B-4771
[1-5]

RESEARCH ARTICLE
Indian Journal of Animal Research

Effect of Sowing Time on Production Potential of Maize Fodder and its Nutritive Value Before and After Ensiling

M. Wadhwa, J.S. Hundal, Haneet Kaur, A.S. Singh, M.P.S. Bakshi,
Pardeep Kumar[1], Mukesh Choudhary[1], Sujay Rakshit[1]

10.18805/IJAR.B-4771

ABSTRACT

Background: This study was taken up to assess the effect of time of sowing and number of irrigations on the yield of maize cultivar J-1006 and to see their impact on the nutritive value of fresh and ensiled fodder.

Methods: Maize cultivar J-1006 was sown at 50 cm row to row and 10 cm plant to plant spacing at 10 days interval in quintuplicate. The crop was harvested after 80-85 days of sowing. The J-1006 on the first date of sowing (B1) was given one irrigation and rest of the sowings (B2-B5) received two irrigations till harvest. The nutritive value (NV) of fresh and ensiled maize fodder was assessed by *in vitro* gas production (IVGP) technique.

Result: Highest biological, DM and protein yield was recorded in B2 maize fodder while the lowest was recorded in B5. The cell wall constituents were the highest (P<0.01) in B1 and the lowest in B5 fodder resulting in highest (P<0.01) microbial biomass production (MBP) and the NV in B5 maize fodder. Irrespective of time of sowing, OM, NDF and hemicellulose contents were reduced (P<0.01) in ensiled maize fodder. The net gas production (NGP; P<0.01) and ME (P<0.05) were depressed and the total and individual VFAs and MBP were improved (P<0.01) in the ensiled maize. Irrespective of processing, the maize given two irrigations resulted in higher (P<0.01) MBP and NV as comparison to that given single irrigation. It was concluded that B5 maize fodder with the lowest yield given two irrigations had the best nutritive value.

Key words: Ensiling, Irrigations, Maize cultivar, Production potential, Sowing time.

INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Poaceae (Gramineae) and based on area and production, maize is the third most important cereal crop after wheat and rice in India and can thrive well even at high temperatures. Depending upon the climatic conditions, maize requires 600-700 mm of water for optimum growth and yield that estimated to be around 60-70 lakh litre of water per hectare (Lamm *et al.*, 2009). Maize production fluctuates with climate change in the different regions of the world at varying level and similar effects are observed in India too (Choudhary *et al.*, 2019). The variations in temperature and rainfall pattern and distribution have made sowing timing of summer maize uncertain in India. Maize is not only used as feed or fodder but also forms a critical part of industries related to alcoholic beverages, bio-fuel, processed food and corn oil (FICCI, 2014). In India, maize is grown exclusively as a green fodder crop in 0.9 million hectare land (Pandey and Roy, 2011). Maize being a rich source of water-soluble carbohydrates and low protein content is considered to be ideal crop for silage production due to its low buffering capacity and easy ensilage.

Maize cultivar J-1006 is generally fed to livestock either fresh or after ensiling in Northern India. The DM content of maize for silage making varies between 32-36% at the time of harvesting, which optimizes both yield and silage quality. The silage quality depends on the efficiency of conversion of soluble carbohydrates into organic acids through microbial activity along with humidity, temperature, presence of oxygen, concentration of soluble carbohydrates and productive characteristics of the plant (Neumann, 2001). It is observed that high yielding cultivars of maize are often sensitive to time of sowing and number of irrigations given. Therefore, this study was taken up to assess the time (period) of sowing and number of irrigations for attaining optimum green fodder yield of maize cultivar J-1006 and to see its effect on its nutritive value.

Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Science University, Ludhiana-141 004, Punjab, India.
[1]ICAR-Indian Institute of Maize Research, Punjab Agricultural University, Ludhiana-141 004, Punjab, India.

Corresponding Author: M.P.S. Bakshi, Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Science University, Ludhiana-141 004, Punjab, India.
Email: bakshimps2@gmail.com

How to cite this article: Wadhwa, M., Hundal, J.S., Kaur, H., Singh, A.S., Bakshi, M.P.S., Kumar, P., Choudhary, M. and Rakshit, S. (2022). Effect of Sowing Time on Production Potential of Maize Fodder and its Nutritive Value Before and After Ensiling. Indian Journal of Animal Research. DOI: 10.18805/IJAR.B-4771.

Submitted: 13-09-2021 **Accepted:** 19-03-2022 **Online:** 03-05-2022

MATERIALS AND METHODS

Maize cultivar J-1006 was sown at 50 cm row to row and 10 cm plant to plant spacing at 10 days interval in quintuplicate (Batch 1 to 5) starting from 25th June 2018 at research farm of ICAR-Indian Institute of Maize Research, Punjab Agricultural University, Ludhiana. The plot size of each batch was 75 m^2. The water applied per irrigation was up to the depth of 70 mm *i.e.* 5250 L water/75 m^2 plot. The fodder of each batch was harvested at about 25 days after flowering at milk to early dough stage of grain *i.e.* 80-85 days after sowing. The fodder of first date of sowing (B1) was given only one irrigation and rest of the sowings (B2-B5) received two irrigations till harvest. The green fodder was ensiled in LDPE bags for 45 days (Wadhwa and Bakshi, 2013). After the stipulated period bags were opened and samples were analyzed for various parameters.

In-vitro studies

The nutritional value of fodder hybrids was assessed by *in-vitro* gas production technique (IVGP; Menke and Steingass, 1988).

Chemical analysis

The finely ground samples of maize fodder before and after ensiling for 45 days in LDPE were analyzed for DM, CP and total ash (AOAC, 2007) and cell wall constituents (Van Soest *et al*., 1991). Silage samples were analyzed for pH, sugars (Dubois *et al*., 1956), lactic acid (Barker and Summerson, 1941) and volatile fatty acids (Cottyn and Boucque, 1968). The fermentation attributes related to hydrogen recovery, VFA utilization index, MBP, efficiency of conversion of fermented hexose energy to VFA and efficiency of conversion of fermented hexose energy to methane energy were calculated (Wadhwa *et al*., 2021). The DM intake, TDN and NE_L were also worked out (Schroeder, 2004).

Statistical analysis

The data were analyzed by 2 × 5 factorial design (Snedecor and Cochran, 1994) using SPSS (2009) version 16.0 and the means were tested for the significant difference by using Duncan's multiple range test.

RESULTS AND DISCUSSION

Biological and dry matter yield

In the present study, DM content of crops varied from 25 to 37.4% at the time of ensiling which is well within the range suggested by McDonald *et al.* (1991). However, Beukes (2013) have recommended 30 to 40% whole plant DM for silage preparation. The data revealed that highest biological yield was recorded in B2 while the lowest was recorded in Batch 5 (Table 1). Similarly on DM basis the highest yield was observed for B2 and declined linearly in the subsequent batches. Protein yield and production efficiency followed the same trend. Reduction in biological yield with time of sowing may be due to lowering of temperature at later stage and more availability of water to early sown crops which enhance vegetative growth. Continuous rainfall for 2-3 days just after sowing of J-1006 of B4 and B5 might have affected its biological yield.

Fermentation characteristics

Generally, well-preserved silage contains 4-7% lactic acid, < 3% acetic acid and, <0.1% butyric acid on DM basis. In the present study, the pH and lactic acid were within the range of good quality silage (McDonald *et al.,*1991) and butyric acid was not detected in silage (Table 2). Fermentation during ensiling lead to decrease in sugars by 62 to 86%. Fermentation of water-soluble sugars in forages to organic acids (mainly lactic acid) under anaerobic condition is mainly responsible for decrease in pH and level of lactic acid (Borreani *et al.,*2018). The lactic acid concentration was comparable in B1, B2 and B5, but higher (P<0.001) than remaining batches. The ammoniacal-N

Table 1: Effect of sowing date on conservation of water.

Batch	DOS	NOI	Crop duration, days	Irrigation water*, L	Rain water, L	Total water, L	Biological yield (q/ha)	DM yield (q/ha)	Protein yield (q/ha)	Production efficiency (q/ha/d)
1	15.6.2018	1	82	5250	43575	48825	566.6	142.7	12.3	6.96
2	25.6.2018	2	84	10500	39255	49755	600.0	173.4	15.0	7.14
3	5.7.2018	2	85	10500	48630	59130	537.3	147.2	12.9	6.27
4	16.7.2018	2	87	10500	43830	54330	400.0	136.8	11.3	4.59
5	26.7.2018	2	84	10500	31170	41670	373.3	139.6	11.7	4.44

DOS- Date of sowing; NOI- Number of irrigations; *Assuming 70 mm irrigation is given to maize (1 mm rain= 75 L water).

Table 2: Chemical composition of silage of maize sown on different dates, % DM basis.

Batch	pH	Sugars	Decline in sugars	Ammoniacal-N*	Lactic acid	Acetic acid
B1	4.05^{a}	0.12^{a}	77	3.97^{b}	4.60^{b}	1.37^{c}
B2	4.09^{a}	0.21^{c}	62	3.71^{ab}	4.70^{b}	1.04^{b}
B3	4.05^{a}	0.15^{b}	72	3.51^{ab}	3.30^{a}	1.09^{b}
B4	4.13^{a}	0.11^{a}	86	2.73^{a}	3.20^{a}	0.87^{a}
B5	4.25^{b}	0.13^{a}	79	3.30^{ab}	4.60^{b}	0.87^{a}
PSE	0.01	0.01		0.089	0.042	0.007
P-value	0.011	0.02		0.043	<0.001	<0.001

*As% of Total nitrogen; Means with different superscripts in a column differ significantly; PSE- Pooled standard error.

varied from 2.73 to 3.97% of TN among different variants, which is well within the upper limit of 5% of TN on DM basis. The smell of silage was very pleasant.

Effect of time of sowing and processing on the quality and biomass yield

Irrespective of processing, B2 had the lowest (P<0.05) CP content as compared to all other batches which were statistically comparable (Table 3). The cell wall constituents were the highest (P<0.01) in B1 and the lowest values were observed in B5. Irrespective of time of sowing, the DM content in maize was not affected by ensiling, but OM, NDF and hemicellulose content was reduced (P<0.01) in ensiled maize fodder. On the contrary total ash, ADF and cellulose content were increased (P<0.01) in the ensiled maize fodder, confirming the earlier report of Bakshi *et al.* (2017).

The IVGP studies revealed that irrespective of processing, the NGP, true OM digestibility and ME availability were the highest (P<0.01) in B5 maize fodder and the lowest (P<0.01) in B3 (Table 4). However, reverse trend (P<0.01) was observed in case of partitioning factor and ammonia concentration. The NDF digestibility varied between 33.2 to 39.09%, confirming the earlier report indicating *in vitro* NDF digestibility of whole-plant corn forage ranged from 25 to 60% for 32 corn hybrids grown in four locations (Allen, 1993). The variation was mainly due to differences in climate, locations and in hybrid genetics. The NGP and true OM digestibility in B5 was comparable with that of B2. Irrespective of time of sowing, the NGP (P<0.05) and ME (P<0.01) availability were depressed in the ensiled maize.

Irrespective of processing, the concentration of total and individual VFAs was the highest (P<0.01) in B5 and lowest (P<0.01) was observed in B1 (Table 5). The best A:P ratio was observed in B4. The total and individual VFAs were improved (P<0.01) after ensiling. The relative proportion of acetate was comparable in B2, B3 and B5, but higher (P<0.01) than B1 and B4. The relative proportion of propionate was comparable in B1 and B4, but higher (P<0.01) than remaining batches. Irrespective of time of sowing, the relative proportion of acetate, propionate and butyrate was not affected by ensiling, however, that of isovalerate was depressed (P<0.01) after ensiling.

Irrespective of processing, the efficiency of rumen fermentation (E) and efficiency of fermented hexose energy to VFA energy (E_1) were comparable in B1 and B4, but higher (P<0.01) than the remaining batches (Table 6). The efficiency of fermented hexose to methane (E2) was comparable in B1 and B4, but lower than B5. The efficiency of energy (E, E1 and E2) utilization was not affected by ensiling. However, methane emission increased (P<0.01) after ensiling. The MBP was the highest (P<0.01) in B5 and the lowest (P<0.01)

Table 3: Effect of sowing time and processing on the chemical composition of maize fodder, % DM basis.

Parameter	Time of sowing[1]					PSE	p-value	Ensiling[2]		PSE	p-value
	B1	B2	B3	B4	B5			Pre	Post		
DM								30.62	28.88	4.93	0.445
OM	93.62[c]	93.62[c]	91.30[a]	93.32[b]	94.08[d]	0.06	<0.001	93.39[b]	92.99[a]	0.04	<0.001
CP	8.9[b]	7.9[a]	8.65[b]	8.72[b]	8.62[b]	0.17	0.019	8.42	8.70	0.11	0.102
EE	1.32[a]	1.92[c]	1.45[ab]	1.75[bc]	2.0[c]	0.12	0.01	1.56[a]	1.82[b]	0.08	0.035
NDF	65.95[e]	62.0[c]	64.40[d]	60.70[b]	59.20[a]	0.27	<0.001	63.18[b]	61.72[a]	0.17	<0.001
ADF	36.08[e]	32.05[c]	34.00[d]	31.08[b]	30.02[a]	0.24	<0.001	31.95[a]	33.34[b]	0.15	<0.001
Cellulose	32.40[d]	28.45[c]	28.10[c]	27.10[b]	25.40[a]	0.16	<0.001	28.06[a]	28.52[b]	0.10	0.010
ADL	5.35[c]	4.28[a]	4.88[bc]	4.60[ab]	4.20[a]	0.17	0.004	4.73	4.59	0.11	0.378

[1]Irrespective of processing; [2]Irrespective of time of sowing; Means with different superscripts in a row differ significantly; PSE- Pooled standard error.

Table 4: Effect of sowing time and processing on the *in vitro* evaluation.

Parameter	Time of sowing[1]					PSE	p-value	Ensiling		PSE	p-value
	B1	B2	B3	B4	B5			Pre	Post		
NGP	142.44[b]	158.44[cd]	131.78[a]	152.00[c]	161.78[d]	3.05	<0.001	152.27[b]	146.31[a]	1.93	0.041
NDFD	36.73	39.09	33.20	35.86	36.82	1.94	0.058	38.20	34.49	1.23	0.370
TOMD	55.96[ab]	60.28[c]	54.18[a]	59.01[bc]	61.17[c]	1.19	0.009	58.85	57.39	0.76	0.20
PF	2.59[ab]	2.36[a]	2.86[b]	2.42[a]	2.27[a]	0.11	0.018	2.48	2.53	0.07	0.617
ME	6.74[a]	7.14[b]	6.59[a]	7.06[b]	7.30[c]	0.049	<0.001	7.04[b]	6.89[a]	0.031	0.006
NH3-N, mg/dL	0.018[c]	0.015[a]	0.016[b]	0.015[a]	0.015[a]	-	<0.001	0.017[b]	0.015[a]	-	<0.001

[1]Irrespective of processing; [2]Irrespective of time of sowing; NGP- Net gas production, ml/g/24h; NDFD-Neutral detergent fiber digestibility, %; TOMD-True OM digestibility, %; PF- Partitioning factor; ME-Metabolizable energy, MJ/kg DM; Means with different superscripts in a row differ significantly; PSE-Pooled standard error.

Table 5: Effect of sowing time and processing on the volatile fatty acid production, mM/dL.

Parameter	Time of sowing[1]					PSE	p-value	Ensiling		PSE	p-value
	B1	B2	B3	B4	B5			Pre	Post		
TVFAs	3.98[a]	5.29[c]	4.97[bc]	4.69[b]	5.87[d]	0.10	<0.001	4.38[a]	5.54[b]	0.06	<0.001
Acetate (A)	2.29[a]	3.28[d]	2.97[c]	2.66[b]	3.50[d]	0.08	<0.001	2.59[a]	3.29[b]	0.05	<0.001
Propionate (P)	1.08[a]	1.30[b]	1.25[b]	1.29[b]	1.49[c]	0.04	0.001	1.12[a]	1.44[b]	0.03	<0.001
Butyrate	0.406[a]	0.480[b]	0.499[b]	0.485[b]	0.593[c]	0.011	<0.001	0.43[a]	0.56[b]	0.007	<0.001
Isovalerate	0.208[a]	0.229[ab]	0.249[bc]	0.252[bc]	0.265[c]	0.008	0.003	0.229[a]	0.252[b]	0.005	0.008
A:P	2.20[ab]	2.55[c]	2.38[bc]	1.98[a]	2.35[bc]	0.08	0.007	2.30	2.28	0.053	0.841
Relative proportion %											
Acetate	57.71[ab]	62.07[c]	59.42[bc]	55.14[a]	59.63[bc]	0.85	0.002	58.62	58.97	0.54	0.659
Propionate	27.00[bc]	24.53[a]	25.36[ab]	28.21[c]	25.38[ab]	0.57	0.006	25.99	26.20	0.36	0.687
Butyrate	10.07[b]	9.07[a]	10.18[b]	10.74[b]	10.09[b]	0.24	0.009	9.97	10.09	0.15	0.598
Isovalerate	5.22[c]	4.33[a]	5.04[bc]	5.99[d]	4.56[ab]	0.17	0.001	5.42[b]	4.61[a]	0.11	<0.001

[1]Irrespective of processing; [2]Irrespective of time of sowing; VFA- Volatile fatty acids; Means with different superscripts in a row differ significantly; PSE- Pooled standard error.

Table 6: Effect of sowing time and processing on the fermentation efficiency,%

Parameter	Time of sowing[1]					PSE	p-value	Ensiling		PSE	p-value
	B1	B2	B3	B4	B5			Pre	Post		
E	77.31[bc]	75.94[a]	76.59[ab]	78.09[c]	76.57[ab]	0.29	0.004	76.89	76.91	0.18	0.949
E1	76.43[bc]	75.23[a]	75.77[ab]	77.06[c]	75.77[ab]	0.26	0.005	75.99	76.11	0.17	0.628
E2	13.94[ab]	15.11[c]	14.60[bc]	13.32[a]	14.60[bc]	0.26	0.005	14.37	14.26	0.16	0.634
Methane	1.08[a]	1.56[d]	1.42[c]	1.25[b]	1.68[e]	0.035	<0.001	1.23[a]	1.56[b]	0.022	<0.001
MBP, g/day	101.16[a]	134.56[c]	126.08[b]	119.11[b]	149.15[d]	2.67	<0.001	110.80[a]	141.23[b]	1.69	<0.001

[1]Irrespective of processing; [2]Irrespective of time of sowing; E- Efficiency of rumen fermentation; E_1- Efficiency of fermented hexose energy to VFA energy; E_2- Efficiency of fermented hexose to methane; Methane mL/100 mg DM/day; MBP- Microbial biomass production; Means with different superscripts in a row differ significantly; PSE- Pooled standard error.

Table 7: Effect of sowing time and processing on the nutritive value, %.

Parameter	Time of sowing[1]					PSE	p-value	Ensiling[2]		PSE	p-value
	B1	B2	B3	B4	B5			Pre	Post		
DMI% BW	1.82[a]	1.94[c]	1.86[b]	1.98[d]	2.03[e]	0.008	<0.001	1.90[a]	1.95[b]	0.005	<0.001
DDM	60.80[a]	63.93[c]	62.41[b]	64.69[d]	65.51[e]	0.18	<0.001	64.01[b]	62.93[a]	0.12	<0.001
TDN	62.59[a]	65.41[c]	64.04[b]	66.09[d]	66.82[e]	0.17	<0.001	65.48[b]	64.50[a]	0.11	<0.001
NEL	1.41[a]	1.48[c]	1.45[b]	1.50[d]	1.52[e]	0.004	<0.001	1.48[b]	1.46[a]	0.003	<0.001

[1]Irrespective of processing; [2]Irrespective of time of time of sowing; DDM- Digestible DM; TDN-Total digestible nutrients; NEL-Net energy lactation, Mcal/kg DM; Means with different superscripts in a row differ significantly; PSE- Pooled standard error.

was observed in B1. The MBP was improved (P<0.01) by ensiling.

Irrespective of processing, the predicted DM intake as per cent of BW was the highest (P<0.01) in B5 and the lowest was observed in B1 (Table 7). The predicted nutritional worth as indicated by digestible DM, TDN and NE_L were the highest (P<0.01) in B5 and lowest were observed in B1 maize. Irrespective of time of sowing, the predicted DM intake was improved (P<0.01) by ensiling. The data revealed that predicted dry matter intake as percent body weight was 16.7% higher (p<0.01) for silage in comparison to that observed for green fodder. But the nutritive value *i.e.* digestible DM, TDN and NE_L were depressed (P<0.01) in ensiled maize fodder.

Effect of number of irrigations and processing on the quality parameters and nutritive value

Irrespective of processing, the maize given two irrigations in comparison to that given single irrigation resulted in higher (P<0.01) DM (31.22 vs 23.88%) and EE (1.78 vs 1.32%) and low NDF (61.58 vs 65.95%), ADF (31.79 vs 36.08%) and cellulose (27.26 vs 32.40%) content. Maize silage had low hemicelluloses and lignin content (28.29 vs 31.37% and 4.67 vs 5.17%) in comparison to that observed in green fodder, irrespective of number of irrigations.

Number of irrigation and processing (green fodder vs silage) showed no effect on NGP, digestibility of nutrients, PF and ME. The total VFAs (5.20 vs 3.98 mM/DL), acetate (3.10 vs 2.29 mM/DL), propionate (1.33 vs 1.08 mM/DL) and butyrate (0.51 vs 0.41mM/DL) were higher (P<0.05) in maize provided two irrigations in comparison to that given single irrigation.

The predicted DMI as percent of body weight was 7% higher (P<0.01) in maize fodder given two irrigations in comparison to that given single irrigation (1.95 vs 1.82% BW). The nutritive value of maize fodder *i.e.* digestible DM was higher (P<0.01) in maize given two irrigations instead of one (94.14 vs 60.80%), resulting in higher (P<0.01) TDN (65.59 vs 62.59%) and NE_L value (1.49 vs 1.41Mcal/kg DM). However, processing, irrespective of number of irrigations showed no effect on these parameters. Maize fodder given two irrigations gave higher (P<0.01) MBP in comparison to that given single irrigation (132.23 vs 101.16 g/day). Similarly, ensiled maize had higher (P<0.05) MBP in comparison to green fodder (129.45 vs 103.94 g/day). It was concluded that B5 maize fodder with the lowest yield given two irrigations had the best nutritive value.

Conflict of interest: None.

REFERENCES

Allen, M.S. (1993). Trouble Shooting Silage based Ration Problems: Ruminal Fermentation of Fiber and Starch. In: Silage Production from Seed to Animal. National Silage Prod. Conf. Syracuse, NY. 23-25 Feb. 1993. NRAES-67. Northeast Regional Agricultural Engineering Services, Ithaca, NY. p. 186-195.

AOAC. (2007). Official Methods of Analysis. 7th edn. Association of Official Analytical Chemists, Gaithersburg, Maryland, USA.

Bakshi, M.P.S., Wadhwa, M. and Kumar, B. (2017). Nutritional evaluation of baby corn fodder and conventional maize fodder in buffaloes. Livestock Research for Rural Development. 29: 7.

Barker, S.B. and Summerson, W.H. (1941). The colorimetric determination of lactic acid in biological material. Journal of Biological Chemistry. 138: 535-554.

Beukes, J. (2013). Maize silage based diets for feedlot finishing of merino lambs. M.Sc. Thesis, University of Stellenbosch, South Africa.

Borreani, G., Tabacco, E., Schmidt, R.J., Holmes, B.J. and Muck, R.E. (2018). Silage review: Factors affecting dry matter and quality losses in silages. Journal of Dairy Science. 101: 3952-3979.

Choudhary, M., Wani, S.H., Kumar, P., Bagaria, P.K., Rakshit, S., Roorkiwal, M. and Varshney, R.K. (2019). QTLian breeding for climate resilience in cereals: Progress and prospects. Functional and Integrative Genomics. 19: 685-701.

Cottyn, B.G. and Boucque, C.V. (1968). Rapid method for the gas-chromatographic determination of volatile fatty acids in rumen fluid. Journal of Agricultural and Food Chemistry. 16: 105-107.

Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Fred Smith. (1956). Colorimetric method for determination of sugars and related substances. Analytical Chemistry. 28: 350-356.

FICCI. (2014). Potential of plastics industry in Northern India with special focus on plasticulture and food processing-2014. A report on plastic industry. The Federation of Indian Chambers of Commerce and Industry.

Lamm, F.R., Aiken, R.M. and Kheira, A.A. (2009). Corn yield and water use characteristics as affected by tillage, plant density and irrigation. Transactions of the American Society of Agricultural and Biological Engineers. 52: 133-143.

McDonald, P., Henderson, A. and Heron, S. (1991). The Biochemistry of Silage. 2nd edn. Chalcombe Publication, 13 Highwoods Drive, Marlow Bottom, Marlow, US.

Menke, K.H. and Steingass, H. (1988). Estimation of the energetic feed value obtained by chemical analysis and *in vitro* gas production using rumen fluid. Animal Research and Development. 28: 7-55.

Neumann, M. (2001). Feedlot Performance of Steers Fed with Silages of Different Sorghum Hybrids (*Sorghum bicolor* L. Moench). 208f. Dissertação (Mestrado em Zootecnia)-Universidade Federal de Santa Maria, Santa Maria.

Pandey, K.C. and Roy, A.K. (2011). Forage Crops Cultivars. IGFRI, Jhansi (India). pp. 1-93.

Schroeder, J.W. (2004). Silage fermentation and preservation. NDSU Extension Service. North Dakota State University Fargo, North Dakota, USA. Pp 1-15. https://library.ndsu.edu/ir/bitstream/handle/10365/5102/as1254.pdf?sequence=1.

Snedecor, G.W. and Cochran, W.G. (1994). Statistical Methods, 7th ed. Oxford and IBH Publications, New Delhi.

SPSS. (2009). Statistical Packages for Social Sciences. Version 16, SPSS Inc., Illinois, USA.

Van Soest, P.J., Robertson, J.B. and Lewis, B.A. (1991). Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 74: 3583-3597.

Wadhwa, M. and Bakshi, M.P.S. (2013). Utilization of Fruit and Vegetable Wastes as Livestock Feed and as a Substrate for Generation of Other Value Added Products. [Makkar, H.P.S. (eds.)], RAP Publication 2013/04. Food and Agriculture Organization of United Nations, Rome, Italy. pp. 56.

Wadhwa, M., Hira Singh, Balwinder Kumar and Bakshi, M.P.S. (2021). *In vitro* evaluation of short duration cassava varieties as llivestock feed. Indian Journal of Animal Science. 91: 965-970.