

## Effect of Crop Maturity Stages on Yield, Silage Chemical Composition and *In vivo* Digestibilities of the Maize, Sorghum and Sorghum-Sudangrass Hybrids Grown in Semi-Arid Conditions

<sup>1</sup>Ismail Gul, <sup>2</sup>Ramazan Demirel, <sup>3</sup>Numan Kilicalp, <sup>4</sup>Mehdi Sumerli and <sup>4</sup>Hasan Kilic

<sup>1</sup>Department of Field Crops, <sup>2</sup>Department of Animal Science,

Faculty of Agriculture, University of Dicle, 21280 Diyarbakir, Turkey

<sup>3</sup>Cukurova Agricultural Research Institute, 01120, Adana, Turkey

<sup>4</sup>Southeastern Anatolian Agricultural Research Institute, Diyarbakir, Turkey

**Abstract:** The effect of different harvesting times on some silage quality of maize, sorghum and sorghum×sudangrass hybrids grown as in a split plot design with 3 replicates during second crop in semi arid condition were evaluated. In this research, whole plant silage chemical composition and DM digestibilities on different times, measured *in vivo* were determined. For this purpose, 2 maize (DK 711, TTM 815), 2 sorghum (Sucro sorgo 506, FS 5) and 2 sorghum-sudangrass hybrids (P 988, Grazer N2) cultivars were harvested at 3 different maturity stages (mid-flowering-MF, milkline-ML and hard dough-HD). The chopped materials were ensilaged in 10 L anaerobic jars, for 60 days. Silage samples were dried (CP, FP, pH, ADF, NDF contents were measured) and incubated in fistulated 3 Holstein Friesian heifers for determining dry matter digestibility. Significant differences were found between plant cultivars and harvesting stages for all investigated parameters. The dry matter yields varied between 12654.2 and 25340.1 kg ha<sup>-1</sup>. The highest dry matter yield was obtained from Sucro Sorgo 506 with ML and HD. Dry matter content of silages were changed from 20.63% (in silage sorghum cv. FS 5) to 27.36% (in sorghum-sudangrass hybrids cv. Grazer N2), pH (3.84 in FS 5 and 3.98 in TTM 815), Fleig point (FP) (90.87 in TTM 815 and 104.6 in Grazer N2), Crude Protein (CP) was 3.92% in Grazer N2 and 6.64% in FS 5, ADF was 44.56% in DK 711 and 49.33% in SS 506, NDF was 59.56% in DK 711 and 65.70% in P 988, whereas *in vivo* DM digestibility at 12 h was 32.82% in SS 506 and 38.91% in TTM 815. Crop maturity increased statistically significantly, silage DM varied from 20.43-25.92% and *in vivo* digestibility of DM at 12 h varied from 32.56-37.66%, however significantly decreased. ADF decreased from 50.17-42.56%, NDF decreased from 64.71-59.62%, WSC (Water Soluble Carbohydrates) increased from (24.59-30.24%). CP decreased from 5.59-5.05%. pH was between 3.78-4.10 and Fleig point was between 94.66-97.58. These values were not changed statistically, when crop maturity increased. Incubation periods were 0, 12, 24, 48 and 72 h for determining dry matter digestibility by using nylon bag technique. Silage NDF values were decreased from flowering to milkline stages. It was concluded that silages *in vivo* DM digestibility were increased with maturity at 12 h rumen incubation.

**Key words:** Maize, sorghum, yield, NDF, ADF, Nylon bags, digestibility

### INTRODUCTION

Ensiling is a common preservation method especially in unfavorable climates because of difficulties in drying forage crops. The stage of maturity at harvesting is a major factor in determining silage digestibility (Johnson *et al.*, 1999). As the crop develops, starch is accumulated in the grain with a decline of digestibility in the stover fraction of the plant (Daynard and Hunter, 1975; Struik *et al.*, 1985). Crop maturity decreases NDF

content significantly (0.60-0.41 DM), without affecting DM digestibility (0.57) (Di Marco *et al.*, 2002). *In vivo* dry matter digestibility of silage remains constant with maturity because the depression in NDF digestibility was compensated by starch accumulation in the grain.

The ability to manage corn silage to maximize the nutritive value of the crop is important. Maturity of corn silage had an impact on DM recovery and feedable DM (Johnson *et al.*, 2002).

**Corresponding Author:** Ismail Gul, Department of Field Crops, Faculty of Agriculture, University of Dicle, 21280 Diyarbakir, Turkey

Whole crop maize is the major crop ensilaged in Turkey. The stage of maturity at harvest is a major factor in determining the nutritive value of maize silage. Johnson *et al.* (1999) have reported that the largest changes in nutritive components in the maize plant occurred in the early stages of maturity. At the Early Dent (ED) stage, Dry Matter (DM) content was low and Water Soluble Carbohydrate contents were (WSC) high, but with no decrease in digestibility. At the blackline (BL) stage, DM yields are the highest, but the WSC decrease sharply owing to starch accumulation and this had an impact on the ensilaging quality of the maize. Adams (1995) has reported that concentrations of Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) in whole crop maize silage decreased as maturity proceeded from ED to 2-3rd Milk Line (ML) stage, but did not change from 2-3rd ML to the BL stage. Buck *et al.* (1969), Bal *et al.* (1998) and Johnson *et al.* (2001) found that NDF and ADF concentrations in whole crop maize silage decreased as maturity proceeded from the milk and ED to the BL stage. Hunt *et al.* (1989) found that despite declining NDF and ADF content, *in situ* rumen DM degradability decreased progressively from early (603 g kg<sup>-1</sup>) to late (564 g kg<sup>-1</sup>) maturity. Russel *et al.* (1992) reported that *in vitro* DM degradability of maize silage decreased with advancing maturity and was highly correlated with ADF and lignin contents. Harvesting maize at BL stage resulted in decreased starch digestibility when compared with maize harvested at 2-3rd ML and one-half ML stages (Harrison *et al.*, 1996). In recent studies with whole crop maize, the contents of WSC, NDF, ADF and Crude Protein (CP) tended to decline and DM and starch increase, with advancing maturity (Bal *et al.*, 1997, 1998; Johnson *et al.*, 2001). However, relationships between maturity of maize silage and DM intake, milk production, milk component yield and digestibility of nutrients were not consistent (Johnson *et al.*, 1999).

Sorghum is becoming an increasingly important forage crop in many regions of the world due to its high productivity and ability to utilize water efficiently even under drought conditions (Zerbini and Thomas, 2003; Sanchez *et al.*, 2002). Its high resistance to drought makes it a suitable crop for semi-arid areas (Tabosa *et al.*, 1999), especially in light of its higher productivity under dry conditions when compared to corn (Tabosa *et al.*, 1986). The major selection criteria for improving forage nutritional value are increased *in vitro* DM digestibility (IVDMD) and reduced lignin content (Casler, 2000). Expanding the use of sorghum as a forage crop obliges to overcome its tendency to lodging that characterizes the tall types especially under irrigation (Reddy *et al.*, 1999; Miron *et al.*, 2005). Another obstacle to expanded use of

tall forage sorghums is their insufficient accumulation of DM content, as proper accumulation is a precondition for successful ensilaging (Carmi *et al.*, 2005; Miron *et al.*, 2005, 2006).

Such improvements may be promoted by genetic breeding and selection, choosing the optimal stage for harvest (Carmi *et al.*, 2005; Miron *et al.*, 2006). and improving growth factors, such as irrigation level and plant density. Improving the nutritive value of forage sorghum for productive ruminants is an important goal (Defoor *et al.*, 2001).

Improvement of forage sorghum productivity by breeding obliges to focus on traits that might affect the yield and nutritive quality of the forage. Such a trait is the resistance to lodging that had become an important target to breeders (Rosenow, 1977; Buttler and Muir, 2003). It is suggested that a minimum DM content of 247 g kg<sup>-1</sup> to ensure a margin of safety against production of effluent. Ensiling sorghum biomass with DM content below this level may result in high chance of spoilage and dry matter loss during ensilage (Savoie and Jofriet, 2003). Another trait of importance, as related to livestock feeding, is high digestibility of silage DM and Neutral Detergent Fiber (NDF). Sorghum forage, especially of BMR varieties, may have high nutritive value, which might be comparable to that of corn (Bean *et al.*, 2002; Hanna *et al.*, 1981).

New sorghum varieties were recently used in field tests in Israel and demonstrated promising forage yield (Kipnis *et al.*, 2001). However, there is still lack of knowledge in the literature about the ensilage characteristics of these new varieties, including: Cell wall polysaccharides, Crude Protein (CP) and Water Soluble Carbohydrate (WSC) content and their participation in the ensilage process, profile of fermentation end-products, silage pH and silage digestibility. There are areas where limited rainfall or unfavourable soil conditions make corn production uncertain. Because of its drought tolerance and high forage production, sorghum is an alternative (Andewakun *et al.*, 1989), thereby providing the opportunity to increase the areas where ensilage crops can be produced. The most important factors which define sorghum silage quality are grain content (Young *et al.*, 1996) and stage of maturity (Bolsen, 2004). The major potential limitation of SS is the lower digestibility of grain due to the dense proteinaceous matrix in the peripheral endosperm layer of the kernel (Gutierrez *et al.*, 1982), which renders starch granules inaccessible to digestion in the rumen. There is little experimental information that evaluates replacement of CS by SS as a supplement to growing steers under grazing conditions.

Gucuk and Baytekin (1999) illustrated that the dry matter yields increases as harvesting time is delayed and

that the yields must be harvested during their dough stage. Hamed and Mohamed (1987) based on a study where they explored the 3 harvesting periods, concluded that the silage sorghum that is harvested during dough stage is more productive than those harvested during the other 2 periods; Manga *et al.* (1991), for maize that was harvested in 4 different stages, showed that the biomass and dry matter yield increases as the harvesting time is delaying; Miaki *et al.* (1991), found out that the nourishment values of maize and silage sorghum is similar after they compare the nourishment value of maize that was harvested during hard dough stage and silage sorghum that was harvested during hard dough stage.

The objective of this study was to evaluate the effect of maturity and compare maize, sorghum and sorghum × sudangrass hybrid whole-plant silages and digestibility of the silages.

## MATERIALS AND METHODS

**Field trials:** Field trials were conducted during the semi-arid region over 2 years (2001 and 2002) at the Southeastern Anatolian Regional Agricultural Research Institute Implementation area in Diyarbakir (37°54'N, 40°14'E altitude 660 m above mean sea level). The average annual temperature is 15.8°C, rainfall is 481.6 mm and the average relative humidity is about 53.8%. The average temperature can reach 30°C in July and August. The lowest average temperature can be 7°C in December and January. Experimental design was a split-plot randomised complete block design with 3 replications. The crops treatments were main plots and harvesting times were sub-plots. Trial experimentals were sown at 9 July for first year and 14 July for second year. Plant population was approximately 142840 plants ha<sup>-1</sup> in maize, 150000 plants ha<sup>-1</sup> in sorghum and sorghum sudangrass hybrids. All plots were irrigated at 10 day intervals according to plant phenological throughout the season.

**Crops and silo filling:** Forages harvested and chopped to about 1.5 cm on 3 dates at approximately 2 week intervals during second cropping season. The chopped silage materials were ensilaged in 10 L jars as 3 replicates for each cultivars and maturing stages. Each jar was filled approximately 9000 g wet weight basis, without space. There were 18 jars for each maturing stages and a total of 54 jars. At the end of the ensilaging period (60 days), silage jars were opened and physically examined, dried and incubated in rumen for ruminal degradability trial.

**Analytical procedures:** Silage samples were dried at 70°C for 48 h and ground (1 mm). Chemical analyses were

triplicated. The DM content of the crops and silages were determined by drying in a special fan-assisted drying cabin. Silages pH levels were measured in filtrated silage water (Polan *et al.*, 1998). The fleig points of the silages were calculated by the following equation as reported by Kilić (1984);

$$\text{Fleig points} = 220 + (2 \times \text{DM}\% - 15) - 40 \times \text{pH}$$

where, fleig points denote the values between 85-100 very good quality; 60-80 good quality, 55-60 moderate quality; 25-40 satisfying quality and <20 worthless.

Crude protein contents of samples were analysed by Leco 528 analyzer, ADF and NDF were analyzed using sodium sulphite addition (Van Soest *et al.*, 1991).

**In vivo digestibility measurements:** Dry matter degradabilities of forages were determined using 3 fistulated Holstein heifers for 0, 12, 24, 48 and 72 h. Samples were placed in 7.5×15.5 cm bags made of dacron, pore size 40 μ, which were inserted into rumen of 3 fistulated Holstein heifers fed on alfalfa forage-based diet. The dacron bags were incubated in the rumen for up to 72 h.

*In vivo* DM digestibilities of silages were determined according to the procedure described by Tilley and Terry (1963) as modified by Marten and Barnes (1980). WSC contents were determined under water by 5 g silage which were dried and put in to dacron bags. The dacron bags were kept under tap water until it become clear. After that bag were kept at 70°C for 48 h and weighed, the difference was used for these criteria.

**Statistical analysis:** The trial was arranged according to split plots design by 3 replicates. The means were compared using Fisher's least significant differences. Digestibility trial was done according to 3×3 latin square method by 3 replicates (Düzgüneş, 1983). Differences were evaluated considering Duncan Test (1955).

## RESULTS AND DISCUSSION

Effects of different plant cultivar silages and their maturity stages on DM yield, DM, CP, ADF, NDF, WSC, pH and FP contents are presented in Table 1 and 2.

**Dry matter yield:** There were statistically significant differences among sorghum × sudangrass hybrids to sorghum and maize cultivars for dry matter yield. The dry matter yield values ranged from 12654.2 and 25340.1 kg ha<sup>-1</sup> for the 2 years average results (Table 1). The highest values attained from cv. Sucro Sorgo 506

**Table 1: DM Yield, CP, ADF, NDF contents of different cultivars according to harvesting stages**

Cultivar	Harvesting stage	DM Yield (Kg ha <sup>-1</sup> )	CP (%)	ADF (%)	NDF (%)
TTM 815	MF	13161.7±837 g	7.12±0.29 a	50.83±1.30	62.00±0.58
	ML	16441.6±1307 ef	5.38±0.61 bc	43.00±1.04	60.81±0.66
	HD	16885.5±1818def	5.02±0.96 cde	42.83±0.60	60.20±1.56
DK-711	MF	12654.2±794 g	7.24±0.51a	49.17±2.49	60.36±2.54
	ML	14560.6±454 fg	5.34±0.46 bc	46.50±3.18	63.28±2.42
	HD	15178.8±935 efg	5.39±0.56 bc	38.00±1.26	55.03±1.49
S.S 506	MF	17641.9±1358 def	3.77±0.58 def	50.50±3.12	66.08±3.26
	ML	24790.1±2692 a	4.68±0.91 c-f	48.50±2.50	64.32±1.97
	HD	25340.1±1819 a	4.53±0.68 c-f	49.00±3.50	65.39±1.94
FS-5	MF	16764.9±520 def	5.72±0.63 bc	50.00±1.61	66.96±0.95
	ML	22381.4±1166 abc	6.70±0.81 ab	46.00±0.29	61.77±3.42
	HD	23651.6±1406 ab	7.50±0.09 a	38.83±0.73	56.63±2.70
P-988	MF	16502.8±962 ef	5.03±0.14 cd	52.17±1.09	68.00±0.66
	ML	19701.0±1133 cd	4.79±0.10 c-f	47.00±0.76	68.69±1.85
	HD	21617.6±1223 bc	4.42±0.63 c-f	44.00±5.22	60.71±3.07
Grazer N2	MF	15143.7±939 efg	4.66±0.30 c-f	48.33±2.62	64.82±1.93
	ML	17948.0±435 de	3.63±0.30 ef	47.33±1.36	64.13±3.02
	HD	18151.8±292 de	3.46±0.63 f	42.67±1.36	59.76±1.63
C.V (%)		16.78	15.78	8.61	5.97
LSD (α=5)		2770	1.39	ns	ns

Within a column, means followed by a different letter different (p<0.05)

**Table 2: DM, WSC, pH Content and Fleig Point Values of Different Cultivars According to Harvesting Stages**

Cultivar	Harvesting stage	DM (%)	WSC (%)	pH	Fleig Point
TTM 815	MF	20.40±0.97 de	25.77± 1.27 c-f	3.77±0.09	95.12±5.46
	ML	23.53±0.76 cd	26.59±1.20 cde	3.90±0.10	96.07±5.23
	HD	23.54±0.96 cd	31.22±1.20 ab	4.27±0.22	81.42±7.06
DK-711	MF	18.21±1.76 e	29.09±1.41 bcd	3.77±0.12	90.75±6.96
	ML	18.27±0.48 e	24.01±1.52 efg	3.90±0.10	85.54±3.84
	HD	27.87±0.74 ab	34.91±0.78 a	4.03±0.03	99.41±2.78
S.S 506	MF	18.88±0.61 e	21.32±1.32 g	3.87±0.09	88.10±4.74
	ML	24.66±2.04 bc	26.04±1.34 c-f	3.87±0.07	99.65±3.04
	HD	22.74±0.29 cd	25.77±2.31 c-f	4.10±0.06	86.47±2.89
FS-5	MF	18.92±1.29 e	25.48±1.03 def	3.73±0.03	93.50±3.53
	ML	21.53±1.75 cde	29.71±2.50 bc	3.77±0.03	97.40±3.41
	HD	21.44±0.88 cde	26.91±1.55 cde	4.03±0.07	86.54±4.42
P-988	MF	21.81±1.30 cde	23.39±0.46 efg	3.80±0.06	96.61±4.83
	ML	27.68±0.75 ab	25.50±0.86 def	3.97±0.12	101.70±5.88
	HD	29.86±1.02 a	29.64±3.14 bc	4.13±0.09	99.39±5.51
Grazer N2	MF	24.40±1.78 bc	22.52±1.20 fg	3.73±0.07	104.46±3.13
	ML	27.63±0.15 ab	24.75±1.24 efg	3.87±0.07	105.59±2.90
	HD	30.06±1.99 a	32.97±1.52 ab	4.03±0.03	103.78±2.92
C.V (%)		9.13	8.90	4.25	8.13
LSD		3.60	4.05	ns	ns

silage sorghum, while the lowest results are from the cv. DK 711 silage maize. In all cultivars, DM yield of plants were increased to considering maturity stages. Dry matter yield of these plants were increased by developing maturity stages (Gucuk and Baytekin, 1999, Manga *et al.*, 1991).

**Crude protein:** There were statistically significant differences among cultivars for crude protein contents. The highest CP content of 6.64% was obtained in FS-5 and lowest 3.92% in cv. Grazer N2 (Table 1). CP contents of other cultivars took place between these 2 cultivars. There was no significant effect of harvesting stages on crude protein contents. When we compare cultivar× harvesting stage interaction, maize cv. have highest CP levels in mid-flowering stage, sorghum cultivars have

highest CP levels in ML and HD stages, but sorghum× sudangrass hybrids in each stage have the lowest CP and these differences were statistically significant.

**ADF:** There were no statistically significant difference between cultivars for ADF and NDF content. The lowest ADF contents of silages were obtained in DK-711 as 44.56 and the highest 49.33% was obtained in Sucro sorgho 506 cultivars (Table 1). However, considering harvesting stage, there were statistically significant differences between harvesting stages. The highest ADF content of silages were 50.17% at mid-flowering stage and the lowest value of 42.56% at HD stages. In MF stages, there was no cob on plant and after this stage, ADF content of maize grain leads to lower ADF content of silage. This finding is in accordance with the findings of Coors *et al.* (1997).

**NDF:** The highest NDF content of 65.80% was obtained in cv. P 988 and the lowest was 59.56% in cv. DK-711 (Table 1). However, considering harvesting stages, there were significant differences between harvesting stages. The highest NDF content of 64.71% was obtained in MF stage and the lowest NDF of 59.62% in HD stages. NDF contents of silages decreased when harvesting time delayed from MF to HD stages. This result is similar to the results of Coors *et al.* (1997).

**DM content:** As shown in Table 2, silage DM content increased from 18.21 in DK 711 cultivar at MF stage to 30.06 in Grazer N2 cultivar at HD stage. There were statistically significant differences among sorghum×sudangrass hybrids to sorghum and maize cultivars for silage DM. In all cultivars, DM contents of silages were increased to considering maturity stages. Dry matter contents of these plants were increased by developing maturity stages (Iptas and Avcıoğlu 1997; Heath *et al.*, 1985).

**Water Soluble Carbohydrate Content (WSC):** There were no statistically significant differences for water soluble contents between cultivars except harvesting stages. Water soluble contents were obtained by soluble dry matter in water (carbohydrate, protein etc.). As seen in Table 2, WSC values were increased from (24.59)-(30.24) at HD stages. Some authors stated that plant doesn't accumulate enough carbohydrates before ML stage and this leads to less carbohydrates for lactic acid bacteria. Soluble carbohydrate content was the lowest in early stages (MF) with increased levels in ML and HD stages. Our findings are in parallel with the findings of Açıkgöz, (1995) and Coors *et al.* (1997).

**pH value:** There were no significant differences between cultivars and harvesting stages for silage pH levels. Silage pH values changed from 3.84 in FS 5-3.98 in TTM 815 (Table 2). Our pH values of silages were in similar lines with the findings of Gaggiotti *et al.* (1992). pH values of silages were increased when harvesting time delayed. All values obtained in this experiment were in the range of good quality silage pH values.

**Fleig Points (FP):** There were statistically significant differences between cultivars for silage FP levels. Silage FP values were changed from 90.84 in TTM 815-104.06 in Grazer N2 for cultivars, but from 94.66 in MF to 92.84 in HD stages (Table 2). Also, all silages were in very good quality according to the fleig point scale.

**In vivo digestibility of DM:** *In vivo* DM digestibilities of silages at 12 and 14 h were statistically significant among

cultivars the highest DM digestibility value of 38.91% was obtained in cv. TTM 815 and the lowest 32.82% was obtained in Sucro Sorgo 506 cultivars (Fig. 1). After 24 h incubation, the highest value of 48.90% was obtained in DK 711, the lowest was 38.38% in cv. Sucro Sorgo 506. After 48 and 72 h incubation, there were not statistically significant ( $p>0.05$ ). Differences between cultivars However, *in vivo* DM digestibility values were increased with maturity. *In vivo* DM digestibility values were in the range of 50.31 in TTM-815 and 57.63 in P-988 as reported by Muller *et al.* (1972), however higher values have also been reported by Rook *et al.* (1977), Oba and Allen (1999) and Tjardes *et al.* (2000) in the range of 60-70% and Deinum *et al.* (1984) in the range of 82-89%. In accordance with findings of Bal *et al.* (1997) and Johnson *et al.* (1999), *in vivo* DM digestibility was not affected by the stage of maturity (MF, ML and HD stages) at 24, 48 and 72 h, except at 12 h. It could be speculated that over than 12 h period of incubation used in this procedure, might have exceed the time period that silages were retained in the Rumen for *in vivo* digestion. Soluble carbohydrates and proteins might have ingested up to 12 h. At 12 h, the highest DM digestibility was obtained 37.66% in HD stage, the lowest was 32.56% in MF stage.

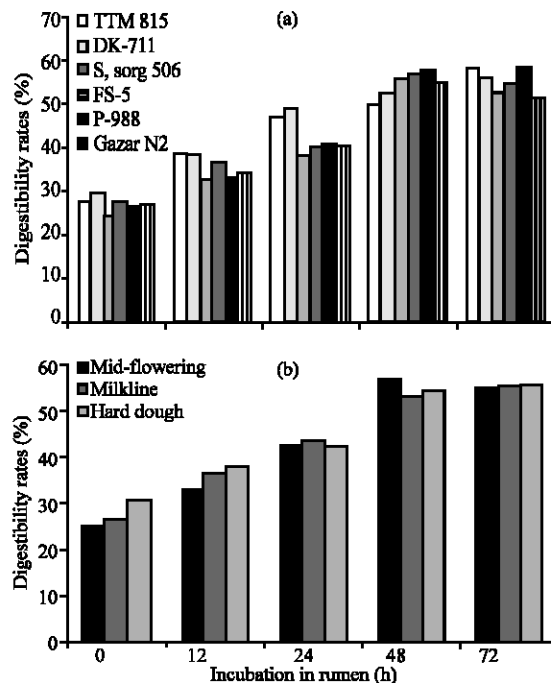


Fig. 1: *In vivo* rumen DM degradability of the ensiled-plants after 60 days of ensilling

## CONCLUSION

Dry matter yields of crops and, DM contents, pH and FP values of silages were increased when harvesting time delaying. NDF contents were similar for maize, sorghum and sorghum×sudangrass hybrid silages. NDF content was increased from MF to ML stages. Harvesting stages were not affected silage CP content. Soluble DM contents were increased from MF to ML stages. At 24 h rumen incubation, DM digestibilities of maize cultivars were higher than sorghum and sorghum × sudangrass hybrids. Harvesting the crop at earlier stages than HD, reduced DM content, pH and FP values but improved CP, ADF and NDF content.

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## REFERENCES

- Acıkgöz, E., 1995. Forage Crops. 2nd Edn. Uludag Uni. Publishing No: 633-2. Bursa.
- Adams, R.S., 1995. Dairy Reference Manual. NRAES-63, 3rd Edn. Northeast Regional Agricultural Engineering Service, Ithaca, NY, USA.
- Andrewakun, L.O., A.O. Famuyiwa, A. Felix and T.A. Omole, 1989. Growth Performance, Feed Intake and Nutrient Digestibility by Beef Calves Fed Sweet Sorghum Silage, Corn Silage and Fescue Hay. J. Anim. Sci., 67: 1341-1349.
- Bal, M.A., J.G. Coors and R.D. Shaver, 1997. Impact of Maturity of Corn for Use as Silage in the Diets of Dairy Cows on Intake, Digestion and Milk Production. J. Dairy Sci., 80: 2497-2503.
- Bal, M.A., K.J. Shinnors, R.J. Straub, R.G. Koegel and R.D. Shaver, 1998. Effect of rolling on ruminal *in situ* degradation of mature and immature whole-plant corn and stover silages. J. Dairy Sci., 81 Suppl (Abstr.), 1: 334.
- Bean, B., T. McCollum, D. Pietsch, M. Rowland, B. Porter and R. VanMeter, 2002. Texas Panhandle Forage Sorghum Silage Trial. The Agriculture Program of Texas A and M University System [http://soilcrop.tamu.edu/publications/pubs/910465\\_silage.pdf](http://soilcrop.tamu.edu/publications/pubs/910465_silage.pdf).
- Bolsen, K.K., 2004. Sorghum Silage: A Summary of 25 Years of Research at Kansas State University. In: Proceeding of The Southeast Dairy Herd Management Conference, Macon, Georgia, USA, pp: 16-17.
- Buck, G.R., W.G. Merrill, C.E. Coppock and S.T. Slack, 1969. Effect of Recutting and Plant Maturity on Kernel Passage and Feeding Value of Corn Silage. J. Dairy Sci., 52: 1617-1632.
- Butler, T.J. and J.P. Muir, 2003. Row Spacing and Maturity of Forage Sorghum Silage in North Central Texas. Forage Research in Texas [http://forageresearch.tamu.edu/2003/Forage\\_Sorghum.pdf](http://forageresearch.tamu.edu/2003/Forage_Sorghum.pdf).
- Carmi, A., N. Umiel, A. Hagiladi, E. Yosef, D. Ben-Ghedalia and J. Miron, 2005. Field Performance and Nutritive Value of a New Forage Sorghum Variety. Recently Developed in Israel. J. Sci. Food Agric., pp: 85
- Casler, M.D., 2000. Breeding Forage Crops for Increased Nutritional Value. Adv. Agron., 71: 51-107.
- Coors, J.G., K.A. Albrecht and E.J. Bures, 1997. Ear-Fill Effect on Yield and Quality of Silage Corn. Crop Sci., 37: 243-247.
- Daynard, T.B. and R.B. Hunter, 1975. Relationships Among Whole-Plant Moisture, Grain Moisture, Dry Matter Yield and Quality of Whole-Plant Corn Silage. Can. J. Plant Sci., 55: 77-84.
- Defoor, P.J., N.A. Cole, M.L. Galyean and O.R. Ones, 2001. Effect of Grain Sorghum Planting Density and Processing Method on Nutrient Digestibility and Retention by Ruminants. J. Anim. Sci., 79: 19-25.
- Deinum, B., A. Steg and G. Hof, 1984. Measurement and Prediction of Digestibility of Forage Maize in the Netherlands. Anim. Feed Sci. Technol., 10: 301-313.
- Di Marco, O.N., M.S. Aello, M. Nomdedeu and S. Van Houtte, 2002. Effect of Maize Crop Maturity on Silage Chemical Composition and Digestibility (*in vivo*, *in situ* and *in vitro*). Anim. Feed Sci. Technol., 99: 37-43.
- Duncan, D.B., 1955. Multiple Range and Multiple F Tests. Biometrics, 11: 1-42.
- Düzgüneş, O., 1983. Statistical Methods-I. Lecture Book, Ankara University, Faculty of Agricultura Publishing. No: 862. Ankara.
- Gaggiotti, M.C., L.A. Romero, O.A. Bruno and O.R. Quaino, 1992. Cultivars of Forage Sorghum for Silage. II. Fermentation and Nutritional Characteristics of the Silage. Revista Argentino de Production Animal, 12 (2): 163-167.
- Gucuk, T. and H. Baytekin, 1999. The effect of harvest time on herbage yield and yield components of the silage maize, silage sorghum and sorghum-sudangrass grown as second crops under the irrigated conditions in Bozova. GAP I. Agricultural Congress: Şanlıurfa, 683 (690): 26-28.
- Gutierrez, G.G., L.M. Schake and F.M. Byres, 1982. Whole Plant Grain Sorghum Silage Processing and Lasalocid Effects on Stocker Calf Performance and Rumen Fermentation. J. Anim. Sci., 54: 863-868.

- Hamed, Y.N. and A.A.H. Mohamed, 1987. Effect of cutting stage, nitrogen fertilization and seeding rate on yield and quality of hybrid forage sorghum. 1. Growth and yield. *Herbage Abstracts*, 057: 02915.
- Hanna, W.W., W.G. Monson and T.P. Gaines, 1981. IVDMD, Total Sugars and Lignin Measurements of Normal and Brown Midrib (bmr) Sorghums at Various Stages of Development. *Agron. J.*, 73: 1050-1052.
- Harrison, J.H., L. Johnson, R. Riley, S. Xu, K. Loney, C.W. Hunt and D. Sapienza. 1996a. Effect of Harvest Maturity of Whole Plant Corn Silage on Milk Production and Component Yield and Passage of Corn Grain and Starch into Feces. *J. Dairy Sci.*, 79 (Suppl.1): 149.(Abstr.).
- Heath, M.E., R.F. Barnes and Metcalfe, D.S., 1985. Forages: The Science of Grassland Agriculture. 4th Edn. Iowa State University Press, Ames, IA.
- Hunt, C.W., Kezar, W. and Vinande, R., 1989. Yield, Chemical Composition and Ruminant Fermentability of Corn Whole Plant, Ear and Stover as Affected by Maturity. *J. Prod. Agric.*, 2: 357-361.
- Iptas, S. and R. Avciöđlu, 1997. Effects of Different Maturity Stages of Maize, Sorghum, Sudangrass and Sorghum-Sudangrass Hybrid on the Quality of Silages, Turkish 1. Silage Congress Proceedings Book Bursa, pp: 42-51.
- Johnson, L., J.H. Harrison, C. Hunt, K. Shinnors, C.G. Doggett and D. Sapienza, 1999. Nutritive Value of Corn Silage as Affected by Maturity and Mechanical Processing: A contemporary review. *J. Dairy Sci.*, 82: 2813-2825.
- Johnson, L., J.H. Harrison, D. Davidson, W.C. Mahanna, K. Shinnors and D. Linder, 2001. Corn Silage Management: Effect of Maturity, Inoculation and Mechanical Processing on Pack Density and Aerobic Stability. *J. Dairy Sci.*, 85: 434-444.
- Johnson, L.M., J.H. Harrison, D. Davidson, W.C. Mahana, K. Shinnors and D. Linders, 2002. Corn Silage Management: Effects of Maturity, Inoculation and Mechanical Processing on Pack Density and Aerobic Stability. *J. Dairy Sci.*, 85: 434-444.
- Kılıc, A., 1984. Silage Feed. Bilgehan Press, Izmir, Turkey, (Bilgehan Basımevi, Izmir), pp: 350.
- Kipnis, T., O. Goren, U. Nir, S. Kitain, A. Silberman, E. Zuckerman, R. Solomon, R. Chen, H. Yovel, Y. Meir, S. Keler and I. Granot, 2001. Sorghum as Alternative Summer Forage to Corn, for Dairy Cattle Feeding. In: Zuckerman, E. (Ed.). Summary of Forage Field Experiments in 2001. Special Publication of the Agricultural Extension Service, Israel, pp: 112-142.
- Manga, N., V. Tansi and T. Saglamtimur, 1991. Researches on the effect of harvest time on the forage yield and some agricultural characters of maize cultivars grown as double crop under Cukurova conditions. Turkish 3. Range and Forage Crops Congress Izmir, 399-408.
- Marten, G.C. and R.F. Barnes, 1980. Prediction of Energy Digestibility of Forages With *in vitro* Rumen Fermentation and Fungal Enzyme Systems, In: Pigden, W.J., C.C. Balch and M. Graham (Eds.). Proceedings of the International Workshop on Standardization of Analytical Methodology for Feed. Int. Dev. Res. Center, Ottawa, Canada.
- Miaki, T., S. Tanaki and O. Kawamura, 1991. Comparison of feeding value between corn silage and sorghum silage for lactating cows. *Maize Abstracts*, 007: 02070.
- Miron, J., E. Zuckerman, D. Sadeh, G. Adin, M. Nikbachat, E. Yosef, D. Ben-Ghedalia, A. Carmi, T. Kipnis and R. Solomon, 2005. Yield, Composition and *in vitro* Digestibility of New Forage Sorghum Varieties and Their Ensilage Characteristics. *Anim. Feed Sci. Technol.*, 120: 17-32.
- Miron, J., R. Solomon, G. Adin, U. Nir, M. Nikbachat, E. Yosef, A. Carmi, Z.G. Weinberg, T. Kipnis, E. Zuckerman and D. Ben-Ghedalia, 2006. Effects of Harvest Stage, Re-growth and Ensilage on the Yield, Composition and *in vitro* Digestibility of New Forage Sorghum Varieties. *J. Sci. Food Agric.*, 86: 140-147.
- Muller, I.D., V.L. Lechtenberg, L.F. Bauman, R.F. Barnes and C.L. Rhykerd, 1972. *In vivo* Evaluation of a Brown Mibrid Mutant of *Zea mays* L. *J. Anim. Sci.*, 35: 883-889.
- Nichols, S.W., M.A. Froetschel, H.E. Amos and L.O. Ely, 1998. Effects of Fiber From Tropical Corn and Forage Sorghum Silages on Intake, Digestion and Performance of Lactating Dairy Cows. *J. Dairy Sci.*, 9: 2383-2393.
- Oba, M. and M.S. Allen, 1999. Effects of Brown Mibrib-3 Mutation in Corn Silage on Dry Matter Intake and Productivity of High Yielding Dairy Cows. *J. Dairy Sci.*, 82: 135-142.
- Polan, C.E., D.E. Stieve and J.C. Garret, 1998. Protein Preservation and Ruminant Degredation of Ensiled Forage Treated With Formic Acid, Ammonia or Microbial Inoculant. *J. Dairy Sci.*, 81: 765-776.
- Reddy, P.R., G.R.M. Snaker and N.D. Das, 1999. Genetic Analysis of Yield, Lodging and Maturing of Winter Season Sorghum Under Irrigated and Non Irrigated Conditions in Dryland Alfisol. *Ind. J. Agric. Sci.*, 69: 456-457.

- Rook, J.A., L.D. Muller D.B. Shank, 1977. Intake and Digestibility of Brown Mibrib Corn Silage by Lactating Dairy Cows. *J. Dairy Sci.*, 60: 1894-1904.
- Rosenow, D.T., 1977. Breeding for Lodging Resistance in Sorghum. In: Loen, H.D. and D. Wilkinson, (Eds.). Proceeding of the 32nd Annual Corn and Sorghum Research Conference. American Seed Trade Association. Washington, DC, pp: 171-185.
- Russel, J.R., N.A. Irlbeck, A.R. Hallauer and D.R. Buxton, 1992. Nutritive Value and Ensiling Characteristics of Maize Herbage as Influenced by Agronomic Factors. *Anim. Feed Sci. Technol.*, 38: 11-24.
- Sanchez, A.C., P.K. Subudhi, D.T. Rosenhow and H.T. Nguyen, 2002. Mapping QTLs Associated With Drought Resistance in Sorghum (*Sorghum bicolor* L. Moench). *J. Plant Mol. Biol.*, 48: 713-726.
- Savoie, P. and J.C. Jofriet, 2003. Silage Storage. In: Buxton, D.R., Muck, R.E., Harrison, J.H. (Eds.). *Silage Science and Technology*. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc, Madison, WI, USA, pp: 405-467.
- Struik, P.C., B. Deinum and J.M.P. Hoefsloot, 1985. Effects of Temperature During Different Stages of Development on Growth and Digestibility of Forage Maize (*Zea mays* L.). *Neth. J. Agric. Sci.*, 33: 405-420.
- Tabosa, J.N., A.S. Arcoverde, M.A. Araugo and J.P. Santos, 1986. Preliminary Evaluation of Forage Sorghum and Maize Lines in Semi-arid Pernambuco, Brazil. *Sorghum Newsletter*, 29: 1.
- Tabosa, J.N. D.J. Andrews, J.J. Tavares-Filho and A.D. Azevedo-Neto, 1999. Comparison Among Forage Millet and Sorghum Varieties in Semi-arid Pernambuco, Brazil: Yield and quality. *Int. Sorghum Millet Newsletter*, 40: 3-6.
- Tilley, J.M.A. and R.A. Terry, 1963. Two Stages Technique for the *in vitro* Digestion of Forage Crops. *Br. J. Grassland Soc.*, 18: 104-111.
- Tjardes, K.E., D.D. Buskirk, M.S. Allen, N.K. Ames, L.D. Bourquin and S.R. Rust, 2000. Brown Mibrib-3 Corn Silages Improves Digestion But Not Performance of Growing Beef Steers. *J. Anim. Sci.*, 78: 2957-2965.
- Van Soest, P.H., J.B. Robertson and B.A. Lewis, 1991. Methods for Dietary Fiber, Neutral Detergent Fiber and Nonstarch Polysaccharides in Relation to Animal Nutrition. *J. Dairy Sci.*, 74: 3583-3597.
- Young, M.A., B.S. Dalke, R.N. Sonon Jr., D.L. Holthaus and K.K. Bolsen, 1996. Effect of Grain Content on Nutritive Value of Whole-Pant Grain Sorghum Silage. In: Proc. of the XIth International Silage Conference, University of Wales, Aberystwyth, UK, pp: 58.
- Zerbini, E. and D. Thomas, 2003. Opportunities for Improvement of Nutritive Value in Sorghum and Pearl Millet Residues in South Asia Through Genetic Enhancement. *Field Crop Res.*, 84: 3-15.