EFFECT OF AGE OF IMPROVED FORAGE SORGHUM ON PRUSSIC ACID TOXICITY AND NUTRITIVE VALUE TO YOUNG RUMINANTS IN SEMI-ARID KENYA

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ABSTRACT
Sorghum (*Sorghum bicolour* (L.) Moench) is suitable fodder to alleviate feed shortage in semi-arid tropics as it is drought tolerant. Two varieties of forage sorghum were studied to ascertain the effect of age on prussic acid concentration and nutritive value and to establish the threshold at which it would be safe to feed the sorghum to young ruminants. Varieties E1291 and E6518, planted in randomized complete block layout with three replicates, were sampled for prussic acid (hydrocyanic acid, HCN) and nutrient composition at 5 and 10 weeks (first and second weeding and thinning) and thereafter, every 2 weeks up to 22 weeks. The data was subjected to analysis of variance and regression which showed that HCN negatively correlated to sorghum age. Variety E1291 contained less prussic acid compared to E6518. During the study, E6518 and E1291 contained 186.7 and 90.8; 167.5 and 139.8 mg/kg DM, HCN at 5 and 10 weeks, respectively, which decreased significantly to 81.6 and 70.8 mg/kg DM at 14 weeks. Prussic acid concentration in E1291 during the whole study period did not surpass the threshold of 200 mg/kg DM but the concentration in E6518 approached this threshold below 10 weeks' growth. After 10 weeks' growth E6518 also did not surpass the toxic threshold. Therefore, E1291 can be fed to young ruminants at any age but E6518 can only be fed after 10 weeks without toxic effects on young ruminants. Dry matter (DM), organic matter and fibre increased whereas crude protein decreased with sorghum age. The sorghum sampled young produced highly nutritious feed for young ruminants. However, the low DM is disadvantageous as ruminants offered these sorghum varieties ingest less DM compared to sorghum containing higher DM. Hence sorghum should be harvested later than 22 weeks of growth for higher DM intake by young ruminants.
Keywords: Concentration, Correlate, Fodder, Surpass, Threshold, Variety

INTRODUCTION
A major challenge facing livestock production in Kenya, particularly in low rainfall areas, is the seasonal variation in terms of quality and quantity of available forages, particularly the natural pasture, as it is influenced by rainfall seasons. The growth and abundance of forage increases at the onset of the rains and trails off to little or no growth at the height of the dry season. Also, the quality of the forages decreases with age and rainfall. The deterioration in the quality of roughages in terms of protein and energy during the dry season means that it cannot sustain high livestock production performance. Protein in particular, is expensive in Kenya and is known to be a major limiting nutrient in all livestock production systems.

Technological innovations, particularly targeting increased feed availability could increase livestock production. This should aim at availing adequate quantity and quality feed year round to guarantee high and stable production continuously (Ashiono et al., 2005). This is particularly useful in areas where dairy production forms the main livestock activity. Sorghum (*Sorghum bicolour* (L.) Moench) is adapted to semi arid areas receiving 400 to 800mm of rainfall annually by virtue of its heat and drought tolerance. With improved varieties, appropriate water and soil management practices this amount of rainfall can support production of sorghum (Ouma et al., 2013). Sorghum varieties E1291 and E6518 have been recommended and popularized for forage production in the dry highlands of Kenya (Ouma et al., 1995; Ashiono et al., 2005). However, their prussic acid concentration (hydrocyanic acid, HCN) and their nutritive value from emergence to their threshold values with increasing age have not been elucidated. The objective of the study was to ascertain the effect of age on prussic acid concentration and nutritive value in two sorghum varieties and establish the threshold at which it would be safe to feed the sorghum to young ruminants.

MATERIALS AND METHODS
The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO) in Lanet located in the outskirts of Nakuru town, within Nakuru County, Kenya. The site is 0^0 18'S, 36^0 09'E and 1920 m above sea level. The area receives bimodal rainfall; with the long rains occurring late March to May and the short rains received in October and November (Jaetzold et al. 2006). The area

receives on average 800 mm rainfall annually with a relative humidity of 83 %. The mean maximum and minimum temperatures are 26^{0}C and 10^{0}C, respectively. The study site falls within agro-ecological zone (AEZ) IV (Jaetzold et al. 2006) with soils classified as humic nitosols under FAO soil classification.

The experimental site was ploughed, harrowed and finally hand levelled to ensure a fine tilth. Experiments were laid out in a Randomized Complete Block Design with three replicates and plot sizes were 4.2 x 4.2 metres. Cold tolerant, medium maturity and late maturity, dual-purpose sorghum cultivars E1291 and E6518, respectively, were used and sown at the onset of long rains. Furrows were made by manually dragging a stick along a string used to mark rows. Furadan 5G granules, used to control soil borne pests, were thinly applied in the rows and later thoroughly mixed with the soil. Phosphorous (P_2O_5) was thinly applied at 30 kg/ha in the furrows and mixed with the soil. Sorghum seeds (E1291 and E6518) were sown in the rows at pacing of 60 cm x 20 cm and 75 x 10 cm, between rows and within rows, respectively, and thinly covered with soil. Nitrogen was applied six weeks after sowing at 40 kg/ha. Plots were kept weed free by hand weeding and Actellic sprayed at one litre/ha to control foliage pests.

Sorghum plants were randomly taken from the middle two rows, quickly chopped and sampled, weighed, placed into test tubes and chloroform dispensed into the tubes. The hydrogen cyanide was absorbed by suspended picrate test paper saturated with alkaline picrate solution. The colour was extracted using distilled water and the absorbance read from the colorimeter set at 550 nm. The cyanide concentration in milligrammes (mg) was read off the standard curve. Samples were further analyzed for nutrient composition using AOAC (1998) procedures and Van Soest et al., (1991) methods of analysis. Analysis of variance was conducted on data using SAS (2003). Least significant difference (LSD) at the 5% level of probability was used to separate treatment means. Simple regression of hydrocyanic acid (HCN) concentration on sorghum age was done.

RESULTS

Hydrocyanic acid (HCN) concentration

The harvesting age affected ($P<0.01$) the hydrocyanic acid (HCN) concentration of the two sorghum varieties (Table 1). Generally the HCN concentration decreased ($P<0.05$) with increased age in E1291 and E6518. However, there was a secondary peak concentration ($P<0.05$) at 18 weeks followed by declined HCN concentration ($P<0.05$) at 22 weeks. Variety E1291 contained less ($P<0.05$) HCN compared to E6518 at 5 and 10 weeks whereas both cultivars contained similar ($P>0.05$) concentration between 14 to 22 weeks. Simple regression showed that HCN was negatively correlated to sorghum age.

Dry matter (DM), Organic matter (OM) and Crude protein (CP)

The harvesting age affected ($P<0.01$) DM, OM and CP in the two sorghum varieties (Table 1). Generally DM increased ($P<0.05$) with increased age in E6518 whereas E1291 maintained similar ($P>0.05$) DM up to 14 weeks beyond which age DM increased ($P<0.05$). The two varieties contained similar ($P>0.05$) DM at 5 and 14 weeks but E1291 recorded higher DM at 10 and 22 weeks. The highest ($P<0.05$) DM was recorded at 18 and 22 weeks in E6518 and E1291, respectively. Generally OM increased ($P<0.05$) with increased age in both sorghum varieties. However, E1291 maintained similar ($P>0.05$) OM between 10 and 18 weeks. Variety E6518 had similar ($P>0.05$) OM at 10 and 14 weeks and also at 18 and 22 weeks, respectively. However, E1291 recorded higher ($P<0.05$) OM compared to E6518 at 10, 14 and 22 weeks but E1291 recorded lower ($P<0.05$) OM than E6518 at 18 weeks. Crude protein decreased ($P<0.05$) with increased age in the two varieties. However, CP did not differ ($P>0.05$) within E1291 and E6518 at 14 and 18 weeks and 18 and 22 weeks, respectively. Varieties E1291 and E6518 recorded similar ($P>0.05$) CP at 5 and 22 weeks although E1291 recorded lower CP compared with E6518 at 10 and 14 weeks.

Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and Acid detergent lignin (ADL)

The harvesting age affected ($P<0.01$) NDF, ADF and ADL in the two sorghum varieties (Table 2). Generally NDF, ADF and ADL increased ($P<0.05$) with increased age in E1291 and E6518. The NDF was similar (P>0.05) within E1291 between 10 and 22 weeks and between 14 and 18 weeks in E6518 respectively. Variety E1291 contained higher (P<0.05) NDF compared to E6518 at 5, 10 and 18 weeks whereas both cultivars contained similar (P>0.05) NDF at 14 weeks. The ADF was similar (P>0.05) within E1291 during 5, 10 and 22 weeks and again during 14 and 18 weeks respectively. Within E6518, ADF was similar (P>0.05) between 10 and 18 week but increase (P<0.05) at 22 weeks. There was no clear trend in ADF between E1291 and E6518 as they recorded similar (P>0.05) ADF at 14 and 18 weeks whereas they differed (P<0.05) at 5, 10 and 22 weeks. However, E6518 tended to record higher (P>0.05) ADF compared to E1291. Within both E1291 and E6518, ADL was similar (P>0.05) between 10 and 18 weeks then it increased (P<0.05) at 22 weeks. Varieties E1291 and E6518 recorded similar (P>0.05) ADL at 5, 14, 18 and 22 weeks but E1291 recorded higher (P<0.05) ADL compared with E6518 at 10 weeks.

Table 1: Effect of age of two improved forage sorghum varieties on hydrocyanic acid concentration and nutrient composition

Variety	Age in weeks						
	5	10	14	18	22	LSD	SED
Hydrocyanic acid, mg/kg DM							
E6518	186.7_2^{c}	167.3_2^{bc}	81.6_1^{a}	132.9_1^{b}	76.7_1^{a}	50.6	24.1
E1291	90.8_1^{ab}	139.8_1^{b}	70.8_1^{a}	105.4_1^{ab}	64.2_1^{a}		
LSD	27.0	SED	9.1				
Dry matter, g/kg DM							
E6518	112.5_1^{b}	90.4_1^{a}	114.3_1^{b}	186.6_2^{d}	167.2_1^{c}	15.8	7.5
E1291	108.2_1^{a}	102.2_2^{a}	116.8_1^{a}	150.9_1^{b}	222.6_2^{c}		
LSD	10.0	SED	10.0				
Organic matter, g/kg DM							
E6518	730.9_1^{a}	866.9_1^{b}	872.6_1^{b}	909.1_2^{c}	903.2_1^{c}	18.8	8.9
E1291	734.9_1^{a}	885.3_2^{b}	894.4_2^{b}	891.1_1^{b}	917.1_2^{c}		
LSD	11.9	SED	4.0				
Crude protein, g/kg DM							
E6518	276.7_1^{d}	221.1_2^{c}	169.8_2^{b}	101.5_1^{a}	86.1_1^{a}	18.8	9.0
E1291	272.2_1^{d}	180.4_1^{c}	127.5_1^{b}	119.7_2^{b}	89.0_1^{a}		
LSD	11.9	SED	4.0				

[abcd] Means within a low bearing different superscript are different (P<0.05)
[1,2]Means within a column bearing different superscript are different (P<0.05)

Table 2: Effect of age of two improved forage sorghum varieties on their fibre composition

Variety	Age in weeks						
	5	10	14	18	22	LSD	SED
Neutral detergent fibre, g/kg DM							
E6518	489.6_1^{b}	430.3_1^{a}	594.5_1^{c}	592.5_1^{c}	633.2_2^{d}	26.7	12.6
E1291	512.4_2^{a}	591.1_2^{b}	597.9_1^{b}	611.2_2^{b}	603.1_1^{b}		
LSD	16.9	SED	5.7				
Acid detergent fibre, g/kg DM							
E6518	288.9_1^{a}	386.4_2^{b}	363.0_1^{b}	372.0_1^{b}	401.9_2^{c}	25.2	11.9
E1291	306.4_2^{a}	323.1_1^{a}	378.6_1^{b}	359.4_1^{b}	326.6_1^{a}		
LSD	15.9	SED	5.4				
Acid detergent lignin, g/kg DM							
E6518	12.7_1^{a}	28.6_1^{b}	35.7_1^{b}	39.1_1^{b}	54.0_1^{c}	10.6	5.1
E1291	12.8_1^{a}	39.4_2^{b}	30.0_1^{b}	38.9_1^{b}	59.8_1^{c}		

LSD	6.7	SED	2.3

[abcd] Means within a low bearing different superscript are different (P<0.05)
[1,2]Means within a column bearing different superscript are different (P<0.05)

DISCUSSION

The decrease in hydrocyanic acid concentration (HCN) of sorghum varieties with increased harvesting age recorded in the current study was in agreement with reports by other workers (Kumar and Devender, 2010; Pandey et al., 2011; Sarfraz et al., 2012). The fact that the two sorghum varieties differed in hydrocyanic acid content (HCN) as reported in the current study agrees with reports from other workers (Kumar and Devender, 2010; Sarfraz et al., 2012; Sher et al., 2012). The similarity in HCN concentration and its low concentration in the two varieties may be due to selection as the two varieties were improved varieties. The peak HCN value may have been caused by sorghum tillers which caused a surge in young plants (Sarfraz et al., 2012). The HCN concentration in the current study was similar to those reported by other workers (Bahrani and Deghani 2004; Kumar and Devender, 2010; Pandey et al., 2011) but the concentration was lower than that reported by Sarfraz et al., (2012). This variation may occur due the season, plant density, variety studied and fertilizer level as they are known to cause such variation (Bahrani and Deghani 2004; Kumar and Devender, 2010; Sher et al., 2012). However, hydrocyanic acid during the whole study period did not surpass the threshold of 200 mg/kg DM beyond which sorghum becomes toxic to young ruminants (Kumar and Devender, 2010; Pandey et al., 2011; Sher et al., 2012).

Dry matter, Crude protein and Organic matter content

The general increase in DM content with increased age in sorghum is in agreement with available literature on forages (Kariuki, 1998; Muia, 2000; Relling et al., 2001). The trend in varietal performance may be attributed to their genetic differences (Bahrani and Deghani 2004; Kumar and Devender, 2010; Sher et al., 2012). The DM values obtained in this study were generally lower than those reported by other workers (Irungu et al., 2002; Ouda et al., 2004; Ashiono et al., 2005). These workers studied sorghum silage that was harvested at later age compared to forage sorghum in the current study. The low DM is disadvantageous as ruminants offered these forage varieties will ingest less DM compared to sorghum containing higher DM. Feeds that contained low DM were reported to depress intake, increased rumen passage rate and decreased digestibility in ruminants (Robinson et al. 1990; Pasha et al. 1994; Relling et al., 2001). Furthermore, the young ruminant may be unable to ingest adequate DM in a day to meet its' energy requirement.

The trend in OM is agreement with previous observations by Snijders et al., (1992) and Kinyua (2013) who showed that as ash content in forages decreased with age, OM typically increased. The similarity in OM within E1291 and E6518 between 10 and 18 weeks and 10 and 14 weeks, respectively, may imply that nutrients were partitioned favourably to other crop functions such as plant growth (Durr and Rangel, 2000; Bahrani and Deghani 2004). This trend in OM content was similar to that observed on DM and is in agreement with reports by Preston and Leng (1987), which showed that the DM content in a feed is positively correlated with its OM. Generally, the OM of the test varieties was in the range reported in the literature (Irungu et al., 2002; Ouda et al., 2004; Ashiono et al., 2005). Organic matter content has been shown to be positively correlated to organic matter digestibility (OMD) (Kamalak et al., 2004; Karabulut et al., 2007) and OM is the main source of energy for ruminants fed forages (Aregheore, 2001). The high OM values in the test cultivars, therefore, make them valuable sources of energy in ruminants (Kariuki et al., 1998; Smit, 2014).

The varietal CP content differed as harvest age increased causing a decline in CP (Relling et al., 2001; Pandey et al., 2011). The similarity in CP within E1291 and E6518 at 14 and 18 weeks and 18 and 22 weeks, respectively, may imply that nutrients were partitioned favourably to other crop functions such as plant growth (Durr and Rangel, 2000; Bahrani and Deghani 2004). The study showed that harvesting age was more important than the cultivar in affecting the CP in forage sorghum. This was particularly so at 5 and 22 weeks when E1291 and E6518 recorded similar CP and E1291 recorded lower CP compared with E6518 at 10 and 14 weeks. The CP values obtained in this study are higher those reported in the literature because the sorghum was harvested at an earlier age (Irungu et al., 2002; Ouda et al., 2004; Ashiono et al., 2005). The CP values were more than the 80 g CP/kg DM below which forage is classified as low quality (Semenye et al. 1989; Snijders et al. 1992; Kariuki et al. 1998). The two sorghum varieties are suitable feeds when fed to ruminants to improve their performance (Semenye et al. 1989; Kariuki et al. 1998; Smit 2014).

Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and Acid detergent lignin (ADL)
The increased NDF and ADF with increased harvesting age in the two sorghum varieties agreed with available literature on forages (Kariuki, 1998; Muia, 2000; Relling et al., 2001). The varietal NDF and ADF content differed as harvest age increased, causing an increase in them (Kariuki, 1998; Muia, 2000; Relling et al., 2001). The similarity in NDF within E1291 and E6518 at 10 and 22 weeks and between 14 and 18 weeks, respectively, may imply that nutrients were partitioned favourably to other crop functions such as plant growth (Durr and Rangel, 2000; Bahrani and Deghani 2004). The NDF and ADF values obtained in this study are lower than those reported in the literature because the sorghum was harvested at an earlier age (Irungu et al., 1999; Ouda et al., 2004; Ashiono et al., 2005). Fibre is essential in ruminants for rumination, saliva flow, rumen buffering and health of the rumen (Minson, 1990; Strasia and Gill, 1990). The relatively low NDF in these varieties was consistent with the general observation that young forages contain lower NDF (Minson, 1990; Relling et al., 2001). Nonetheless, these cultivars had NDF higher than 150 g/kg DM the level recommended by Strasia and Gill (1990) as being suitable for growing ruminants. These varieties, however, generally contained NDF below 600 g kg/kg DM beyond which a feed is classified as poor quality (Meissner et al., 1991). High NDF has been shown to be negatively correlated to organic matter digestibility (OMD) (Relling et al., 2001; Kamalak et al., 2004; Karabulut et al., 2007). Hence the low NDF in the studied sorghum varieties make them valuable feeds to ruminants (Semenye et al. 1989; Kariuki et al., 1998; Smit, 2014).

The general increase in the ADL observed with increased age is in agreement with reported literature (Relling et al., 2001) that reported decreased forage quality due to senescence and decreased leaf. This led to increased proportion of stem to leaf with prolonged harvesting interval. Plant stems are known to contain more fibre than young leaves (Durr and Rangel, 2000; Relling et al., 2001). The similarity in ADF and ADL within E1291 and E6518 at 14 and 22 weeks and between 10 and 18 weeks, respectively, may imply that nutrients were partitioned favourably to other crop functions such as plant growth (Durr and Rangel, 2000; Bahrani and Deghani 2004). The ADF and ADL values observed in the present study were lower than to those reported in the literature (Irungu et al., 1999; Ouda et al., 2004; Ashiono et al., 2005). Generally, low ADL is beneficial as it does not hinder diet digestibility in ruminants.

CONCLUSION

Variety E1291 contained less prussic acid compared to E6518. Prussic acid concentration in E1291 during the whole study did not surpass the threshold of 200 mg/kg DM but the concentration in E6518 approached the threshold below 10 weeks' growth. After 10 weeks' growth E6518 also did not surpass the toxic threshold. Therefore, E1291 can be fed to young ruminants at any age but E6518 can only be fed after 10 weeks without toxic effects on young ruminants. The sorghum was sampled at young growth stage producing highly nutritious feed for young ruminants. However, the low DM is disadvantageous as ruminants offered these forage cultivars will ingest less DM compared to sorghum containing higher DM.

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