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Research Paper

Perennial ryegrass and novel festulolium forage grasses in the tropical highlands of Central Kenya: Preliminary assessment

Nuevos pastos de ryegrass y festulolium en tierras altas del trópico de Kenia central: Evaluación preliminar

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Abstract

Two perennial ryegrass (*Lolium perenne*) varieties and 5 festulolium hybrids (*L. perenne* × *Festuca* spp.) were evaluated on-farm for their performance over one growing season on clay loam soils at Ol-joro-Orok in the central highlands of Kenya at about 2,600–2,800 masl. Seed was sown in May 2015 and fertilizer (90 kg N + 90 kg P/ha) was applied at planting. The study continued for 8 months with harvests after 113, 99 and 32 days (3 growth cycles). Growth attributes assessed included dry matter yield (DMY) and plant height, while forage nutritive value was measured in terms of crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations. At the end of the first growth cycle, 61 local dairy farmers rated the grasses on criteria they nominated as being important, including DMY, growth rate, height, frost tolerance, disease tolerance and leafiness. Total herbage yields for the whole study period (8 months) ranged from 14.6 to 18.0 t DM/ha for perennial ryegrass and 14.3 to 20.9 t DM/ha for festulolium with very poor growth in the third growth cycle. All perennial ryegrass and festulolium lines contained similar ($P>0.05$) concentrations of CP (163–190 g/kg DM), ADF (264–281 g/kg DM) and NDF (448–493 g/kg DM). For perennial ryegrass, farmers gave a minimum weighted score of 6.7 and for festulolium, 7.9. Based on herbage production, forage nutritive value and farmers' assessments, we conclude that all perennial ryegrass and festulolium lines tested have the potential to contribute to improving the forage resource base in this and other similar areas, especially for farmers whose land sizes allow grazing instead of stall-based feeding only. Further studies with N applications after each harvest would determine whether yields can be maintained at high levels for longer than in this study, while grazing and feeding studies would determine how well the pastures support weight gains and milk yields. Studies over a number of years are needed to assess how persistent these varieties/hybrids are in this and other environments.

Keywords: Fodder, participatory research, rainfall-use-efficiency, tropical grass.

Resumen

En Ol-joro-Orok, zona alta de Kenia central (2,600–2,800 msnm), en suelos franco-arcillosos se evaluó la producción de forraje de dos variedades de ryegrass perenne (*Lolium perenne*) y cinco híbridos de festulolium (*L. perenne* × *Festuca* spp.). La siembras se efectuaron en dos fincas en mayo de 2015 con la aplicación de 90 kg N + 90 kg P/ha. El estudio se realizó durante 8 meses con mediciones después de 32, 99 y 113 días de crecimiento. En cada medición se determinaron el rendimiento de materia seca (MS), la altura de planta y las concentraciones de proteína cruda (PC), fibra detergente ácida (FDA) y fibra detergente neutra (FDN). Al final del primer ciclo de crecimiento, 61 productores de leche locales calificaron los pastos según los criterios que consideraron importantes: rendimiento de MS; tasa de crecimiento; altura de la planta; tolerancia a heladas; resistencia a enfermedades; y frondosidad. El rendimiento total de forraje para el período de 8 meses varió entre 14.6 y 18.0 t MS/ha para ryegrass perenne y entre 14.3 y 20.9 t MS/ha para festulolium; durante el tercer ciclo

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el crecimiento fue muy pobre. Todas las líneas de ryegrass perenne y festulolium contenían concentraciones similares (P>0.05) de PC (163–190 g/kg MS), FDA (264–281 g/kg MS) y FDN (448–493 g/kg MS). Tanto el ryegrass perenne como festulolium fueron ampliamente aceptados por los productores de la zona y tienen alto potencial de contribuir a mejorar la base del recurso forrajero en esta y otras áreas similares, especialmente para los productores con suficiente tierra para poder practicar el pastoreo en vez de alimentación del ganado únicamente en confinamiento. Se señalan una serie de estudios que se consideran necesarios para avanzar el desarrollo de estos pastos.

Palabras clave: Eficiencia en el uso de agua de lluvia, forraje, gramínea tropical, investigación participativa.

Introduction

In recent times, the dairy industry in Kenya has been growing because of improving milk markets coupled with increasing per capita milk consumption (Auma et al. 2017). Predominantly, dairy is concentrated in the wet highlands and is practiced by smallholder farmers who keep either improved and/or crosses of Friesian or Ayrshire cattle (Muia et al. 2011). Due to decreasing land holdings because of land subdivision over generations, available grazing land has also been reduced, leading to dairy intensification, where cattle are kept in confinement under cut-and-carry systems of feeding. However, inadequate fodder in terms of both quantity and quality, especially during the dry season (Lukuyu et al. 2011; Njarui et al. 2012), leads to low milk yields that fall in the range 1,300–4,575 kg/lactation (Omore et al. 1999; Mugambi et al. 2015). Tropical grasses, e.g. Napier grass (*Cenchrus purpureus* syn. *Pennisetum purpureum*) and Rhodes grass (*Chloris gayana*), have been used successfully to support milk production but perform poorly at elevations above 2,000 masl (Boonman 1993). Forages adapted to temperate environments could possibly be preferable under such conditions.

Recently temperate grass breeding has focused on increasing the water-soluble carbohydrate (WSC) fraction to improve forage intake by ruminants and increase grassland productivity in terms of meat and milk (Humphreys et al. 2014a). These breeding efforts have resulted in new and novel high-sugar grasses (HSG) that combine good agronomic performance with high WSC (Humphreys and Theodorou 2001). Research shows that feeding HSG increases milk and meat production and decreases greenhouse gas emissions. These HSG include both *Lolium* species and festulolium hybrids (Humphreys and Theodorou 2001). Perennial ryegrass (*Lolium perenne*) is the most important grass used in grazing dairy systems in temperate environments worldwide (Wims et al. 2013; Humphreys et al. 2014a), especially in developed countries. Festuloliums (*Lolium* spp. × *Festuca* spp.), on the other hand, are natural or bred hybrids between any *Festuca* (fescue) and *Lolium* (ryegrass) species, designed for their combined complementary characteristics (Humphreys et al. 2014a; 2014b). As festuloliums are more tolerant of drought and cold than perennial ryegrass (Humphreys et al. 2014b), they are now attracting more interest for livestock production. Approximately 6,000 t of HSG seed has been sown in the UK since 2005, covering an area of 175,000 ha, and the impact on the livestock sector has been significant. The benefits to the dairy sector over the period 2005–2010 have been estimated at up to £78.2 (USD 90.2) million (Farming Futures 2013).

We hypothesized that HSG would help overcome forage shortages in winter in tropical highlands, e.g. the foothills of Mt. Kilimanjaro, Mt. Kenya, the Aberdare ranges in Central Kenya and especially in Nyandarua region (Muia et al. 2011). In the former sites, relatively low temperatures (5.5–10.7 °C mean minimums) create conditions similar to temperate climates, and dairy production is a common enterprise, as it generally is in Kenya (Njarui et al. 2012). Temperate grasses would withstand low temperatures better than tropical pastures (Larcher 2003) and would be more nutritious, more digestible and capable of recuperating after grazing (Lee et al. 2010; Humphreys et al. 2014a, 2014b). Weller and Cooper (2001) reported maximum crude protein (CP) concentration of 239 g/kg DM in a 2-year-old perennial ryegrass pasture with monthly yields in the range 1.68–2.34 t DM/ha, while Dierking et al. (2008) observed 200 g CP/kg DM in festulolium. By comparison, Napier grass in the tropics and subtropics, has crude protein concentrations in the range 80–130 g CP/kg DM (Wijitphan et al. 2009; Tessema et al. 2010), in addition to performing poorly in cold areas (Boonman 1993).

The work reported here evaluated new perennial ryegrass varieties and novel festulolium hybrids with the aim of quantifying their production potential in the dairy-dominated Nyandarua County (Mwendia et al. 2015) of Central Kenya. The grass varieties tested include new and novel products from the breeding program at the Institute of Biological, Environmental and Rural Sciences (IBERS) at Aberystwyth University in Wales, UK, including diploid and tetraploid perennial ryegrass as well as festulolium hybrids generated by combining

L. multiflorum or *L. perenne* with either *F. arundinacea* var. *glaucescens* or *F. mairei*.

Materials and Methods

Site description

Two on-farm trials were conducted at Ol-joro-Orok in Nyandarua County in Central Kenya (00°09' S, 36°17' E; 2,808 masl; Farm 1); and (00°09' S, 36°18' E; 2,667 masl; Farm 2). Soils in the area are lithosols with humic topsoil, dark reddish brown, well-drained, highly fertile clay and clay loam soils (Jaetzold and Schmidt 1983). The soils on the 2 farms were classified as slightly acidic clay loams with similar characteristics (Table 1).

The Ol-joro-Orok climate is described as temperate. Average annual temperature is 13.7 °C, with a mean minimum of 6.5 °C and about 950 mm annual precipitation (Climate-Data.org 2016), with rainfall occurring throughout the year, although most falls in August and the least in January-February. Weather conditions during the study are summarized in Table 3a and for calendar years 2015 and 2016 in Table 3b.

Approach and experimental design

We conducted the study in a participatory approach with Nyamarura farmers' group. The individual farmers keep 2–5 dairy cows on their farms, and a group discussion was held to determine which 2 farms (described above) were to host the trials.

Seed of 2 varieties of perennial ryegrass and 5 hybrids of festulolium (Table 2) was sourced from IBERS. The experiments were conducted in a randomized complete block design with 3 replicates for each of the entries on each farm.

Trial establishment and maintenance

Farmers prepared the land using hoes to break soil lumps and obtain a fine seedbed and, on 12 May 2015, seed was sown in plots of 2 m^2 for perennial ryegrass (20 kg/ha) and 1 m^2 for festulolium (16 kg/ha) in furrows about 6 mm deep with 10 cm between rows. A mixed NP fertilizer (23:23) was applied at a rate of 90 kg N/ha to all plots. A thin layer of soil was placed over the seed. Plots were hand-weeded according to need.

Plant height and dry matter yield measurement

Plant height (PH) was measured from the base of a bunch of tillers to the tips of the leaves at 4 randomly selected positions within each plot, just before each harvest. Unlike the conventional monthly harvests for ryegrass and festulolium, a 3-month growth period was nominated to accumulate substantial biomass that would be preferable under a manual cut-and-carry scenario. However, to allow sufficient time for establishment, the growth period for the first cycle was longer than this target, while leaf senescence was observed in the third cycle, leading to earlier harvesting than the desired time. To assess dry matter yield (DMY), forage in quadrats of

Table 1. Soil properties at trial farms in Ol-joro-Orok, Central Kenya.

Site	Total N (%)	Total C (%)	Bray P (mg/kg)	pH	Clay (%)	Sand (%)	Silt (%)	Soil texture
Farm 1 (N = 5)	0.27	2.9	12.9	5.6	37.5	34.5	28.0	Clay loam
Farm 2 (N = 5)	0.30	3.5	12.6	5.0	36.1	31.6	32.3	Clay loam

Source: International Center for Tropical Agriculture (CIAT) Laboratory, Duduville, Nairobi.

Table 2. Details of forage grasses assessed in Ol-joro-Orok, Central Kenya.

Variety or hybrid	Ploidy level, hybrid[1]
Perennial ryegrass	
AberBite (AB)	*Lolium perenne* (4x)
AberWolf (AW)	*Lolium perenne* (2x)
Festulolium	
AberNiche (AN)[2]	*Lolium multiflorum* × *Festuca pratensis*
Hybrid 1	*L. perenne* (2x) × *F. arundinacea* (6x)
Hybrid 2	*L. perenne* (2x) × *F. arundinacea* var. *glaucescens* (4x)
Hybrid 3	*L. perenne* (4x) × *F. arundinacea* var. *glaucescens* (4x)
Hybrid 4	*L. perenne* (4x) × *F. mairei* (4x)

[1]Information from Humphreys et al. (2014b), Wilkins and Lovat (2011) and M.W. Humphreys (pers. comm.). [2]First festulolium registered in the UK.

0.5 × 0.5 m located at the center of each plot was hand-harvested at a stubble height of 4 cm with a sickle on 2 September and 11 December 2015 and 13 January 2016, i.e. 1st, 2nd and 3rd growth cycle, respectively.

Total fresh herbage was weighed in the field with a digital weighing balance and subsamples of about 250 g were selected at random. These samples were then dried to constant weight in an oven at 65 °C for 48 h for DM determination. Samples were then ground in a mill (Retich RM 100, Germany) to pass a 1 mm sieve and stored in sample bottles for subsequent laboratory analyses. Dry matter concentration was used to calculate DMY for each growth cycle as well as the herbage growth rate (HGR) during the growth period. Rainfall use efficiency (RUE, kg DM/ha/mm) was calculated by dividing daily herbage growth rate by total daily rainfall. After each harvest, the remaining forage within each plot was cut back to the uniform stubble height in preparation for subsequent growth cycles.

Chemical analyses

Cost limitations restricted laboratory analyses to samples from the initial harvest only. For precision and accuracy, nitrogen concentration was determined by the combustion method at 900 °C with Max Cube Elementar, Hanau, Germany (AOAC 1990) and the results multiplied by 6.25 to obtain crude protein (CP) concentration. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were estimated by Ankom bag technique analyzer (Ankom 143 Technology Fairport, NY, USA) following the AOAC procedure (AOAC 1975) at CIAT laboratory, Duduville, Nairobi.

Digestible dry matter, dry matter intake and relative feed value

Acid detergent fiber and NDF values were used to calculate/estimate digestible dry matter (DDM), dry matter intake (DMI) relative to body weight and, subsequently, relative feed value (RFV) using the formulae according to Jeranyama and Garcia (2004) as follows: DDM = 88.9 − (0.779 × %ADF); DMI = 120/(%NDF); and RFV = (DDM × DMI)/1.29.

Participatory evaluation

At 3 months after planting towards the end of the first growth cycle, 61 dairy farmers from Nyamarura group were invited to undertake a participatory evaluation of the varieties/hybrids. In a focus group discussion, the farmers generated a list of criteria they considered important in forages, before scoring these criteria on a scale of 1 to 10, where 1 represents the least important and 10 the most important. All plots were tagged with labels bearing the name or hybrid number. Farmers were requested to stand around the perimeter of the entire experimental block and were guided in identifying the varieties or hybrids. A variety or hybrid was pointed out in each of the 3 replicates, and farmers scored it on a particular criterion, while interacting amongst themselves, and only an agreed consensus score was recorded. This was repeated in sequence for all varieties/hybrids on that criterion before repeating the procedure for the second criterion. The process continued until scores had been allocated to all varieties/hybrids for all criteria.

Statistical analyses

Data were managed in Microsoft Excel software and analyzed in GenStat statistical software 14 (GenStat 2011). All data except for the scores and correlation coefficients were subjected to repeated measures analysis of variance and means separated by least significant difference at P≤0.05. The participatory scores were weighted according to Abeyasekera (2001) by the formula:

$$ws = \frac{\sum(C_1V_1+\cdots+C_nV_1)}{C_1+\cdots+C_n}$$

where: ws = weighted score; c = score of criterion; and v = score of variety/hybrid. This was repeated for each variety/hybrid. Significance of correlation coefficients (r) was checked by the Pearson's correlation coefficient critical values table at 16 degrees of freedom (df) for perennial ryegrass and 22 df for festulolium.

Results

Climatic conditions

Key weather variables, including average maximum and minimum temperatures and rainfall during the growth cycles, are summarized in Table 3. True minimum temperature (Table 3a) is the lowest temperature recorded during the experimental period. The 2015 annual precipitation was 899 mm, only 9% less than the long-term mean precipitation stipulated for Ol-joro-Orok (Climate-Data.org 2016).

Plant height and herbage yields

Generally, the ryegrasses and festuloliums produced similar (P>0.05) plant heights, dry matter yields, growth rates and rainfall use efficiencies within each of the 3 growth cycles (Table 4). The only exception was that festulolium hybrid AberNiche grew taller than all other varieties and hybrids

(Table 5). Estimated plant height, dry matter accumulated, daily herbage growth rate and rainfall use efficiency were lowest in the third growth cycle for all varieties and hybrids. Total DMY for the 8-month period ranged from 14.3 t/ha (Hybrid 4) to 20.9 t/ha (AberNiche).

Forage quality

There were no differences between any of the hybrids and/or varieties for the quality attributes assessed, including CP, ADF, NDF, DDM, DMI or RFV (Table 6). Acid detergent fiber range was 264–272 g/kg DM in perennial ryegrass and 273–281 g/kg DM in festulolium, while the corresponding NDF values were 449–467 g/kg DM and 448–493 g/kg DM, respectively. Crude protein concentrations were in the ranges 169–190 g/kg DM and 163–180 g/kg DM for perennial ryegrass varieties and festuloliums, respectively. In perennial ryegrass, RFV range was 139.8–142.5% and 126.6–140.2% in festulolium.

Herbage DMY was positively correlated with plant height (P<0.001), ADF concentration (P<0.001), NDF concentration (P<0.01) and surprisingly with CP concentration (P<0.01) (Table 7). CP concentration was also unexpectedly positively correlated with plant height.

Participatory evaluation

Farmers developed the following criteria as most important to them in identifying a forage grass of choice, and in order of importance: biomass production; growth rate; plant height; leafiness (leaf:stem ratio); frost tolerance; and disease tolerance (Table 8). Weighted scores were similar for ryegrass varieties AberBite and AberWolf (6.8 and 6.7), while those for all festulolium hybrids were higher with AberNiche rated most highly (9.6) and Hybrid 2 the lowest (7.9). No evidence of disease or frostbite was observed by farmers, leading them to assign maximum scores on these attributes for all varieties/hybrids. Although participatory evaluation was not conducted in Cycles 2 and 3, no visible symptoms of disease or frostbite were observed in either of these cycles.

Table 3a. Summary of growth conditions during 3 growth cycles at Ol-joro-Orok, Central Kenya.

Growth cycle	Period	Duration (days)	Temperature (°C)			Rainfall (mm)	Mean rainfall/ day (mm)
			Mean max.	Mean min.	True min.		
1	12/05/15–02/09/15	113	22.5	8.6	1.9	263	2.3
2	03/09/15–11/12/15	99	22.1	9.9	2.6	289	2.9
3	12/12/15–13/01/16	32	21.0	9.9	6.6	127	4.0

Table 3b. Monthly temperatures and rainfall over 2015 and 2016 calendar years at Ol-joro-Orok, Central Kenya.

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Mean max. temp. (°C)	24.0	25.0	25.0	23.0	22.2	21.7	22.0	22.5	24.0	23.5	21.0	21.1
	Mean min. temp. (°C)	5.8	7.0	6.7	9.6	9.0	9.3	6.1	6.2	6.3	8.8	11	10
	Total rainfall (mm)	2	28	1	115	99	102	71	36	68	52	167	158
	Number of wet days	1	2	4	14	15	14	11	8	9	9	21	13
2016	Mean max. temp. (°C)	21.8	23.3	25.6	24.1	22.0	21.8	20.0	20.1	22.6	23.1	21.3	21.8
	Mean min. temp. (°C)	10.1	8.1	8.9	10.2	9.4	7.1	8.4	7.3	6.1	7.2	9.0	8.4
	Total rainfall (mm)	61	30	41	166	164	160	157	172	61	53	61	15
	Number of wet days	11	2	3	11	12	11	18	16	9	8	19	6

Source: Weather data obtained from KALRO Ol-joro-Orok.

Table 4. Growth attributes of perennial ryegrass varieties and festulolium hybrids assessed over 3 growth cycles in Ol-joro-Orok, Central Kenya.

Attribute	Grass	Growth cycle			LSD
		1	2	3	
Plant height (m)	Festulolium	0.47a[1]	0.40a	0.27bc	
	Ryegrass	0.40a	0.29b	0.20c	0.07
DMY (t/ha)	Festulolium	8.3a	8.8a	1.0b	
	Ryegrass	8.0a	7.6a	0.7b	2.7
HGR (kg DM/ha/d)	Festulolium	73.3a	88.7a	29.8b	
	Ryegrass	70.6a	76.9a	21.6b	24.7
RUE (kg DM/ha/mm)	Festulolium	35.1a	30.4a	7.5b	
	Ryegrass	33.8a	26.3a	5.4b	11.3

[1]Within attributes, means followed by different letters are significantly different ($P<0.05$).
DMY = dry matter yield; HGR = herbage growth rate; RUE = rainfall use efficiency.

Table 5. Growth attributes of ryegrass varieties and festulolium hybrids averaged over 3 growth cycles (May–Jan), and total yields in Ol-joro-Orok, Central Kenya.

Grass	Variety/hybrid	Plant height (m)	Total DMY (t/ha)	HGR (kg DM/ha/d)	RUE (kg DM/ha/mm)
Ryegrass	AberBite	0.33bc[1]	14.6b	53.8a	21.8a
	AberWolf	0.31c	18.0ab	64.4a	26.5a
Festulolium	Hybrid 1	0.37bc	18.6ab	68.3a	27.0a
	Hybrid 2	0.36bc	20.2ab	70.5a	28.4a
	Hybrid 3	0.38bc	16.0ab	58.7a	23.6a
	Hybrid 4	0.39b	14.3b	55.2a	22.2a
	AberNiche	0.50a	20.9a	76.0a	30.8a
LSD		0.07	4.7	23.0	10.5

[1]Within attributes, means followed by the same letters do not differ ($P>0.05$).
DMY = dry matter yield; HGR = herbage growth rate; RUE = rainfall use efficiency.

Table 6. Crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations and calculated values for digestible dry matter (DDM), dry matter intake (DMI) and relative feed value (RFV) for perennial ryegrass varieties and festulolium hybrids at 113 days after planting at Ol-joro-Orok, Central Kenya.

Grass	Variety	CP (g/kg DM)	ADF (g/kg DM)	NDF (g/kg DM)	DDM (g/kg DM)	DMI (g/kg LW)	RFV (%)
Ryegrass	AberBite	190a	264a	449a	684a	26.9a	142.5a
	AberWolf	169a	272a	467a	677a	26.7a	139.8a
Festulolium	Hybrid 1	180a	280a	465a	671a	25.8a	134.6a
	Hybrid 2	165a	281a	493a	670a	24.3a	126.6a
	Hybrid 3	177a	273a	452a	676a	26.7a	139.8a
	Hybrid 4	163a	278a	448a	672a	26.9a	140.2a
	AberNiche	178a	277a	476a	673a	25.4a	132.4a
LSD (P=0.05)		34.4	20.6	51.4	16.0	3.4	18.7

[1]Within columns, means followed by the same letter do not differ ($P>0.05$) for either ryegrass or festulolium.

Table 7. Correlation coefficients (r) amongst measured attributes during the first growth cycle pooled for ryegrass and festulolium in Ol-joro-Orok, Central Kenya.

Attribute	DMY	PH	CP	ADF	NDF
DMY (t/ha)	1.000				
PH (m)	0.791***	1.000			
CP (g/kg DM)	0.382**	0.360**	1.000		
ADF (g/kg DM)	0.500***	0.439**	0.176	1.000	
NDF (g/kg DM)	0.421**	0.146	0.027	0.294*	1.000

DMY = dry matter yield; PH = plant height; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber.

Table 8. Weighted scores (1 = low; 10 = high) for ryegrass and festulolium varieties/hybrids according to criteria generated by Nyamarura dairy farmers in Ol-joro-Orok, Central Kenya, during the first growth cycle.

Grass	Variety	Criterion score						
		Biomass	Growth rate	Height	Leafiness	Frost tolerance	Disease tolerance	Weighted score
		10	9	6	6	4	2	
		Variety score						
Ryegrass	AberBite	6	6	6	7	10	10	6.8
	AberWolf	6	7	6	5	10	10	6.7
Festulolium	Hybrid 1	8	9	7	9	10	10	8.7
	Hybrid 2	7	8	7	8	10	10	7.9
	Hybrid 3	8	8	8	7	10	10	8.2
	Hybrid 4	9	9	8	8	10	10	8.8
	AberNiche	9	10	9	10	10	10	9.6

Discussion

Growth and herbage yield

The new perennial ryegrass varieties and novel festulolium hybrids performed very well, especially during the first 2 growth cycles. During these cycles, daily herbage rate exceeded 70 kg DM/ha, which was much greater than the 10 and 17 kg DM/ha/d reported by Boonman (1993) for kikuyu grass (*Cenchrus clandestinus* syn. *Pennisetum clandestinum*) and star grass (*Cynodon* spp.), respectively, in the area. However, growth rate in Cycle 3 of 21.6 (ryegrass) and 29.8 (festulolium) kg DM/ha/d was much lower than the initial yields. As mean maximum temperature was only 1–1.5 ºC lower than in cycles 1 and 2 and mean minimum temperatures, true minimums and rainfall per day were at least equal to those in cycles 1 and 2, some other factor must have been responsible for the drop in growth. Since no N fertilizer was applied after the 90 kg N/ha at planting, it would seem that low amounts of available N may have been largely responsible for the poor growth in cycle 3. Further studies with N application after each cut would clarify this hypothesis.

Plant heights and biomass yields realized in this experiment (Tables 4 and 5) were comparable with those reported elsewhere. For example, Humphreys et al. (2014b) quoted plant heights of 0.22–0.62 m in festulolium under field conditions following a month of growth, which were similar to the 0.27–0.47 m recorded in the various growth cycles in the current study. Yield studies on ryegrass and festulolium in a subtropical environment in Australia reported annual yields of 12.5–20.7 t DM/ha in various ryegrasses and 20.1 t DM/ha in a festulolium hybrid Felopa (Lowe and Bowdler 1995). These performances in monthly estimates translate to about 1.08–1.78 t DM/ha/month for ryegrass and 1.57 t DM/ha/month for festulolium. While mean monthly yields of 2.2–2.6 t DM/ha in cycles 1 and 2 were markedly greater, over a complete year mean monthly yields would probably be lower. This is supported by the 0.85 t DM/ha in cycle 3, which is synonymous with reports that show perennial ryegrasses are most productive early in the season (Givens et al. 2000). The good yields when soil moisture and available N were not limiting in cycles 1 and 2 were possibly a reflection of the favorable soils in the study farms (Table 1). Clay-loam soils have better water holding capacity than sandy soils, coupled with P and N values that were at medium levels (Table 1) according to ratings by Hazelton and Murphy (2007). Further, available N and P were boosted by fertilizer application at planting with no top dressing subsequently, possibly leading to the low yields in cycle 3.

Herbage nutritive value

Forage nutritive value of both perennial ryegrass and festulolium was much superior to the commonly used Napier grass, although the values were from the first cut only. The RFVs we calculated (126.6–142.5%) were nearly double those reported by Mwendia et al (2016) for Napier grass. These values for perennial ryegrass and festulolium exceed those for lucerne/alfalfa (*Medicago sativa*), which is used as the standard of 100, i.e. the reference fodder crop in the estimations (Jeranyama and Garcia 2004). This would make either of them preferable to lucerne when quality is the main consideration. The relatively low NDF values (448–493 g/kg DM) compared with 675 g/kg DM observed in Napier grass (Mwendia et al. 2016) are also beneficial, as they imply better digestibility. The estimated DMIs (24.3–26.9 g/kg LW) (Table 6) were largely close to 24.3–24.7 g/kg LW reported by Kidane et al. (2018), which is a key driver of animal performance. Although there is a dearth of information on quality of ryegrass or festuloliums grown in tropical environments, the range of crude protein concentrations (163–190 g/kg DM) was greater than the 94–156 g/kg DM observed by Humphreys et al. (2014b) in festulolium, but within the range of 112–239 g/kg DM reported by Weller and Cooper (2001) in perennial ryegrass planted without N in the UK. However, observed values in this study were much greater than the 80–130 g/kg DM recorded in Napier grass under tropical conditions (Wijitphan et al. 2009), indicating the superior quality of forage produced by perennial ryegrass and festulolium varieties under the study conditions. Despite quality attributes not being measured in the 2nd and 3rd cuts, it is doubtful they could have deteriorated to less than those for Napier grass given the herbage had a high leaf:stem ratio.

Potential farmers' acceptance and fit into production systems

Studies on fodder adoption in Kenya have shown that farmers' perceptions of different attributes like drought tolerance govern adoption along with other factors like labor availability and economy on land (Sinja et al. 2004). The 6 important attributes, identified by the farmers (Table 8) and duly scored, rated biomass production highly as in a previous study in the area (Mwendia et al. 2015). As such, the likelihood of farmers adopting the studied forages in the area would be promising. We consider that involving farmers in the observations from an early stage of the evaluation should enhance the likelihood of adoption of these pastures. Further, in the central Kenyan highlands it is only in the study area, where individual farms are large enough for some farmers to practice some grazing (Muia et al. 2011), that these pasture grasses would be well suited. However, further observations and especially during dry seasons are essential. Perennial ryegrass may look much better after its usually slow establishment, and scrutiny over more growth cycles would be important, especially in this regard. Although the farmers involved in this participatory evaluation did not have a chance to compare these grasses with other pasture grasses, the evidence generated on yield, quality and farmers' ratings is likely to boost potential adoption in an area where only about 41% of the farmers use improved fodders (Muia et al. 2011). However, seed availability could be a major impediment, and sustainable supply possibly via the private sector would be most appropriate to account for situations when persistence is low and re-seeding is required.

Conclusion

The preliminary forage evaluation work reported here has shown potential for using the tested new perennial ryegrass and novel festulolium varieties bred for temperate Europe to improve forage resources and, therefore, cattle nutrition in Nyandarua, and other similar tropical highland areas. From the study, we deduce the following:

i) Herbage production of these varieties and hybrids is acceptable, coupled with farmers' positive perceptions, but further assessment including nitrogen application and management is needed as well as in a range of environments;
ii) Persistence needs to be evaluated for a longer period including under grazing conditions, as well as animal production; and
iii) Reliable seed supply would be essential to allow adoption, and preferably through the private sector. Essentially, it would entail registration and licensing the varieties first, then encouraging seed companies to list them in their portfolios.

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