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Research article

Quality and production potential of green fodder and silage for *kharif* maize hybrid under rainy season in Punjab

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Abstract

A field study was carried out at Ladhowal Research Farm of ICAR-Indian Institute of Maize Research, Ludhiana, with the objective of finding out the best planting density and sowing date for *kharif* maize hybrid to maximize green fodder yield and quality silage production. The treatments consisted of two plant densities, *i.e.*, normal density (ND; 60×20 cm) and high density (HD; 60×10 cm), with four dates of sowings in RBD factorial design with three replications. The hybrid PMH 1 sown in mid-July was comparatively superior to other sowing dates at both plant densities. However, yield ND had an edge over HD. Higher biological yield (611.1 q/ha) (p <0.001) and dry matter yield (205.3 q/ha) were reported for ND plots sown in mid-July. The dry matter (DM) content of forage varied (p <0.05) from 32.1 to 35.0%. Crude protein (CP) was high in early sowing and declined to a low level with advanced dates of sowing, whereas ether extract (EE) followed exactly the reverse trend. The dry matter intake and digestible dry matter values were significantly (p <0.001) higher in mid-July sowing. Silages prepared exhibited good ensiling characteristics for all dates of sowing and plant densities. However, mid-July sowing exhibited the lowest values with respect to neutral detergent fiber and acid detergent fiber, with improved nutritive profile, better feeding values, higher *in-vitro* potential and good fermentation characteristics. Based on this study it was concluded that mid-July sown hybrid PMH 1 had high yield, feed value, NGP as well as NDF digestibility compared to other dates of sowing.

Keywords: Green fodder, *In-vitro* potential, Maize hybrid, Plant density, Silage

Introduction

Maize can be grown in all seasons in different parts of India and is ideal for fodder crops due to its rapid growth, high biomass and good digestibility (Kumar *et al.*, 2018). Further, maize fodder is free from harmful chemicals/ toxicants and any crop growth stage can be fed safely without any adverse effects (Arif *et al.*, 2022). Green forages are a major factor for successful dairy farming, as the inadequate supply of green fodder around the year is one of the main reasons for the low productivity of dairy animals (Mahanta *et al.*, 2020). In the Indian subcontinent, the crops grown for fodder are non-commercial in nature and production of forage is mainly from degraded and marginal lands with minimal inputs, which leads to a huge gap in the demand and supply of green fodder (Gosh *et al.*, 2016). At present, India faces a net deficit of 30.65% green fodder and 11.85% dry forage (Anonymous, 2015), which is one of the major reasons for poor livestock productivity (Anjum *et al.*, 2012; Kumar *et al.*, 2016). The area under fodder cultivation in India is shrinking due to increased cultivation of cereals and cash crops and hence stagnant progress has been witnessed in green fodder production. Shortage of feed and fodder led to the development of alternative fodder/feed production systems for livestock through conservation and storage methodologies. Silage production ensures round the year fodder availability for dairy animals. Among different fodder crops, maize is most suitable for silage-making due to the high concentration of soluble sugars and starch in its forage (Hundal *et al.*, 2019). Preservation of maize as silage, when the grains are in milk stage, helps not only in providing nutritionally uniform feed but also spares land for the cultivation of other commercial crops (Brar *et al.*, 2017). Recently, it was reported that maize kernels at the milking stage have maximum protein with the best quality (Sethi *et al.*, 2021)

For the production of quality maize silage, the identification of novel planting material is important to achieve higher (maximum) yields in terms of biomass and grain under both cultivated and non-cultivated lands (Gosh *et al*., 2016; Kumar *et al*., 2023). Hybrids selected for silage production should have high forage yield, high total digestibility, low fiber levels, highly digestible stover and also higher grain yield, as grain is highly digestible and adds greatly to total dry matter (Griffiths *et al*., 2004). In forage crops, the time of sowing and plant density are considered as the critical factors to harvest maximum forage yield within minimum time. Timely sowing is critical for maximizing yield for both grain and biomass in maize and optimum maize sowing date may vary from area to area due to differences in climate and the length of the growing season where the crop is cultivated (Maresma *et al*., 2019).

In the north-western Indo-Gangetic plains zone, maize for silage production is gaining much popularity. However, maize for silage is predominantly cultivated during the spring season, which is ecologically not sustainable due to high requirement of water. Silage maize may play an important role in the diversification of rice-based cropping systems in Punjab and adjoining states. However, production practices to maximize silage yield and quality have not been standardized for maize. Hence, this work was initiated with the objective of the effect of different dates of sowing and plant density on silage yield and quality.

Materials and Methods

Study site and genotype: The field study was carried out at Ladhowal Research Farm of ICAR-Indian Institute of Maize Research, Ludhiana, while the quality analysis was carried out at Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana in *Kharif* 2019. Soil of the experimental field was sandy loam in texture (82.6% sand, 5.6% silt and 12.8% clay) with low in organic carbon (0.29 %), available nitrogen (133 kg N/ha) and potassium (102 kg K_2O/ha) and medium in available phosphorus (18 kg P_2O_5) with normal EC (0.24 dS/m) and neutral pH (7.3). The genotype used in the study was PMH 1, a hybrid released by Punjab Agricultural University, Ludhiana.

Treatments and crop management: Treatments consisted of two plant densities, *i.e*., normal density- ND (60×20 cm) and high density- HD (60×10 cm), with four dates of sowing, *i.e*., 23.06.2019 (DS 1), 03.07.2019 (DS 2), 15.07.2019 (DS 3), 26.07.2019 (DS 4). The experiment was laid down in RBD factorial with three replications. The crop was sown on the ridges 60 cm apart by dibbling seed manually. The fields were irrigated up to the depth of 70 mm/ irrigation, which accounts for 8.21 to 8.95× 10^6 L/ha among different treatments, including rainwater. The first date of sowing was given two irrigations and the rest of the sowings received three irrigations till harvest. Agronomic practices were uniformly followed in all treatments, according to Bamboriya *et al.* (2021).

Harvesting and silage preparation: Crop was harvested manually from the milk stage to the dough stage (when the milk line was 1/3 to ½ down the kernel) after 81 to 83 days of sowing, and the data was recorded for plant height, number of leaves per plant, leaf length, leaf width, stem girth, plant fresh weight, biological yield and dry matter yield. Maize crops were chopped to approximately 1 to 3 cm particle length and were ensiled individually for 45 days in low-density polypropylene bags under anaerobic conditions and without adding any additive.

Quality analysis of green fodder and silage: For green fodder quality analysis, after harvesting, the fresh maize crop was chaffed and dried at 60°C for further analysis. On the other hand, for silage, after the termination of the fermentation process (after 45 days), silage bags were opened and representative samples were taken out from each bag and divided into two parts. One part was used to prepare water extract and the other part was dried. A fresh silage sample was churned with 225 mL of lukewarm distilled water in a mixer. The extract was used to determine pH, lactic acid (Barker and Summerson, 1941), acetic acid (Cottyn and Boucque, 1968) and ammonia-N content. Other samples were dried at 60°C, finely grounded and were analyzed for dry matter (DM), crude protein (CP) and total ash (AOAC, 2007), cellulose (Crampton and Maynard, 1938) and other cell wall constituents (Robertson and Van Soest, 1981). The feed values in terms of dry matter intake (DMI), digestible dry matter (DDM), relative forage value (RFV), relative forage quality (RFQ), total digestible nutrients (TDN) and net energy lactation (NE_l) were also worked out (Schroeder, 2004)- DMI (%BW) = 120 / (%NDF); (DDM = 88.9 - (0.779 × %ADF); RFV = (%DDM × %DMI) / 1.29; RFQ = (TDN × DMI) / (16.8+39.2); TDN = 87.84- (0.79 × %ADF); NE_l (Mcal/kg) = 0.0245 × TDN - 0.12; while Flieg score (FS) for silages was worked out with equation as suggested by Kilic (1986)- FS = 220 + (2 × DM% -15)-40 × pH.

In-vitro evaluation of green fodder and silages: The nutritional value of green fodder produced and silages prepared according to treatments were assessed by the *in-vitro* gas production (IVGP) technique described by Menke and Steingass (1988). The quality attributes like net gas production, digestibility of nutrients, acetic acid (AA) production, and metabolizable energy (ME) availability were assessed. Blank and sample of standard hay were run in triplicate with each set. Syringes were incubated in a water bath at 39ºC and swirled every 60 minutes over 8 8-hour incubation period. If the volume of gas in the syringe exceeded 70 mL after 8 hours, the volume was recorded and the gas was expelled (Menke *et al*., 1979; Menke and Steingass, 1988). After 24 hours of incubation, the volume of gas produced in each syringe was recorded. The contents of the syringes were then transferred to a spout-less beaker, boiled with 20 mL neutral detergent solution for assessing the *in-vitro* true organic matter (TOMD) and neutral detergent fiber degradability (NDFD). The flask content was refluxed for 1-hour and filtered through pre-weighed sintered crucibles (grade 1). The dry matter content of the residue was weighed and *in-vitro* true degradability of feeds was calculated. Net gas production in the treatments was calculated by deducting the gas production in the blank syringes. The partitioning factor (PF) was calculated by the ratio of substrate OM truly degraded *in-vitro* (mg) to the volume of gas (mL) produced by it (Blummel *et al.*, 1997). The microbial biomass production (MBP) was calculated by using truly degraded OM, gas volume and stoichiometrical factor: MBP (mg/g) = *in-vitro* truly degraded OM (mg/g) − (gas volume (mL/g) × stoichiometrical factor), where the stoichiometrical factor was 2.2 (Blummel *et al*., 1997).

Statistical analysis: The data related to different plots and their interaction with harvest stage were subjected to analysis of variance (Snedecor and Cochran, 1994) by using SPSS (2012) software version 20.0, taking date of sowing as one factor and plant density as the second factor. The means were tested for significant difference by using Tukey's test. The statistical model used was: $Yijk = \mu + Si + Dj + (S \times D)ij + eijk$; Where, Y_{ijk} was the dependable variable (nutritive composition, feed values, fermentation characteristics etc.), μ was population mean, S_i was the effect of i^{th} date of sowing (23-06-2019, 03-07-2019, 15-07-2019, 26-07-2019), D_j was the effect of j^{th} density (normal and high), S × D was the effect of i^{th} date of sowing at j^{th} density, eijk was the error. The data related with plant density (normal and high) were subjected to an independent t-test to observe effects. Significance was considered at $p \leq 0.05$.

Results and Discussion

Yield attributes and green fodder yield: Significant effect of date of sowing and date of sowing × planting density interaction was observed for plant height and stem girth, whereas the yield/plant and leaf length were significantly affected by plant density and date of sowing, respectively (Table 1). Significantly higher plant height was observed under crop sown at the end of July (DS 4) as compared to early sowing dates. This might be due to warm weather during early vegetative growth under late-sown crops, which could stimulate plants to develop larger vegetative structures. Plant height increased with delayed sowing was also reported earlier (Abendroth *et al*., 2017; Maresma *et al*., 2019).

The leaf length and leaf width were reduced in mid and late-July sown plots. On the other hand, the number of leaves varied from 13.5 to 15 per plant, whereas leaf width varied from 3.84 to 4.28 cm. However, these were statistically insignificant among different treatments. The yield/plant was significantly higher (p <0.01) under ND (0.86 kg/plant) than HD (0.65 kg/plant). At HD, the interplant competition for available resources was more which reduced the yield/plant. This also led to significantly higher biological and DM yield of maize hybrid sown under ND, irrespective of sowing dates (Table 2). Ferreira *et al.* (2014) also reported a higher dry matter yield of green-chopped corn for silage at a normal density.

The trend was entirely reversed with the biological yield at DS 2 (03-07-2019) sown plots, but recorded comparable DM yield (142.3 vs 142.8 q/ha). The effect of date of sowing and date of sowing × plant density varied among different treatments. In general, biological and DM yield varied from 400 to 611.1 q/ha and 144 to 205.3 q/ha, respectively among different treatments. The higher values (P<0.001) of biological (611.1 q/ha) and DM yield (205.3 q/ha) was recorded under ND plots sown on DS 3 (15.07.2019). It was due to fact that warm weather during early vegetative growth under late sown crop (DS 3) with lower interplant competition for available resources under ND sowing resulted in better growth and development of crop, leading to higher biological and DM yield.

Chemical composition and in-vitro fermentation characteristics: The nutritive composition of maize hybrid PMH 1 sown at different dates with different plant densities was recorded (Table 3). The DM content of forage varied from 32.1% (DS 2) to 35.0% (DS 4) among different plots at the time of harvesting (P<0.05), which was well within the range as described by McDonald *et al.* (1991) for silage making and results were also in confirmation with Hundal *et al.* (2019; 2020). The optimum DM content was critical for effective packing of fodder in the silo pit as well as for growth of lactic acid bacteria (McDonald *et al*., 2002). Low DM content results in higher butyric acid content in silages due to higher clostridial activity, hence associated with undesirable fermentation (Moon *et al*., 1981; Woolford *et al*., 1982). Some other researchers (Wiersma *et al*., 1993) also recommended same optimum DM range (30 to 40%) for whole plant silage. The significant differences in the crude protein (CP), ether extract (EE), neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents were also observed among different sowing dates. However, plant density did not affect any nutrient component among maize plots. Significant interactions between the date of sowing and the plant density were reported for all observed parameters except EE and acid detergent lignin (ADL). CP was high in early sown plots (DS 1 and DS 2) and declined to a low level with advanced date of sowing (DS 3 and DS

Table 1. Physical parameters of maize hybrids

Parameter	Date of sowing (DS)					Plant density (D)			DS×D
	DS 1	DS 2	DS 3	DS 4	P-value	ND	HD	*P-value*	
Plant height (cm)	215.2^{a}	232.85^{c}	226.0^{b}	247.8^{d}	***	226.1	234.8	NS	**
Leaves no./plant	14.5	13.95	13.7	13.95	NS	13.8	14.2	NS	NS
Leaf length (cm)	38.2^{b}	37.9^{b}	35.8^{a}	36.9^{ab}	*	37.6	36.8	NS	NS
Leaf width(cm)	4.19	4.32	4.20	3.91	NS	4.18	4.13	NS	NS
Stem girth (mm)	148.5^{b}	151.3^{c}	141.1^{a}	149.2^{b}	***	148.6	146.5	NS	***
Yield/plant(kg)	0.67	0.86	0.78	0.71	NS	0.86	0.65	**	NS

DS 1: 23-06-2019; DS 2: 03-07-2019; DS 3: 15-07-2019; DS 4: 26-07-2019; ND: Normal density (60×20 cm); HD: High density (60×10 cm); Figures with different superscripts in a row differed significantly; *P<0.05; **P<0.01; ***P<0.001

Table 2. Biological and dry matter yield of maize hybrid

Plant density (D)	Dates of sowing			
	DS 1	DS 2	DS 3	DS 4
ND	555.6^{b} (185.6^{b})	422.2^{a} (142.3)	611.1^{b} (205.3^{b})	488.9^{b} (162.2^{b})
HD	500.0^{a} (161.0^{a})	466.7^{b} (142.8)	555.6^{a} (182.8^{a})	400.0^{a} (144.0^{a})
Mean	527.8^{b} (173.3^{c})	444.4^{a} (142.5^{a})	583.3^{c} (194.0^{d})	444.4^{a} (153.1^{b})
DS	***	***	***	***
D	***	***	***	***
DS × D	***	***	***	***

Values showing biological yield (q/ha) and DM yield (q/ha) under parenthesis; 10 q = 1 ton; Values with different superscripts in a row differed significantly; ***P<0.001

4), whereas EE followed exactly reverse trends (p <0.05). The effect of the date of sowing and different plant densities on predicted feed values of maize hybrid PMH 1 forage was also recorded (Table 3). The predicted feed values were not influenced by the plant density. However, the effect of the date of sowing and their interactions with plant density was observed (p <0.01) among all predicted feed values for maize hybrid PMH 1 forage. DMI and DDM values were significantly (p <0.001) higher (2.43 and 69.4%, respectively) under DS 3 plots in comparison to other plots of PMH 1. The energy content of feedstuffs expressed in terms of TDN (%) or $NE_{L,}$ (Mcal/Kg) were significantly higher (p <0.001) for maize hybrid under ND (60×20 cm). TDN, RFV and RFQ were significantly (p <0.001) higher for hybrids sown on DS 3 and DS 4, because these values depended upon NDF and ADF content of forage, which was found significantly lower among plots sown at DS 3 and DS 4.

The data on effect of date of sowing, plant density and their interactions on NGP and digestibility of nutrients (Table 3) revealed that NGP varied (p <0.001) from 108.1 (DS 1 maize sown in late June) to 128.7 mL/g (DS 3 maize sown in mid-July) and digestibility of NDF varied (p <0.01) from 28.1% (DS 1 maize sown in late June) to 24.2% (DS 4 maize sown in late July). However, values remained similar among hybrids sown in late June (DS 1), early (DS 2) or mid-July (DS 3). The digestibility of true organic matter was not affected by date of sowing or plant density. Moreover, most *in-vitro* fermentation characteristics remained comparable (p >0.05) between ND and HD plots. The partitioning factor (PF) was low in late sown maize (p <0.01) in comparison to maize hybrid sown in late June (DS 1) or early July (DS 2). The availability of ME was higher in early sown maize hybrids in comparison to late sown maize, this could be attributed to higher CP content of the forage in early sown crops.

Fermentation pattern of silage: The effect of the date of sowing on pH, acetic acid and Fleig point was significant (Table 4). However, the density of plants did not influence silage fermentation parameters among different plots. The ammonia-nitrogen content of all silages varied from 5.0 to 6.54% of total nitrogen, which indicated good fermentation took place among all hybrids during ensiling (Wilkinson, 1990). Moreover, it was also influenced by the date of sowing × plant density interaction (p < 0.001). The pH of silage ranged from 3.98 to 4.17, which agreed with the findings of Filya (2003). Kaiser and Piltz (2004) reported pH of well-preserved silages was within the range of 3.5 to 4.2. Similarly, lactic acid content ranged from 3.85 to 4.15% on DM basis. Under anaerobic conditions, the fermentation of water-soluble sugars in forages to organic acids was

Table 3. Nutrient composition of green fodder maize hybrid

Parameter	Date of sowing (DS)					Plant density (D)			DS×D
	DS 1	DS 2	DS 3	DS 4	P-value	ND	HD	P-value	
Dry matter (%)	32.8^{ab}	32.15^{a}	33.25^{ab}	35^{b}	*	33.67	33.92	NS	NS
Crude protein (%)	8.02^{c}	8.12^{c}	7.57^{b}	7.27^{a}	***	7.89	7.94	NS	***
Ether extract (%)	2.2^{a}	2.2^{a}	2.37^{ab}	2.45^{b}	*	2.28	2.34	NS	NS
Neutral detergent fibre (%)	53.9^{c}	55.8^{d}	49.3^{a}	52.4^{b}	***	52.5	53.2	NS	**
Acid detergent fibre (%)	28.8^{c}	28.6^{c}	25.1^{a}	26.7^{b}	***	26.6	28.0	NS	***
Acid detergent lignin (%)	3.62	3.67	3.45	3.65	NS	3.6	3.6	NS	NS
Cellulose (%)	24.35	23.4	22.95	23.95	NS	23.35	23.97	NS	***
Ash (%)	5.05	5.27	5.45	5.25	NS	5.13	5.39	NS	***
Organic matter (%)	94.95	94.37	94.55	94.75	NS	94.9	94.6	NS	***
Feed values									
DMI % BW	2.23^{b}	2.15^{a}	2.43^{d}	2.29^{c}	***	2.29	2.26	NS	**
DDM %	66.4^{a}	66.6^{a}	69.4^{c}	68.0^{b}	***	68.2	67.0	NS	**
TDN %	67.6^{a}	67.8^{a}	70.3^{c}	69.1^{b}	***	69.2	68.1	NS	***
RFV	114.7^{b}	111.1^{a}	130.9^{d}	120.9^{c}	***	121.1	117.8	NS	***
RFQ	2.69^{b}	2.61^{a}	3.06^{c}	2.83^{c}	***	2.83	2.76	NS	***
NE_L, M cal/kg	1.54^{a}	1.54^{a}	1.60^{c}	1.57^{b}	***	1.58	1.55	NS	***
***In-vitro* fermentation characteristics**									
NGP (ml/g)	108.1^{a}	114.0^{a}	128.7^{b}	127.3^{b}	***	120.1	118.9	NS	NS
NDFD (%)	28.1^{b}	28.5^{b}	27.2^{b}	24.2^{a}	**	27.76	26.23	NS	***
TOMD (%)	59.2	58.6	58.9	58.8	NS	58.8	58.9	NS	NS
ME (MJ/kg)	5.47^{a}	5.52^{a}	5.97^{b}	5.89^{b}	***	5.68	5.72	NS	NS
PF (mg/ml)	5.48^{b}	5.33^{b}	4.61^{a}	4.76^{a}	**	5.07	5.01	NS	NS
MBP (mg/g)	354^{c}	343^{bc}	307^{a}	316^{ab}	**	331.9	328.4	NS	NS

BW: Body weight; DDM: Digestible dry matter; TDN: Total digestible nutrients; RFV: Relative feed value; RFQ: Relative feed quality; NEl: Net energy lactation; NGP: Net gap production; PF: Partitioning factor; MBP: Microbial protein biosynthesis; Values with different superscripts in a row differed significantly; *P<0.05; **P<0.01; ***P<0.001; NS: Non-significant

mainly responsible for the decline in pH and high lactic acid content (Borreani *et al.*, 2018). A low pH resulted in optimum production of lactic acid to inhibit the growth of unwanted microorganisms such as *Clostridia* and *Enterobacteria*. In the current study, *p*H and lactic acid levels were within the range of good-quality silage as described by McDonald *et al.* (1991). Acetic acid, which had the biggest impact on aerobic stability, ranged from 1.12 to 1.42% on DM basis for different silages and fell within the normal range (1.08–1.84% DM) advisable for good silages (Muck, 2010). With regards to Fleig score, silages from almost all of the plots were of high quality and ranged from 110.2 to 108.5, with the highest value in silage DS 3 and the lowest one in that of silage DS 1.

Chemical composition and in-vitro fermentation characteristics of silage: After termination of the fermentation process, moisture determination of silage revealed that DM content of tested maize hybrid under different sowing dates and plant density varied from 311 to 324 g/kg and 315 to 317 g/kg, respectively, but the differences were statistically non-significant for date of sowing, plant density or date of sowing × plant density interaction (Table 4). The results were in confirmation with Hundal *et al*. (2020). Brar *et al.* (2019) also reported significantly higher DM content of silage prepared from PMH 1. Similar effects were also observed for EE content of different silages. All parameters were reported as statistically similar at both plant densities. Significantly

Table 4. Analysis of silage extracts of maize hybrid

Parameter	Date of sowing (DS)					Plant density (D)			DS×D
	DS 1	DS 2	DS 3	DS 4	P-value	ND	HD	P-value	
pH	4.17^{b}	4.05^{a}	3.98^{a}	4.03^{a}	***	4.04	4.08	NS	NS
LA, % DM	4.05	4.15	4.0	3.85	NS	4.20	3.82	NS	NS
AA, % DM	1.25^{a}	1.42^{b}	1.12^{a}	1.15^{a}	**	1.30	1.20	NS	***
NH_3-N,% of TN	6.43	6.35	5.0	6.54	NS	6.18	5.98	NS	***
Fleig point	100.2^{a}	106.8^{b}	108.0^{b}	108.6^{b}	**	106.5	105.3	NS	NS
Nutrient composition									
Dry matter (%)	31.1	31.9	31.2	32.4	NS	31.53	31.75	NS	NS
Crude protein (%)	8.43^{c}	8.21^{c}	7.64^{b}	7.38^{a}	***	7.82	7.67	NS	NS
Ether extract (%)	2.22	2.22	2.42	2.47	NS	2.29	2.39	NS	NS
Neutral detergent fibre (%)	52.0^{c}	54.0^{c}	47.6^{a}	50.1^{b}	***	50.6	51.3	NS	*
Acid detergent fibre (%)	27.7^{b}	28.1^{b}	23.9^{b}	26.9^{b}	**	26.6	26.4	NS	NS
Acid detergent lignin (%)	3.45^{b}	3.62^{b}	3.20^{a}	3.65^{b}	***	3.50	3.46	NS	*
Cellulose (%)	24.6^{b}	24.7^{b}	22.5^{a}	24.4^{b}	**	24.1	24.0	NS	***
Ash (%)	5.26^{ab}	5.54^{b}	4.40^{a}	5.12^{ab}	*	5.10	5.07	NS	***
Organic matter (%)	94.7^{ab}	94.5^{a}	95.6^{b}	94.9^{ab}	*	94.9	94.93	NS	***
Feed values									
DMI (%) BW	2.31^{b}	2.22^{a}	2.52^{d}	2.39^{c}	***	2.38	2.35	NS	*
DDM (%)	67.3^{a}	66.9^{a}	70.3^{b}	67.9^{a}	**	68.2	68.1	NS	NS
TDN (%)	68.4^{a}	68.1^{a}	71.1^{b}	69.0^{a}	**	69.2	69.1	NS	NS
RFV	120.4^{a}	115.6^{a}	137.5^{c}	126.1^{b}	***	125.7	126.9	NS	*
RFQ	2.82^{a}	2.71^{a}	3.21^{c}	2.95^{b}	***	2.94	2.97	NS	*
NE_L (Mcal/kg)	1.56^{a}	1.55^{a}	1.62^{b}	1.57^{a}	**	1.58	1.57	NS	NS
***In-vitro* fermentation characteristics**									
NGP (ml/g)	133.3^{a}	131.3^{a}	160.7^{b}	144.1^{ab}	**	142.2	142.6	NS	*
NDFD (%)	24.6^{b}	24.6^{b}	24.9^{b}	22.2^{a}	*	24.69	23.47	NS	NS
TOMD (%)	58.0	58.1	58.9	57.9	NS	58.53	57.95	NS	*
PF (mg/ml)	4.47	4.47	3.70	4.25	NS	4.34	4.10	NS	*
MBP (mg/g)	293.9	292.5	237.6	273.4	NS	284.6	264.1	NS	NS
ME (MJ/kg)	6.0	6.0	6.74	6.24	NS	6.16	6.34	NS	*

LA: Lactic acid; AA: Acetic acid; NH3-N: Ammonia nitrogen; DDM: Digestible dry matter; TDN: Total digestible nutrients; RFV: Relative feed value; RFQ: Relative feed quality; NE: Net energy lactation; Values with different superscripts in a row differed significantly; *P<0.05; **P<0.01; ***P<0.001; NS: Non-significant

(p <0.001) higher CP content in silage from hybrid sown on late June (DS 1) or early July (DS 2) was observed because of its higher CP at the time of ensiling. Significant differences were also reported for date of sowing or date of sowing × plant density interactions for NDF, ADF, ADL, cellulose, organic matter and ash. Depending on the date of sowing, NDF concentration varied between 47.6 to 54% and ADF content between 23.9 to 28.1%. However, the lowest values for NDF and ADF were observed in the mid-July sown hybrid (DS 3). The values were close to those reported by Hundal *et al*. (2020).

The effect of date of sowing and plant density on feed values of maize silages (Table 4), revealed significantly higher DMI, DDM, TDN, RFV, RFQ and NE_L values for mid-July (DS 3) sown maize hybrid in comparison to the others. This could be attributed to the lowest NDF and ADF content in DS 3. The RFV, used to compare DM intake and digestible DM (Kilic, 2010) qualities of similar forages, was reported highest for DS 3. The energy content of feedstuffs in terms of NE_L varied from 1.55 to 1.62 Mcal/kg, with the highest value for the silage from a mid-July sown hybrid. Hundal *et al.* (2019), in their study of comparing corn hybrids, also reported similar feed values of superior maize silage. ND and HD did not influence either of the feed values. However, the interaction between plant density and date of sowing had a significant effect on DMI, RFV and RFQ values among different silages.

The date of sowing and the date of sowing × plant density interaction had a significant effect on net gas production (NGP) and NDF digestibility (NDFD; Table 4), whereas the date of sowings or plant density individually did not influence OM digestibility (OMD), PF, microbial mass production (MBP) or ME among different silages. Similar results were reported by Opsi *et al.* (2013) who observed that NGP of different cultivars of maize silage varied with planting dates, whereas IVDMD and IVNDFD remained unaffected by the date of planting. In the present study, the decreasing order of NGP content among the different dates of sowing was DS 2, DS 1, DS 4 and DS 3. The NGP (mL/g/24 h) was observed to be higher for DS 3 in comparison to DS 1 and DS 2, whereas it remained at par with DS 4 silage. However, the NDF digestibility (%DM) content among DS 1, DS 2 and DS 3 remained comparable, but the significantly lowest value was observed in late July sown hybrid (DS 4). Higher digestibility of NDF was an indicator of higher cell wall digestibility due to less linking between lignin and polysaccharides (Wadhwa *et al.*, 2022).

Conclusion

Based on yield, feed values and NGP as well as NDF digestibility of forage, it was concluded that PMH 1 sown in mid-July (DS 3) was comparatively superior to its counterparts (DS 1, DS 2, DS 4) at both plant densities, however in terms of forage yield, ND (60×20 cm) had an edge over HD (60×10 cm). As per the silage quality, all silages exhibited good ensiling characteristics at all dates of sowing and plant densities. However, improved nutritive profile, better feeding values, higher *in-vitro* potential and good fermentation characteristics of hybrid sown in mid-July (DS 3), indicated it as a more recommendable date of sowing for forage as well as for ensiling under given conditions at both ND and HD. Since hybrid seed cost is higher and HD will require more seed than ND, it was recommended that ND should be followed.

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