Comparative Evaluation of Sorghum and Pearl Millet Forage Silages with Maize

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ABSTRACT

Seven sorghum (CSH 20 MF, CSH 24 MF, GK 909, GK 917, HC 308, SPSSV-30 and SSG Priya Hybrid 5000) and five pearl millet (ICMA 00444 × IP 6202, Milkon, PAC 931, Poshan, and AVKB 19) cultivars were compared with a forage maize (P 3546) reference using laboratory and *in vivo* analyses. The forages were harvested at 76 days from sowing, wilted, chopped, and ensiled in plastic drums, compacted without additives, and hermetically sealed for 94 days. When fed to growing Nellore ram lambs, cultivar-dependent variations for organic matter digestibility (OMD), organic matter intake (OMI), and nitrogen (N) balance were observed among the silages. The OMI of pearl millet silages was only about two thirds that of sorghum silages (mean-311 vs. 464 g/d). However, the digestibility of pearl millet was higher than sorghum silages (62.2 vs. 60.8%) although not-\ significantly and the nitrogen balance of sorghum silage was 4.8 times that of pearl millet (3.0 vs. 0.6g/d). Of the seven sorghum forages, GK 909, GK 917, and SPSSV 30 had similar fodder quality to the forage maize. None of the pearl millet forages had fodder quality traits comparable to that of the maize forage. Except for nitrogen (N), across the silages the laboratory fodder quality investigated, neutral (NDF) and acid detergent (ADF) fiber, acid detergent lignin (ADL), *dhurrin*, and organic matter digestibility (IVOMD) and metabolizable energy (ME) were all unsatisfactory. None of the pearl millet forages had fodder quality traits comparable to maize or sorghum yet had generally favorable laboratory fodder quality traits but showed poor *in vivo* performance. Fodder quality factors seem to be at work that is not captured by routine laboratory fodder traits analyzed such as N, NDF, AF, ADL, IVOMD, and ME. *Dhurrin* was only recovered in significant amounts in pre-ensiled sorghum, not maize and pearl millet, but post ensiling sorghum cultivars had no *dhurrin*.

Keywords: Digestibility, Forage, Pearl millet, Silage, Sorghum

INTRODUCTION

Maize is globally one of the prime crops based on its versatile uses including for food and forage because of high dry matter yield, digestibility, and mineral composition (Blümmel *et al*,2013a; Vinayan *et al*, 2013). However, high water requirements for maize cultivation are a major constraint in semi-arid areas (Miron *et al*, 2007; Bean *et al*, 2013). The efficiency of water usage in livestock production can be increased by selecting forages for planting which have high water-use efficiency and high biomass yields, e.g., sorghum (*Sorghum bicolor* and hybrids) and pearl millet (*Pennisetum glaucum*) (Zhang *et al*,. 2016). However, when suffering moisture stress, sorghum forage can accumulate *dhurrin*, a cyanogenic glucoside (Emendack, *et al*, 2017) which is an anti-nutritional factor, while oxalates and nitrates can accumulate in pearl millet forages (Rahman *et al*, 2011; Sher *et al*, 2012). While there are numerous references in the literature on the feeding of stock with maize forage, only limited data are available on livestock performance when fed sorghum and pearl millet forages (Amer *et al,* 2012). Livestock productivity trials directly reflect the nutritive value of forages, while laboratory analyses provide only indirect indications until a close relationship can be established between the two sorts of measurements (Miron *et al,* 2007). Hence a study was conducted to assess the quality of silage made from sorghum and pearl millet forage harvested and conserved at 76 days from sowing in comparison with maize silage through both laboratory and *in vivo* studies, including Near-Infrared Reflectance Spectroscopy (NIRS).

MATERIALS AND METHODS

Plant material

Seven sorghum cultivars (CSH 20 MF, CSH 24 MF, GK 909, GK 917, HC 308, SPSSV30 and SSG PH 5000) and five pearl millet cultivars (AVKB 19, ICMA 00444 × IP 6202, Milkon, PAC 931 and Poshan) and a forage maize cultivar as a check (P 3546) were evaluated. These forage entries were selected based on suggestions from plant breeders at the International Crops Research Institute for the Semi-Arid Tropics (ICRSAT). The sowing was performed in the 2014 post-rainy season in black soils (vertisols) at ILRI-ICRISAT, Patancheru, Hyderabad, India. The average monthly rainfall (mm), evaporation (mm), maximum temperature (ºC), minimum temperature (ºC), relative humidity (%) (at 700 and 1400 hrs) during the experiment from crop cultivation up to the *in vivo* trial is presented (Fig 1). The experimental design was a randomized complete block design (RCBD) with two 0.1 hectare replications for each entry. For maize spacing between rows was maintained at 75cm×10cm (spacing between plants), for sorghum and pearl millet plant density was maintained at 45cm×10cm. The basal dose of DAP (diammonium phosphate @100 kg/ha) was applied during sowing and standard management practices (weeding and earthing up) were followed. In 2014, the average rainfall during the crop growth was 65 mm (total rainfall was 312.87mm, Supplementary Table 1). Harvesting was undertaken manually, at 76 days after planting above ground level (5 inches) and the material was transported to an open area where plants were wilted and sub-sampling was taken from the wilted samples for the assessment of nutritional quality. Complete plants along with cobs/ panicles were ensiled.

Ensiling

The crop was wilted under the sun after harvesting, for maize 24 hours and 7-8 hours for sorghum and pearl millet, chopped into pieces of 15-25 mm, and ensiled in plastic drums (0.88m height × 0.29m radius), with no additives included. The air was removed using large heavy metallic discs (same size as drum open end) placed on top of the chopped biomass, attached to a shaft for compacting. After topping up with chopped biomass material until complete compactness was achieved, where no more biomass could be added into the drum, the drum was tightly sealed. Silage drums were stored in the shed from October

2014 up to end of January 2015 (94 days), during which the average rainfall was 20.12 mm, temperature was 30 and 12ºC (maximum and minimum, respectively), and the relative humidity was 90 and 43%, (maximum and minimum, respectively).

In vivo feeding trials

Seventy-eight growing Nellore brown ram lambs with an average body weight of 15.16 ± 0.27 kg were randomly segregated into 13 groups each consisting of six ram lambs. The experiment was conducted sequentially in two groups, first ten groups of six rams each and then three groups of six rams each immediately afterward, due to a limitation in the number of metabolic cages (60). The rams were kept in metabolic cages to facilitate the measurement of feed intake, feed digestibility, feed refusals, faeces voided, urine excretion by urinary funnels and nitrogen balance. A flat rate of 200 g of a concentrate mixture was offered daily from 08:00 to 10:00 h, after which silages were offered *ad libitum*. The *ad libitum* to groups was offered at about 10-15% above the amount consumed on the previous day, with a range of 2-5% variation of feed provided, allowing for about 10-15% of refusals. Refusals were removed each morning before daily feeding at 08:00 h. The faeces were weighed, dried and the urine, collected daily, was sampled (bulked later), 10 ml of conc. H_2SO_4 added and stored at a temperature of 4ºC. The faeces (dry matter basis) and urine were assessed for nitrogen content. This procedure was followed for an adaptation period of 3 weeks, measurements of feed intake and fecal and urine output was made and the data, recorded for the next 7 days, was used for an estimation of the *in vivo* traits.

Fodder Silage quality analysis

Silage samples were analyzed for nitrogen (N), NDF, ADF, acid detergent lignin (ADL), *dhurrin*, *in vitro* organic matter digestibility (IVOMD) and ME by Near-Infrared Reflectance Spectroscopy (NIRS) prediction, calibrated for the experiment against conventional wet chemistry analysis. The NIRS instrument used was a FOSS Forage analyzer 5000 with software package WinISI II.

Dhurrin estimation

Samples at harvest and silage were placed in an oven at 60ºC until dried completely, then ground and sieved (100µ pore size). The samples were weighed (100 mg) into Eppendorf tubes (2 ml) containing 750 µl of 50% methanol. The tubes were immediately placed into a hot water bath at 75ºC for 15 min. The tubes were then cooled to room temperature; 750µl of 50% methanol was added to make the volume up to 1.5 ml, mixed and then centrifuged in an Eppendorf 5417C at 11000 rpm for 5 mins. The supernatant (1ml) was collected and transferred to fresh tubes and stored at 4ºC. The analysis was performed in an Acquity UPLC system (Waters, Model D13 CHA708G). The mobile phase was prepared with 10% acetonitrile and run on a C-18 column, with a photodiode array (PDA) detector. *Dhurrin* was detected by monitoring the absorbance at 232 nm (Nicola *et al*, 2011). Samples were injected automatically from the vials for analysis (5 µl). The peak corresponding to *dhurrin* was identified by comparing the retention time and spectra to that of pure *dhurrin*. The *dhurrin* standard was purchased from Sigma-Aldrich (CAS Number 499-20-7, ≥95% (HPLC)).

Urine and fecal analysis

Feed leftover, faeces and urine samples were analyzed for nitrogen using 'Terbotherm' and 'Vapodest' (Gerhard, "Königswinter", Germany) analysers based on the micro-Kjeldhal method (AOAC 1997; procedure no. 4.2.02). Dry matter, and total ash were determined according to procedures (nos. 4.1.03 and 4.1.10) described by AOAC (1997). The traits measured were organic matter digestibility (OMD-%) and intake (OMI- g/kg LW/d), digestible organic matter intake (DOMI- g/kg LW/d), nitrogen (N)-balance (g/d) and N-balance (g/kg LW/d).

Statistical analysis

SAS 9.4 (2012) statistical package was used for analysis of variance (ANOVA) by the general linear model (PROC GLM) procedure. The model $Y_{ij}=\mu+t_i+e_{ij}$ was used for the analysis of the data, where Y_{ij} represents j^{th} observation ($j=1,2\ldots,n_i$) on the i^{th} treatment ($i=1,2\ldots.k$), μ is the overall mean, t_i represents the i^{th} treatment effect and e_{ij} represents the random error in j^{th} observation on the i^{th} treatment. The errors e_{ij} were assumed to be normally and independently (NID) distributed with a mean of zero and variance of σ^2. The Comparison of means between treatments was determined using Fisher's least significance difference (LSD) test at 5% level of significance. Simple correlations among traits were determined by the PROC CORR procedure, stepwise multiple regressions between laboratory traits and *in vivo* measurements were determined by PROC REG.

RESULTS

Silage laboratory analysis

Quality parameters for silage (Table 1) show that the N concentration in maize silage was 1.7%, while the mean nitrogen concentration of the 7 sorghum silages was 2.0% (range 1.8-2.4%), with the highest nitrogen concentration in sorghum recorded for the cultivar SSG PH 5000 (2.4%). Whereas, pearl millet cultivars had an average nitrogen concentration of 1.6% (range 1.3-1.9%), with the highest concentration in cultivar AVKB 19 (1.9%). The mean concentrations of NDF and ADF in sorghum silage were 66.2 and 35.9%, in pearl millet silage 60.6 and 32.4%, and maize silage 65.6 and 33.4% respectively. The cultivar GK 917 recorded the highest values of NDF (69.1%) and ADF (38.5%) in sorghum, while the cultivar

Poshan had the highest NDF (63.0%) and ADF (35.8%) in pearl millet. The mean ADL concentrations recorded in sorghum and pearl millet silages were 4.2 and 3.9%, respectively, with the lowest values recorded in SPSSV 30 (3.7%) in sorghum and PAC 931 (3.4%) in pearl millet. The mean metabolizable energy (ME) content of sorghum silage was 9.0 MJ/kg DM (range 8.5-9.6 MJ/kg DM) and IVOMD was 60.2% (range 57.3-63.3%). SPSSV 30 had the highest ME (9.6 MJ/kg DM) and IVOMD (63.3). Pearl millet silages had a mean ME of 8.8 MJ/kg DM (range 8.3-9.2 MJ/kg DM) and 59.2% IVOMD (range 55.9-62.2%) and the highest ME (9.2 MJ/kg DM) and IVOMD (62.3) were recorded in the cultivar AVKB 19. Fresh forage *dhurrin* (DH_F) was higher in sorghum (mean: 95 ppm, range: 61- 226 ppm) than in pearl millet or in the reference maize crop, however, the concentrations were not significant about the range of toxicity as given in Patel *et al*, 2013. Post ensiling, recovery of *dhurrin* in silage (DH_S) was in the range of 0.2-7.4 ppm in sorghum (Table 1). Cultivar SPSSV 30 contained the highest concentration of *dhurrin* (226 ppm) which was reduced after ensiling (74.0ppm) among the sorghum cultivars.

Feeding trial with growing ram lambs

The *in vivo* feeding data of 13 groups of ram lambs (Table 2) showed significant ($P <0.05$) cultivar dependent variations for all the parameters. The average intake of sorghum silage (297 grams per day (g/d)) was lower than maize (352 g/d) but higher than in the pearl millet cultivars (137 g/d). Among the sorghum cultivars, GK 909 had the highest silage intake of 343 g/d, followed by GK917 (319 g/d) and SPSSV 30 (306 g/d) whereas, for pearl millet, the highest silage intake was PAC 931 (172 g/d) followed by Poshan (132 g/d). The maize recorded highest OMD (63.5%) of all the entries tested. The pearl millet cultivars recorded an average OMD of 62%, and within the millet group in descending order was Poshan (63%), AVKB 19 (62.6%), and Milkon (62.3%). While in the sorghum cultivars, GK 917 (64%), SPSSV 30 (63.6%) and CSH 24 MF (62.9%) recorded the highest OMD and were the only ones above 60% out of the seven entries. The OMI g/kg LW/d was highest in sorghum cultivar SPSSV 30 (30.4 g/kg LW/d) while Poshan, PAC 931 and ICMA 0044×IP6202 (22 g/kg LW/d) were similar to pearl millet, however, none of the entries recorded OMI above maize (31.6 g/kg LW/d). A similar trend was observed for digestible organic matter intake (DOMI), with the highest level recorded in SPSSV 30 (19.3g/kg LW/d) in sorghum and Poshan (14.0 g/kg LW/d) in pearl millet. The N g/d and N g/kg LW/d, in sorghum was highest in GK 917 (3.7 and 0.21) followed by the reference maize, P 3546 (3.3 and 0.21), and in pearl millet PAC931 had an N recorded of 1.5 g/d and 0.09 g/kg LW/d.

DISCUSSION

The forage breeding objectives can be prioritized into increasing feed intake, improving digestibility, and reducing anti-nutritional factors (such as *Dhurrin* in sorghum) (Harinarayana *et al*, 2005 and Smith *et al*, 1997). Our research findings are a good fit for these categories and will be discussed further accordingly. All research objectives were mostly addressed by tapping into the natural variation in the crop. In the current experiment the sorghum cultivars used was sourced from across a diverse range of types (a detailed description of the kind of sorghum) and all the pearl millet cultivars were of the forage type (Table 1).

Quality of the feed is crucial:

Feed intake depends mostly on animal preferences and the availability of quality feed/forage. However, basic quality criteria can be ensured before providing the feed to livestock. Of the many quality criteria, nitrogen content of the fodder is crucial as it forms the building blocks for protein. Further, nitrogen in sorghum silage was higher than in pearl millet and the reference maize cultivar. None of the cultivars in the current study recorded nitrogen concentrations lower than the critical level (1.0-1.2%) below which dry matter intake may be depressed (Van Soest, 1994). Hassan *et al*, (2015) and Rai *et al*, (2012) have suggested that low N concentration in forage millet was a major concern, as higher nitrogen concentration is usually correlated with a reduction in forage yields. Hence, in tropical forage-breeding programs it is a challenge to breed material for both high nitrogen concentration and forage yield. However, while breeding new forages, targeting both increased nitrogen concentration and high forage yield is essential and economical as suggested by Aruna *et al*, (2015) and Marsalis *et al*, (2010). The fiber fractions showed significant variations ($P<0.05$) which may be a genetic trait. This finding is similar to Amer *et al*, (2012), who showed that millet had more neutral and acid detergent fiber than forage sorghum when harvested at 45 days of crop growth. Contrastingly, in our study harvesting at 76 days of cutting from sowing has shown higher fiber fractions in sorghum than millet, indicating the influence of harvesting stage.

Feed intake is related to digestibility:

Intake, digestibility, and nutrient retention are of vital importance to livestock productivity and these traits are related to one another. Logically, the higher is the digestibility the higher the intake of feed, which in turn would indicate higher nutrient retention. SPSSV 30 (19.3) performed similarly to the reference maize (20.1) in terms of digestible organic matter intake. Nevertheless, higher digestibility with lower intake was also observed in pearl millet. Organic matter intake of pearl millet was significantly lower than that of sorghum silage whereas, average digestibility of pearl millet silages was higher than sorghum silages. For reasons based on silage intake, organic matter intake and digestible organic matter intake, animals had a higher preference for sorghum silages than millet. Higher digestibility results in more nutrients available for absorption which can be measured by body weight gain or by nitrogen balance.

Anti-nutritional quality factors as key discriminants:

Finally, putative anti-nutritional quality factors to rank the forages or silages of the crop species were explored. *Dhurrin* (cyanogenic glucoside-substrate) is localized in vacuole cells and *dhurrinase* (active enzyme in cleaving and releasing volatile HCN) in mesophyll cells. *Dhurrin* represents a potential problem to livestock when consumed in sorghum crops at the early stages of growth and the crop grown under stress (Sher *et al*, 2012, Patel *et al*, 2013, Vinutha *et al*, 2015a, 2015b). Patel *et al*, (2013) reported that ensiling provides a sufficient duration for the volatile HCN to disperse and thus reduces its recovery in silages. The effect of ensiling on nutritional traits was of keen interest, but there was no significant difference for pre and post silage analysis of feed except for *dhurrin*. The significant decreases in DH_S in sorghum cultivars during ensiling were similar to the findings of Wheeler and Mulcahy (1989), where *dhurrin* concentrations in sorghum silage were significantly lower than in the fresh green forage. Hence, *dhurrin* is a potential tool to assess the anti-nutrition quality of sorghum forages before being fed to livestock. However, this is applicable only for sorghum quality assessment (and only when fed fresh as ensiling reduced it), not for pearl millets where oxalates are harmful to livestock (Patel *et al*, 2013).

Relations between in vivo and laboratory traits:

The *in vivo* and silage quality parameters did not show any significant relation with each other (Table 3). Yet, considering neither negative relation nor any trade-off observed amongst these traits, we can try to breed these as complementary traits (Hall *et al*, 2004). Within the pearl millet cultivars nitrogen is positively correlated with OMI and within sorghum silage intake is positively correlated with ME and IVOMD. No other laboratory trait was significantly correlated with any of the *in vivo* measurements across the 13 cultivars. The OMD (%) measured by the *in vivo* experiment and NIRS predicted IVOMD (%) is represented in Fig 2, the average OMD and IVOMD (%) for sorghum was 60.8 and 60.2 and 62.2 and 59.2 percent in pearl millet, respectively. The OMD (%) is highest in sorghum SPSSV 30 (63.7 %) and GK917 (63.9 %) followed by maize P 3546 (63.5 %) and then by CSH 24 MF (62.9%), the next top two entries are pearl millet - PAC 931 (62.3 %) and AVKB 19 (62.6 %). The highest IVOMD recorded in pearl millet was AVKB 19 (62.2 %), with SSG PH 5000 (62.4) and SPSSV 30 (63.3 %) in sorghum. The SSG PH 5000, SPSSV 30 and HC 308 had an N balance that is comparable to that of maize, whereas the pearl millet entries are lower than the maize silage (Table 2). In this study NIRS could predict IVOMD with an R^2_{cal}=0.98, while an R^2_{cal} =0.8 is considered as robust globally. Nevertheless, no statistically significant correlation was observed between quality and *in vivo* traits (as mentioned earlier). The silage intake for sorghum was significantly related to IVOMD and in pearl millet the OMI was significantly related to nitrogen (Supplementary Table 2).

Correlation studies help to determine an association between traits and to optimize breeding objectives. Fodder quality traits were not significantly associated with any other traits which are true for digestibility traits from laboratory and *in vivo* trials. Thus, laboratory traits may have limited information (ex. presence and effect of anti-nutritional factors) compared to feeding trials for evaluation of cultivars for feed purpose. So, animal feeding experiments become a realistic approach to assess the feed quality of a particular crop species, accounting for factors like voluntary intake, digestibility and absorption of nutrients (Miron *et al*, 2007). In a study reported by Blümmel *et al*, (2013b), a difference of 5% units in *in vitro* digestibility (IVOMD) in sorghum stover was highly correlated with stover pricing. This was associated with a price premium of 20% and higher in the fodder market. In our current study, in comparison with maize for digestibility, only Milkon was significantly different in terms of digestibility. Hence, all of the sorghum and pearl millet cultivars (except Milkon) could potentially be used to replace maize under water limiting conditions. However, in terms of IVOMD, SPSSV-30 and SSG PH 5000 of the sorghum cultivars and AVKB 19 cultivar of pearl millet are similar to maize. Nonetheless, negative selection for *dhurrin* (negatively correlated with forage yield) (Tariq *et al*, 2012) and concurrent improvement in fodder yield and quality traits (independent traits) (Aruna *et al*, 2015) are the most reliable approaches for forage breeding.

Next best alternate

Sorghum could be a possible alternative in marginal areas where maize production is constrained by the agronomic requirements, mainly irrigation, as reported by Abdelhadi and Santini (2006) and Bean *et al*, (2013). Besides, the *in vitro* organic matter digestibility of sorghum (conventional forage and sweet sorghum) and maize silage did not differ significantly (694 vs. 705 g/kg DM) (Zhang *et al*, 2016). Among corn and sorghum silages the estimated total body weight production was more in sorghum silages (483 kg/ha) than corn silages (469 kg/ha) (Abdelhadi and Santini, 2006). Thus, there was more LWG/ha by feeding sorghum silage than maize. Additionally, an increase in milk yield when comparing different silages made from different kinds of (*bmr* and conventional forage) sorghum and maize was observed. Although maize silage (33.8 kg/d) yielded more milk over conventional forage sorghum (31.0 kg/d), *bmr* sorghum (34.1 kg/d) recorded more than maize (Oliver *et al*, 2004). Next is nitrogen balance, a higher nitrogen balance was observed in maize (3.3) followed by sorghum (3.0) and least in pearl millet (0.6). These differences were significant across the crops but not within the groups. Similarly, a high retention of nutrient was recorded in sweet corn than pearl millet silage in studies performed by Rao *et al*, (2014). Feed quality and acceptance by animals was inclined towards silages made from some forage sorghum cultivars which is equivalent to maize silage.

CONCLUSION

There was significant variation between cultivars in the quality of silage made from crops harvested at 76 days from sowing in terms of nitrogen, NDF and ADF concentrations and DM digestibility. The laboratory parameters for forage quality were not very discriminatory and putative factors like *dhurrin* (sorghum) presented no issues as it was destroyed in the ensiling process. The findings presented in the current work suggest that feeding silage made from selected forage sorghum cultivars will result in similar levels of livestock performance to those expected from maize forage. Farmers in semi-arid and tropical regions can use SPSSV 30 followed by CSH 24 MF in sorghum (both dual-purpose crop) and in pearl millet AVKB followed by PAC 931 can be used for cultivation as forage. Sorghum and pearl millet are known to be climate resilient drought-tolerant crops, based on the above discussion sorghum could be the first choice to replace maize in semi-arid and tropics.

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Table 1. Nutritive value and in vitro organic matter digestibility (IVOMD) in silages and *dhurrin* concentration in both fresh forage (DH_F) and silage (DH_S) made from maize, sorghum, and pearl millet cultivars.

[†]Multi-cut sorghum Sudan grass (SSG) Hybrids developed with low HCN content and high digestible fodder from a private partner Ganga Kaveri

Crop	Cultivars	Description	Nitrogen (%)	NDF (%)	ADF (%)	ADL (%)	ME (MJ/kg DM)	IVOMD (%)	*DH_F* (ppm)	*DH_S* (ppm)
Maize	P 3546		1.7	65.6	33.4	3.4	9.3	61.9	2.62	0.00
Sorghum	CSH 20 MF	Multi cut forage sorghum hybrid	1.9	68.3	37.4	4.3	8.5	57.3	73.0	0.19
	CSH 24 MF		2.1	67.8	36.0	4.1	9.1	60.4	60.8	1.08
	GK 909[†]	Multi-cut sorghum Sudan grass (SSG) Hybrids*	1.9	66.4	37.7	4.5	8.6	57.8	85.6	0.22
	GK 917[†]		2.1	69.1	38.5	4.4	8.7	58.6	105.6	0.41
	HC 308	Single cut forage variety	1.9	63.9	34.3	3.8	9.2	61.5	29.9	0.17
	SPSSV-30	Dual purpose sweet sorghum variety	1.8	60.6	33.1	3.7	9.6	63.3	225.8	7.40
	SSG Priya Hybrid 5000	Multi-cut sorghum Sudan grass (SSG) Hybrids	2.4	68.3	36.6	4.3	9.1	62.4	84.4	1.78
Mean			**2.0**	**66.3**	**36.2**	**4.2**	**9.0**	**60.2**	**95.0**	**1.61**
Pearl millet	AVKB 19	Forage purpose	1.9	57.9	30.1	3.6	9.2	62.2	0.99	2.03
	ICMA 00444 × IP 6202	High green/dry biomass for forage purpose	1.3	60.9	31.6	3.9	9.1	59.8	0.27	1.44
	Milkon	Forage purpose	1.5	62.2	34.4	4.3	8.3	55.9	0.82	0.18
	PAC 931	Forage purpose	1.5	59.2	30.1	3.4	9.1	61.1	0.00	2.50
	Poshan	Forage purpose	1.6	63.0	35.8	4.4	8.5	57.2	2.67	2.24
Mean			**1.6**	**60.6**	**32.4**	**3.9**	**8.8**	**59.2**	**0.95**	**1.68**
	Overall mean		**1.82**	**64.10**	**34.5**	**4.01**	**8.95**	**60.0**	**51.7**	**1.51**
	LSD		**0.17**	**2.46**	**2.75**	**0.40**	**0.49**	**3.07**	**28.0**	**1.44**
	P		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

Table 2. The effects on intake, digestibility and N balance of feeding silage made from maize, sorghum, and pearl millet cultivars to growing ram lambs.

Crop	Cultivars	Silage intake (g/d)	OMD (%)	OMI (g/kg LW/d)	DOMI (g/kg LW/d)	N-balance (g/d)	N-balance (g/kg LW/d)
Maize	P 3546	352	63.5	31.6	20.1	3.3	0.21
Sorghum	CSH 20 MF	254	57.3	27.1	15.6	2.5	0.16
	CSH 24 MF	303	62.9	27.7	17.5	2.8	0.18
	GK909	343	58.2	28.4	16.6	3.2	0.18
	GK917	319	64.0	28.0	17.9	3.7	0.21
	HC-308	278	59.0	28.2	16.7	3.0	0.18
	SPSSV-30	306	63.6	30.4	19.3	3.1	0.19
	SSG PH 5000	274	60.3	28.3	17.1	2.4	0.15
Mean		**297**	**60.8**	**28.3**	**17.2**	**3.0**	**0.18**
Pearl millet	AVKB19	113	62.6	21.2	13.4	0.0	0.00
	ICMA 0044 × IP 6202	130	60.8	22.1	13.5	0.2	0.02
	Milkon	131	62.3	22.3	13.9	0.8	0.06
	PAC931	172	62.2	22.0	13.8	1.5	0.09
	Poshan	137	63.0	22.6	14.4	0.6	0.05
Mean		**137**	**62.2**	**22.0**	**13.8**	**0.6**	**0.04**
	Overall Mean	**264**	**61.4**	**26.2**	**16.3**	**2**	**0.13**
	LSD	**61.0**	**3.03**	**2.75**	**1.76**	**1.01**	**0.07**
	P	**<0.001**	**<0.0001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

OMD - organic matter digestibility (%), OMI- organic matter intake (g/kg LW/d), DOMI - digestible organic matter intake (g/kg LW/d), N-balance (g/d), N-balance (g/kg LW/d), LSD- Least Significant Difference, P- Probability @1%

Table 3. Correlation matrix between quality parameters at silage and *in vivo* parameters from ram trial

Traits	N %	NDF%	ADF%	ADL%	ME (MJ/kg)	IVOMD%	DH_S (ppm)
OMD (%)	0.16	0.09	0.03	0.05	-0.16	-0.06	-0.43
OMI (g/kg LW/d)	-0.24	-0.09	-0.23	-0.36	0.31	0.27	0.1
DOMI (g/kg LW/d)	-0.19	-0.06	-0.21	-0.34	0.25	0.24	-0.02
N-balance (g/d)	-0.14	-0.009	-0.11	-0.23	0.31	0.27	0.12
N-balance (g/kg LW/d)	-0.12	-0.03	-0.12	-0.22	0.34	0.31	0.2

OMD - organic matter digestibility (%), OMI- organic matter intake (g/kg LW/d), DOMI - digestible organic matter intake (g/kg LW/d), N-balance (g/d), N-balance (g/kg LW/d),N %- concentrations of nitrogen , NDF-neutral detergent (%) and ADF- acid detergent (%) fiber, ADL- acid detergent lignin (%) and ME- metabolizable energy (MJ/kg) and IVOMD in vivo organic matter digestibility (%), DH_S *-dhurrin concentration in and silage (ppm)*

Fig. 1. Weather parameters during the experiment from crop cultivation, silage storage and *in vivo* trial conducted at Manmool, ILRI-ICRISAT, India for year 2014-15.

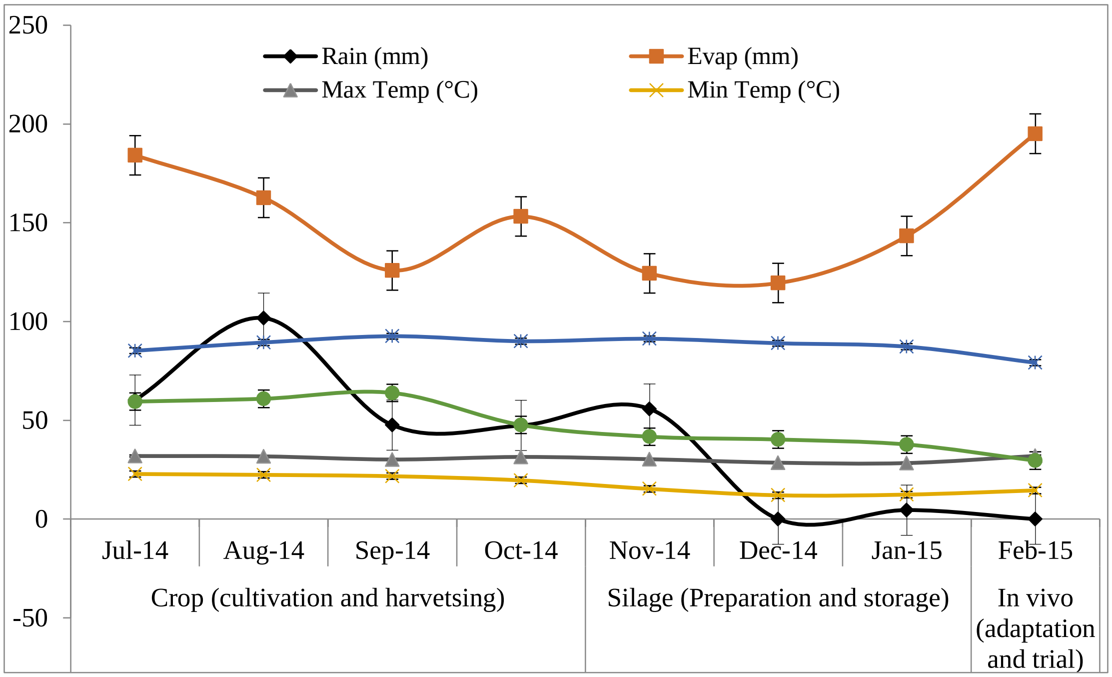

Fig. 2. Box plot representation for OMD (%) and IVOMD (%) for all cultivars (after silage data used)