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RESEARCH PAPER

Silage yield and quality of maize cultivars in central Gujarat conditions

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Abstract: A field experiment was conducted during *kharif* 2020 at the Fodder Demonstration Unit, National Dairy Development Board, Anand, Gujarat, to evaluate ten maize cultivars for fodder yield and silage quality using a randomized block design with three replications. Significant differences were observed among the cultivars for fodder yield, silage yield, and quality traits. The inter- cropping treatment of DMRH-1410 + fodder cowpea produced the highest green fodder yield (31.73 t ha^{-1}) and crude protein yield (0.81 t ha^{-1}), while hybrid P-3502 recorded the highest dry matter yield (10.30 t ha^{-1}), ether extract yield (0.24 t ha^{-1}) and silage yield (25.93 t ha^{-1}). Compared with the national check PMC-6, hybrid P-3502 produced 17.1% and 13.1% higher dry matter and silage yields, respectively. Silage pH ranged from 3.97 to 4.93, indicating satisfactory fermentation across the treatments. The DMRH-1410 + fodder cowpea treatment also recorded the highest crude protein content in fodder (11.34%) and silage (9.27%). Neutral detergent fibre and acid detergent fibre contents varied significantly among cultivars in both fodder and silage. Overall, P-3502 proved superior performance for dry matter and silage production, whereas inter-cropping of DMRH-1410 with fodder cowpea enhanced fodder yield and protein productivity. Public- and private-sector cultivars exhibited comparable overall performance for fodder and silage production.

Keywords: ADF • Hybrids • NDF • Silage • Quality

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Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in India and is widely utilized as food, feed, fodder, and industrial raw material. In recent years, maize has gained considerable importance as a fodder and silage crop due to its high biomass production, palatability, and suitability for silage preparation. The growing livestock population and increasing demand for quality feed have further enhanced the significance of maize in dairy-based farming systems. The livestock sector plays a crucial role in the Indian agricultural economy; however, fodder scarcity remains a major constraint to improving animal productivity. India faces an estimated deficit of approximately 23% in green fodder and 14% in dry fodder availability (Roy *et al*., 2019). Such shortages are particularly critical during periods when fresh green fodder is not readily available, highlighting the need for efficient fodder conservation strategies. Among the available conservation methods, silage preparation is one of the most effective methods for preserving green fodder, maintaining its nutritive value, and ensuring year-round availability of quality feed.

Maize is considered an ideal crop for silage because of its high green fodder yield, optimum dry matter content, and favorable fermentation characteristics. Pandey and Roy (2011) reported that maize is cultivated exclusively as a fodder crop on nearly 0.9 million hectares in India. Rakshit *et al*. (2021) further highlighted the growing importance of maize silage in reducing fodder deficits, improving livestock productivity, and enhancing dairy farm profitability. However, the yield and nutritional quality of maize silage are influenced by several factors, including genotype, crop management practices, environmental conditions, harvesting stage, and ensiling methods. Among these factors, cultivar selection plays a critical role in

determining fodder yield, dry matter production, nutrient composition, and silage quality. Significant variability among maize cultivars for fodder yield and ensiling traits has been reported by Singh *et al*. (2025), emphasizing the importance of identifying suitable genotypes for silage production. Likewise, Kumar *et al*. (2025) observed substantial variation in nutritional quality and silage potential among maize-derived fodder materials. In addition, Wadhwa *et al*. (2025) reported that sowing time significantly affects fodder yield and nutritive value before and after ensiling. Central Gujarat has a strong livestock sector with increasing demand for quality fodder; however, information on the comparative performance of different maize cultivars for fodder yield and silage quality under this region is limited. Therefore, the present study was undertaken to evaluate maize hybrids and composites for their growth performance, fodder yield, and ensiling quality under Central Gujarat conditions to identify suitable cultivars for silage production.

Materials and methods

The experiment was undertaken during *kharif* 2020 at fodder demonstration unit (FDU) of National Dairy Development Board, Anand (Gujarat) situated at 22° 33' N latitude and 72° 57' E longitude at an elevation of 41 meter above mean sea level. The soil of the experimental site was loamy in texture with EC (0.25dS/m), pH (7.67), organic carbon (0.44%), available phosphorus (58.07 kg ha^{-1}) and available potash (315.10 kg ha^{-1}). The soil contained DTPA-extractable Fe (7.28 ppm), Mn (18.84 ppm), Zn (4.65 ppm), available S (5.99 ppm) and Cu (1.46 ppm). During *kharif* 2020 season; crop was sown on 20th July, 2020 and harvested on 8th October, 2020. The weather parameters during *kharif* 2020 are depicted in Figure 1.

The experiment was conducted in a Randomized Block Design (RBD) with three replications comprising ten maize cultivars as treatments. The gross plot size for each treatment was 5.0 × 4.0 m, with a net harvested area of 11.4 m^2. The crop was sown at a seed rate of 20 kg ha^{-1} with a spacing of 60 × 25 cm. A fertilizer dose of 20 t FYM, 200 kg N, 75 kg P_2O_5 and 90 kg K_2O ha^{-1} was applied. The full quantity of FYM, phosphorus, potassium and one-third nitrogen were applied as basal dose, while the remaining nitrogen was applied in two equal splits at 30 and 45 DAS. Recommended agronomic practices, including irrigation, weed management and plant protection measures, were followed uniformly across treatments. Atrazine was applied as a pre-emergence herbicide at 0.75 kg a.i. ha^{-1}, followed by hand weeding and earthing-up at 25 DAS. The crop was harvested at 77 days after sowing for assessment of fodder yield and subsequent silage quality.

The treatments comprised five private-sector hybrids (P-1855, P-3502, DKC-9081, PAC-755 and TATA-901), two public-sector fodder composites [Shalimar Fodder Maize-1 (SFM-1) and Pratap Makka Chari-6 (PMC-6)], two public-sector hybrids (DMRH-1308 and DMRH-1410), and one inter-cropping treatment of DMRH-1410 + fodder cowpea (UPC-9202). The cultivars were evaluated against the national fodder maize check, PMC-6, for growth performance, fodder yield and silage quality traits.

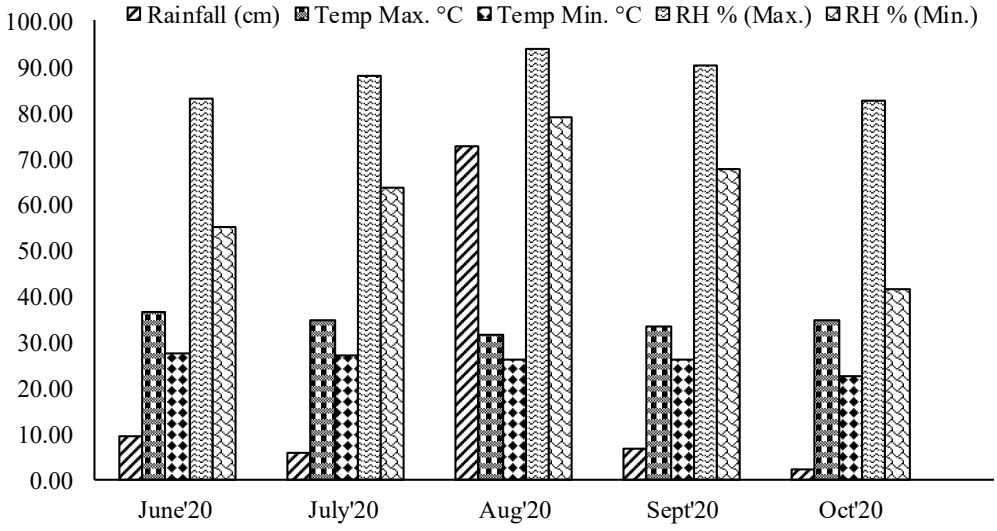


Figure 1. Weather parameters during *kharif* 2020 season

Plant population was recorded from two randomly selected sections of the net plot and expressed as plants m^{-1} row length. Growth parameters were recorded from six randomly selected plants from each plot. Green fodder yield, biomass yield and total soluble solids (°Brix) were recorded at harvest. For dry matter estimation, a 300 g representative fodder sample from each plot was collected and oven-dried at 75°C to constant weight, and then dry matter yield was calculated accordingly. For silage preparation, representative fodder samples from each treatment were chopped into 1–2 cm pieces and ensiled in airtight plastic containers (8 kg capacity) without addition of any additives, following the procedure described by Muck and Kung (2007). After 45 days of ensiling, silage samples were analyzed for pH, dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF) and acid detergent fibre (ADF). Silage pH was measured using a digital pH meter. Nitrogen and crude protein contents were estimated following ISO 5983-2 (2009), while proximate analysis was performed according to AOAC (2012). NDF and ADF contents were determined using the method of Van Soest *et al*. (1991). Total soluble solids were measured using a handheld refractometer and expressed as °Brix. Data recorded were pooled and subjected to analysis of variance (ANOVA) appropriate for a RBD. Treatment means were compared using the critical difference (CD) at the 5% level of significance, following the procedures described by Sheoran *et al*. (1998).

Results and discussion

Growth parameters

Significant differences were observed among the maize cultivars for growth parameters, including plant height, stem girth, plant population, number of leaves below and above the cob, leaf-to-stem ratio (L:S), and number of cobs per plant (Table 1). The fodder maize check, PMC-6, recorded greatest plant height (229.83 cm) which was significantly higher than the other cultivars. On average, the public-sector cultivars exhibited greater plant height

Table 1. Effect of cultivars on growth and development of maize crop

Treatments	Plant height (cm)	Stem Thick-ness (cm)	Plant Popula-tion (Lakh ha^{-1})	No. of Leaves below cobs $plant^{-1}$	No. of leaves above cob $plant^{-1}$	L:S	No. of cobs/ plant	Green cobs weight $plant^{-1}$ (kg)	Green leaves weight $plant^{-1}$ (kg)	Green stem $plant^{-1}$ (kg)
Private Sector Cultivars										
P-1855	161.90	4.33	0.55	4.39	5.96	0.51	1.00	0.20	0.06	0.13
P-3502	184.07	4.89	0.58	5.82	6.06	0.52	1.00	0.22	0.08	0.16
DKC-9081	158.00	4.61	0.56	3.72	6.34	0.61	1.00	0.18	0.06	0.10
PAC-755	176.67	5.17	0.42	5.28	5.39	0.38	1.00	0.25	0.07	0.19
TATA-901	178.80	4.94	0.50	5.00	5.56	0.50	1.00	0.20	0.07	0.15
Mean	171.89	4.79	0.52	4.84	5.86	0.50	1.00	0.21	0.07	0.15
Public Sector Cultivars										
DMRH-1308	156.57	5.06	0.49	5.22	5.56	0.42	1.00	0.15	0.06	0.15
DMRH-1410	182.03	4.78	0.55	6.39	5.33	0.56	1.00	0.16	0.07	0.13
SFM-1	211.50	5.22	0.46	5.89	5.89	0.46	1.00	0.21	0.09	0.21
PMC-6 (NC)	229.83	5.67	0.47	4.94	5.22	0.33	1.00	0.15	0.07	0.22
Mean	194.98	5.18	0.49	5.61	5.50	0.44	1.00	0.17	0.07	0.18
Mixed Cropping										
DMRH-1410 + Fodder Cowpea	150.93	4.28	0.17	4.55	4.67	0.22	0.67	0.20	0.04	0.19
S. Em ±	5.03	0.26	0.04	0.25	0.28	0.07	0.06	0.04	0.01	0.02
C. D. (P =0.05)	15.05	0.79	0.12	0.75	0.82	0.22	0.18	NS	NS	0.07
CV %	4.86	9.36	14.15	8.44	8.51	27.81	10.96	32.05	31.40	24.20

NC: National check, L:S- leaf to stem ratio

(186.17 cm) than the private-sector hybrids (171.89 cm). Among the evaluated entries, PMC-6 and SFM-1 were the only cultivars exceeding 200 cm in plant height. PMC-6 also recorded the highest stem girth (5.67 cm), which was significantly superior to several cultivars but remained at par with SFM-1 (5.22 cm), PAC-755 (5.17 cm), DMRH-1308 (5.06 cm), TATA-901 (4.94 cm) and P-3502 (4.89 cm). Plant population varied significantly among cultivars, with P-3502 recording the highest population compared to PAC-755, DMRH-1308 and DMRH-1410 + fodder cowpea.

DMRH-1410 (6.39), which was statistically at par with P-3502 and SFM-1, recorded a significantly higher number of leaves below the cob than the remaining cultivars. In contrast, DKC-9081 (6.34) produced a significantly higher number of leaves above the cob compared with PAC-755, DMRH-1410, PMC-6 and DMRH-1410 + fodder cowpea, but remained statistically similar to P-1855, P-3502, TATA-901, DMRH-1308 and SFM-1. The number of leaves above the cob is an important indicator of leafiness and photosynthetic potential of the crop. However, none of the evaluated cultivars exhibited the leafy-maize characteristic of having 10–12 leaves above the cob. Glenn (2013) reported that leafy maize cultivars generally produce greater whole-plant dry matter yields and are particularly suitable for silage production. The leaves above the cob contribute substantially to photosynthate production and starch accumulation in the grain.

The leaf-to-stem ratio was significantly higher in DKC-9081 (0.61) compared with PAC-755, PMC-6 and DMRH-1410 + fodder cowpea, but remained at par with the other cultivars. The number of green cobs per plant was approximately one in most cultivars and was significantly higher than that recorded in the DMRH-1410 + fodder cowpea treatment (0.67). Green stem weight per plant was significantly higher in PMC-6 (0.22 kg plant^{-1}) than in P-1855 and DKC-9081, while remaining statistically similar at par with the other cultivars. In contrast, differences among cultivars for green cob weight and green leaf weight were non-significant, with values ranging from 0.15–0.25 kg plant^{-1} and 0.04–0.09 kg plant^{-1}, respectively. Significant differences were also observed among cultivars for green fodder yield (GFY), dry matter yield (DMY), ether extract yield (EEY) and silage yield (SY) (Table 2), indicating considerable

Table 2. Effect of cultivars on yield (t ha^{-1}) of maize crop

Treatments	Green Fodder Yield (GFY)	Dry Matter Yield (DMY)	Crude Protein Yield (CPY)	Ether Extract Yield (EEY)	Silage Yield (SY)
Private Sector Cultivars					
P-1855	28.53	8.64	0.55	0.20	25.66
P-3502	29.51	10.30	0.56	0.24	25.93
DKC-9081	21.73	8.37	0.51	0.17	17.26
PAC-755	23.89	6.44	0.39	0.14	18.80
TATA-901	25.34	8.34	0.45	0.19	22.48
Mean	25.80	8.42	0.49	0.19	22.03
Public Sector Cultivars					
DMRH-1308	23.19	7.97	0.48	0.18	18.67
DMRH-1410	25.32	8.06	0.49	0.18	21.13
SFM-1	24.35	8.18	0.48	0.16	19.56
PMC-6 (NC)	28.99	8.54	0.51	0.16	22.54
Mean	25.46	8.19	0.49	0.17	20.48
Mixed Cropping					
DMRH-1410 + Fodder Cowpea	31.73	7.12	0.81	0.18	24.96
S. Em ±	1.18	0.44	0.04	0.01	2.89
C. D. (P =0.05)	3.54	1.32	0.12	0.04	2.04
CV %	7.81	9.28	13.35	13.44	16.29

NC: National Check

variability in fodder productivity and ensiling potential. Similar variability for fodder yield traits among maize cultivars has been reported by Singh *et al*. (2020).

The highest green fodder yield (31.73 t ha^{-1}) was recorded in the DMRH-1410 + fodder cowpea treatment, which was significantly superior to DKC-9081, PAC-755, TATA-901, DMRH-1308, DMRH-1410 and SFM-1, but remained at par with P-1855 (28.53 t ha^{-1}), P-3502 (29.51 t ha^{-1}) and PMC-6 (28.99 t ha^{-1}). The superior fodder yield in the inter-cropping system may be attributed to the complementary growth pattern and efficient utilization of available resources like light, water, nutrient and space by the maize and cowpea. Dry matter yield was significantly higher in P-3502 (10.30 t ha^{-1}) than in all other cultivars. Similarly, P-3502 recorded the highest ether extract yield (0.24 t ha^{-1}), which was statistically at par with P-1855 (0.20 t ha^{-1}) but significantly superior to the remaining cultivars. Silage yield was also highest in P-3502 (25.93 t ha^{-1}), which was significantly higher than that of most cultivars, although statistically comparable to P-1855 (25.66 t ha^{-1}) and DMRH-1410 + fodder cowpea (24.96 t ha^{-1}). Compared with the national check PMC-6, the private-sector hybrid P-3502 produced 17.09%, 33.33% and 13.07% higher dry matter yield, ether extract yield and silage yield, respectively. Likewise, cultivation of DMRH-1410 in association with fodder cowpea improved green fodder yield and silage yield by 20.20% and 15.34%, respectively, compared with sole DMRH-1410. Among the evaluated cultivars, PAC-755 recorded the lowest dry matter yield (6.44 t ha^{-1}) and ether extract yield (0.14 t ha^{-1}), whereas DKC-9081 produced the lowest green fodder yield (21.73 t ha^{-1}) and silage yield (17.26 t ha^{-1}). Overall, based on mean performance, public- and private-sector maize cultivars exhibited comparable productivity for fodder and silage production. The higher green fodder yield in the DMRH-1410 + fodder cowpea treatment may be attributed to the beneficial effects of legume inclusion and efficient resource utilization. Similar findings were reported by Mishra (2019), who recorded higher fresh forage yield under maize–cowpea intercropping (50.45 t ha^{-1}) compared with sole maize (48.76 t ha^{-1}) and sole cowpea (23.03 t ha^{-1}). The present findings therefore support the potential of maize–cowpea mixed cropping as an approach for increasing fresh fodder availability while maintaining satisfactory silage production.

Chemical composition

Significant differences among maize cultivars were observed for dry matter (DM) content of fodder, silage pH, crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF), and acid detergent fibre (ADF) contents in both fodder and silage (Table 3). Dry matter content is an important indicator of forage quality and plays a key role in determining animal intake and performance. Among the evaluated cultivars, DKC-9081 recorded the highest DM content (38.38%), which was statistically at par with P-3502 (34.77%) and DMRH-1308 (35.08%). In contrast, the lowest DM content was recorded in the DMRH-1410 + fodder cowpea treatment (22.34%). Similar genotypic variation for dry matter content in maize has been reported by Saleem *et al*. (2007). Hundal *et al*. (2020a) also reported significant variation in dry matter content of maize silage ranging from 29.45 to 35.44%.

Total soluble solids (TSS), expressed as °Brix, represent the concentration of soluble sugars available for fermentation during the ensiling process. Although differences among cultivars were non-significant, °Brix values ranged from 7.50 to 10.70%, indicating adequate fermentable sugars for silage production. Silage pH, a key indicator of fermentation quality and stability, differed significantly among the treatments. The lowest pH was recorded in PMC-6 (3.97), which was statistically at par with SFM-1 and P-1855 (4.00), DMRH-1410 (4.10), PAC-755 (4.13), and P-3502 (4.17). Silage pH values below 4.2 are generally considered indicative of excellent fermentation quality, whereas values between 4.2 and 4.5 are categorized as good quality silage. In the present study the silage pH values recorded for most of the treatment were largely within the desirable range of 3.7–4.2 for maize silage (Karsten *et al*., 2003; Kung *et al*., 2018). However, the DMRH-1410 + fodder cowpea treatment recorded the highest pH (4.93), indicating comparatively poorer fermentation quality. The higher pH in the mixed silage may be attributed to its lower dry matter content (22.34%), which could have favored undesirable clostridial fermentation. Similar observations were reported by Kung and Shaver (2001), who noted that legume-containing silages ensiled at less than 30% dry matter often exhibit higher pH and reduced fermentation quality.

Table 3. Effect of cultivars on chemical composition of maize

Treatments	Dry Matter Content (%)	°Brix	pH	Crude Protein (CP) %		Ether Extract (EE) %		Ash %		NDF %		ADF %	
				Fodder	Silage	Fodder	Silage	Fodder	Silage	Fodder	Silage	Fodder	Silage
Private Sector Cultivars													
P-1855	30.40	7.50	4.00	6.35	6.51	2.30	2.35	9.05	10.15	48.33	49.97	21.74	25.27
P-3502	34.77	8.17	4.17	5.49	6.10	2.35	2.40	9.85	9.20	54.05	48.98	23.87	24.38
DKC-9081	38.38	9.23	4.27	6.09	7.02	2.05	2.55	9.60	9.85	56.03	47.46	27.60	24.04
PAC-755	26.98	7.90	4.13	6.06	6.60	2.10	2.30	9.45	10.20	52.60	54.03	24.58	28.60
TATA-901	33.18	7.80	4.23	5.42	6.61	2.25	2.40	9.70	9.55	54.14	47.76	25.11	25.27
Mean	32.74	8.12	4.16	5.88	6.57	2.21	2.40	9.53	9.79	53.03	49.64	24.58	25.51
Public Sector Cultivars													
DMRH-1308	35.08	8.43	4.10	5.97	7.28	2.25	2.10	10.70	11.75	53.73	54.14	25.19	32.50
DMRH-1410	31.88	8.47	4.30	6.11	6.81	2.25	2.60	9.90	10.00	54.35	53.08	25.38	28.49
SFM-1	33.65	9.00	4.00	5.88	6.74	2.00	2.55	9.45	9.85	56.70	50.48	28.46	26.19
PMC-6 (NC)	29.32	10.70	3.97	5.92	6.67	1.85	2.15	9.40	10.65	55.42	53.91	28.91	27.87
Mean	32.48	9.15	4.09	5.97	6.88	2.09	2.35	9.86	10.56	55.05	52.90	26.99	28.76
Mixed Cropping													
DMRH-1410 + Fodder Cowpea	22.34	8.27	4.93	11.34	9.27	2.55	2.45	11.35	12.10	50.84	47.43	30.32	26.98
S. Em ±	1.57	0.6	0.31	0.41	0.25	0.09	0.15	0.30	0.35	0.69	1.36	0.96	0.98
C. D. (P =0.05)	4.69	NS	0.22	1.32	0.81	0.30	NS	0.96	1.15	2.25	4.40	3.12	3.19
CV %	8.59	12.05	8.86	8.91	5.06	5.90	8.76	4.23	4.85	1.83	3.78	5.19	5.16

NC: National Check

The DMRH-1410 + fodder cowpea treatment recorded significantly higher crude protein content in both fresh fodder (11.34%) and silage (9.27%) compared with the other cultivars. In contrast, the lowest crude protein content was observed in TATA-901 for fodder (5.42%) and in P-3502 for silage (6.10%). The reduction in crude protein content following ensiling may be attributed to protein degradation and conversion of true protein into non-protein nitrogen compounds during fermentation (Huber *et al*., 1980). Similar variation in crude protein content among maize cultivars has been reported by Basit *et al*. (2018), while Kussie *et al*. (2024) observed substantial improvement in forage crude protein content through maize–cowpea intercropping systems. Ether extract content in fodder was significantly higher in the DMRH-1410 + fodder cowpea treatment (2.55%) than in DKC-9081, PAC-755, and SFM-1, but remained statistically at par with the other cultivars. The lowest ether extract content was recorded in PMC-6 (1.85%). In silage, however, differences in ether extract content among cultivars were non-significant. Significant variation was also observed for ash content in both fodder and silage. The DMRH-1410 + fodder cowpea treatment, along with DMRH-1308, recorded the highest ash content in fodder (11.35%) and silage (12.10%), whereas the lowest values were observed in P-1855 for fodder (9.05%) and P-3502 for silage (9.20%).

Neutral detergent fibre (NDF), an important indicator of forage intake potential, differed significantly among cultivars. In fodder, SFM-1 recorded the highest NDF content (56.70%), which was statistically similar to DKC-9081 (56.03%) and PMC-6 (55.42%). In silage, DMRH-1308 recorded the highest NDF content (54.14%), although it remained at par with PAC-755, PMC-6, DMRH-1410, SFM-1, and P-1855. Acid detergent fibre (ADF), which is negatively associated with forage digestibility, also varied significantly among the treatments. In fodder, the DMRH-1410 + fodder cowpea treatment recorded the highest ADF content (30.32%), while in silage the highest ADF content was observed in DMRH-1308 (32.50%). The lowest ADF values were recorded in P-1855 for fodder (21.74%) and DKC-9081 for silage (24.04%). The observed variation in fibre fractions among cultivars indicates substantial differences in forage quality and digestibility. Similar ranges of NDF and ADF contents in maize fodder and silage have been reported by Singh *et al*. (2023), highlighting the influence of genotype on forage quality characteristics.

Conclusion

The study revealed significant differences among maize cultivars for fodder yield, silage yield, and quality traits under Central Gujarat conditions. The maize- cowpea Intercropping treatment (DMRH-1410 + fodder cowpea) proved superior for green fodder production, resulting in 20.20% higher green fodder yield and 15.34% higher silage yield than sole DMRH-1410, highlighting the potential of maize-cowpea association for enhancing fodder production. Among the sole maize cultivars, P-3502 emerged as the best performer, producing significantly higher dry matter and silage yields than the national fodder maize check PMC-6. Overall, P-3502, P-1855, PMC-6, TATA-901, and DMRH-1410 were identified as promising cultivars for silage production, owing to their high fodder productivity, superior silage yield, and desirable fermentation quality under Central Gujarat conditions.

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