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EVALUATING THE AGRONOMIC CHARECTERISTICS AND NUTRITIONAL QUALITY OF SILAGE FROM VARIOUS MAIZE (*Zea mays*) VARIETIES

Sunita Sanjyal[1], Shishir Singh Bohara[2*], Rabin Acharya[2] and Arjun Acharya[1]

National Pasture and Fodder Research Program, Nepal Agricultural Research Council,

[2]Institute of Agriculture and Animal Science, Tribhuvan University, Nepal,

*Corresponding author's email: shishirsinghbohara@gmail.com

Sunita Sanjyal: https://orcid.org/0000-0003-1752-5324

Rabin Acharya: https://orcid.org/0000-0002-8867-0636

Arjun Acharya: https://orcid.org/0009-0008-9356-9920

Shishir Singh Bohara: https://orcid.org/0009-0009-4218-1229

ABSTRACT

High-quality fodder is one of the most essential components of Livestock feeding as it ensures that animals meet their nutritional requirements. Maize (Zea mays) silage provides an important solution to mitigate herbage shortages during lean periods, helping to counteract the rising feed prices. A study was conducted at Lamjung Campus, Lamjung, from March to July 2023 to assess the quality of silage produced from seven maize varieties: MX-77, Pioneer, Rampur Hybrid-10, Raj Kumar, CP-666, All Rounder, and CP-838. The experiment was carried out with three replications in a randomized complete block design. The chemical composition of the silage was analyzed to determine the dry matter content, crude protein, crude fiber, neutral detergent fiber (NDF), acid detergent fiber (ADF), and pH. The agronomic traits like plant height, stem diameter, 50% tasseling, leaf number, leaf area and herbage yield were also recorded. Results showed a significant difference in agronomic and chemical traits where MX-77 had the herbage yield (25.76 MTha-1), plant height (208.556cm) and crude protein (7.91) which was comparable to the Pioneer variety. The least was recorded for variety Raj Kumar (4.36). Rampur Hybrid-10 took the longest duration (84.67 days after sowing) to reach the 50% tasseling stage, while CP 666 was the earliest variety to reach 50% tasseling at 72.66 days after sowing. MX-77 and Pioneer were identified as the best varieties for quality silage production, offering higher herbage yield (HY), dry matter yield (DMY), and crude protein (CP). Acid detergent fiber (ADF) was highest in CP 838 (45.1%), indicating lower digestibility and nutritional value of the silage, while the lowest ADF was found in Raj Kumar (30.71%). HY in maize showed moderate positive correlations with leaf area ($r = 0.57^{**}$, $p < 0.01$), stem diameter ($r = 0.45^{*}$, $p < 0.05$), and plant height ($r = 0.54^{*}$, $p < 0.05$), as well as with crude protein ($r = 0.68^{***}$, $p < 0.001$) and crude fiber ($r = 0.6^{**}$, $p < 0.01$). Furthermore, ADF and neutral detergent fiber (NDF) were positively correlated with dry matter (DM) percentage ($r = 0.5^{*}$, $p < 0.05$; $r = 0.49^{*}$, $p < 0.05$), with delayed maturity leading to increased ADF ($r = 0.56^{*}$, $p < 0.01$) and reduced digestibility. This study offers valuable insights for farmers and livestock producers in selecting the most suitable maize varieties for silage production to ensure high yields and superior nutritional value for livestock.

Keywords: herbage, dry matter, yield, production, nutrient content

INTRODUCTION

The livestock sub-sector plays a crucial role in agriculture by producing nutritious food such as meat, milk, and eggs, which not only boost farmers' incomes but also create employment opportunities (Otte *et al.,* 2012). Feed resources, including herbage, concentrates, and crop residues, are vital for animal nutrition. However, the rising cost of commercial feed, which has increased by 60-70%, underscores the need to incorporate affordable local feed alternatives. Among them green herbages are one of the most crucial factors for successful dairy business. However, the year-round shortage of feed is a major challenge to the low productivity of dairy animals. Silage offers an effective method to preserve surplus fodder

for use during shortages. Silage, made through controlled fermentation of green fodder crops under anaerobic conditions, allows for the steady supply of high quality feed during lean periods (Verma, 1995; McDonald *et al.,*1991). Nepal currently faces a feed deficit of 20.05 % in TDN basis (Singh & Singh, 2019), which has been identified as a major factor contributing to low livestock productivity (Sanjyal *et al.,* 2022). Inadequate nutritional support during lean periods adversely impacts the health of dairy animals, leading to issues such as weight loss, poor fertility and reproductive function, reduced breeding efficiency, and diminished draft energy (Kumar *et al.,* 2019).

Maize fodder is highly nutritious feed for animals being rich in vitamin A, protein, and fiber content (Khatun & Khan, 2015). The crop exhibits relatively stable yields across diverse environmental and agronomic conditions, along with high energy content and excellent ensiling properties (Brar *et al.,* 2024). Therefore, evaluating different maize varieties for silage quality is crucial as genetic diversity significantly impacts nutritional content and preservation. In Nepal, silage production offers multiple benefits, including enhanced livestock nutrition, increased farm income, and improved climate resilience. By preserving nutritious herbage for lean periods, silage addresses seasonal feed shortages, promotes alternative crop use, and reduce waste. It supports balanced diets for livestock, promoting better health and productivity while reducing reliance on costly feed imports. While maize silage is efficient to produce and also allows the utilization of damaged crops, however faces challenges in marketing and transportation. This study evaluates the silage quality of various maize varieties to assist farmers in selecting the best options. By focusing on improving silage quality, the research aims to enhance livestock health and productivity, addressing gaps in previous studies that emphasized on preservation methods and maize maturity.

MATERIALS AND METHODS

The experiment was conducted from March to June 2023 at Lamjung Campus, Sundar Bazar, Nepal, with an objective to assess the silage quality of seven maize varieties namely Rampur Hybrid-10, MX-77, Pioneer, Raj Kumar, CP-666, All Rounder, and CP-838.The study site is situated at 610 masl in a sub-tropical climate with an average annual rainfall of 203 mm and an average temperature of 20.28°C. The soil type was clay loam soil. The varieties were chosen for their comparable maturity periods and suitability to local conditions. The experimental design used was randomized complete block design with three replicates. 10 kg of farm yard manure was applied per plot during field preparation, followed by chemical fertilizer at the rate of 120:60:40 NPK kg/ha, where nitrogen was applied in two splits at sowing and pre-flowering stage. Maize seeds were sown at 60 cm row spacing and 25 cm plant spacing. Growth parameters such as emergence, plant height, stem diameter, leaf count, leaf area and herbage yield were recorded. The crop was harvested at the milk line stage ensuring optimal nutritional content. To prepare silage, the maize was harvested and shade dried for a day to reduce the moisture which was then chopped to 2-3 cm for ensiling and then mixed with additives (molasses, urea, salt, curd), and sealed in 50 kg airtight bags for 45 days. Silage samples were oven-dried at 70°C for dry matter content analysis and then taken to laboratory for proximate analyses (moisture, crude protein, and fiber) at designated laboratories. Data were processed using MS-Excel and analyzed with one-way ANOVA and Duncan's test in R-studio.

RESULTS AND DISCUSSION

Comparison of agronomic traits of different maize varieties

Table 1 describes the agronomic traits of different maize varieties. Plant height showed significant variation (P<0.01) among the varieties, with Pioneer attaining the tallest height of 210.11 cm, followed closely by MX-77 at 208.56 cm (Table 3.1). CP 666 had the shortest height of 165.44 cm. Stem diameter differences were significant (P<0.05), with CP 666 recording the smallest diameter of 11.90 mm and MX-77 the largest of 17.39 mm (Table 3.1). The duration from sowing to 50% tasseling also varied significantly among the maize varieties (P<0.01). CP 666 was the earliest to reach this stage, taking 73 days after sowing (DAS), while Rampur Hybrid-10 required the longest time at 85 DAS (Table 3.1). The tasseling time for Raj Kumar, CP 838, Pioneer, and All-Rounder variety was relatively similar as shown in Table 1.

Table 1: Comparison of yield components of different maize varieties

Treatments	Plant height (cm)	Stem Diameter (mm)	50% tasseling (DAS)
RH 10	186.22^{b}±3.93	13.45^{bc}±0.97	84.67^{a}±2.67
MX 77	208.56^{a}±4.83	17.39^{a}±1.06	81.33^{ab}±0.67
Pioneer	210.11^{a}±4.91	14.01^{ab}±0.66	75.67^{cd}±2.33
Raj Kumar	169.67^{b}±1.60	12.15^{c}±1.14	77.33^{bcd}±0.67
CP 666	165.44^{b}±3.12	11.90^{c}±1.25	72.67^{d}±1.67
All-rounder	185.67^{b}±5.79	13.88^{bc}±1.04	79.33^{bc}±1.33
CP 838	175.79^{b}±3.81	15.53^{ab}±1.36	78.67^{bc}±0.67
Grand Mean	185.93	14.05	78.52
F-Test	**	*	**
CV %	5.839	11.741	3.504
SEM (±)	4.1860	0.5261	0.9527
LSD (0.05)	19.310	2.934	4.894

Note: Means with letter (ns) do not differ significantly, *Significant at 0.05 percent level, ** significant at 0.01 percent level and *** significant at 0.001 percent level, mm=millimeter, cm= centimeter, %= percentage, CV=coefficient of variation, SEM=standard error of mean and LSD= least significant difference

Maturity of plant has been identified as an important quality factor for silage in which a significant relationship between DMC and silage DM intake occurs (Demarquilly, 1988; and Bohm *et al.,* 1984). Herbage yield in maize increases with the advancement of plant maturity but the quality of herbage decreases considerably (Nelson *et al.,* 1994). The maturity period of maize has a significant impact on the physical and chemical characteristics of silage (Horst *et al.,* 2021). Therefore, harvesting at early heading stage is usually optimum period for getting higher quality and quantity of herbage. In case of maize, when the crop is grown for silage production, it usually harvested at 2-3 weeks earlier than grown for grain production (Amin *et al.,* 2011). At earlier maturity stages, the dry matter content is usually lower and the concentration of water- soluble carbohydrates is higher, thus leading to lower pH values and better fermentation (Johnson *et al.,* 2003). Taller plants and thicker stems generally show higher silage biomass yield per unit area,

which also corresponds to the trend found in this study. Plants with thicker stems have higher stalk strength that resists root lodging, a very important criterion in selecting maize varieties for silage. According to Ogunniyan *et al.* (2019), yield is characterized by major genotypic differences in plant height, stem thickness and days to 50 % tasseling.

Vegetative yield components of different varieties of maize

Leaf area showed highly significant variation among the maize varieties (Table 2). MX 77 and CP 838 recorded the highest leaf area with values of 545.15 cm^2 and 488.74 cm^2, respectively. Pioneer, Rampur Hybrid-10, Raj Kumar, and All-Rounder also exhibited relatively high leaf areas, while the lowest leaf area was observed in CP 666. Herbage yield at harvest varied significantly ($P<0.05$) among the varieties (Table 2). MX-77 produced the highest herbage yield (25.76 MT ha^{-1}), followed closely by Pioneer (24.29 MT ha^{-1}), with both performing significantly better than All-Rounder and CP 838. The lowest herbage yield was recorded in Rampur Hybrid-10 (13.92 MT ha^{-1}) (Table 3.2). Dry matter content in maize fodder was not significantly affected by the varieties ($P>0.05$). However, MX-77 had the highest dry matter content at 37.46%, and Rampur Hybrid-10 had the lowest dry matter content at 31.03% (Table 2).

Table 2 Comparison of vegetative yield components of different maize varieties

Treatments	Leaf area (cm^2)	Leaf number per plant	Biomass yield ($MTha^{-1}$)	Silage DM content %
RH 10	$412.73^{c}\pm10.76$	$12.67^{a}\pm0.33$	$13.92^{c}\pm1.74$	$32.85^{a}\pm2.17$
MX 77	$545.15^{a}\pm11.64$	$13.33^{a}\pm0.33$	$25.76^{a}\pm2.07$	$36.16^{a}\pm0.17$
Pioneer	$401.31^{c}\pm17.22$	$13.67^{a}\pm0.33$	$24.29^{ab}\pm1.96$	$36.20^{a}\pm0.52$
Raj Kumar	$409.40^{c}\pm10.41$	$12.33^{a}\pm0.33$	$15.07^{c}\pm2.05$	$33.79^{a}\pm0.67$
CP 666	$313.49^{d}\pm18.25$	$13.00^{a}\pm0.58$	$17.23^{bc}\pm2.39$	$33.16^{a}\pm2.65$
All-rounder	$382.65^{c}\pm9.96$	$13.67^{a}\pm0.33$	$19.84^{abc}\pm2.32$	$35.31^{a}\pm0.89$
CP 838	$488.74^{b}\pm24.14$	$13.00^{a}\pm0$	$20.50^{abc}\pm2.04$	$31.05^{a}\pm1.80$
Grand Mean	421.93	13.01	19.51	34.79
F-Test	***	ns	*	ns
CV %	5.732	6.489	19.58	8.851
SEM (±)	16.32	0.1813	1.135	0.738
LSD (0.05)	43.04	1.511	6.799	5.479

Note: Means with letter (ns) do not differ significantly, *Significant at 0.05 percent level, ** significant at 0.01 percent level and *** significant at 0.001 percent level, cm^2 =square centimeter, $MTha^{-1}$ =metric ton per hector, %= percentage, CV=coefficient of variation, SEM=standard error of mean and LSD= least significant difference

The selection of high yielding maize varieties is thus very important for optimum silage production and improvement in feeding efficiency of livestock. Maize has been found superior regarding herbage yield attributes like the number of cobs per plant, the number of leaves, leaf area, and plant height for the cultivation as a silage crop. Variability in the yield attributes among the varieties is reported to depend on the genetic makeup and intrinsic ability of different varieties to access the growth resources, further affecting their yield potential (Karnatam *et al.*, 2023).

Nutritional content of silage prepared from different maize

The nutritional content of seven maize varieties is presented in Table 3. The pH of maize silage was not significantly influenced by the varieties ($p < 0.05$) and ranged from 3.96 (MX-77) to 4.26 (Raj Kumar), falling within the normal range for high-quality silage. The crude protein (CP) content among the maize varieties varied substantially, ranging from 5.14% (All Rounder) to 9.09% (MX-77), indicating notable differences in the protein concentration of the silage. Similarly, the crude fiber content varied across the varieties, with the highest content observed in MX-77 (37.46%), followed by All Rounder (36.58%), and the lowest in CP 666 (28.65%). This variation reflects differences in the structural composition and digestibility of the silage. The acid detergent fiber (ADF) content of maize silage was significantly affected by the varieties ($p < 0.05$). The highest ADF value was recorded in CP 838 (45.1%), and the lowest was observed in All Rounder (30.7%). Additionally, the neutral detergent fiber (NDF) content of maize silage was highly significant among the varieties ($p < 0.01$), with values ranging from 53.56% (All Rounder) to 74.69% (CP 666).

Table 3 Nutritional content of silage prepared from different maize

Treatments	pH	CP %	CF %	ADF %	NDF %
RH 10	$4.23^{a}\pm0.23$	$6.47^{bc}\pm0.13$	$29.35^{bc}\pm0.51$	$38.58^{ab}\pm1.83$	$61.77^{c}\pm3.12$
MX-77	$3.96^{a}\pm0.15$	$9.09^{a}\pm1.79$	$37.46^{a}\pm1.65$	$35.84^{ab}\pm0.40$	$72.32^{ab}\pm3.12$
Pioneer	$4.00^{a}\pm0.15$	$7.91^{ab}\pm0.48$	$35.97^{ab}\pm3.71$	$31.53^{b}\pm1.57$	$68.42^{abc}\pm0.23$
Raj Kumar	$4.26^{a}\pm0.16$	$4.37^{d}\pm0.31$	$32.05^{abc}\pm2.11$	$36.12^{ab}\pm5.23$	$65.44^{bc}\pm2.40$
CP 666	$4.13^{a}\pm0.10$	$6.35^{bc}\pm0.09$	$28.66^{c}\pm1.59$	$42.61^{a}\pm2.72$	$74.69^{a}\pm4.52$
All-rounder	$4.17^{a}\pm0.05$	$5.14^{cd}\pm0.49$	$36.58^{a}\pm1.12$	$30.42^{b}\pm5.97$	$53.56^{d}\pm0.74$
CP 838	$4.23^{a}\pm0.13$	$7.38^{ab}\pm0.41$	$31.97^{abc}\pm1.93$	$45.10^{a}\pm2.15$	$69.94^{abc}\pm1.88$
Grand Mean	4.14	6.73	33.14	37.65	66.59
F-Test	ns	*	*	*	**
CV %	3.789	14.647	10.501	14.34	6.92
SEM (±)	0.053	0.377	0.975	1.43	1.704
LSD (0.05)	0.279	1.739	6.19	9.49	8.198

Note: Means with letter (ns) do not differ significantly, *Significant at 0.05 percent level, ** significant at 0.01 percent level and *** significant at 0.001 percent level, DM=dry matter, pH=potential of hydrogen, CP=crude protein, CF=crude fiber, ADF=acid detergent fiber, NDF=neutral detergent fiber, %= percentage, CV=coefficient of variation, SEM=standard error of mean and LSD= least significant difference

Silage with higher crude protein (CP) content has superior nutritional quality particularly for animals requiring higher protein levels, such as lactating dairy cattle and young calves. Highest CP for MX-77(9.09%) followed by Pioneer (7.91 %) might be because of effective preservation during the ensiling process. Variability concerning CP and CF content among the studied maize varieties could be due to changes in genetic composition, maturity stages, silage preservation process and, therefore, also a varied nutritional value of the genotypes. Late-maturing hybrids tend to produce significantly higher dry matter yields and fiber content compared to earlier-maturing varieties, further emphasizing the effect of maturity on silage composition and quality (Graybill *et al.,* 1991). The higher ADF content in some varieties might be due to the non-solubilization of cell wall components, which are less digestible (Nazli *et al*., 2018). In general, ADF concentration is expected to decrease as starch content increases and is negatively related

to starch content (Sutton *et al.,* 2000). Likewise, herbages with higher NDF content occupy more space in the animal's stomach, potentially reducing overall feed intake. Highest NDF and ADF contents in varieties CP666 and CP838 could be because of increased cellulose and lignin in maize stover with advancing growth stages coupled with grain development and the deposition of a large amount of carbon- containing compounds (Li *et al.,* 2022).

Physical characteristics of silage

Silage is regarded as a good feed source for the livestock during the dry season because of its consistent acceptance by animals (Restle *et al*., 2006). One of the most apparent features to observe the silage quality is the color. The color of all the varieties of silage was dark yellow to brown thus indicating a well-preserved product, often resulted from proper fermentation processes (Kung et al., 2018), leading to the desirable preservation of nutrients. The smell of silage was mild, slightly acidic and fruity smell indicates high-quality silage (Woolford, 2000) resulted from the production of organic acids, primarily lactic acid, during the fermentation process. And the vicious and the slimy appearance can be attributed to the presence of polysaccharides produced during fermentation (Weinberg & Ashbell, 1998).

Correlation among silage quality and yield attributing characters

Herbage yield showed a moderate positive correlation with leaf area ($r = 0.57^{**}$, $p < 0.01$), stem diameter ($r = 0.45^{*}$, $p < 0.05$), plant height ($r = 0.54^{*}$, $p < 0.05$), crude protein ($r = 0.68^{***}$, $p < 0.001$), and crude fiber ($r = 0.60^{**}$, $p < 0.01$). Similarly, agronomic traits of maize, such as plant height ($r = 0.60^{*}$, $p < 0.01$), leaf area ($r = 0.57^{*}$, $p < 0.01$), and stem diameter ($r = 0.55^{*}$, $p < 0.01$), had a moderate influence on the protein content in silage. Crude fiber in silage showed a moderate positive correlation with plant height ($r = 0.59^{*}$, $p < 0.01$) but was not significantly correlated with other agronomic traits, unlike crude protein. Both acid detergent fiber (ADF) and neutral detergent fiber (NDF) displayed moderate positive correlations with the dry matter percentage of biomass yield, with $r = 0.50^{*}$ ($p < 0.05$) and $r = 0.49^{*}$ ($p < 0.05$), respectively. A longer time to reach 50% tasseling was positively correlated with higher ADF content in silage ($r = 0.56^{*}$, $p < 0.01$). However, ADF showed a moderate negative correlation with leaf number ($r = -0.51^{*}$, $p < 0.05$). Additionally, ADF content increased moderately with higher NDF levels, as indicated by a Pearson correlation of $r = 0.58^{**}$ ($p < 0.01$).

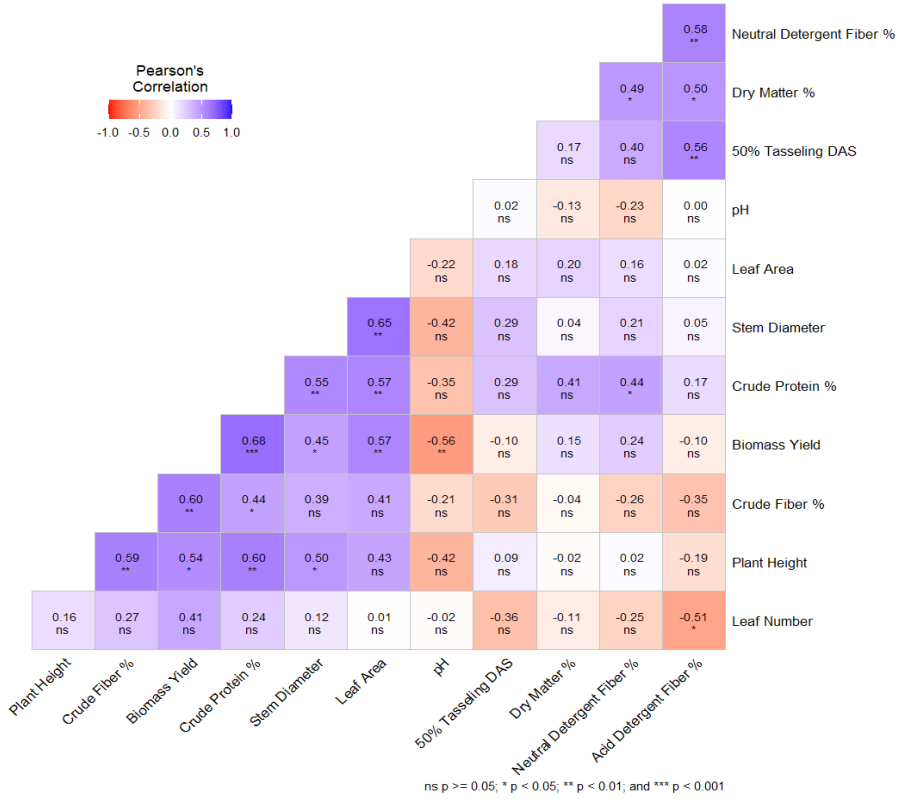

Figure 1: Correlation among silage quality and yield attributing characters

The moderate positive associations observed in herbage yield with other yield attributes and nutritional characteristics shows that the multiple agronomic traits improve the herbage yield. The highly positive correlation between herbage yield and crude protein (r =0.68, p <0.001) signifies that the protein content is one of the most important contributors to improving the overall yield, especially in the context of feeding livestock (Barker, 2021). Similarly, the fair correlations of leaf area and stem diameter, with herbage yield of (r =0.75) and p < 0.01 and r = 0.45 and p <0.05) shows that both of these morphological traits were highly influential on herbage yield because bigger leaf area and thick stems enhance photo synthetic capacity and structural support, thus increasing yields (Jones et al., 2018).Therefore agronomic characteristics could be some of the selection criteria that may be of value in the breeding programs for the nutritional quality of silage (Anderson et al., 2020). The moderate positive correlation between plant height and crude fiber in silage (r = 0.59, p < 0.01) further emphasizes the relationship between physical plant traits and nutritional content (Thompson et al., 2017). The moderate positive correlations that occurred between both ADF and NDF with dry matter suggests that as fiber content increases, the dry matter yield also tends to increase, which is essential in optimizing herbage quality and yield (Williams et al., 2022). The positive correlation between ADF and longer time to 50% tasseling (r = 0.56, p < 0.01) indicates that plants taking longer to mature may develop higher fiber content, as also observed by Lopez et al. (2016). In contrast, the negative correlation between ADF and leaf number (r = -0.51, p < 0.05) may indicate a trade-off between fiber accumulation and leaf proliferation, consistent with findings by Green et al. (2019). There

was also a positive relationship, though lower, between ADF and NDF, indicating that as one component increases in the plant, the others are bound to increase in the process, hence highly related, with $r = 0.58$ at $p < 0.01$, according to Johnson et al, (2023). Overall, these findings focus on the need to incorporate the agronomic and nutritional characteristics while selecting the maize variety for silage.

CONCLUSIONS

The availability of high-quality feed to meet the nutritional needs of livestock is a crucial for cost-effective and sustainable production. During the lean season, feed shortages and rising feed costs makes maize (Zea mays) silage production an effective strategy to bridge the gap between the supply and demand for green herbage. The study showed significant differences ($P < 0.05$) among the varieties for both agronomic and silage characteristics. MX-77 recorded the highest biomass production (25.76 MT/ha) and plant height (208.56 cm), comparable to Pioneer's biomass yield (24.29 MT/ha) and plant height (210.11 cm). MX-77 had the highest CP content (9.09%), followed by Pioneer (7.91 %). Rampur Hybrid-10 had the longest flowering period (84.67 days), while CP-666 had the shortest (72.66 days). Lab analysis revealed that ADF was highest for CP-838 (45.1 % ADF making it least digestible and Raj Kumar was the most digestible (30.71 % ADF) among all the varieties. Higher NDF levels, as seen in CP-666 (74.69 %) and CP-838 (69.94 %), are associated with reduced dry matter intake due to the increased cell wall content, which negatively impacts herbage quality. The study showed that among the seven varieties of maize MX-77 and Pioneer were the best varieties for silage from the perspective of herbage yield and nutrient content. These two varieties best suited in Lamjung condition however further research is needed to validate these results. This study provides valuable insights for farmers and animal nutritionists, helping them select the optimal maize variety for silage production. This will aid in promoting more sustainable and economically viable livestock farming, especially in regions experiencing seasonal feed shortages.

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7. Declaration of Conflict of Interest, Funding and Author's Contribution

The authors contributing authors declare that they do not have any type of conflicting interest regarding the manuscript.