dry season and high level of human population density

(Mutimura and Everson, 2011). The farmer participatory research approach elevates local knowledge to the role of science in food security by increasing productivity at the farm level.

In the past, adoption of forage technologies by smallholder farmers has been poor in Bugesera and Ngoma districts. This paper is a survey of the performances of some forage species perceived by smallholder farmers in both districts. It takes the structure of a "participatory research approach" by smallholder farmers for seven forage species grown under semi-arid conditions in Bugesera and Ngoma districts. Experiences in Africa and Asia have shown that participatory approaches in the development of forage technologies are the key to forage integration into smallholder farmers for dairy cattle (Roothaert *et al.*, 2003; Kabirizi *et al.*, 2004; Roothaert *et al.*, 2005; Mutimura, 2012).

The participation of farmers in forage varietal selection is very important for forage development and adoption to increase livestock productivity (Tufail *et al.*, 2017). Collaborative research with farmers results in the identification and selection of better forage varieties (David, 2004). Participatory evaluation of fodder is important to understand traits or combinations of traits of interest to farmers to well understand the farmers' preferences and their local skills in setting forage criteria, comparing and prioritizing the criteria through discussions (Ceccarelli and Grando, 2019). Farmer participatory evaluation offers a valuable means to assess the performance of forages and will likely contribute to their improved utilization (Garcia *et al.*, 2018).

However, the on-farm evaluation of different forage species has not been tested in the study areas under farmers' management level to see the adaptability and preference of the community. Hence, introducing adaptable, palatable and drought tolerant forage species in a participatory way should be practiced in the areas to increase livestock productivity. Therefore, this survey was conducted to evaluate farmers' preference based on growth, color, soil cover, drought tolerance, palatability and leaf/stem ratio and to disseminate at least two types of forage grass and one type of forage legume in both Bugesera and Ngoma districts of Rwanda.

Literature review

Theoretical review: Forage species: 7 species under experimentation

Signal grass (Brachiaria decumbens cv. Basilisk)

Brachiaria decumbens has quite high biomass production of over 25 T of dry matter/ha. This enables rapid carbon uptake, therefore enhancing soil fertility and structure. This grass provides good soil cover and promote water infiltration.

The sensitivity test has shown that *Radopholus similis* and *Pratylenchus coffeae*, the two main banana nematodes, do not propagate on *Brachiaria decumbens cv. Basilisk* (Gnénakan *et al.*, 2020).

Illustration 1. *Brachiaria decumbens cv. Basilisk.*

Illustration 2. *Brachiaria brizantha cv. Xaraes*.

Brachiaria brizantha cv. Xaraes

The *cv. Xaraes* also known as Toledo is originated from the rift valley region of Burundi. It grows in the soil of medium fertility with annual rainfall between 800 mm and 2300 m above sea level. It holds the soil firmly and can be used for erosion. The grass has a longer flowering cycle than *Brachiaria Piata* cultivars (Silva Roberto *et al.*, 2020).

Mucuna pruriens

Mucuna pruriens or Velvet bean is a forage legume, twining annual and grown in tropical and subtropical

regions (Mamatha *et al.*, 2010) as a cover crop (Mugendi and Njagi, 2010). The forage can be grown in association with other crops such as maize, sugar cane and coffee to maintain soil fertility and improve crop yields (Ortiz Ceballos *et al.*, 2012). It produces more than 10 T of dry matter/ha, and fixes around 331kg of nitrogen/ha (Feedipedia, 2016). The cultivars *Kakamega* 1 is among the accessions with the highest dry matter yield (41 T/ha/year). It is tolerant to Napier stunt disease and can be grown to improve forage availability in hot climate areas (Kabirizi *et al.*, 2017).

Illustration 3. *Mucuna pruriens cv. Utilis.*

Chloris gayana

Chloris gayana, a C4 forage perennial grass is originated from Sub-Saharan Africa (SSA) and is used for pasture improvement and hay making (Osman *et al.*, 2014). It is a good source of fodder in arid regions (Andama *et al.*, 2019). The grass can be grown up to 2000 m altitude above sea level (Mohamed and Gebeyew, 2018). Furthermore, Chloris gayana is also one of grass families which is identified as drought resistant and highly productive with average dry matter yield ranging from 10-16 T DM/ha (Hidosa *et al.*, 2018).

Illustration 4. *Penissetum purpureum cv. Kakamega 1*.

Illustration 5. *Chloris gayana.*

Illustration 6. *Brachiaria brizantha cvs Piata.*

Brachiaria brizantha cv. Piata

The cultivar *Piata* is one the most adapted *Brachiaria* cultivars to water stress due to deep root system and osmoregulation behaviour (Santos *et al.*, 2013). When fed to dairy cattle, *Brachiaria brizantha cv*. Piata improves feed intake leading to high milk yield (Mutimura *et al.*, 2018). *Brachiaria brizantha cvs Piata and Xaraes* are important in developing new crop pest management strategies, such as push-pull technology, rapid crop management and yield improvement in developing countries (Cheruiyot *et al.*, 2020).

Desmodium distortum

Desmodium distortum (Greenleaf) is a nitrogen-fixing legume characterized by fast growth, easily degradable biomass, compatibility with maize crops but selective adaptability to soil and climatic conditions (Kaho *et al.*, 2004).

Greenleaf is mainly used for cut and carry to increase milk production in dairy cattle (Cheruiyot *et al.*, 2020). It has been widely promoted in Rwanda as a source of protein for forage supplementation (Mutimura *et al.*, 2018).

METHODOLOGY

Study locations

This survey concerns smallholder farmer living in semi-arid area of Eastern part of Rwanda, specifically in Ngoma and Bugesera districts (Figure 1). Ngoma district is located at approximately 100 km south-east of Kigali, the capital city of Rwanda with an average altitude ranging from 1,400 to 1,700m asl, average annual temperature of 20°C and annual precipitation of 1,100 mm (Kim *et al.*, 2013). The region is characterized by rain-fed cultivation where the economy is typically agrarian, with more than 81% of the population working in the agriculture sector. A small rainy season occurs from mid-October until the end of December. Bugesera region is located in the south-eastern plains of the Eastern Province of Rwanda. The region covers a total area of 1,303 Km2 represented by latitudes 2°01'55'' S and 2°24'45'' S, and longitudes 29°56'50'' E and 30°23'19'' E. The Bugesera district is largely a plateau rising at an altitude ranging from 1,323 to 1,544 m asl (Jean-fiston *et al.*, 2014). It is bordered by the Republic of Burundi to the south, lake Rweru to the south-east, lake Cyohoha to the south-west, Nyabarongo river to the North-East, and Akanyaru river to the west. The landscape is characterized by very broken reliefs consisting of a range of hills and borders the fluvial depositions of the Nyabarongo river (Jean-fiston *et al.*, 2014). The Eastern part receives an average annual rainfall of about 850 to 1,000 mm, falling in a bi-modal rainy season. The area experiences 7 months of drought and average temperatures of 21°C. The climate is too dry for optimal plant growth and agriculture suitability for development (Mutabazi, 2010).

Illustration 7. Desmodium distortum.

Forage establishment

The demonstration sites were located on the land of local cattle farmers with an interest in planting and evaluating the grass varieties and legume forage options. Five forage grass species viz: *Brachiaria brizantha var Xaraes, Brachiaria brizantha var Piata, Brachiaria decumbens var Basilisk, Chloris gayana and Penissetum purpureum var kakamega* 1 and two legumes: *Mucuna pruriens var utilis* (white seeds) and *Desmodium distortum* were planted in two demonstration plots in both districts. Farmers who participated in forage evaluation were previously involved in forage planting and management. Demonstration plots were cleared, ploughed and made to be suitable for forage cultivation. Demonstration plots were managed by farmers and the frequent visit was made by researchers and extension workers to monitor, evaluate and collect data.

Perception data

Approximately 90 days after planting, participatory workshops were held at two of the study sites and involved exclusively small dairy farmers from all of the demonstration plots. Farmers first worked together with researchers and extension workers to define a set of key criteria for assessing fodder grass and legume. The six main criteria included: growth, soil cover, foliage colour (all estimated visually) and perceived palatability (assessed by smell and texture), drought tolerance and leaf/stem ratio. Each fodder was then ranked by the farmers on a scale of 1 to 5 (1 = poor; 2 = fair; 3 = good; 4 = very good; 5 = excellent) to develop weight of the relative importance of each to be used in the final calculation of an overall score for each grass and legume materials. A total of 48 farmers participated in the trial for the species selection in each district (96 farmers in both districts). Farmers were trained and asked to closely observe forage grown in the demonstration plots in each site/district. The participatory evaluation carried out was not only to capture farmer perceptions of the forage genetic materials tested, but also to facilitate dissemination of these materials among other farmers in the area and therefore engage in preliminary training of dairy cattle producers and local veterinary technicians in Bugesera and Ngoma districts.

Data collection method

The criteria and performance levels were defined by local farmers to evaluate the performance of the forage established. Using a structured questionnaire, data were collected based on farmers' opinions on the six indicators of growth, colour, soil coverage, palatability, drought tolerance and leaf/stem ratio.

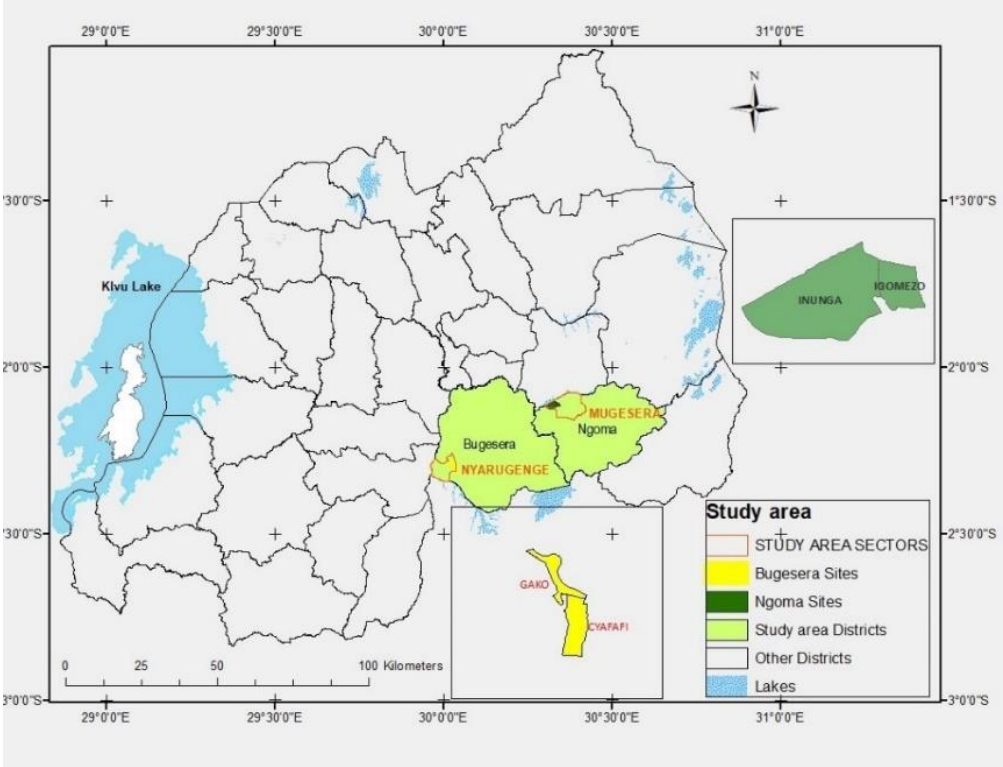

Figure 1. Map of the study area.

Criteria (indicators) and performance benchmarks defined by local farmers for evaluation

Farmer's evaluation was conducted by the following criteria:

Growth

Growth characteristic was defined as the observed volume of forage (height, volume and thickness). Greater volumes were associated with higher rankings. In farmers' opinion, any forage species that performed above 60% was selected as the best performance in growth.

Soil coverage

The soil coverage was characterized by the soil cover of forage species. More ground cover was associated with higher rankings (>70%).

Forage color

The forage color referred to the colour of the leaves. A green colour (>60%) was ideal.

Palatability

Forage palatability was referred to as scent and texture and measured by rubbing a few leaves gently between fingers. Scent of corn with a soft texture (>60%) was ideal.

Drought tolerance

Drought tolerance was the degree to which a plant was adapted to the arid area or drought climatic conditions (>60%).

Leaf/stem ratio

Leaf/stem ratio was referred to as forage quality and fibre digestibility (>60%). The leaf/stem ratio is an important factor that affects diet selection, quality, and forage intake.

Index coverage/indicator

Index coverage/indicator was the average indicator of the total forage species. Therefore, the best Index coverage/indicator was rating by farmers at > 60%.

Index coverage/forage

The Index Coverage/forage was determined as the average of the indicators for each forage species. The

rate of >55% were considered by farmers as the overall best performance of the forage.

Pair-wise ranking matrix for selection criteria

Pair-wise ranking of the farmers' selection criteria was made to rank the selection criteria and to identify the most important trait for the community for future forage improvement. Farmers were voluntary to compare the criteria and rank them in order of importance.

Forage chemical composition analysis

Feed samples were weighed into pre-dried porcelain crucibles and then dried at 105ºC in an oven for 48 hours (dry matter (DM) content was the dry weight, as a proportion (g/Kg) of the original weight of the sample (AOAC, 2000). The dried samples were incinerated in a furnace (550ºC for 8h) to determine organic matter (OM) content.

The OM was the dry weight of the sample not recovered in the ash expressed as the proportion (g/Kg DM) dry weight of the sample (AOAC, 2000). The nitrogen content of the feed samples was determined using Kjeldhal method of the feed (AOAC, 2000). The nitrogen in feed was converted to NH_4SO_4 acid digestion (12N H_2SO_4) at 550ºC (≥ 1h) and recovered in boric acid using steam distillation into boric acid using 40% NaOH (w/v) (industrial grade). The N content was determined by back titration using 0.1 M HCl. The NDF was the residual cell wall contents of feed materials after refluxing in neutral detergent solution (1h), rinsing with deionized distilled water and acetone (70%) w/w; (Goering and Van-Soest, 1970).

Data analysis and discussions

Laboratory analysis

Pair-wise comparison for qualitative traits

In the pair-wise comparison, all the indicators were compared. Results from Bugesera farmers showed that palatability ranked first against all criteria while drought tolerance and leaf/stem ratio ranked second and third respectively. Forage colour was ranked last by farmers and the trait was considered less important than others for future forage improvement in both regions.

Table 1. Chemical composition of forages (g/kg DM).

	Chemical component (g/Kg DM)					
Feed materials	DM	ASH	CP	NDF	ADF	OM
Brachiaria brizantha var Xaraes	249.90	83.40	63.90	654.80	427.60	837.20
Brachiaria brizantha var Piata	293.10	82.00	43.50	718.70	436.70	848.20
Brachiaria decumbens var Basilisk	164.30	74.50	158.60	610.30	550.90	846.10
Mucuna pruriens var utilis	285.60	54.30	73.40	714.10	512.50	864.90
Chloris gayana	226.70	82.10	73.90	709.30	479.50	840.60
Desmodium distortum	161.40	95.40	240.10	509.60	473.60	825.20
Penissetum purpureum var kakamega 1	116.00	138.00	138.40	617.90	403.50	786.70

DM=dry matter, ASH=Ash, CP=crude protein, NDF=neutral detergent fibre, ADF=acid detergent fiber, OM=organic matter

Table 2. Pair wise ranking for Bugesera district.

Indicators	Growth	Colour	Coverage	Palatability	Drought tolerance	Leaf/Stem ratio	Points	Rank
Growth		1	1	0	0	0	2	4
Colour	0		0	0	0	0	0	6
Coverage	0	1		0	0	0	1	5
Palatability	1	1	1		1	1	5	1
Drought tolerance	1	1	1	0		1	4	2
Leaf/Stem ratio	1	1	1	0	0		3	3

Source: Own study (2021)

Table 3. Pair wise ranking for Ngoma district.

Indicators	Growth	Colour	Soil overage	Palatability	Drought tolerance	Leaf/Stem ratio	Points	Rank
Growth		1	0	0	0	0	1	5
Colour	0		0	0	0	0	0	6
Soil coverage	1	1		0	0	0	2	4
Palatability	1	1	1		1	1	5	1
Drought tolerance	1	1	1	0		0	3	3
Leaf/Stem ratio	1	1	1	0	1		4	2

Based on these criteria, farmers who participated in the pair wise ranking system in both districts preferred palatability as the number one grass due to its performance on intake when feeding dairy cattle. However, drought tolerance was ranked number two in Bugesera district while it was number three in Ngoma district. The leaf/stem ratio was then ranked number two in Ngoma district while it was third place in Bugesera district. This shows that the above three indicators were mor important in livestock feeding for both districts than any other indicator in this study. In this section, a survey has done whose respondents were local farmers is presented in terms of frequency tables. Farmer's perceptions on the key indicators with respect to the quality of various established forages are exhibited.

Perception of Ngoma farmers on the various established forages versus key indicators

In this subsection, frequency distribution of the data is are presented and discussed.

Growth characteristic for each forage under study

The growth characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) histogram. Excluding both levels "Poor and Fair", local farmers had different opinions ranging from "good, very good and excellent" level attributed to this characteristic. *Brachiaria decumbens cv. Basilisk* is the highest "good" (68.8%), *Brachiaria brizantha cv. Piata* the highest "very good" (62.5%) and both *Desmodium distortum* the highest "excellent" (52.1%) level respectively.

Colour characteristic for each forage under study

The color characteristic perception level from farmer in Ngoma district is visualised in the following frequency (in percentage) histogram.

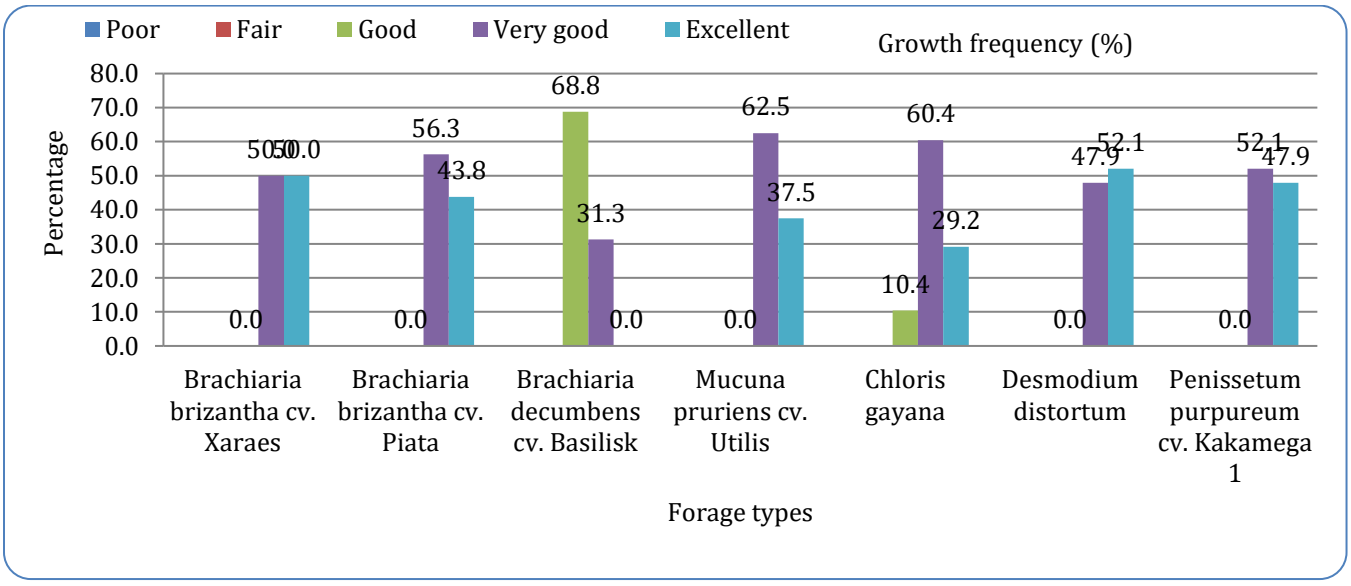

Figure 2. Perception of "Growth characteristic" associated with each forage.

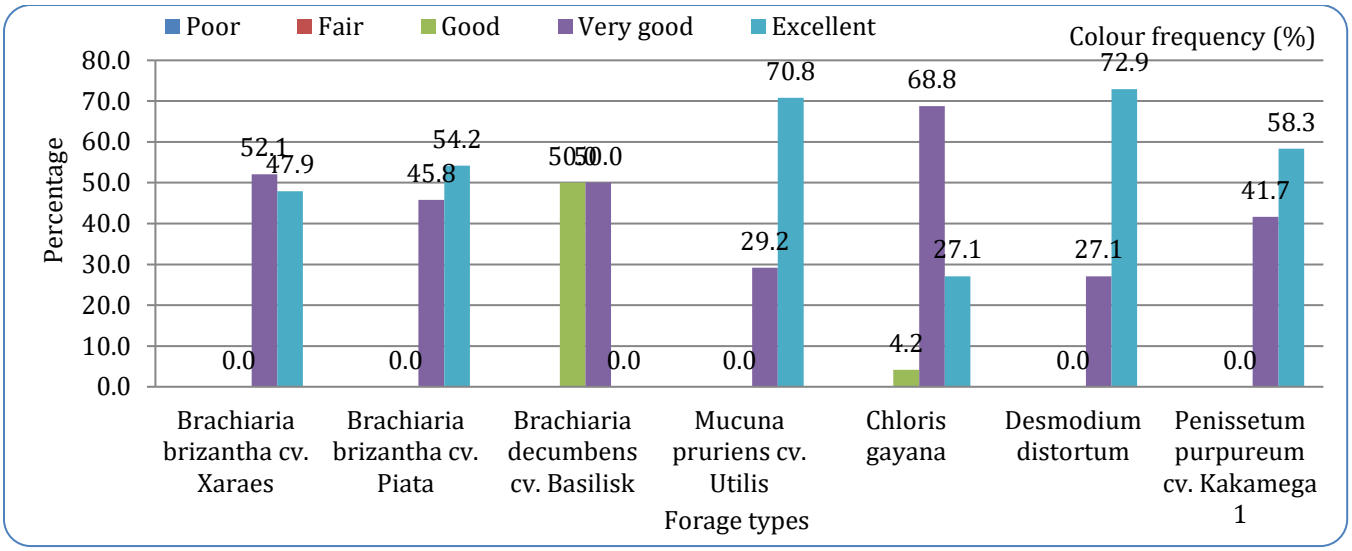

Figure 3. Perception of "Colour characteristic" associated with each forage.

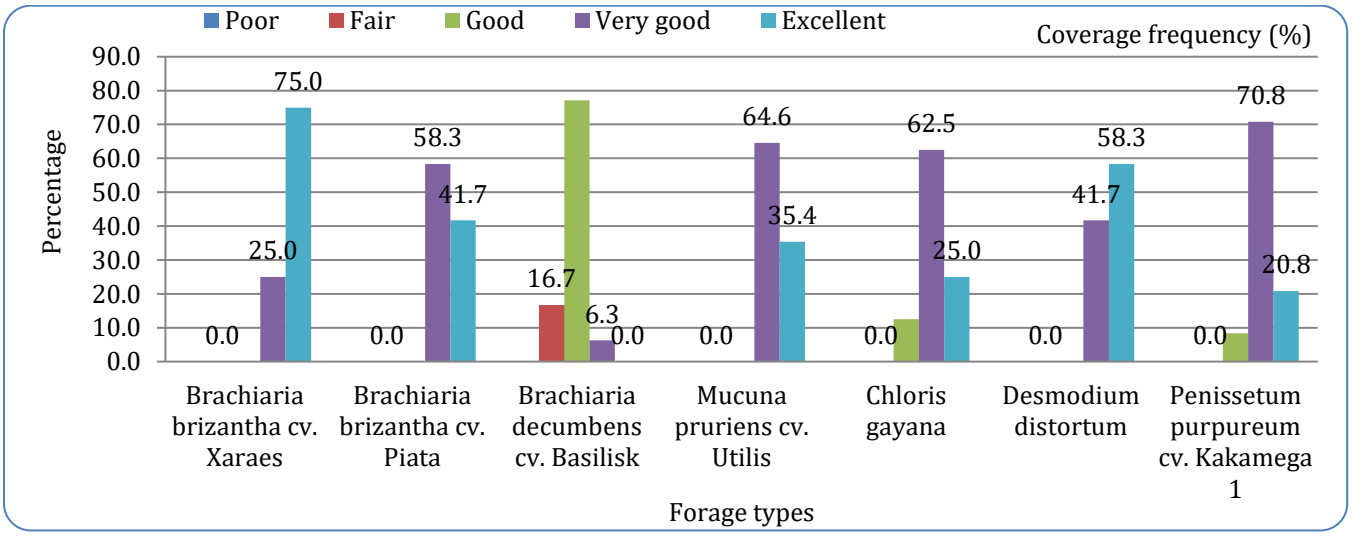

Figure 4. Perception of "Coverage characteristic" associated with each forage.

Excluding both levels "Poor and Fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, *Brachiaria decumbens var Basilisk* is the highest "good" (50.0%), *Chloris gayana* the highest "very good" (68.8%) and both *Desmodium distortum* the highest "excellent" (72.9%) levels respectively.

Coverage characteristic for each forage under study

The coverage characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) table and visualised in subsequent graph. Excluding level "Poor", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, *Brachiaria decumbens cv. Basilisk* is the highest "good" (77.1%), *Penissetum purpureum var kakamega* 1 the highest "very good" (70.8%) and *Brachiaria brizantha cv. Xaraes* the highest "excellent" (75.0%) levels respectively. Observe that also *Mucuna pruriens var utilis* (64.6%) and *Chloris gayana* (62.5%) are at the "very good" level.

Palatability characteristic for each forage

The coverage characteristic perception level from farmer in this district is visualised in the following frequency (in percentage) graph.

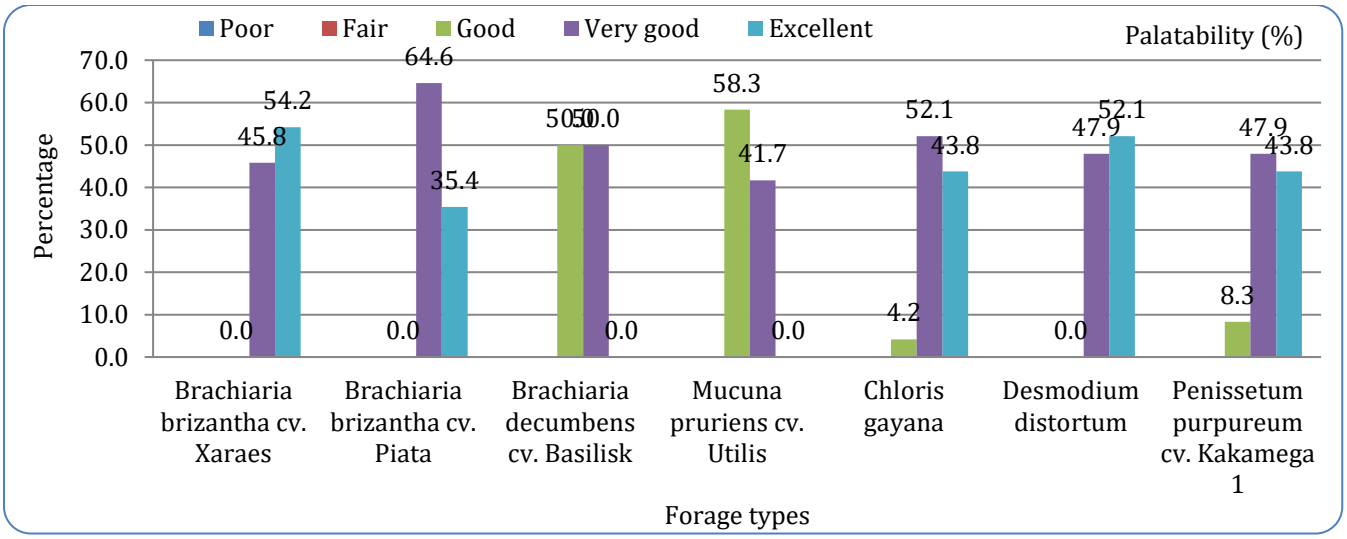

Figure 5. Perception of "palatability characteristic" associated with each forage.

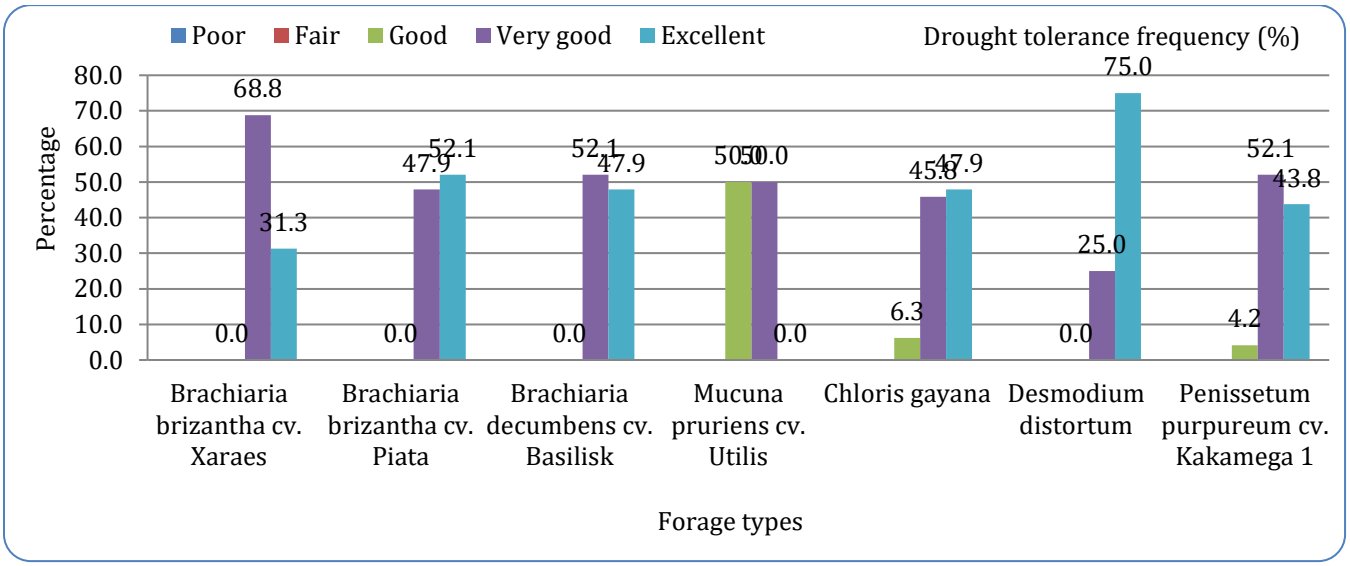

Figure 6. Perception of "Drought tolerance characteristic" associated with each forage.

Excluding both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, Mucuna pruriens var utilis is the highest "good" (58.3%), *Brachiaria brizantha cv. Piata* the highest "very good" (64.6%) and *Brachiaria brizantha cv. Xaraes* the highest "excellent" (54.2.0%) levels respectively.

Drought tolerance characteristic for each forage under study

The coverage characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph. Excluding both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, Mucuna pruriens var utilis is the highest "good" (50.0%), *Brachiaria brizantha cv. Xaraes* the highest "very good" (68.8%) and *Desmodium distortum* the highest "excellent" (75.0%) levels respectively.

Leaf/stem ratio characteristic for each forage under study The Leaf/stem ratio characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph.

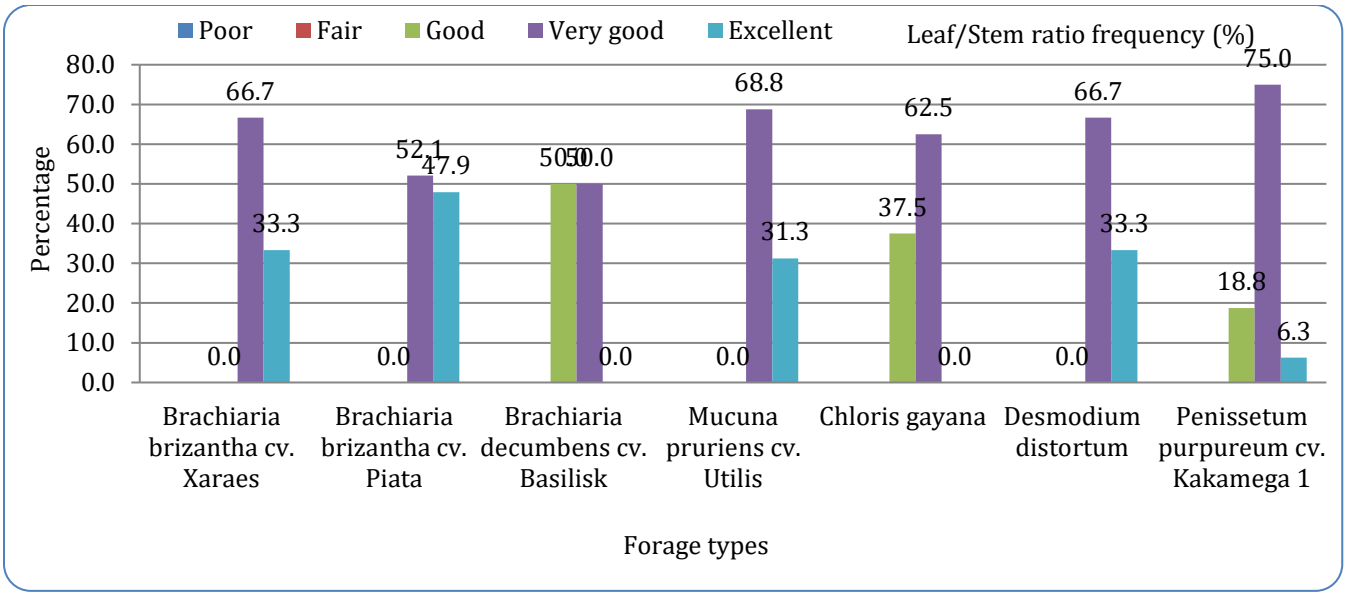

Figure 7. Perception of "Leaf/stem ratio characteristic" associated with each forage.

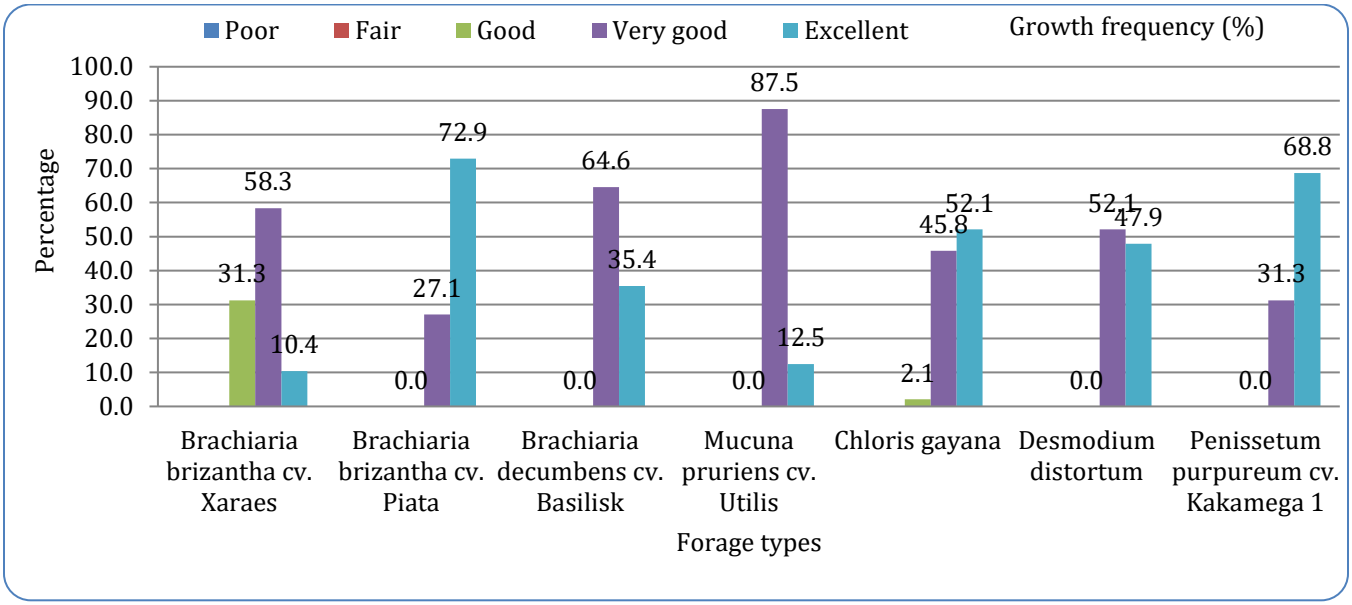

Figure 8. Perception of "growth characteristic" associated with each forage.

Excluding both levels "Poor and fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, *Brachiaria decumbens cv. Basilisk* is the highest "good" (50.0%), *Penissetum purpureum cv. kakamega* 1, the highest "very good" (75.0%) and *Brachiaria brizantha cv. Piata* the highest "excellent" (47.9%) levels respectively. It is important to note also that other forages, including Mucuna pruriens var utilis (68.8%), *Desmodium distortum* (66.7%), *Brachiaria brizantha cv. Xaraes* (66.7%), and *Chloris gayana* (62.5%) are all at the "very good" levels respectively.

Perception of Bugesera farmers on the various established forages

In this subsection, frequency distribution of the data is presented and discussed.

Growth characteristic levels for each forage

The perception level from farmer is displayed in the following frequency (in percentage) graph. Excluding

both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, *Brachiaria decumbens var Xaraes* is the highest "good" (31.3%), Mucuna pruriens var utilis, the highest "very good" (87.5%) and *Brachiaria brizantha var Piata* the highest "excellent" (72.9%) levels respectively.

It is important to note also that other forages, including *Penissetum purpureum var kakamega* 1 (68.8%), is all at the "excellent" level.

Colour characteristic levels for each forage

The colour characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph.

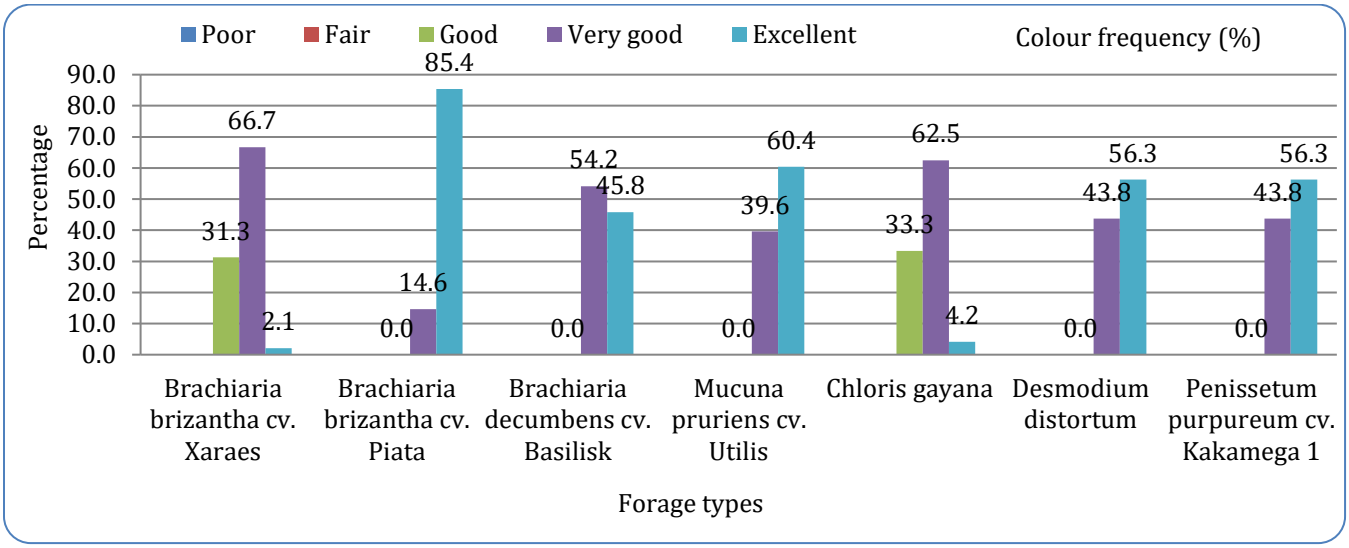

Figure 9. Perception of "color characteristic" associated with each forage.

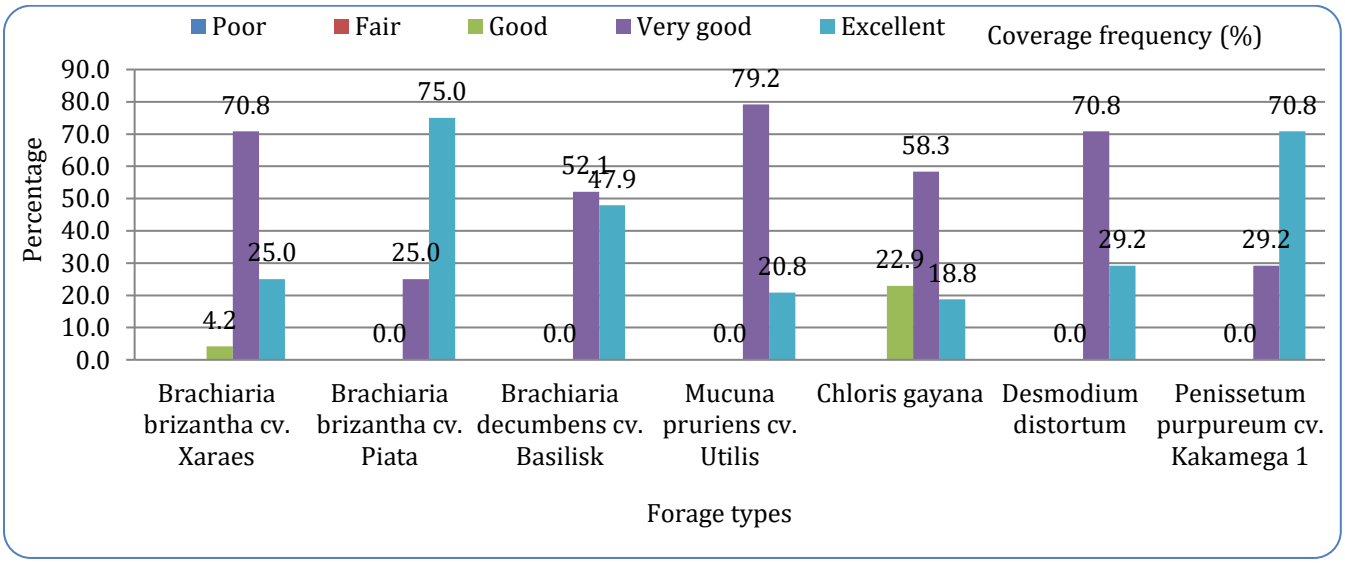

Figure 10. Perception of "coverage characteristic" associated with each forage.

Excluding both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, Chloris gayana is the highest "good" (33.3%), *Brachiaria brizantha cv. Xaraes*, the highest "very good" (66.7%) and *Brachiaria brizantha cv. Piata* the highest "excellent" (85.4%) levels respectively.

Coverage characteristic levels for each forage under study

The coverage characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph. Excluding both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, *Chloris gayana* is the highest "good" (22.9%), Mucuna pruriens var utilis, the highest "very good" (79.2%) and *Brachiaria brizantha cv. Piata* the highest "excellent" (75.0%) levels respectively. It was observed also that both *Brachiaria brizantha cv. Xaraes* and *Desmodium distortum* were at (70.8%) "very good" levels and also *Penissetum purpureum cv. kakamega* 1 at (70.8%) "excellent" levels respectively.

Palatability characteristic levels for each forage under study

The palatability characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph.

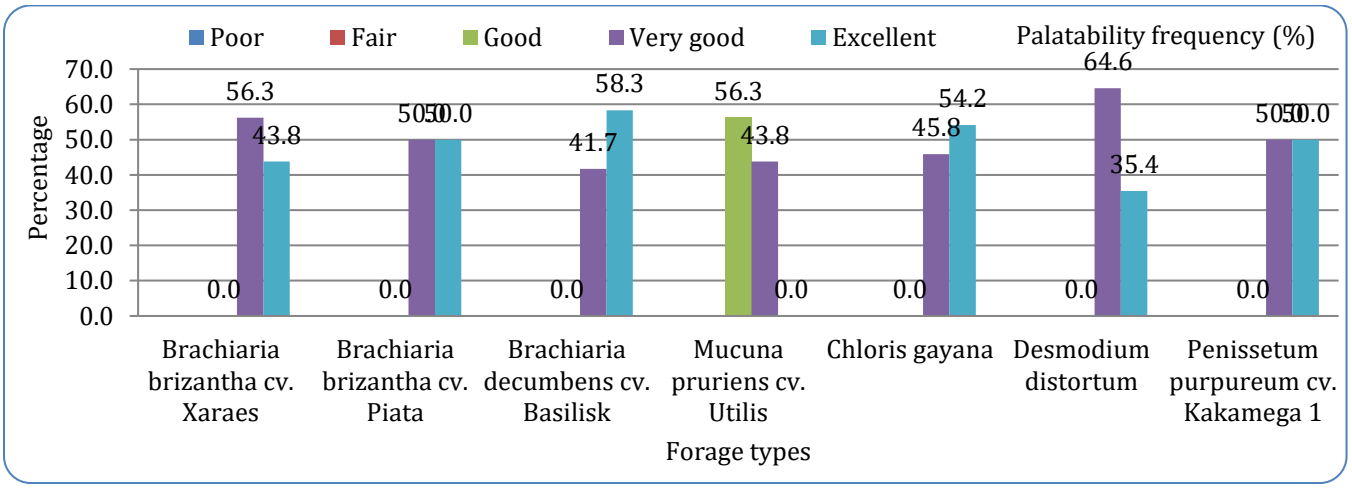

Figure 11. Perception of "palatability characteristic" associated with each forage.

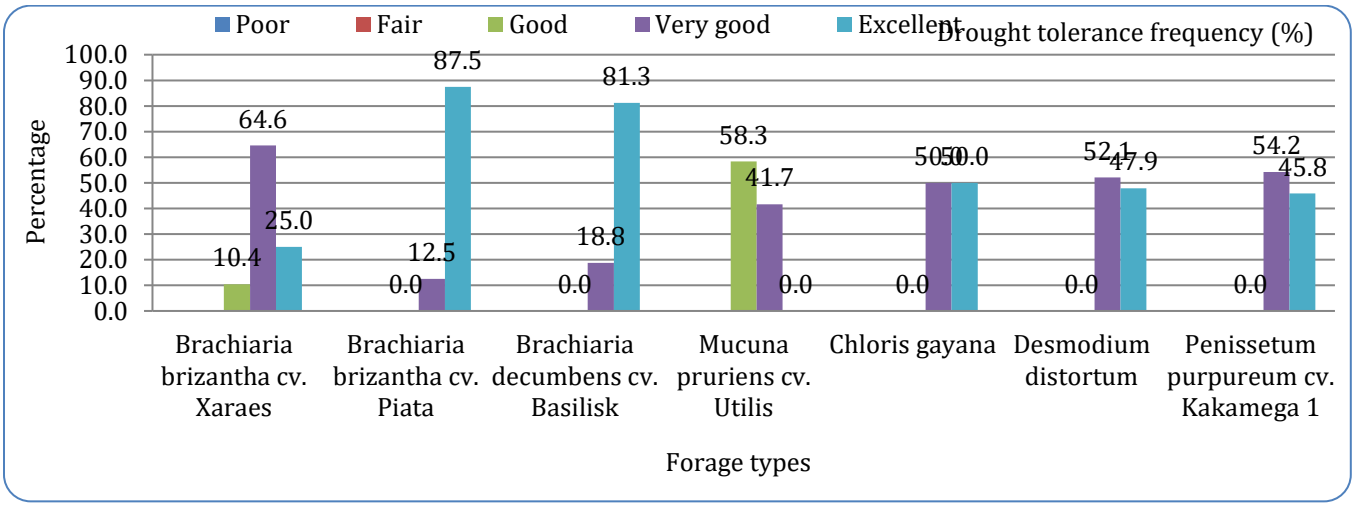

Figure 12. Perception of "drought tolerance characteristic" associated with each forage.

Excluding both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, Mucuna pruriens var utilis is the highest "good" (56.3%), *Desmodium distortum*, the highest "very good" (64.6%) and *Brachiaria brizantha cv. Basilisk* the highest "excellent" (58.3%) levels respectively.

Drought tolerance characteristic levels for each forage under study

The drought tolerance characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph. Excluding both levels "Poor, fair", local farmers had different opinions ranging from "fair. good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, *Mucuna pruriens var utilis* has the highest "good" (58.3%) level, *Brachiaria brizantha cv. Xaraes*, the highest "very good" (64.6%) level and *Brachiaria brizantha cv. Piata* has the highest "excellent" (87.5%) respectively.

It was also observed that *Brachiaria decumbens cv. Basilisk* is at (81.3%) "excellent" level in this district for this characteristic.

Leaf/stem ratio characteristic levels for each forage under study

The leaf/stem ratio characteristic perception level from farmer in this district is displayed in the following frequency (in percentage) graph.

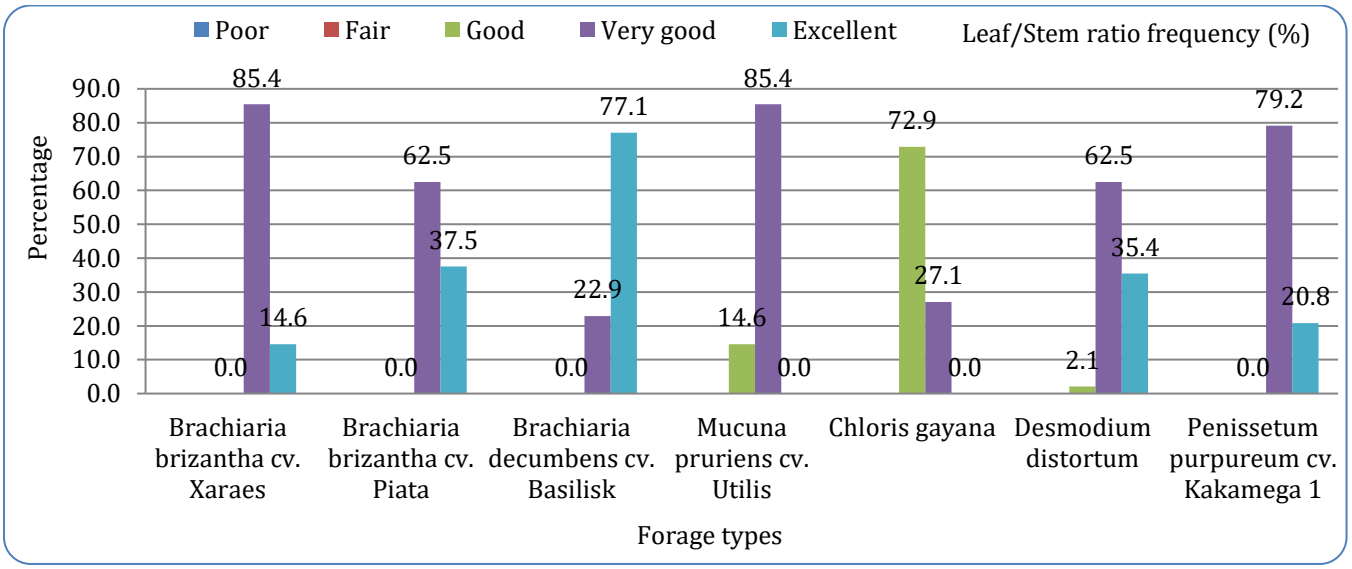

Figure 13. Perception of "leaf/stem ratio characteristic" associated with each forage.

Excluding both levels "Poor, fair", local farmers had different opinions ranging from "good, very good and excellent" levels attributed to this characteristic. Among all forages viewed under used scales, Chloris gayana has the highest "good" (72.9%) level, *Brachiaria brizantha cv. Xaraes*, the highest "very good" (64.6%) level and both *Brachiaria brizantha cv. Xaraes and Mucuna pruriens cv. Utilis* have highest level "excellent" (85.4%), and *Brachiaria decumbens cv. Basilisk,* has the highest level at (77.1%) respectively. It was observed that *Brachiaria decumbens cv. Basilisk* is at (81.3%) "excellent" level in this district for this characteristic.

General summary of findings

A general summary of the findings is presented in this section. It consists of the highest perceived performance of forage species under examination in line with each indicator described in the following section.

Performance levels of planted grasses in Ngoma district

From the table 5.1.1, one observes that *Brachiaria brizantha cv. Xaraes* covered more than 61.1% of the index coverage/ forage while the rest of the forages covered below 60% of the total forage index in Ngoma district. From this table, one observes that *Brachiaria decumbens cv. Basilisk* (68.80%) and *Chloris gayana* (60.50%) were ranked as best pet forages for growth performance. *Chloris gayana* was attributed a good note for the green color of leaves (68.80%) and leaf/stem ratio (62.50%). *Brachiaria brizantha cv. Xaraes* (75.00%), *Brachiaria decumbens cv. Basilisk* (71.10%) and *Penissetum purpureum cv. Kakamega* 1 (70.80%) were the best forage for soil cover hence their importance in erosion control. *Brachiaria brizantha cv. Piata* did best (64.60%) in palatability than other any forage established in Ngoma district. Drought tolerance

characteristic was attributed to *Brachiaria brizantha cv. Xaraes* with (68.80%). *Brachiaria brizantha cv. Xaraes* (66.70%), *Chloris gayana* (62.50%) and *Penissetum purpureum cv. Kakamega* 1 (75.00%) performed well in terms of leaf/stem ratio. However, all the types of grasses introduced in Ngoma district can be disseminated (>55%) as livestock feed for smallholder dairy farmers. According to the farmer's opinion, *Mucuna pruriens cv. Utilis* was ranked best in terms of growth performance (62.50%), green color (70.80%) and leaf/stem ratio (68.80%). Color (72.90%), Drought tolerance (75.00%) and leaf/stem ratio were attributed to *Desmodium distortum*. However, for both legumes, the index coverage/forage was appreciated (>55%) by farmers as a protein supplement for livestock in the region.

Table 4. Performance levels (%) of fodder grasses versus indicators in NGOMA district.

Forage type	Forage indicators						
	Growth	Colour	Coverage	Palatability	Drought tolerance	Leaf/Stem ratio	Index coverage/forage
Brachiaria brizantha cv. Xaraes	50.00	52.10	75.00	54.20	68.80	66.70	61.13
Brachiaria brizantha cv. Piata	56.30	54.20	58.30	64.60	52.10	52.10	56.27
Brachiaria decumbens cv. Basilisk	68.80	50.00	71.10	50.00	52.10	50.00	57.00
Mucuna pruriens cv. Utilis	62.50	70.80	64.60	58.30	50.00	68.80	62.50
Chloris gayana	60.50	68.80	62.50	52.10	47.90	62.50	59.05
Desmodium distortum	52.1	72.90	58.30	52.10	75.00	66.70	62.90
Penissetum purpureum cv. Kakamega 1	52.10	58.30	70.80	47.90	52.10	75.00	59.37
Index coverage/indicator	57.47	61.01	65.80	54.17	56.86	63.11	

Performance levels of planted grasses in BUGESERA district

The following table display the levels at which each forage under study was performed in the study district.

Table 5. Performance levels of fodder grass versus the 6 indicators in BUGESERA district.

Forage type/grasses	Forage indicators						
	Growth	Colour	Coverage	Palatability	Drought tolerance	Leaf/Stem ratio	Index coverage/forage
Brachiaria brizantha cv. Xaraes	58.3	66.7	70.8	56.3	64.6	85.4	67.0
Brachiaria brizantha cv. Piata	72.9	85.4	75.0	50.0	87.5	62.5	72.2
Brachiaria decumbens cv. Basilisk	64.6	54.2	52.1	58.3	81.3	77.1	64.6
Mucuna pruriens cv. Utilis	84.5	60.4	79.2	56.3	58.3	85.4	70.7
Chloris gayana	52.1	62.5	58.3	54.2	50.0	72.9	58.3
Desmodium distortum	52.1	56.3	70.8	64.6	52.0	62.5	59.7
Penissetum purpureum cv. Kakamega 1	68.8	56.3	70.8	50.0	54.2	79.2	63.2
Index coverage/indicator	64.8	63.1	68.1	55.7	64.0	75.0	

The farmer's opinion indicated that *Brachiaria brizantha cv. Piata* (72.9%), *Brachiaria decumbens cv. Basilisk* (64.6%) and *Penissetum purpureum cv. Kakamega* 1(68.8%) grew better than other forages in the region. At the time of the workshop, green color of *Brachiaria brizantha cv. Xaraes* (66.7%), *Brachiaria brizantha cv. Piata* (85.4%) and *Chloris gayana* (62.5%) was appreciated by farmers. In addition, farmers attributed a

good score for *Brachiaria brizantha cv. Xaraes* (70.8%), *Brachiaria brizantha cv. Piata* (75.0%) and *Penissetum purpureum cv. Kakamega* 1 (70.8%) as forage that can be used for soil erosion control. *Brachiaria cvs. Xaraes* (64.6%), *Piata* (87.5%) and *Basilisk* (81.3%) could be very well used as drought tolerant species in *Bugesera*, therefore greening the region. All the forage grasses in *Bugesera* were appreciated by farmers in terms of leaf/stem ratio as an indicator of good digestibility for livestock feeding. In addition, all the grasses had good index coverage forage (>55%) as a sign of forages that can be disseminated for livestock feeding. Livestock farmers attributed good performance of Mucuna pruriens cv. Utilis in growth (84.5%), color (60.4%), coverage (79.2%). and leaf/stem ratio (85.4%) while *Desmodium distortum* performed best in coverage (70.8%), palatability (64.6%) and leaf/stem ratio (62.5%).

Involvement of local farmers in forage evaluation informs the assessment of adaptability of new species while increasing the potential of adoption and impact (Peters et al., 2003). The participatory methodology utilized in this study to evaluate the perception of farmers on forage species proved to be effective, as farmer response closely coincided with the agronomic adaptability that was seen in the field during evaluation. However, farmer participatory evaluations can sometimes differ from scientific findings or other farmer's opinions in another region. For example, when ranking perceived palatability, Mutimura *et al.* (2020) favoured *Brachiaria decumbens cv. Basilisk* while farmers in both districts did not consider the same grass to have palatability. However, Peters *et al.* (2003) show the same results as the findings of this study where *Brachiaria decumbens cv. Basilisk* was not considered to have high palatability in Central America. The same results were confirmed by Gaspar *et al.* (2021) and Assumaidaee and Mustapha (2012) where *Brachiaria decumbens* was proven to be toxic due to its high *protodioscin toxine* level in leaves causing outbreaks in ruminant animals.

The variability observed in forages across all the sites highlights the need to consider site-specific conditions when making forage recommendations to smallholder dairy farmers in the region. For example, *Brachiaria cvs. Basilisk, Piata and Xaraes and Penissetum purpureum cv. Kakamega* 1 which demonstrated a great capacity for soil coverage and drought resistance across all sites could be an appropriate choice on soils susceptible to erosion and severe drought (Peters *et al.*, 2003).

The introduction of forage genetic materials in Bugesera and Ngoma districts would be an important advancement for the productivity and sustainability of livestock production systems. Based on the results provided in this paper, incorporating improved grasses and legumes as forage crops could lead to a higher increase in forage production, which allows for higher milk yield, better income (Hadush, 2021) and rapid dissemination, assuming adequate forage management. Increased soil coverage associated with the improved fodder grass (*Brachiaria brizantha cv. Xaraes, Brachiaria decumbens cv. Basilisk, Penissetum purpureum cv. Kakamega 1 and Brachiaria brizantha cv. Piata*) could help mitigate soil erosion, suppress weeds and contribute to Carbon sequestration through the extensive root production system (Lemaire *et al.*, 2014). In addition, *Brachiaria* cultivars have been shown to improve soil fertility with a significant reduction of pests and diseases on crops (Mutimura *et al.*, 2020).

Improved forages have also been shown to increase the nutritional balance of livestock feed and reduce Green House Gas (GHG) emissions associated with cattle production (Montenegro et al., 2016), while forage legumes (*Desmodium distortum and Mucuna pruriens*) could contribute to soil fertility through atmospheric Nitrogen fixation. Ngoma (Mugesera sector) and Bugesera district (Nyarugenge sector) are characterized by low soil fertility and a prolonged dry season, thus forage production scheme has been designed through collaboration between producers and extension workers and put more effort in zero-grazing to achieve greater efficiency of smallholder dairy production (Hadush, 2021). This co-design of forage production considered climate change mitigation associated with increase in drought conditions, as well as explore the suitability of multiple options such as forage conservation (silage, hay).

The positive response of farmers towards legume species should not be ignored in future efforts to improve livestock-based systems for meat and/or dairy production. However, legumes also have a wide range of other uses that could provide additional economic benefit to farmers (Kebede *et al.*, 2016). For instance, legumes could potentially be intercropped with annual crops or fodder grasses, used for human consumption as protein banks for cut and carry management and also

contribute to silage production (Lima-Orozco *et al.*, 2016).

We suspect that improved familiarity of the established grasses and legumes and efforts to better integrate them could further improve perception of both forages, therefore facilitate future adoption. We also note that increased focus on dairy production in zero-grazing system could improve the ability of smallholder farmers to invest more in improved forages.

CONCLUSION AND RECOMMENDATIONS

It has been demonstrated that farmers' skills and knowledge can complement scientific research, and that their contribution through a participatory research approach is key in validating the potential of forage materials in a given area.

In general, the participatory forage survey was accomplished at both sites. The process was well appreciated by farmers since it allowed full participation of the group members in contrast to structured interviews which limit the expression of individual responses. Most farmers in the groups expressed their appreciation of the fodder development within a short period (approximately three months). Findings in this survey revealed that certain forage species, precisely *Brachiaria brizantha cvs. Xaraes, Piata, Penissetum purpureum cv. Kakamega* 1 and *Desmodium distortum* were viewed as drought tolerance species and as a breakthrough in terms of milk and meat production in Bugesera and Ngoma districts.

Moreover, findings also suggest that three indicators viz: palatability, leaf/stem ratio and drought tolerance were more important in evaluating forages as livestock feeding for both districts than any other indicator used in this participatory survey. The benefits of the proposed forages can be read in table 4.1.1 in terms of chemical composition. Importantly, as proven by authors Santos *et al.* (2013); Mutimura *et al.* (2020), Brachiaria cultivars will undoubtedly contribute to the climate change mitigation through carbon sequestration, soil cover and soil erosion control.

Given the findings in the current survey, it is reasonable to recommend the following actions to farmers exercising in both sites:

- To exclusively cultivate *Brachiaria brizantha cvs. Xaraes, Piata, Penissetum purpureum cv. Kakamega* 1 and *Desmodium distortum*;
- To extend on large scale the cultivation of these species for dissemination purposes.

For sustainability and management of forage cultivation, it is also reasonable to recommend the following institutional action plan:

- To provide continuous training in forage plantation and management, seed production and processing and forage conservation;
- To initiate forage farmers to agro-business to be exercised in the region and beyond.

Further research is required to determine the intake and animal performance of the most promising cultivars.

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