EFFECT OF GROWTH STAGE AND METHOD OF CONSERVATION OF *Hyparrhenia filipendula* AND *Hyperthelia dissoluta* ON NUTRIENT COMPOSITION AND DIGESTIBILITY†

[EFECTO DE LA ETAPA DE CRECIMIENTO Y MÉTODO DE CONSERVACIÓN DE *Hyparrhenia filipendula* Y *Hyperthelia dissoluta* SOBRE LA COMPOSICIÓN DE NUTRIENTES Y LA DIGESTIBILIDAD]

J. Gusha[1,*], T.E. Halimani[2], N.T. Ngongoni[3], M. Masocha[4], S. Katsande[1] and P.H. Mugabe[2]

[1]Department of Paraclinical Veterinary Studies, University of Zimbabwe, P.O. MP167 Mount Pleasant Harare. Email: jtgusha@gmail.com
[2]Department of Animal Science, University of Zimbabwe, P. O. MP167 Mount Pleasant Harare.
[3]Faculty of Agriculture, Zimbabwe Open University, Harare.
[4]Department of Geography and Environmental Sciences, University of Zimbabwe, P. O. MP167 Mount Pleasant, Harare.
**Corresponding author*

SUMMARY

Native species such *Hyparrhenia filipendula* and *Hyperthelia dissoluta* have great potential in livestock production but not much has been done to improve their contribution to that sector. This factorial study examined 2 grass species (*H. filipendula* and *H. dissoluta)* × 2 conservation methods (drying and ensiling) × 3 different growth stages, namely: elongation stage (January), early flowering (February) and late flowering stage (March) of *H. filipendula* and *H. dissoluta* during growing season in terms of nutritional composition and digestibility. There was no difference (P>0.05) in nutritional composition between the two-grass species. The method of conservation had an effect (P<0.05) on nutritive value, with silage having more phosphorus (P), neutral detergent fibre (NDF) and crude protein (CP) than hay. Stage of growth had an effect (P<0.05) on all nutritional properties of both hay and silage. Phosphorus, Calcium, NDF, CP concentrations and digestibility of hay and silage decreased with maturity, while acid detergent fibre (ADF) concentration increased. Silage pH value was significantly higher at elongation 5.1 and 4.9 for *H. filipendula* and *H. dissoluta*, respectively. Silage pH for early flowering stage was within the recommended ranges from 4.1 to 4.4 on the pH scale, with higher than the recommended range for the late flowering growth stages (4.8 and 4.5) for *H. filipendula* and *H. dissoluta*, respectively. Dry matter digestibility of the conserved material reached levels as high as 80% for silage made at the elongation stage with all values at least 60%. The study results reveal that *H. filipendula* and *H. dissoluta* can be conserved as both silage and hay to produce a good quality feed. Harvesting at the early flowering stage provide a good compromise between quantity and quality of harvested forage. Further studies are necessary to assess the acceptability of the forage by livestock as well as to determine dry matter yields in different areas and a range of seasonal conditions.
Keywords: Neglected perennial native grass species; silage; hay; quality; air-drying; plastic bag silo.

RESUMEN

Las especies nativas como *Hyparrhenia filipendula* e *Hyperthelia dissoluta* tienen un gran potencial en la producción ganadera, pero no se ha hecho mucho para mejorar su contribución a ese sector. Este estudio factorial examinó 2 especies de gramíneas (*H. filipendula* y *H. dissoluta*) × 2 métodos de conservación (secado y ensilado) × 3 etapas de crecimiento diferentes: etapa de alargamiento (enero), floración temprana (febrero) y etapa de floración tardía (marzo) de *H. filipendula* y *H. dissoluta* durante la temporada de crecimiento en términos de composición nutricional y digestibilidad. No hubo diferencia (P<0.05) en la composición nutricional entre las dos especies de gramíneas. El método de conservación tuvo un efecto (P <0.05) sobre el valor nutritivo, ya que el ensilaje tiene más fósforo (P), fibra detergente neutra (FDN) y proteína cruda (PC) que el heno. La etapa de crecimiento tuvo un efecto (P>0.05) en todas las propiedades nutricionales del heno y el ensilaje. Las concentraciones de fósforo, calcio, FDN, PC y la digestibilidad del heno y el ensilaje disminuyeron con la madurez, mientras que la concentración de fibra detergente ácida (FDA) aumentó. El valor del pH del ensilaje fue significativamente mayor en el alargamiento 5.1 y 4.9 para *H. filipendula* y *H. dissoluta*, respectivamente. El pH del ensilaje para la etapa de floración temprana estuvo dentro de los rangos recomendados de 4.1 a 4.4 en la escala de pH, con un rango mayor que el recomendado para las etapas de crecimiento de floración tardía (4.8 y 4.5) para *H. filipendula* y *H. dissoluta*, respectivamente. La digestibilidad de la materia seca del material conservado alcanzó niveles tan altos como 80% para el ensilaje hecho en la etapa de alargamiento con todos los valores al menos 60%. Los resultados del estudio revelan que *H. filipendula* y *H. dissoluta* se pueden conservar como ensilaje y heno para

† *Submitted September 18, 2018 – Accepted February 5, 2019.*
ISSN: 1870-0462

producir un alimento de buena calidad. La cosecha en la etapa de floración temprana proporciona un buen compromiso entre la cantidad y la calidad del forraje cosechado. Se necesitan estudios adicionales para evaluar la aceptabilidad del forraje por el ganado, así como para determinar los rendimientos de materia seca en diferentes áreas y un rango de condiciones estacionales.
Palabras clave: Especies de pasto nativas desatendidas; ensilaje; heno; calidad; secado al aire; bolsa de plástico silo.

INTRODUCTION

In tropical and subtropical regions, smallholder farmers face animal feed shortages during the annual dry period of 7–9 months from April to December (Mapiye *et al.,* 2006; Ngongoni *et al.,* 2006). The quality of forage generally declines as plants mature and become more fibrous and crude protein levels fall to as low as 2% DM (Smith, 2002), resulting in accumulation of poor-quality biomass, which is lowly digestible and low in nutrients (Ball *et al.,* 2001). The biomass is either consumed by veld fire during the dry season or breaks down during the following rainy season. This can result in low productivity, long calving intervals, and high livestock mortality (Lukuyu *et al.,* 2011).

Zimbabwe has abundant native, well-adapted grass resources of tropical C_4 grass species such as *H. filipendula* and *H. dissoluta,* which have been neglected as animal feeding resources. Little attempt had been made to find ways of utilizing these grass species except for a few studies (Mufandaedza, 1976a,1976b). Thereafter, these species were not considered as options for improving livestock production. Earlier studies by Smith (1962), reported the nutritive value of the mature *Hyparrhenia* grasslands which include (*H. filipendula* and *H. dissoluta*) as 'standing hay' progressively dropped to 38% digestible organic matter and negative crude protein (CP) digestibility, where nitrogen excreted in the faeces exceed nitrogen intake from feed by mid-dry-season in July and were grossly deficient in both energy and protein. These results were not encouraging to pastures and rangelands researchers. Researchers then shifted their attention to exotic species with better nutritive value such as *Cynodon nlemfuensis*. Most exotic forage species require fertilisers for them to do well and most communal farmers and many smallholder farmers may not be able to afford the management requirements to produce good yield. Traditionally, exotic fodder species and cereals have been planted to produce hay and silage; but the rate of success under dry land farming is low and some are in direct competition for land with those crops used to produce foodstuffs for human consumption (Gusha *et al.,* 2014). *Hyperthelia filipendula* and *H. dissoluta* grass species do not require land preparation, irrigation, weeding, and fertiliser application but to identify the optimum time to harvest from the rangelands and conserve only.

Because of the increase in abundance of *H. filipendula* and *H. dissoluta*, a rethink with regards to research and utilization of these species is imperative. These species are well adapted to local climatic conditions and are most dominant grass species in most communal rangelands (Gusha *et al.,* 2017). *Hyparrhenia filipendula* and *H. dissoluta* may have the potential to modify the perennial feed deficit problems if appropriate techniques are applied during harvesting and conservation. In order to improve livestock productivity, the use of native high-producing veld grasses is important. A good quality feed from forages can only be produced if harvesting is done when pastures are at a vegetative stage and still nutritious (Ball *et al.,* 2001) and then conserved as hay or silage for later use during times of deficit.

In order to bridge the perennial feed deficit and to reduce animal loses, property and ecosystem destruction because of high intensity veld fires fuelled by these grass species which are neglected in the rangelands. Therefore, the study was aimed at evaluating the potential of adapted native grass species, with *H. dissoluta* and *H. filipendula* as example, to produce conserved forages for dry season feeding. Moreover, the study also identified the most suitable harvesting and conservation strategies to produce high quality herbage for livestock feeding. The study further evaluated the effects of stage of growth and conservation method of *H. filipendula* and *H. dissoluta* on nutrient composition and digestibility.

MATERIALS AND METHODS

The study was conducted at Henderson Research Institute, 30 km north of Harare (17°35' S, 30°58' E; 1,300 masl). Henderson Research Institute is livestock research centre with the mandate a researching on animal nutrition and production. The area receives an average rainfall of 870 mm annually (www.drss.com), which falls mainly between December and late March. The vegetation consisted mainly of tree savanna or bush clump savanna with tall perennial grasses such as *H. dissoluta* and *H. filipendula* on red clay soils.

Silage and hay preparation

The experimental design was a 2×2×3 factorial treatment. There were two grass species (*H. filipendula* and *H. dissoluta*) and two methods of conservation of the grass (either ensiled or dried as hay) and three growth stages [elongation stage in January (early growth stage), early flowering stage in February (middle growth stage), and late reproductive stage in March (late growth stage)]. At each stage of harvest, 60 kg per site of *H. filipendula* and 60 kg per site of *H. dissoluta* were harvested by cutting with a sickle at 5 cm above the ground from three different sites within the farm. The harvested *H. filipendula* and *H. dissoluta* forage was transported to the Pasture section at Henderson research institute and chopped into approximately 3 cm pieces manually using machetes. Ten-kilogram samples of the chopped herbage were thoroughly mixed with 500 grams molasses to improve fermentation before packing in polythene bags with a thickness of 150 microns. The contents of the bags were compacted, and the bags compressed to remove air, tied to prevent the entry of air and inserted into another polythene bag. Three samples were prepared at each site and each stage of growth. The bags were left to ferment for seven weeks at room temperature of about 25 ºC. The other 30 kg herbage at each site was divided into three 10 kg heaps, which were spread and dried under shade for 7 days, and the dried material was stored in hessian bags at room temperature. Nine bags of silage and nine heaps of hay were made at each harvesting stage for each grass species and were used as replicates in the study.

Nutrient chemical composition analysis

Representative samples were collected from each treatment bag at day 35 post ensiling and were oven-dried for 48 h at 60 ºC. The samples were then ground through a 1 mm sieve and analysed for nitrogen (N), dry matter (DM), acid detergent insoluble nitrogen (ADIN), and ash according to AOAC (2000). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using the method of Goering and Van Soest (1970). Phosphorus and calcium concentrations were determined by the spectrophotometric method (Danovaro, 2009) and the EDTA method (Kaur, 2007), respectively. Digestibility was determined according to Tilley and Terry (1963) and pH using a digital pH meter.

Statistical analysis

The experiment was carried out in factorial design of three harvesting periods x 2 conservation methods x 2 grass species and was done in complete randomized design. The model for data analysis included the main factors of harvesting time, conservation method, the grass species, and their interaction. Analysis of variance was carried out using the general linear model procedure (SAS, 2010). Significant differences of means were tested using the least significant difference (LSD) method. Only the main effects are reported and discussed in this experiment because there were no interactions of these main factors at (P>0.05). The following model was fitted:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + C_k + (\alpha * \beta * C) + \varepsilon_{ijk}$$

Where:

Y_{ijk}= the response variable (digestibility and nutritive content);

μ = the overall mean common to all observations;

α_j = effect of i^{th} grass species (*H. filipendula* and *H. dissoluta*);

$\beta_{j\,=}$ effect of j^{th} conservation method (Silage and hay);

C_k = effect of the k^{th} harvesting time (elongation stage, early flowering stage, late reproductive stage);

$(\alpha * \beta * C)$= interaction between the three factors and ε_{ijk} = the residual error.

RESULTS

The study revealed *Hyparrhenia filipendula* and *Hyperthelia dissoluta* were not significantly (P = 0.089) different. The species difference did not influence much a the quality of hay or silage produced. The method of conservation had significant influence (P = 0.0001) on the quality of hay or silage produced as shown on table 1. Likewise, the stage of growth at harvest significantly affected the quality of hay and silage made using *H. filipendula* and *H. dissoluta.* There was no significant interaction (P = 0.73) among grass species used, stage of growth at harvest and the method of conservation used. This was also true for grass species and stage of growth at harvesting, which showed that there was no significant interaction which could influence the quality of silage or hay produced.

Quality of silage from the two grass species

H. dissoluta and *H. filipendula* silage made during the elongation stage of growth had the highest CP concentrations of 11.2 and 12.1% (DM basis), respectively (Table 1). Crude protein concentrations declined progressively with later harvesting to 4.5% for both *H. dissoluta* and *H. filipendula* grass species at late reproductive stage. Silage pH values were 4.9 and 5.2 at the elongation stage, 4.3, and 4.4 at the early reproductive stage and 4.7 and 4.5 at the late reproductive stage for *H. dissoluta* and *H. filipendula* respectively. Corresponding DM concentrations of the silages were *H. dissoluta* (26.3, 31.7 and 38.3%) and *H. filipendula* (25.9, 33.7, and 38.0%) for elongation stage, early reproductive and late reproductive stage respectively. Phosphorus and calcium concentration in conserved forage declined significantly with age and at all stages but not different between these species. Apparent digestibility of dry matter declined significantly as harvesting stage was delayed for both grass species and was generally higher for *H. dissoluta* than for *H. filipendula* for all the stages.

Table 1: The effects of grass species, stage of growth and method of conservation on the nutrient composition (% DM) for silages and hay.

Grass species	*Hyperthelia dissoluta*						*Hyparrhenia filipendula*						Mean	SE	P value
Method of conservation	Silage			Hay			Silage			Hay					
Stage of harvest	A	B	C	A	B	C	A	B	C	A	B	C			
DM	26.3^{d}	31.7^{c}	38.3^{a}	90.1^{ab}	90.2^{a}	91.4^{a}	25.9^{d}	33.7^{b}	38.0^{a}	89.6^{b}	89.7^{b}	90.7^{a}	61.70	0.29	0.0001
Ash	8.3^{a}	7.5^{b}	6.1^{c}	9.3^{a}	6.4^{b}	6.0^{c}	6.0^{c}	5.4^{e}	5.7^{d}	6.4^{b}	6.6^{b}	3.5^{d}	6.37	0.12	0.0001
P	1.66^{c}	1.19^{d}	2.16^{b}	2.66^{a}	1.93^{b}	1.56^{c}	2.5^{a}	2.63^{a}	1.64^{c}	2.04^{b}	1.67^{b}	1.76^{b}	0.06	0.001	0.0001
Ca	0.03^{a}	0.01^{a}	0.21^{a}	0.21^{b}	0.19^{c}	0.16^{c}	0.03^{a}	0.03^{a}	0.03^{a}	1.69^{a}	0.63^{b}	0.64^{b}	1.28	0.07	0.0001
NDF	77.9^{a}	72.5^{b}	64.9^{c}	65.9^{a}	63.5^{b}	54.3^{d}	64.9^{c}	66.5^{c}	57.7^{d}	67.6^{a}	62.4^{b}	56.8^{c}	64.52	0.44	0.0001
ADF	42.2^{dc}	47.5^{ab}	49.0^{a}	41.7^{d}	49.5^{c}	54.6^{a}	44.6^{c}	45.8^{c}	47.0^{b}	44.4^{d}	50.1^{bc}	51.8^{b}	47.19	0.42	0.0001
ADIN	0.17^{a}	0.30^{a}	0.28^{a}	0.26^{b}	0.26^{b}	0.31^{a}	0.22^{a}	0.21^{a}	0.27^{a}	0.24^{b}	0.23^{b}	0.26^{b}	0.25	0.008	0.005
CP	11.2^{a}	9.3^{b}	4.5^{d}	9.5^{a}	5.1^{c}	3.2^{d}	12.1^{a}	7.6^{c}	4.5^{d}	8.2^{b}	5.6^{c}	3.5^{d}	6.69	0.14	0.0001
Dig	80.0^{a}	74.3^{b}	64.4^{d}	72.1^{a}	71.0^{ab}	63.1^{c}	69.4^{c}	62.7^{d}	60.0^{de}	68.1^{b}	58.6^{d}	56.6^{d}	65.36	0.65	0.0001
pH	4.9^{b}	4.3^{d}	4.8^{b}	-	-	-	5.1^{a}	4.4^{cd}	4.5^{c}	-	-	-	4.63	0.1	0.0001

A = elongation stage; B = early reproductive stage; C = late reproductive stage; DM = dry matter; Phosphorus; Ca = calcium; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADIN = acid detergent insoluble nitrogen; CP = crude protein; and Dig = DM digestibility coefficient. Means within rows followed by different superscript letters differ ($P<0.05$). SE = Standard error.

Quality of hay from the two grass species

Hyperthelia dissoluta and *H. filipendula* hay which was made during the elongation stage of growth had the highest CP concentrations of 9.5 and 8.2% (DM basis), respectively (Table 6.1). Crude protein concentrations declined progressively with later harvesting to 3.2% and 3.5 for *H. dissoluta* and *H. filipendula* grass species at late reproductive stage respectively. Dry matter concentrations of the hay were *H. dissoluta* (90.1, 90.2, and 91.4%) and *H. filipendula* (89.6, 89.7, and 90.7%) for elongation stage, early reproductive and late reproductive stage respectively. Apparent digestibility coefficient of dry matter declined significantly with maturity for both grass species and was generally higher for *H. dissoluta* than for *H. filipendula* for all the stages. Apparent digestibility coefficient was ranging between 72.1 to 63.1% for *H. dissoluta* and between 68.1 to 56.6% for *H. filipendula.*

DISCUSSION

An important finding in the current study was the high *in vitro* DM apparent digestibility of the conserved material. The highest digestibility coefficient obtained was 80% for silage made at the elongation stage of growth, while the lowest was 56.6% for hay made at late flowering stage. These values were much higher than the values of 54.5% reported by Heuzé *et al.* (2012) and below 50% reported by Smith (1962). They are outstanding for a tropical grass and strongly suggest that these species warrant further study as a potential source of forage for livestock. According to Ball *et al.* (2001), immature leaf plant tissues may be 80 to 90% digested, while less than 50% of mature stemmy material is digested. The results for digestibility coefficient could be related to harvesting time before the physical incrustation of plant fibres by lignin, rendering them inaccessible to enzymes that would normally digest them (Mertens, 2009; McDonald *et al.,* 2011). Smith (1962) reported that the seasonal drop in digestibility values is accentuated by the drop in dry-matter intake so that a diet of mature veld herbage in mid dry season is grossly deficient in both energy and protein.

It is widely accepted that tropical grasses have lower digestibility coefficient than temperate grass species but more should be done with regards to these tropical native species, which require low fertiliser input to produce large quantities of biomass. Cell wall digestibility also depends on the structure of the plant tissues hence it should make sense to harvest the biomass before the physical incrustation with lignin thus changing the structure of the plant tissues making them indigestible. In addition, harvesting *H. filipendula* and *H. dissoluta* during the dry season as hay result is harvesting more stems than leaf materials due to shattering thus affecting the digestibility coefficient because of the stem to leaf ratio. According to Smith (1962) Ball *et al.* (2001) and Scarbrough *et al.* (2005), mature veld grasses harvested at the late reproductive growth stages as veld hay or green forage, contains below 50% digestible organic matter and further delays in harvesting is accompanied by a progressive decline to 38% digestible organic matter by mid-dry-season in July. Even at late reproductive stage of growth, the material will be still moist enough to be highly digestible (Skerman and Riveros, 1990). Unfortunately, very little studies were done at those growth stages with these particular species hence from this work it is strongly recommended to do more and exploit the potential shown using *in vivo* studies.

Quality in terms of CP and fiber concentrations and DM digestibility coefficients of the conserved material, declined as harvesting was delayed from the elongation stage to the late flowering stage. This is consistent with the findings reported by Rotz and Muck (1994), Ball *et al.* (2001) and Scarbrough *et al.* (2005). They reported that with prolonged delay in harvesting CP digestibility decline to below 0.6%. Very low levels of crude protein of approximately 3% found in veld grass harvested at the end of rain season resulted in a low apparent CP digestibility. Forage quality decline with advancing maturity and this is related to increase in structural carbohydrates at the expense of cell components. Moore *et al*. (1991) reported that at late maturity forages become lignified with reduced digestibility. It was also reported by Scarbrough *et al.* (2005) that during the first 3 weeks after growth initiation at the onset of the rain season, digestibility will be greater than 80% and will progressively decline by 1/3% to 1/2% units per day until it reaches a level below 50%. This assertion agrees with this study results on digestibility and CP levels as they progressively decrease from as high as 80% and 12.1% to as low as 56.6 and 3.2 percent respectively. Animals sustained on such forage conserved late at the end of rain season consequently suffer from protein deficiency (Smith, 1962; Dilley *et al.*, 2013).

The desirable level of NDF in feedstuffs is <55% (Mertens, 2009). Despite the higher levels of NDF than the recommended desirable levels, harvesting the grasses at elongation and early flowering growth stage produces better quality feed with high digestibility coefficient. This could be due to less degree of lignification at those growth stages especially at elongation and early reproductive growth stage (Moores *et al.*, 1991; Ball *et al.*, 2001). According to Mertens (2009), the amount of lignin varies with maturity and the strong chemical bonds between lignin and other compounds increases with maturity. In our study, all treatments had values above this, which should depress intake. It would be expected that intake of forage with DM digestibility in the range 60–82 % would be quite acceptable, suggesting that feeding studies with animals to test acceptability of the material, possible intake levels and *in vivo* digestibility are needed.

For grass silages the recommended pH for a well-preserved silage is between 4.2 and 4.7 (Pyatt and Berger, 2000; Bosworth, 2005). The pH values for elongation growth stages for the two grass were above these recommended levels for grass silage. This could be related to low soluble sugars during the elongation stage of growth (Bosworth 2005) combined with high moisture levels in the fast-growing crop. The silage quality at late flowering stages were within the range but on the higher side and could be a result of the low moisture levels at late flowering that prevented adequate compaction to remove air effectively (Ball *et al.,* 2001). Pyatt and Berger (2000) reported that forages with a DM above 35% at ensiling, as the material ensiled at late flowering, have less efficient fermentation because they are difficult to compact.

While the decline in CP and P concentrations in conserved material with delay in harvesting time were to be expected, the consistently higher CP and P concentrations in silage compared with hay were surprising. MacDonald and Clark (1987) reported results from eight separate studies, showing there is an average of 34% CP loss during the drying process. Thus, in the current study the lower CP levels in hay could be associated with leaf loss and weathering damage during drying. These results reaffirm what was reported by Scarbrough *et al.* (2005) that leafy shattering, respiration and leaching during field drying of hay can cause a significant reduction in forge quality. Method of conservation had no significant effect at P<0.05 on the Ca levels but stage of ensiling had a significant effect in silage with a trend of increasing Ca concentration with maturity (Morales *et al.,* 2011). The Ca concentration in both hay and silage was below the minimum requirement for all classes of livestock (Fox *et al.*, 1988) and if hay made from *H. dissoluta* is to be fed as a complete ration, a Ca supplement like limestone flour should be fed (Fox *et al.*, 1988). Silage contained adequate levels of P for livestock feeding but hay made at early or late flowering had insufficient levels of P for livestock, especially lactating females (Coates and Ternouth, 1992) and supplements may be necessary if this material constitutes a major part of the diet.

The CP concentrations in hay were generally lower than the levels found in previous studies of 6.4% in late summer (Heuzé *et al.,* 2012). If these conserved fodders were to be fed as a major part of the ration for livestock, especially lactating females, a protein supplement would need to be added to the ration. In this study ADIN concentration was similar for both methods of conservation and stages of harvest and the quantity of ADIN was less than 12% of the total N in the forages, indicating that little heat damage took place during drying and ensiling (Seglar, 2003).

More research is needed to determine the fermentation patterns of the silages. Further studies seem warranted to confirm that the high *in vitro* digestibility levels recorded in this study can be repeated with animals and to determine acceptability and intake with and without N and P supplements. Dry matter yields of this forage during a range of seasons and on a range of soil, types would provide evidence whether satisfactory DM yields can be obtained in a range of situations.

CONCLUSION

Hyparrhenia filipendula and *H. dissoluta* can produce good quality forage, which could be conserved as silage or hay for dry season feeding of livestock. Best timing of harvest would depend on whether farmer requires quantity or quality of conserved material. Whether hay or silage is made would depend to some extent on weather conditions during the optimal time of harvesting and the ability to reliably dry hay.

REFERENCES

AOAC (Association of Agricultural Chemists). 2000. AOAC official methods of analysis. 17th Edn. AOAC, Gaithersburg, MD, USA.

Ball, D.M., Collins, M., Lacefield, G.D., Martin, N.P., Mertens, D.A., Olson, K.E., Putnam, D.H., Undersander, D.J., Wolf, M.W. 2001. Understanding forage quality. American Farm Bureau Federation Publication, 1(01).

Bosworth, S. 2005. Corn silage forage quality in Vermont for 2005. In: The Vermont Crops and Soils Home Page, Plant and Soil Science Department, University of Vermont, Burlington, VT, USA. http://pss.uvm.edu/vtcrops/articles/ForTestLab/CornSilageQuality05.pdf.

Bosworth, S., Hudson, D. 2005. Sensory evaluation of hay for quality. Plant and Soil Science Department, University of Vermont, Burlington, VT 05405.

Coates, D.B., Ternouth, J.H. 1992. Phosphorus kinetics of cattle grazing tropical pastures and implications for the estimation of their phosphorus requirements. The Journal of Agricultural Science, 119(3): 401-409. https://doi.org/10.1017/S0021859600012247.

Danovaro, R. 2009. Total organic carbon, total nitrogen and organic phosphorus in marine sediments. In 'Methods for the study of deep-sea sediments, their functioning and biodiversity'. In Danovaro R Ed (2009) Methods for the study of deep-sea sediments for functioning and biodiversity CRC Press, NW, USA

Dilley, A., Bell, M.A., Coite, E., Honeycutt, E. 2013. Hay making. https://onslow.ces.ncsu.edu/wp-content/uploads/2013/07/FenceJuly-Sept13.pdf?fwd=no accessed on 10 July 2015.

Fox, D.G., Sniffen, C.J., O'Connor, J.D. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variations. Journal of Animal Science, 66(6):1475-1495. https://doi.org/10.2527/jas1988.6661475x.

Goering, H.K., Van Soest, P.J. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). USDA Agricultural Handbook No 379, Agricultural Research services, Washington D.C, USA.

Gusha, J., Halimani, T.E., Katsande, S., Zvinorova, P.I. 2014. "Performance of goats fed on low quality veld hay supplemented with fresh spiny cactus (*Opuntia Megacantha*) mixed with browse legumes hay in Zimbabwe" Tropical Animal Health and Production, 46(7):1257–63. https://doi.org/10.1007/s11250-014-0636-z.

Gusha, J., Masocha, M., Mugabe, P.H. 2017. Impact of grazing system on rangeland condition and grazing capacity in Zimbabwe. The Rangeland Journal, 39(3): 219-225. https://doi.org/10.1071/RJ15130.

Heuzé, V., Tran, G., Hassoun, P. 2012. Yellow thatching grass (*Hyperthelia dissoluta*). Feedipedia.org. A programme by INRA, CIRAD, AFZ and FAO: 2–3. Available at: http://www.feedipedia.org/node/429.

Kaur, D. 2007. Development of a cheap and rapid method to determine calcium in milk fraction in an industrial environment, Master of Applied Science Thesis, Auckland University of Technology, Auckland, New Zealand. http://hdl.handle.net/10292/742.

Lukuyu, B., Franzel, S., Ongadi, P.M., Duncan, A.J. 2011. Livestock feed resources: Current production and management practices in central and northern Rift Valley provinces of Kenya. Livestock Research for Rural Development, Volume 23, article #112. Retrieved October 28 2017, from http://www.lrrd.org/lrrd23/5/luku23112.htm.

MacDonald, A.D., Clark, E.A. 1987. Water and quality loss during field drying of hay. Advances in Agronomy, 41:407-437.

Mapiye, C., Mwale, M., Mupangwa, J.F., Poshiwa, X., Mugabe, P.H., Chikumba, N. 2006. A review of improved forage grasses in Zimbabwe. Tropical and Subtropical Agroecosystems, 6:125–131. http://www.redalyc.org/pdf/939/93960301.pdf

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D., Morgan, C.A., Sinclair, L.A., Wilkinson, R.G. 2011. Animal nutrition. 7th edition

Saffron house, 6-10 Kirby street London UK.

Mertens, D.R. 2009. Impact of NDF content and digestibility on dairy cow performance. Western Canadian Dairy Seminar Advances in Dairy Technology, 21: 191-201. http://handle.nal.usda.gov/10113/30864.

Moore, K.J., Moser, L.E., Vogel, K.P., Waller, S.S., Johnson, B.E., Pedersen, J.F. 1991. Describing and Quantifying Growth Stages of Perennial Forage Grasses. Agronomy and Horticulture, Faculty Publications, Paper 507. http://digitalcommons.unl.edu/agronomyfacpub/507.

Morales, J.U., Alatorre, J.A.H., Escalante, A.A., Lopez, S.B., Vazquez, H.G., Gomez, M.O.D. 2011. Nutritional characteristics of silage and hay of pearl millet at four phenological stages. Journal of Animal and Veterinary Advances, 10(11):1378-1382. DOI: 10.3923/javaa.2011.1378.1382.

Mufandaedza, J.T. 1976a. Effects of frequency and height of cutting on the yield, composition, and quality of grass only and grass legume mixtures. Rhodesia Division of Livestock and Pastures Annual Report. Salisbury. (Herbage Abstracts 48 [1978]).

Mufandaeza, J.T. 1976b. Effects of frequency and height of cutting on some tropical grasses and legumes. *Hypharrenia filipendula* and *Heteropogon contortus.* Rhodesian Journal of Agricultural Research, 14:21-38.

Ngongoni, N.T., Mapiye, C., Mwale, M., Mupeta, B. 2006. Factors affecting milk production in the smallholder dairy sector of Zimbabwe. Livestock Research for Rural Development, 18(05):1–21. Available at: http://www.lrrd.org/lrrd18/5/ngon18072.htm.

Pyatt, N.A., Berger, L.L. 2000. Management and storage alternatives for corn silage. http://livestocktrail.illinois.edu/dairynet/paperDisplay.cfm?ContentID=440 accessed 28 October 2017.

Rotz, C.A., Muck, R.E. 1994. Changes in forage quality during harvest and storage. Forage Quality, Evaluation, and Utilization, 1:828-868. https://doi.org/10.2134/1994.foragequality.c20.

SAS Institute, 2010. SAS/STAT user's guide. 9th Edn. (SAS Institute, Cary).

Scarbrough, D.A., Coblentz, W.K., Humphry, J.B., Coffey, K.P., Daniel, T.C., Sauer, T.J., Jennings, J.A., Turner, J.E., Kellogg, D.W. 2005. Evaluation of dry matter loss, nutritive value, and in situ dry matter disappearance for wilting orchardgrass and bermudagrass forages damaged by simulated rainfall. Agronomy Journal, 97(2):604-614. doi:10.2134/agronj2005.0604.

Seglar, B. 2003. Fermentation analysis and silage quality testing. http://conservancy.umn.edu/bitstream/handle/11299/108997/1/Seglar.pdf, accessed on 28 October 2015.

Skerman, P.J., Riveros, F. 1990. Tropical grasses. FAO Plant Production and Protection Series No (23). FAO, Rome.

Smith, T. 2002. Some tools to combat dry season nutritional stress in ruminants under African conditions. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/33/032/33032982.pdf accessed on 28 October 2017.

Smith, C.A. 1962. The utilization of Hyparrhenia veld for the nutrition of cattle in the dry season III. Studies on the digestibility of the produce of mature veld and veld hay, and the effect of feeding supplementary protein and urea. The Journal of Agricultural Science, 58(2):173-178.

Tilley, J.M.A., Terry, R.A. 1963. A two-stage technique for the in vitro digestion of forage crops. Journal of the British Grassland Society, 18:104-111. https://doi.org/10.1111/j.1365-2494.1963.tb00335.x.