Brachiaria Grass for Sustainable Livestock Production in Rwanda under Climate Change

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Contents

Abstract

Brachiaria grass is an important tropical forage of African origin. It produces high amount of palatable and nutritious biomass, tolerates abiotic and biotic stresses, improves soil fertility, increases livestock productivity, and reduces adversities of climate change. Since 2007, several improved *Brachiaria* grass cultivars (*Brachiaria brizantha* cvs. Marandú, MG4, Piatã, and Xaraés; *B. decumbens* cv. Basilisk; *B. humidicola* cvs. Humidicola and Llanero; *Brachiaria*

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hybrid cvs. Mulato, Mulato II, and Cayman; and other hybrid lines Bro2/0465, Bro2/1452, and Bro2/1485) have been introduced and evaluated in Rwanda for adaptation, biomass yields, animal nutrition, livestock productivity, and environmental qualities. Both on-farm and on-station evaluations of 13 improved *Brachiaria* grass cultivars and 2 checks – local *Brachiaria* grass and buffel grass at two different agroecological zones of Rwanda showed superior adaptation, higher biomass yields, and higher nutritive values of all *Brachiaria* grass cultivars compared to buffel grass. Subsequent study evaluating the impact of cutting regimes on agronomic and nutritional characteristics of improved *Brachiaria* cultivars and Napier grass showed forages harvested at 90 days after planting with high crude protein content (between 137 and 167 g/kg DM for Mulato II and Piatã, respectively) and high metabolizable energy (up to 9 MJ/kg DM for Piatã). These attributes have shown to increase animal production optimizing retention time of the particle phase of digesta in dairy cows which was shorter for Piatã (62.8 h) than Napier grass (83.1 h). Piatã had higher voluntary dry matter intake than Napier grass hence increased milk yield up to 50%. Furthermore, heifer fed on Mulato II had up to 54.7% more body weight and less enteric methane (14%) than heifers fed on Napier grass. These studies have shown *Brachiaria* grass as the most productive forage of high farmer preference due to its adaptation in low rainfall and acidic soils and the production of green foliage year-round. Therefore, improved *Brachiaria* grass has been promoted in 20 of 30 districts of Rwanda through various livestock development initiatives benefitting more than 4,800 farmers from South, Eastern, and Northern Provinces of Rwanda. In this chapter, we also discussed the prospects of *Brachiaria* grass in supporting the growing livestock sector in Rwanda and emerging challenges.

Keywords

Biomass yield · Enteric methane · Milk yield · Nutritional characteristics

Introduction

Importance of Livestock in Rwanda

Livestock is one of the most important agriculture sectors in Rwanda. It provides food and nutrition, income, and employment and is the basis of livelihood of over 68% of smallholder farmers in Rwanda. Livestock contributes about 14% of agricultural gross domestic product (AGDP) and 3.5% to the national GDP (NISR 2019). The high population growth rates, urbanization, affluence, and changes in the food habits have been the major drivers for high demand for animal source food in the developing nations. A substantial increase in the demand for livestock products (twofold and threefold increase for milk and meat, respectively) has been projected for Rwanda by 2032 compared to demand in the year 2017.

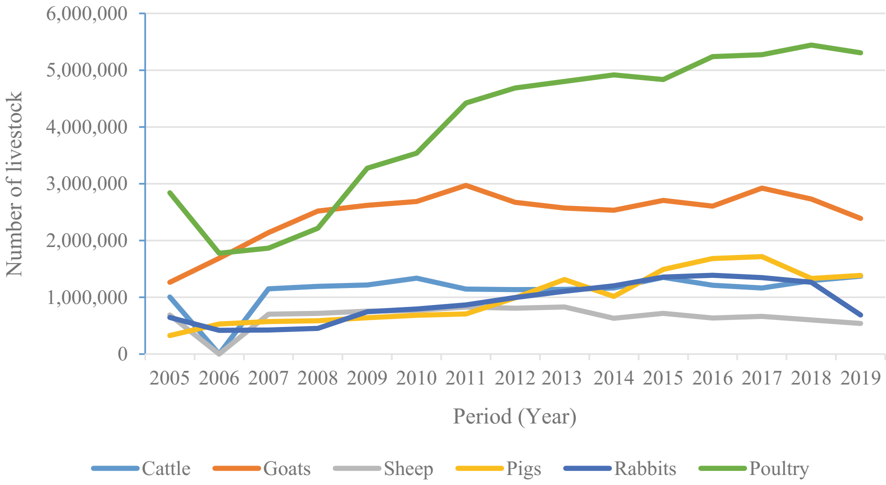

Fig. 1 Trends of animal population across years (RAB unpublished)

However, livestock production in Rwanda is expected to rise about 50% over the next 20 years (RLSA 2017).

Livestock enterprise in Rwanda is dominated by dairy cattle. The dairy cattle farming is composed of three management systems: extensive grazing, semi-intensive, and zero grazing. The extensive system is common in western highlands and part of the eastern province where the land size per household ranges from 5 to 25 hectares. The semi-intensive system is the most common among the households with land sizes of up to 25 ha and therefore adequate land for forage production, compared to the national average landholding of 0.33 ha/household. This system evolved from the traditional extensive communal grazing system following the introduction of land tenure laws with confinement regulations, which led to a major shift in husbandry and feeding practices. The zero grazing system is ubiquitous in the country. The average cattle herd size and cultivated land per household range between two and five animals. This system has received significant outreach among the poor families through the Girinka (one cow per poor family) program (RARDA 2006) and the communal Kraal system. The commercial dairy farming is also referred to as "modern" stockbreeding. They are concentrated mainly in the suburbs of Kigali, the capital city of Rwanda. In this system, farmers raise a large number of mostly purebred or crossbred dairy cows.

Rwanda has made tremendous strides in rebuilding its livestock sector in the last two decades. Figure 1 shows the trends in the number of different livestock species in the past 15 years in Rwanda. The national herd is about 1.17 million cattle, 670 thousand sheep, 2.94 million goats, 1.7 million pigs, and about 5.3 million layers, broilers, and indigenous chicken, produces currently about 94.2 thousand metric tons (MT) of meat, 747 thousand MT of milk, and 243 million eggs per year. In

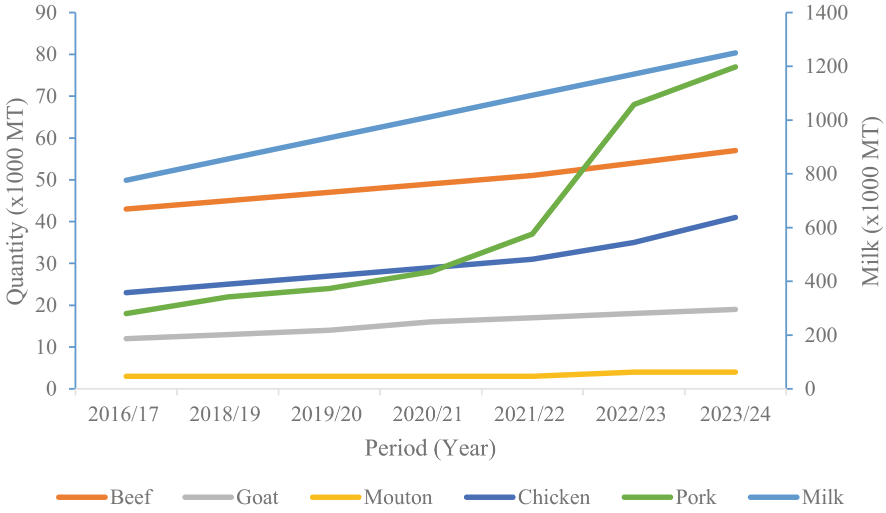

Fig. 2 Estimated animal products. (Source: Adapted from MINAGRI 2018)

addition, the herd provides about 6.8 million MT of organic fertilizer (MINAGRI 2018).

Ruminant livestock production is shared in all agroecologies. The low- and mid-altitude zones support 75% of cattle population and high-altitude zone supports 25%. Most of the sheep are found in high-altitude (48%) and mid-altitude (43%) production zones, while in the low altitude (9%) sheep production is less important. The largest proportion of goats (40%) are found in the low-altitude zone followed by mid-altitude zone (31%) and high-altitude zone (29%) (RLSA 2017).

Furthermore, specialized layer and broiler systems constitute 25% of the chicken population, and the remaining 75% are indigenous/local chickens which are managed under the family/village systems. Additionally, pig farming systems are dominated by the smallholder family system and limited commercial-oriented farming system. However, specialized pig fattening and breeding systems are emerging. In an effort to increase livestock products, the government has set a 7-year strategy for agricultural transformation phase 4 (PSTA 4). The strategy has projected a substantial increase in animal products where milk will be increased by 37.9% from 2017 to 2024 (Fig. 2).

Looking at the increasing trends for livestock products, it is important to think of the inputs that will be required to increase the production. One of the core inputs in livestock development is feeding. Feeding is one of the most important aspects of livestock production, and the feed accounts for 65–75% of total livestock production costs (Kırkpınar and Açıkgöz 2018). It is, therefore, that feed resources will be underscored in this chapter.

Major Livestock Production Constraints

Despite significant contribution of livestock to Rwandan economy and livelihood of the people of Rwanda, the country experiences the lowest livestock productivity in the region. Today, the livestock industry faces a number of challenges: limited quality feed resource base due to severe land and other abiotic and biotic constraints, low genetic potential of livestock breeds, infectious and vector-borne diseases, some of which attract public health and biosafety concerns, as well as high postharvest losses and quality assurance challenges that impede access to markets. Of these constraints, the major factors contributing to low livestock productivity are inadequate and poor-quality feeds where the contribution of planted forages as livestock feed is limited. Natural pasture acreage has shrunk over the years due to increased cropping than livestock rearing, and the pasture productivity has been declining due to overgrazing, poor pasture management, and drought (Mutimura and Everson 2012). Similarly, crop residues are low in nutritive values at the level that is often not adequate for the maintenance of animals. Other challenges include limited access to agricultural technologies and market for agricultural produce. There is a niche for introducing improved forages, as well as scope for improving the quality of crop residues.

Forage and crop residues are the major constituents of livestock feed in Rwanda. Poor quality of crop residues; seasonal availability of forage; poor nutritive values of most local forages and low biomass production potential; and sharp decline in productivity of commonly cultivated forage like Napier grass due to diseases have led the Rwandan government to explore other options for improving the availability of quality forage to support the rapidly growing livestock sector. Therefore, Rwanda has been introducing, evaluating, and promoting improved forages that are high biomass producers, nutritious and resilient to adverse climatic conditions including drought. The exploration and wider-scale cultivation of climate-smart forages is the most pragmatic option for sustainable increase in livestock productivity in Rwanda. One of the proven options to increase access to a high-quality forage and to enhance livestock productivity is a wide-scale cultivation of improved *Brachiaria* grass. *Brachiaria* grass is one of the best forages for improving forage production, year-round forage availability, and livestock productivity simultaneously addressing the issues of climate change across the tropical and subtropical regions of the world.

Feed and Forages

Feed shortage has been a major limiting factor for animal production in Rwanda. Livestock productivity has been increasing at a low rate, and the serious constraint which emerged overtime is a lack of sufficient feed (forage or pasture and concentrates) accessible to farmers (RAB 2017). This has been a concern of the majority of farmers who practice various livestock enterprises. Success of intensive dairy in the East African region has been attributed to high biomass fodder species, especially the Napier grass (*Pennisetum purpureum*). Napier grass has enabled farmers to raise the bulk of the roughage feeds from small land (<0.5 ha) to maintain at least one lactating cow. The grass is adapted exclusively for a cut and carry system, a common system adopted by the majority of farmers in the country. However, Napier grass has been attacked by diseases, and productivity has severely diminished (Kabirizi et al. 2015). In addition, acreage and productivity of natural pasture, a major source of forage in the country, is in declining trend due to conversion of pasture for crop production and nonagricultural uses and land degradation associated with overgrazing, poor pasture management practices, and extreme climatic conditions. As the livestock sector growing and forage availability lessening, the role of cultivated forage has been increasingly realized as a sustainable means of supporting the growing livestock sector in the country. Available information suggests that land limitation is an eminent constraint of fodder production for the majority of farmers in Rwanda (Mutimura et al. 2013).

Brachiaria is one of the important tropical forage grasses of African origin. It is widely cultivated in South America and less so in Asia, the South Pacific, and Australia (Keller-Grein et al. 1996) and has demonstrated success in transforming beef and dairy industries. It is palatable and nutritious; thus, feeding livestock on *Brachiaria* grass significantly increases livestock productivity (Mutimura et al. 2016, 2018; Njarui et al. 2016). The perennial *Brachiaria* species produces high tonnage of foliage biomass, possesses large root systems, fixes atmospheric carbon into soils, is adapted to drought and low fertility soils, is tolerant to pests and diseases, and provides several environmental benefits and ecosystem services (Subbarao et al. 2009; Ghimire et al. 2015). Therefore, *Brachiaria* grass is considered as climate-smart with a multitude of adaptive features to alleviate adversity of climate changes to agriculture and the environment. In this chapter, we review the *Brachiaria* grass research and development activities carried out in Rwanda and underline the prospect and challenges of sustainable production of improved *Brachiaria* grass in the country.

Evaluation of *Brachiaria* Grass in Rwanda

Biomass Production

Improved *Brachiaria* grass cultivars have been introduced to Rwanda in different occasions starting from 2007 through different projects including “Fighting drought and aluminum toxicity: Integrating functional genomics, phenotypic screening and participatory evaluation with women and small-scale farmers to develop stress-resistant common bean and *Brachiaria* for the tropics,” Climate-Smart *Brachiaria* Grass Program, Climate-Smart Dairy, InnovAfrica, and Rwanda Dairy Development Project. Improved *Brachiaria* grasses introduced to Rwanda were *Brachiaria brizantha* cvs. Piatã, MG4, Marandú, and Xaraés; *Brachiaria humidicola* cvs. Llanero and Humidicola; *Brachiaria* hybrid cvs. Mulato, Mulato II, and Cayman; other hybrid lines Bro2/0465, Bro2/1452, and Bro2/1485; and *Brachiaria decumbens* cv. Basilisk. They were evaluated since then by Rwanda Agricultural

Table 1 Dry matter (DM) production and chemical composition of improved *Brachiaria* variety harvested at 90 days after planting under rain-fed conditions in Rwanda

Forage varieties	DM (ton/ha/yr)	CP (g/kg DM)	NDF (g/kg DM)	ADF (g/kg DM)	References
B. hybrid cv. Mulato II	31.0	137	412	–	Mutimura et al. (2017)
B. hybrid cv. Mulato	30.1	120.4	–	–	Mutimura and Everson (2012)
B. hybrid cv. Cayman	9.2[a]	116	549.2	374.2	Mutimura et al. (unpublished)
B. hybrid Bro2/0465	15.8	92	–	–	Mutimura and Everson (2012)
B. hybrid Bro2/1452	17.8	109	–	–	Mutimura and Everson (2012)
B. hybrid Bro2/1485	28.0	156.7	–	–	Mutimura and Everson (2012)
B. brizantha cv. Piatã	11.6[a]	166	576	406.9	Mutimura et al. (unpublished)
B. brizantha cv. Xaraés	5.6[a]	143	382	–	Mutimura et al. (2017)
B. brizantha cv. MG4	10.1[a]	156	612	454.9	Mutimura et al. (unpublished)
B. brizantha cv. Marandú	27.5	159	275	–	Mutimura et al. (2017)
B. decumbens cv. Basilisk	28.7	167	565.2	399.4	Mutimura et al. (unpublished)
B. humidicola cv. Humidicola	2.5[a]	152	335	–	Mutimura et al. (2017)
B. humidicola cv. Llanero	5.4[a]	152	409	–	Mutimura et al. (2017)
Napier grass (control)	9.1	137	357	–	Mutimura et al. (2017)
Cenchrus ciliaris (control)	7.1	78	–	–	Mutimura and Everson (2012)

[a]Dry matter (ton/ha) for one harvest after 90 days of planting

Research Institute (ISAR: French acronym) – currently, Rwanda Agriculture and Animal Resources Development Board (RAB). The evaluation was aimed for agronomic performance under different climatic conditions including tolerance to acidic soil, aluminum toxicity, and drought (Mutimura and Everson 2012) at on-station and on-farm conditions. The major characteristic considered in this evaluation was the amount of the dry matter (DM) production. The DM yields were significantly different among *Brachiaria* cultivars (Table 1). For example, *Brachiaria* hybrid cvs. Mulato II and Mulato had the highest biomass (31 and 30 t/ha/year, respectively), followed by *B. decumbens* cv. Basilisk, *Brachiaria* hybrid line Bro2/1485, and *B. brizantha* cv. Marandú (28.7, 28.0, and 27.5 t/ha/year, respectively). The cutting intervals (60 days, 90 days, and 120 days of planting) had significant effects on DM production of *Brachiaria* grass cultivars under a semiarid environment where DM production increased up to 90 days after planting (DAP) and declined at 120 DAP (Mutimura et al. 2017). Considering the DM production, B. brizantha cvs. Piatã, MG4 and Brachiaria hybrid cv. Cayman harvested at 90 DAP, produced higher DM yields than other cultivars evaluated (Mutimura et al., unpublished). The high biomass produced by these *Brachiaria* varieties is because of their ability to produce a large number of tillers, leafy canopy, erect growth habits, and faster regrowth enabling multiple harvests in a year.

Nutrient and Mineral Composition

The crude protein (CP) and fiber contents – neutral detergent fiber (NDF) and acid detergent fiber (ADF) – play a major role in ruminant feeding and feed intake. *Brachiaria* grass cultivars and hybrids were analyzed for these nutrients at different growth stages. All *Brachiaria* grass cultivars evaluated have shown high crude protein content at 90 days which varied from 92 g/kg DM to 167 g/kg DM for *Brachiaria* hybrid line Bro2/0465 and *B. decumbens* cv. Basilisk, respectively (Table 1). All cultivars that had CP above 120 g/kg DM, could sustain a dairy cow producing milk between 15 to 20 liters per day (McDonald et al. 2011). Similarly, the NDF and ADF also are in good range for a significant number of *Brachiaria* grass cultivars. This is because NDF below 450 g/kg DM and ADF between 300 and 400 g/kg DM could allow good intake and energy supply, respectively, in ruminants (Leng 1990).

Macro element including calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and phosphorous (P) are the consituents of the animal body (McDonald et al. 2011) and they are important in improving health of animals. Therefore, these minerals were considered in *Brachiaria* grass cultivar evaluation. At 90 DAP (the best age for highest combined biomass and nutritive value), most of these *Brachiaria* grass cultivars showed a significant level of the macro-minerals (Table 2). These minerals’ levels could meet the daily requirement for various types of livestock. For example, a heifer of 300 kg body weight requires at least 11 g/day of Ca (McDonald et al. 2011), meaning that all the *Brachiaria* grass varieties could meet the daily requirements except cv. Cayman.

Metabolizable Energy, Organic Matter Digestibility, and Retention Time of the Particle Phase of Digesta

One of the challenges in animal feeding is the persistent gaps in nutritional attributes that compromise feed efficiency including metabolizable energy (ME) and net energy values, protein degradability estimates, and digestion kinetic coefficients. Therefore, when evaluating forages in terms of nutritional values, ME and digestion kinetic coefficients are the core aspects in characterizing feed resources.

Table 2 Macroelement minerals especially calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), and phosphorus (P) in g/kg DM of different *Brachiaria* varieties harvested at 90 days after planting

Forage varieties	Ca	K	Na	Mg	P	References
B. hybrid cv. Mulato II	18.7				2.3	Mutimura and Everson (2012)
B. hybrid cv. Mulato	21.3				1.7	Mutimura and Everson (2012)
B. hybrid cv. Cayman	10.0	27.5	0.7	6.9	1.4	Mutimura et al. (unpublished)
B. hybrid Bro2/0465	21.6				2.1	Mutimura and Everson (2012)
B. hybrid Bro2/1452	17.2				1.1	Mutimura and Everson (2012)
B. hybrid Bro2/1485	18.1				2.3	Mutimura and Everson (2012)
B. brizantha cv. Piatã	27.3	22.4	3.0	35.1	13.0	Mutimura (2016)
B. brizantha cv. Xaraés	26.2	23.8	3.1	31.9	13.8	Mutimura (2016)
B. brizantha cv. MG4	27.8	23.9	4.0	42.0	16.8	Mutimura (2016)
B. brizantha cv. Marandú	29.0	26.2	4.0	31.3	15.1	Mutimura (2016)
B. decumbens cv. Basilisk	25.4	23.8	3.1	36.8	13.9	Mutimura (2016)
B. humidicola cv. Humidicola	15.9	20.5	6.2	22.5	11.8	Mutimura (2016)
B. humidicola cv. Llanero	19.2	25.4	3.6	36.2	13.0	Mutimura (2016)
Napier grass (control)	27.3	22.4	3.0	35.1	13.0	Mutimura (2016)
Cenchrus ciliaris (control)	15.7	–	–	–	1.1	Mutimura and Everson (2012)

Brachiaria grass cultivars evaluated for nutritive values in Rwanda showed good levels of metabolizable energy (ME), organic matter digestibility (OMD), and better retention time of the particle phase of digesta in the digestive tract of dairy cows (Table 3). These parameters are essential in feed evaluation in order to select the best-bet forage grasses or legumes. For example, cvs. Piatã, Mulato II, Basilisk, and MG4 were the best in terms of the ME and OMD. The ME is the best indicative of how much animal will produce while a low total mean retention time (TMRT) is suggestive to high intake. This will increase in energy supply in the animal and thus, lead to increase production. For example, Piatã has the TMRT of 62.8 h in the digestive tract, while Napier grass has 83.1 h. The low values of TMRT for Piatã lead to increase feed intake and thus increase productivity of a dairy cow (Mutimura et al. 2018).

In Vitro Gas Kinetic Parameters

The kinetic parameters are among the nutritional attributes as they inform on quality of forages in terms of degradability in the digestive tract of an animal. An *in vitro* gas

Table 3 Metabolizable energy (ME) and organic matter digestibility (OMD) and total mean retention time (TMRT) of Brachiaria grass cultivars and Napier grass harvested at 90 days after planting

Forage varieties	ME (MJ/kg DM)	OMD (g/kg DM)	TMRT (Hour)	References
B. hybrid cv. Mulato II	8	509	–	Mutimura et al. (2017)
B. hybrid cv. Mulato	7.7	494	–	Mutimura et al. (2017)
B. hybrid cv. Cayman			–	Mutimura et al. (unpublished)
B. brizantha cv. Piatã	9	550	62.8	Mutimura et al. (2017, 2018)
B. brizantha cv. Xaraés	6.8	433	–	Mutimura et al. (2017)
B. brizantha cv. MG4	8.1	510	–	Mutimura et al. (2017)
B. brizantha cv. Marandú	7	437	–	Mutimura et al. (2017)
B. decumbens cv. Basilisk	8.2	523	–	Mutimura et al. (2017)
B. humidicola cv. Humidicola	7.4	467	–	Mutimura et al. (2017)
B. humidicola cv. Llanero	7.7	489	–	Mutimura et al. (2017)
Napier grass (*P. purpureum*)	7.1	453	83.1	Mutimura et al. (2017, 2018)

production technique is used for faster analysis of forage samples for kinetic parameters. The technique involves the production of gas under fermentation of the forage samples and then calculation of kinetic parameters from the gas production. The parameters are the fast-degradable fraction (A), slowly degradable fraction (B), the rate of degradation (C), and the time to produce half of gas ($T_{1/2}$; Menke et al. 1979). When the gas volume is high, A and B are also high while C and $T_{1/2}$ are low. These attributes predict the quality of forage species. With these characteristics, *Brachiaria* grass harvested at 90 days after planting showed that cvs. Mulato, Mulato II, Piatã, and Basilisk were the best among other *Brachiaria* cultivars (Table 4).

Brachiaria Grass and Livestock Productivity

High rates of human population growth and increasing demand for food are the main preoccupation driving agriculture towards intensification (Singh et al. 2004). In many areas of Africa including Rwanda, crop intensification program (CIP) is based on a crop-livestock integration system. The CIP coupled with land consolidation to grow one crop, it is likely that forage like *Brachiaria* grass can be a good biological agent for soil fertility improvement. *Brachiaria* grass is a high nutritional quality forage and can be integrated into the crop-livestock system, especially to increase soil carbon and livestock productivity – both milk and meat yields.

Table 4 *In vitro* digestion parameters of *Brachiaria* grasses harvested at 90 days after planting

Forage varieties	GP (ml/g DM)	A (g/kg DM)	B (g/kg DM)	C (%/h)	$T_{1/2}$ (h)	References
B. hybrid cv. Mulato II	243	66	177	0.029	19	Mutimura et al. (2017)
B. hybrid cv. Mulato	253	96	155	0.029	19	Mutimura et al. (2017)
B. hybrid cv. Cayman	218.3	0.2	218.1	0.032	26.6	Mutimura et al. (unpublished)
B. brizantha cv. Piatã	266	69	197	0.032	20	Mutimura et al. (2017)
B. brizantha cv. Xaraés	210	50	160	0.025	23	Mutimura et al. (2017)
B. brizantha cv. MG4	234	87	148	0.028	20	Mutimura et al. (2017)
B. brizantha cv. Marandú	188	65	124	0.028	22	Mutimura et al. (2017)
B. decumbens cv. Basilisk	240	70	170	0.033	20	Mutimura et al. (2017)
B. humidicola cv. Humidicola	216	61	155	0.033	22	Mutimura et al. (2017)
B. humidicola cv. Llanero	253	86	168	0.028	21	Mutimura et al. (2017)
Napier grass (*P. purpureum*)	243	65	178	0.028	26	Mutimura et al. (2017)

A, fast-degradable fraction; B, slowly degradable fraction; C, rate of degradation; $T_{1/2}$, time to produce half of gas ($T_{1/2}$)

Evaluated *Brachiaria* cultivars including Mulato II, Piatã, Basilisk, and MG4 showed high biomass production across the agroecologies of Rwanda (Mutimura et al. 2017). The integration of *B. brizantha* cv. Piatã into smallholder dairy farmers showed higher milk yields up to 50% more than cows fed on sole Napier grass diet which was the forage used by majority of farmers (Mutimura et al. 2018). Similarly, cv. Mulato II fed to dairy heifer increases body weight up to 54.7% compared to locally available Napier grass (Mutimura et al. 2016).

Environmental Qualities

Brachiaria grass is known for its environmental attributes. We evaluated cv. Mulato II together with the common forage grass, the Napier grass in terms of enteric fermentation output that contributes to greenhouse gas emissions, especially methane (CH_4). The ruminant model (Herrero et al. 2008) was used and predicted highly significant differences between *Brachiaria* hybrid Mulato II and Napier grass as the sole diet for rearing replacement heifers. Besides the other parameters generated by the model, it was found that the daily volume of methane (L/day) and volumes of

Table 5 Farmer participatory variety selection and ranking of Brachiaria grass

Forage species	Negative aspects	Positive aspects	Rank
Piatã	No negative aspect	High biomass, palatable, less hairy, drought tolerant, quick regrowth, perennial, easy to cut and carry	1
Cayman	Dry up when drought persists, difficult to cut	High biomass, palatable, quick regrowth, perennial	2
MG4	Less palatable, difficult to cut, less biomass, less regrowth after cut	Drought tolerant, perennial	5
Panicum coloratum (local check)	Less biomass	Faster regrowth, palatable, smoothness, easy to cut, and drought tolerant	3
Basilisk	Not persist to multiple cuttings	Drought tolerant, easy to cut, erosion control, high biomass, quick regrowth, palatable, perennial	4

methane per unit weight gain (L/kg body weight gain) were highly significant between cv. Mulato II and Napier grass. The enteric methane production was low for cv. Mulato II (126.8 L/day) compared to Napier grass (145.9 L/day) (Mutimura et al. unpublished). This means that except the nutritional values of *Brachiaria* grass, it is also a good feed to mitigate enteric methane production in ruminant livestock.

Scaling *Brachiaria* Grass

Since the introduction of *Brachiaria* grass in Rwanda, different initiatives have been promoting the grass for livestock feeding. Except individual farmers, government projects including Rwanda Dairy Development Project (RDDP), Climate-Smart *Brachiaria* Grass Projects, and NGOs like Send a Cow Rwanda are promoting *Brachiaria* grass in the country. Furthermore, improved *Brachiaria* grass is being evaluated and promoted in high rainfall and acidic soils and low rainfall areas of Rwanda by InnovAfrica and Climate-Smart Dairy Projects.

The RAB has been using participatory selection approaches involving male and female farmers in selecting improved *Brachiaria* grass cultivars. Farmers prepare a list of attributes they like in a forage, rank these attributes based on priority, and use a set of top-ranked attributes to select the best-bet cultivars. In participatory evaluations, farmers liked most improved *Brachiaria* grass cultivars than local forages because of their adaptation to low rainfall and acidic soils, high biomass production, rapid regeneration, and production of green forage year-round (Table 5). Generally, improved *Brachiaria* grass is considered as an excellent alternative to commonly grown Napier grass predominantly used in a cut and carry system of forage production in Rwanda.

Currently, *Brachiaria* grass has been promoted at least in 20 districts among 30 districts of Rwanda. A suitability map developed by the International Center for

Tropical Agriculture (CIAT) in Climate-Smart Dairy Project showed that most of the whole Rwanda is suitable for improved *Brachiaria* grass cultivation. This means that scaling of improved *Brachiaria* will continue to the remaining districts. Under the InnovAfrica, RDDP, and Climate-smart dairy, funded projects, more than 4,800 farmers from Southern, Eastern, Western, and Northern Provinces of Rwanda have established some *Brachiaria* cultivars and hybrid (e.g., Basilisk, Piatã, Xaraés, MG4, and Mulato II). Additionally, a high government investment project, the Gabiro Agribusiness Hub proposes to promote *Brachiaria* grass, among others, under irrigation for a livestock-intensive feeding system.

Potential of *Brachiaria* Grass to Transform Livestock Sector in Rwanda

Cultivated improved pastures increase the availability of quality forage, produce high-quality green herbage, increase livestock productivity, and provide forage throughout the year including in the dry season. These characteristics of improved forages can reduce the need for feed supplements and raise the potential for lager herds. In many tropical regions, pastures are grown on infertile soils that are not suited to food crops, leading to a low forage yield. In southern and eastern Australia where dryland salinity is a threat to the agriculture, pastures tolerant to salinity could help farmers to increase agricultural productivity in these areas (O'Connell et al. 2006). Forage can be utilized as a feed resource for livestock and play an important role in maintaining the natural resource base. For example, in Western Australia, alfalfa (*Medicago sativa*) has been used in crop rotation to reduce the invasion of weeds in cropping land. In southern Australia, a range of forages grown for non-irrigated farms helped farmers to feed dairy cows year-round and could be a reserve during the period of feed shortage (Chapman et al. 2008). It is important for farmers to exploit the synergy between crop and livestock production in order to minimize the dependence on external inputs and to enhance the overall productivity of the system. Research on animal nutrition found that the better the supply of energy in animals' diet, the more they increased production. In the Philippines, only a few farmers could succeed in satisfying the needs of their animals because they planted enough legumes for optimal production (Roothaert et al. 2003). In developing countries, most animal feeds are collected from different indigenous or introduced tropical pasture species. These indigenous pastures may have low nutritive value and lead to low livestock productivity and then hamper the sustainability of livestock production.

Brachiaria has played major roles in the transformation of livestock sector across tropical America, particularly in Brazil (Jank et al. 2014). The important role of *Brachiaria* grass in the intensification of livestock production system in Africa has been gradually documented with its significant contribution to livestock productivity (Njarui et al. 2016; Mutimura et al. 2016, 2018). Since the introduction of *Brachiaria* grass in Rwanda, its evaluation in terms of adaptation, nutritional values, livestock production, and greenhouse gas emission showed that the grass has potentiality to increase livestock productivity while mitigating greenhouse gas emission. Studies on forage suitability map have shown that *Brachiaria* grass varieties are adapted to all agroecologies of Rwanda with possible changes in the face of climate change in the country (CIAT 2019). Because *Brachiaria* grass is adapted to various ranges of agro-ecologies in the countries, it is an opportunity to be adopted and used by farmers in integrated crop-livestock farming system which system is the dominant in Rwanda. The growth habits of *Brachiaria* grass fit well with the small scale farming. This is because it can be planted along terrace banks or farm boundaries thus, spares the land for food crops. It can also improve soil fertility and reduce pest and diseases on crops. For example, in a push-pull experiment conducted in Rwanda, *Brachiaria* hybrid cv. Mulato II showed that it reduces positively the infestation of fall-army worm (FAW) on maize.

Notwithstanding the ecological benefits of *Brachiaria* grass, it can be a source of income generation through production and sale of hay and vegetative planting materials as seeds to livestock owners. For example, one hay bale of 10 kg cost about 2.2 USD, while a rooted tiller/one split cost about 0.02 USD (RAB 2019). This means that the grass has the potential to transform livestock sector irrespective of the size of the land a farmer may have. This is because under smallholder famers, the grass can be planted to any available niche and harvested and conserved as a hay and address feed shortage, especially during the dry season. *Brachiaria* grass regrows faster after harvesting and can be harvested at least five times per year under rain-fed condition (Mutimura and Everson 2012).

Challenges

Brachiaria grass has multiple benefits to livestock and the environment. However, there are some challenges that could hinder the progress in the dissemination of the grass. Lack of seeds is one of the major challenges because *Brachiaria* grass cultivars do not produce seeds for commercial purposes because the grass does not produce enough seeds in areas close to equator (2° latitude south for Rwanda). Vegetative propagation is the commonly used method in Rwanda, but this requires high biomass and leads to transport difficulties, especially when travelling the long distance movement. Also, relying on seed companies is costly and it is protracting in delivery of seeds. Furthermore, in emerging climate change, there is increasing of pests and diseases. Currently, some of *Brachiaria* grass varieties in Rwanda are being attacked by various diseases including leaf spot, especially on cv. Humidicola and cv. Basilisk, while rust and leaf blight attack much on Mulato and Mulato II (Uzayisenga et al. 2020).

Furthermore, other challenges might be the knowledge of farmers on improved *Brachiaria* grass establishment and management. Smallholder farmers are much more familiar with food crop cultivation management but less so with forages. This could be a challenge because the grass harvested under a cut and carry system mines soil fertility quickly if no fertilizer/manure is added to land under *Brachiaria* grass production. Capacity building of famers on improved forage management and utilization practices would increase their knowledge and thus address challenges related to soil fertility depletion due to continuous mining of soil nutrient by the perennial grass managed under a cut and carry system of forage production.

Conclusion

Brachiaria grass cultivars have been introduced to Rwanda at different occasions since 2007. These cultivars have been evaluated for adaptation, nutritional values, livestock production, and environmental benefit attributes. Of the 13 *Brachiaria* cultivars including hybrids, Of 13 Brachiaria cultivars including hybrids, cvs. Mulato, Mulato II, Piatã, MG4 and Basilisk were the best bet among others based on the above evaluation parameters. However, the dissemination and scaling of *Brachiaria* grass cultivars should also be based on famers' preference; thus, their involvement in the cultivar selection is very important as practiced in Rwanda. Furthermore, the forage suitability map for Rwanda has shown that *Brachiaria* grass cultivars are adapted to all agroecologies of Rwanda with possible changes in the face of climate change in the country. This is a great opportunity to be materialized so that farmers across Rwanda can harness potential of *Brachiaria* grass to intensify an integrated crop-livestock farming system which is the dominant system in the country. This is because, the growth habits of *Brachiaria* grass fit well with the small scale farming where it can be planted along the terrace banks or in farm boundaries. The grass can also improve soil fertility while reducing pests and diseases on crops. However, there is a need to control pests and diseases in *Brachiaria* grass, as well as establishing a functional *Brachiaria* seed system for rapid dissemination and scaling up of *Brachiaria* grass, thus increase livestock productivity while maintaining the natural resource base.

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