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Optimizing varietal selection and cutting intervals for enhanced fodder productivity quality and energy content in multi-cut oats

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ABSTRACT

A field experiment was conducted during the rabi season of 2021–22 at ICAR–National Dairy Research Institute, Karnal, to assess the effects of oat (*Avena sativa* L.) varietal selection and cutting management on fodder yield, nutritional quality, and energy parameters. Four oat varieties (HFO-114, HFO-607, JHO-851, and Kent) were evaluated under four cutting schedules- single cut at 45, 55, and 65 days after sowing (DAS) and no cut—in a split-plot design with three replications. Varietal choice and cutting time significantly influenced green fodder yield (GFY), straw yield, and quality traits. Kent recorded highest GFY (24.37 t ha^{-1}), achieving a 13.9% increase over JHO-851, while HFO-114 produced maximum straw yield (82.85 t ha^{-1}), which was 27.9% higher than JHO-851. In contrast, JHO-851 exhibited superior fodder quality, with higher crude protein (CP) and ether extract (EE) contents and lower neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations. Early cutting at 45 DAS significantly improved dry matter intake (DMI), dry matter digestibility (DMD), and total digestible nutrients (TDN), whereas cutting at 65 DAS increased GFY and straw yield by 35.1% and 23.3%, respectively, over 45 DAS. Overall, JHO-851 harvested at 45 DAS is recommended for high-quality fodder production under irrigated rabi conditions, with applicability to regions having similar agro-climatic and management conditions.

Keywords: Cutting management, Energy content, Nutritional quality, Oat, Varietal selection

The optimization of animal nutrition is paramount to enhancing livestock productivity, health, and economic efficiency. Fodder quality plays a critical role in meeting the nutritional needs of ruminants, influencing growth rates, milk yield, and overall herd health. Among the various forage options, oats (*Avena sativa* L.) have gained prominence for their balanced nutritional profile, adaptability to diverse climates, and potential for multi-cut cultivation strategies (Bharti *et al.* 2021; Verma *et al*. 2023). The multifaceted benefits of oats include their rich crude protein (CP) content, digestible fiber, and high energy value, making them a vital component in sustainable animal feed programs (Chawla *et al*. 2023).

The selection of the appropriate oat variety is a pivotal aspect of maximizing both the yield and quality of fodder. Varieties differ significantly in their nutrient profiles, including CP content, fiber fractions, and digestibility metrics, which directly impact the feed's energy value and palatability (Redaelli and Berardo, 2007). Multi-cut management of oats offers substantial advantages, allowing multiple harvests within a single growing season, which ensures continuous availability of fresh fodder and improved land use efficiency (Bharti *et al*. 2021). This practice can boost cumulative yields and mitigate seasonal forage shortages, aligning with sustainable agriculture goals (Tiwana and Singh, 2012).

However, multi-cut practices pose challenges, particularly regarding the consistency of nutritional quality across different cuts. Early cuts typically offer higher nutrient content due to reduced lignification, whereas later cuts may have increased fiber and reduced digestibility (Chawla *et al*. 2023; Verma *et al*. 2023). Thus, understanding the interaction between the choice of variety and the timing of cuts is essential for optimizing fodder quality and energy values (Li *et al*. 2022).

The existing body of research has provided valuable insights into the influence of nitrogen levels, single versus double cut management, and other agronomic factors on oat yields and quality (Kumar *et al*. 2017). However, there is a notable lack of studies focusing on the combined

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effects of oat varietal differences and cutting schedules on key nutritional parameters such as dry matter intake (DMI), digestibility, total digestible nutrients (TDN), and energy values. Addressing this gap is essential to generate more refined, evidence-based recommendations for farmers seeking to optimize both fodder quantity and nutritive quality. Therefore, the present study was designed to evaluate the effect of different oat varieties on fodder yield and nutritional quality and assess the influence of cutting time on fodder productivity, fiber composition, and feed value indices to finally compare oat varieties and cutting schedules in determining digestibility, intake potential, and energy parameters.

It was hypothesized that early cutting would enhance fodder nutritive value and digestibility, whereas delayed cutting would increase structural biomass, and that varietal differences would significantly modulate these responses under a dual-purpose oat production system.

MATERIALS AND METHODS

The experiment was conducted at research farm, Agronomy Section, ICAR-National Dairy Research Institute, Karnal, Haryana, during rabi season of 2021. The area is located at 29º71'N latitude, 76º97' E longitude and at an altitude of 245 m above mean sea level (MSL). The soil texture of experimental site was clay loam in nature. The experimental soil had a slightly alkaline reaction with a pH of 7.65 ± 0.07, an electrical conductivity (EC) of 0.30 ± 0.04 dS m^{-1}, and an organic carbon content of 0.62 ± 0.04%. The soil was medium in available nutrients, containing 176.50 kg ha^{-1} nitrogen (N), 21.20 kg ha^{-1} phosphorus (P), and 184.40 kg ha^{-1} potassium (K).

The experiment was laid out in a split-plot design with three replications. The treatment comprised of four dual purpose oat varieties (V_1: HFO-114, V_2: HFO-607, V_3: JHO-851 and V_4: Kent) allocated the main-plots. The sub-plot treatments consisted of four cutting management practices namely C_0: control (no cutting was done and crop was harvested once the grain is matured; C_1: cut taken at 45 days after sowing (DAS), then left for grain production; C_2: cut taken at 55 DAS, then left for grain production and C_3: Cut taken at 65 DAS, then left for grain production. The seed rate was kept 80 kg ha^{-1} while the spacing was 30 cm for optimum fodder plant density. The crop was supplied with the recommended dose of fertilizers for fodder oat, comprising 150 kg ha^{-1} nitrogen (N), 60 kg ha^{-1} phosphorus

Table 1. Agronomic package and field operations followed during the experimental period

S. No.	Name of activity	Date	Remarks
1	Pre-sowing irrigation	16.10.2021	Irrigation applied prior to field preparation to ensure adequate soil moisture
2	Preparatory tillage	21.10.2021	Two passes of harrow and cultivator followed by planking and cross-harrowing to obtain a fine seedbed
3	Layout of experiment	21.10.2021	Preparation of plots, bunds, and irrigation channels
4	Initial soil sampling	21.10.2021	Soil samples collected from 0–15 cm depth in a zigzag pattern
5	Fertilizer application (basal)	22.10.2021	Basal application of full P and K and first split of N using SSP, MOP, and urea
6	Sowing of crop	22.10.2021	Oat varieties (Kent, HFO-114, HFO-607, JHO-851) sown @ 80 kg seed ha^{-1}
7	Herbicide application	23.10.2021	Pre-emergence application of pendimethalin @ 0.75 kg a.i. ha^{-1}
8	Irrigation (common)	09.11.2021	First irrigation at 15 days after sowing (DAS)
9	First observation	20.11.2021	Observations recorded at 30 DAS
10	Hand weeding	20.11.2021	One hand weeding to control early weed competition
11	Second irrigation (common)	26.11.2021	Irrigation at 35 DAS
12	Third irrigation (common)	21.12.2021	Irrigation at 60 DAS
13	Irrigation after 1st cut (45 DAS)	08.12.2021	Irrigation applied immediately after first cutting
14	Irrigation after 1st cut (55 DAS)	19.12.2021	Irrigation applied immediately after cutting
15	Irrigation after 1st cut (65 DAS)	28.12.2021	Irrigation applied immediately after cutting
16	Second observation and first cutting	07.12.2021	Observations, harvesting, and sampling at 45 DAS
17	Third observation and second cutting	18.12.2021	Observations, harvesting, and sampling at 55 DAS
18	Fourth observation and third cutting	27.12.2021	Observations, harvesting, and sampling at 65 DAS
19	Subsequent irrigations (common)	10.01.2022; 08.02.2022; 12.03.2022	Irrigations at later crop growth stages
20	Final observation and harvesting	16.04.2022	Final harvest and sampling from each plot
21	Threshing	20.04.2022	Straw samples collected from each plot

(P_2O_5), and 40 kg ha^{-1} potassium (K_2O), applied through urea, single superphosphate (SSP), and muriate of potash (MOP), respectively. Phosphorus and potassium were applied entirely as a basal dose at sowing. Nitrogen was applied in three split doses, with the first dose at sowing and the second dose at 30 DAS. The third nitrogen dose was applied immediately after cutting to promote rapid vegetative regeneration, except in the no-cut treatment (C_0), where the final nitrogen dose was applied at 60 DAS.

The field was made well tilth by two passes of harrow followed by planking and then pre-sowing irrigation was provided which ensured around 98% of seed germination. The subsequent irrigations were given at approximately 15 days interval. As a part of weed control measure; pendimethalin at the rate 0.75 kg a.i ha^{-1} was applied 2 days after sowing and one subsequent hand weeding was conducted at 30 DAS. No further herbicide or pesticide was applied to prevent their interference in fodder quality or residue coming to the fodder.

Fodder oat crop was harvested (as fodder and as straw at final harvest) as per the cutting schedule treatments from the net plot area eliminating two border rows to ensure lowest possible border effect. The detailed agronomic package and practices reported in this experiment has been reported in Table 1. The fresh samples collected from the field were dried in sun for 7 days followed by hot air oven at 65°C till constant by weight was achieved. The dried samples were then grounded by wiley mill and passed through one mm sieve for analysis of proximate compositions.

The crude protein (%) of sample was calculated by multiplying the N content with the factor 6.25. Ether extract (EE) was analyzed by Soxhlet's extraction apparatus (AOAC 2005). Total ash was determined by placing the sample in muffle furnace for ignition at 550°C for 2-3 h (AOAC, 2005). The acid insoluble ash (%) was estimated by treating the total ash with 25 mL of 10% HCl, boiling for 5-10 minutes, filtering through ashless filter paper, rinsing with hot distilled water, and then ashing the residue at 550°C in a muffle furnace for 1-2 hours (AOAC, 2005). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analyzed as described by Van Soest et al. (1991) and AOAC (2005), respectively.

The cellulose content (%) was determined by calculating the difference between the neutral detergent fiber (NDF) and acid detergent fiber (ADF) values, following the methods described by Van Soest et al. (1991) and AOAC (2005). Dry matter intake (DMI), digestible dry matter (DDM), total digestible nutrients (TDN), net energy for lactation (NEl), and relative feed value (RFV) were calculated according to the following equation (Horrocks and Vallentine, 1999) whereas, relative feed quality (RFQ) adapted from Undersander *et al*. (2010). Digestible energy (DE) was estimated using the equation mentioned by Fonnesbeck *et al*. (1984) while metabolizable energy (ME) was adapted from Gonzalez and Everitt, (1982).

Experimental data were statistically analyzed using a split-plot design ANOVA, followed by Tukey's HSD post-hoc test. The minimum significant difference (MSD) was determined at p = 0.05, following the methodology described by Gomez and Gomez (1984). The analyses were conducted using the 'doebioresearch' package in the R statistical software.

$$\text{Dry matter intake (DMI)} = \frac{120}{\text{NDF(\%)}} \quad ...(1)$$

$$\text{Dry matter digestibility (DMD)} = 88.9 – (0.779 \times \text{ADF\%}) \quad ...(2)$$

$$\text{Total digestible nutrients (TDN)} = (–1.291 \times \text{ADF\%}) + 101.35 \quad ...(3)$$

$$\text{Net energy for lactation (MJkg}^{-1}) = [1.044 – (0.0119 \times \text{ADF\%}) + 101.35 \times 4.184 \quad ...(4)$$

$$\text{Relative feed value (RFV)} = \frac{(\text{DMI} \times \text{DMD})}{1.29} \quad ...(5)$$

$$\text{Relative feed quality (RFQ)} = \frac{(\text{DMI} \times \text{DMD})}{1.23} \quad ...(6)$$

$$\text{Digestible energy (MJkg}^{-1})\text{(DE)} = 0.27 + [0.0428 \times \text{DMD(\%)}] \times 4.184 \quad ...(7)$$

$$\text{Metabolizable energy (MJkg}^{-1})\text{(ME)} = \text{DE(MJkg}^{-1}) \times 0.821 \quad ...(8)$$

RESULTS AND DISCUSSION:

Green fodder and straw yield: The green fodder yield (GFY) and straw yield and dry matter content (DM content) of oat were significantly affected by both the varietal difference and cutting management practices (Table 2).

Among the selected oat varieties, Kent exhibited highest GFY (24.37 t. ha^{-1}) and DM content (23.05%) while HFO-114 produced highest DFY (82.85 t ha^{-1}). In comparison to the lowest performing variety, JHO-851, which recorded 21.39 t. ha^{-1} GFY and 64.73 t. ha^{-1} DFY, Kent achieved a 13.9% higher GFY, while HFO-114 showed a 27.9% higher DFY.

The superiority of Kent in terms of GFY and DM content corroborates prior observations that late-maturing and high tillering varieties typically achieve substantial biomass yields due to extended vegetative growth periods. This aligns with the understanding that varieties with enhanced plant architecture, such as larger leaf area and robust tillering, contribute to higher yields (Pant *et al*., 2022). Conversely, HFO-114 recorded the maximum DFY, suggesting its robust capacity for dry matter accumulation, which is advantageous for silage or dry feed production. This trait indicates efficient biomass conversion, a key characteristic for feed use, particularly under multiple harvest conditions (A. Kumar *et al*., 2001). JHO-851, although recorded lower yields, has been noted for higher quality attributes, balancing yield and nutritional value (D. Singh & Chauhan, 2017).

Among the cutting management practices, cutting at 65 DAS recorded highest GFY (35.23 t ha^{-1}), Straw yield (76.95 t ha^{-1}) and DM content (22.62%). As compared to cutting at 45 DAS; the yield advantage in GFY and DFY was 35.1% and 23.3% respectively. Cutting at later stages

Table 2. Effect of different varieties and cutting management on green and straw yield and dry matter content of fodder oat

Treatments	Green Fodder Yield (t ha^{-1})	straw Yield (t ha^{-1})	Dry matter content (%)
		Varieties	
V_1: HFO-114	22.93±3.98^{ab}	82.85±1.79^{a}	20.87±0.74^{ab}
V_2: HFO-607	23.76±4.06^{a}	73.53±1.78^{ab}	21.34±0.67^{ab}
V_3: JHO-851	21.39±3.71^{b}	64.73±2.73^{bc}	19.5±0.51^{b}
V_4: Kent	24.37±4.16^{a}	56.47±3.21^{c}	23.05±0.60^{a}
CV	7.28	12.57	10.68
MSD	1.68	8.71	2.39
		Cutting Management	
C_0: No cut	0	68.54±3.48^{b}	
C_1: Cut at 45 DAS	26.07±0.71^{c}	70.88±3.47^{b}	19.87±0.58^{b}
C_2: Cut at 55 DAS	31.38±0.59^{b}	62.62±4.27^{c}	21.08±0.57^{ab}
C_3: Cut at 65 DAS	35.23±0.51^{a}	76.95±2.03^{a}	22.62±0.54^{a}
CV	5.79	9.92	9.06
MSD	1.68	5.80	1.62
		Varieties × Cutting management	
CV	5.24	3.28	9.06
MSD	NS	NS	4.47

yielded the maximum yield, indicating that extended vegetative growth allows plants to capitalize on their full growth potential before the first harvest due to longer period of photosynthesis and biomass accumulation (Tiwana & Singh, 2012).

The interaction between varieties and cutting management were non-significant in yield attributes which suggests that cutting practices exert a consistent influence across different varieties. This indicates that once the cutting practice is standardized, it can be kept constant for all the varieties — the similar outcome has also been reported by Ahmed *et al*., (2020).

Fodder quality attributes: The significant variation in CP, EE and TA content observed among different oat varieties and cutting management practices underscores the complexity of optimizing fodder quality (Table 3; Fig. 1). Amongst the varieties, JHO-851 recorded the highest CP (8.92 and 3.30%), EE (1.81 and 1.85%) and TA (9.15 and 8.59%) content in fodder and straw respectively. Comparing it with HFO-114 which recorded the lowest quality attributes; JHO-851 recorded 5.2 and 21.2% higher CP, 6.5 and15.6% higher EE, 5.1 and 7.6% higher TA in fodder and straw respectively. These findings align with studies that highlight the genetic potential of specific oat varieties for enhanced nutritive quality, where certain genotypes inherently produce higher CP and EE contents (Verma *et al*., 2023). The superior CP levels in JHO-851 can be attributed to its robust nitrogen utilization, which facilitates higher protein synthesis while higher EE content suggest favourable lipid profile in fodder contributing better energy density (Zakirullah *et al*. 2017).

The TA content is indicative of the mineral composition, crucial for maintaining animal health and metabolic processes (Kaur and Goyal, 2017). Among different cutting management practices; in case when cuts were taken before leaving for grain production, cutting at 45 DAS recorded maximum CP (12.50%) and EE (2.50%) while cutting at 65 DAS recorded highest TA content (12.16%) in the fodder at cutting stage (Table 3). Early cuts ensure the retention of high nutrient concentrations due to less lignification, which preserves protein and energy components (Tiwana & Singh, 2012). However, 65 DAS cuts recorded the highest TA (12.16%), emphasizing the accumulation of minerals as the plant matures (Bhilare and Josh, 2007).

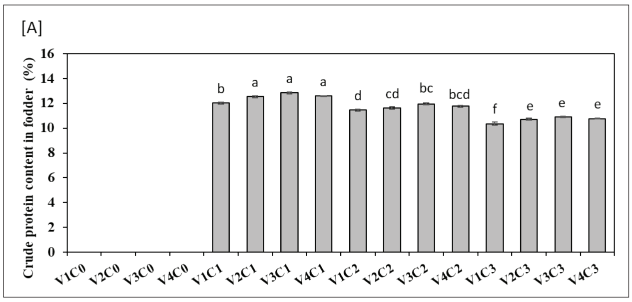
Post-harvest, straw analyses indicated that leaving crops for grain production without cutting resulted in maximum CP (3.09%) and TA (8.57%) contents, whereas EE was highest (1.94%) when one cut was taken at 65 DAS. This supports the idea that reduced cutting frequency can lead to more balanced nutrient retention in straw, improving its utility as secondary forage (Singh *et al*. 2020).

The significant interaction between varieties and cutting management observed for fodder quality but not for straw highlights the adaptive response of specific genotypes to management practices. JHO-851, cut at 45 DAS, recorded the highest CP (12.84%), showcasing its suitability for early cutting to maximize protein content. This result was closely followed by Kent (12.58%) and HFO-607 (12.54%) under the same cutting schedule. The highest TA (12.48%) was recorded with JHO-851 when cut at 65 DAS, suggesting that this combination is optimal for enhancing mineral content (Makarana *et al*. 2018).

Fiber fraction attributes: The significant variations in fiber fractions, including NDF, ADF, cellulose, and ADL,

Table 3. Effect of different varieties and cutting management on crude protein, ether extract, Total ash and acid insoluble contents of fodder oat

Treatments	Crude protein content (%)		Ether extract content (%)		Total ash content (%)	
	Fodder	Straw	Fodder	Straw	Fodder	Straw
Varieties						
V_1: HFO-114	8.46±1.42^C	2.60±0.04^c	1.70±0.29^b	1.60±0.05^c	8.71±1.45^b	7.98±0.10^c
V_2: HFO-607	8.72±1.47^b	2.92±0.07^b	1.75±0.29^{ab}	1.72±0.05^b	8.86±1.48b	8.25±0.10^b
V_3: JHO-851	8.92±1.50^a	3.30±0.06^a	1.81±0.30^a	1.85±0.06^a	9.15±1.53^a	8.59±0.09^a
V_4: Kent	8.77±1.47^{ab}	2.90±0.05^b	1.77±0.30^{ab}	1.69±0.05^{bc}	8.85±1.48^b	8.26±0.10^b
CV	1.39	3.93	3.30	4.73	1.74	1.49
MSD	0.17	0.16	0.08	0.11	0.21	0.17
Cutting management						
C_0: No Cut	0.00	3.09±0.07^a	0.00	1.48±0.03^d	0.00	8.57±0.06^a
C_1: Cut at 45 DAS	12.50±0.09^a	2.69±.0.08^c	2.50±0.02^a	1.63±0.03^c	11.59±0.06^c	7.83±0.10^c
C_2: Cut at 55 DAS	11.69±0.06^b	2.83±0.07^b	2.32±0.02^b	1.79±0.03^b	11.79±0.08^b	8.12±0.07^b
C_3: Cut at 65 DAS	10.69±0.07^c	3.08±0.08^a	2.20±0.03^c	1.94±0.04^a	12.16±0.07^a	8.54±0.06^a
CV	1.25	3.14	2.92	3.12	1.36	1.82
MSD	0.12	0.10	0.06	0.06	0.13	0.17
Varieties × Cutting management						
CV	1.25	3.14	2.92	3.12	1.36	1.82
MSD	0.34	NS	NS	NS	0.37	NS



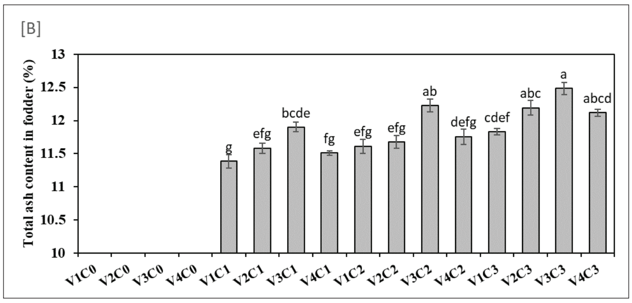


Fig. 1 Effect of interaction between different varieties and cutting management on crude protein content [A], and total ash content [B] in fodder oat

among different oat varieties and cutting management practices reflect the intricate balance between maximizing yield and maintaining fodder quality. The variety HFO-114 recorded the highest fiber content across NDF (42.83% in fodder, 69.38% in straw), ADF (26.45% in fodder, 43.57% in straw), and cellulose (23.11% in fodder, 29.68% in straw) (Table 4). These findings align with research emphasizing that genotypic variation significantly impacts fiber accumulation, as earlier shown by Redaelli and Berardo (2007), who had highlighted how cultivars differ in their fiber content due to genetic predispositions.

Conversely, JHO-851 exhibited the lowest levels of NDF, ADF, and cellulose, demonstrating its potential as a high-digestibility variety suitable for enhancing forage quality. Lower ADL content in JHO-851 suggested reduced lignification, which supports better digestibility and energy extarction and aligns with findings that emphasize the advantages of reduced lignin for improved fodder use (Kaur and Goyal, 2017).

The timing of cutting significantly influenced fiber content, with the maximum values for NDF (59.50%), ADF (36.11%), ADL (4.92%), and cellulose (31.19%) recorded at 65 DAS (table 4). This outcome is consistent with findings from studies that indicate 65 DAS harvest led to increased fiber content due to greater lignification as plants mature (Verma *et al.* 2023). Earlier cuts at 45 DAS resulted in lower fiber metrics (NDF at 51.93%, ADF at 32.42%, ADL at 3.74%, and cellulose at 28.68%), showcasing how early harvesting stages can minimize fiber buildup and boost digestibility.

The cutting management also influenced the fiber fractions with the highest NDF (7.28%), ADF (44.63%), ADL (14.26%), and cellulose (30.37%) found in the 45 DAS cut before grain harvest. This suggests that intermediate cutting stages can retain useful fiber components, enhancing the value of straw as a secondary feed source (Kumar *et al.* 2001).

Table 4. Effect of different varieties and cutting management on neutral detergent fiber, acid detergent fiber, acid detergent lignin and cellulose content of fodder oat

Treatments	Neutral detergent fiber (%)		Acid detergent fiber (%)		Acid detergent lignin (%)		Cellulose content (%)	
	Fodder	Straw	Fodder	Straw	Fodder	Straw	Fodder	Straw
Varieties								
V_1: HFO-114	42.83±7.2[a]	69.38±0.76[a]	26.45±4.44[a]	43.57±0.55[a]	3.34±0.57[a]	13.89±0.13	23.11±3.87[a]	29.68±0.47[a]
V_2: HFO-607	42.46±7.13[a]	67.63±0.82[a]	26.21±4.39[a]	41.43±0.74[ab]	3.21±0.55[b]	13.80±0.11	23.00±3.85[a]	27.64±0.64[ab]
V_3: JHO-851	40.02±6.70[b]	61.47±0.65[b]	24.97±4.17[b]	40.56±0.84[b]	3.08±0.53[b]	13.59±0.11	21.88±3.66[b]	26.97±0.81[b]
V_4: Kent	42.08±7.06[ab]	68.65±0.79[a]	25.93±4.35[a]	42.62±0.56[ab]	3.26±0.56[ab]	13.86±0.11	22.67±3.80[ab]	28.76±0.48[ab]
CV	3.66	2.79	1.87	4.25	2.55	1.85	3.31	5.94
MSD	2.16	2.63	0.68	2.52	0.11	NS	1.06	2.37
Cutting management								
C_0: No Cut	0.00	64.47±0.77[c]	0.00	40.38±0.55[b]	0.00	13.34±0.04[c]	0.00	27.03±0.55[b]
C_1: Cut at 45 DAS	51.93±0.46[c]	70.28±1.12[a]	32.42±0.16[c]	44.63±0.43[a]	3.74±0.04[c]	14.26±0.10[a]	28.68±0.15[b]	30.37±0.38[a]
C_2: Cut at 55 DAS	56.10±0.52[b]	67.64±0.98[b]	35.11±0.35[b]	42.81±0.40[a]	4.25±0.03[b]	13.98±0.04[b]	30.85±0.34[a]	28.91±0.43[ab]
C_3: Cut at 65 DAS	59.50±0.65[a]	64.83±0.9[c]	36.11±0.42[a]	40.52±0.81[b]	4.92±0.06[a]	13.56±0.05[c]	31.19±0.37[a]	26.96±0.80[b]
CV	2.25	1.72	3.07	4.42	2.04	1.49	3.12	6.79
MSD	1.06	1.29	0.89	2.09	0.07	0.23	0.79	2.16
Varieties × Cutting management								
CV	2.25	1.72	3.07	4.42	2.04	1.49	3.12	6.79
MSD	0.93	NS	2.47	NS	0.20	NS	2.19	NS

The significant interaction between oat varieties and cutting management practices observed for fodder, but not for straw, indicates that varietal response varies depending on the timing of the harvest (Figure 2). HFO-114 cut at 65 DAS displayed the highest fiber contents, supporting findings that late cutting enhances structural fiber components which suggests adjustment in cutting schedules according to variety specific traits in order to optimize fodder quality (Tiwana and Singh, 2012).

Intake, digestibility and feed quality:

The dry matter intake (DMI), dry matter digestibility (DMD), and total digestible nutrients (TDN) of fodder and straw were significantly affected by both variety and cutting management (Table 5; Figure. 3).

Among the varieties, JHO-851 recorded the maximum DMI (1.69 and 1.95 %) and TDN (43.78 and 48.99%) in fodder and straw as well as highest DMD (57.31%) in straw whereas in fodder the DMD content was non-significant.

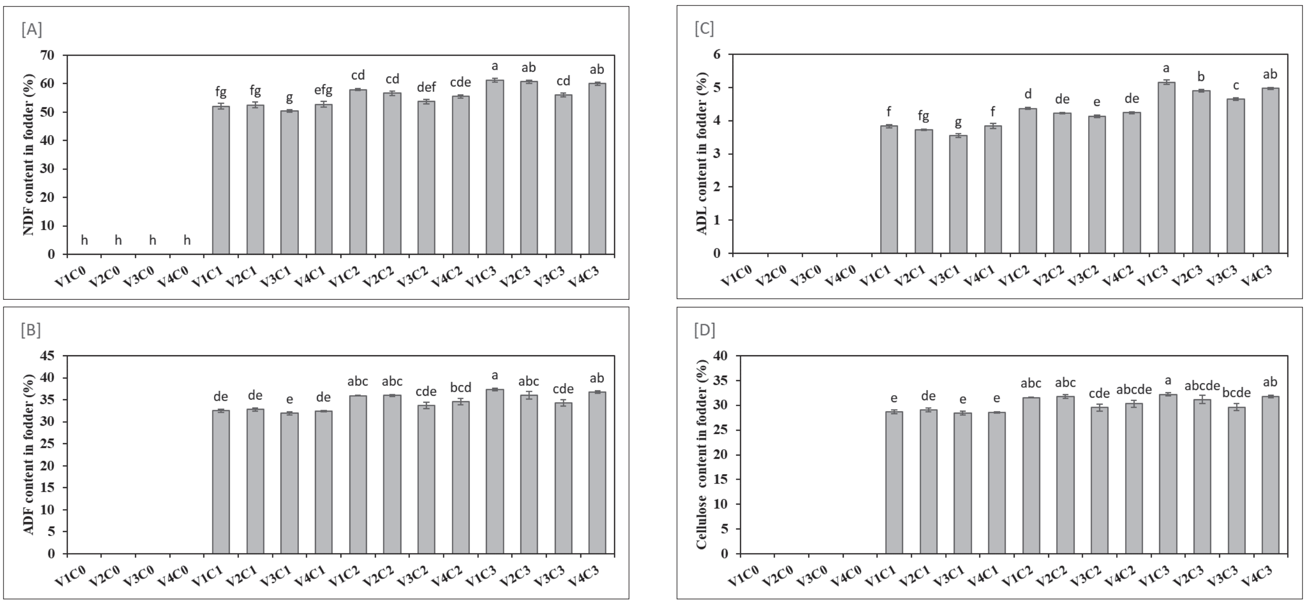


Fig. 2 Effect of interaction between different varieties and cutting management on NDF content [A], ADF content [B] and ADL content [c] in fodder oat

Table 5. Effect of different varieties and cutting management on dry matter intake, dry matter digestibility and total digestible nutrient content of fodder oat

Treatments	DMI (%)		DMD (%)		TDN (%)	
	Fodder	Straw	Fodder	Straw	Fodder	Straw
			Varieties			
V_1: HFO-114	1.58±0.27^{b}	1.73±0.02^{b}	46.00±7.68	54.96±0.43^{b}	41.87±7.01^{b}	45.11±0.70^{b}
V_2: HFO-607	1.60±0.27^{b}	1.78±0.02^{b}	46.27±7.72	56.62±0.58^{ab}	42.09±7.03^{b}	47.86±0.96^{ab}
V_3: JHO-851	1.69±0.28^{a}	1.95±0.02^{a}	47.15±7.86	57.31±0.66^{a}	43.78±7.31^{a}	48.99±1.09^{a}
V_4: Kent	1.61±0.27^{ab}	1.75±0.02^{b}	46.40±7.74	55.70±0.43^{ab}	42.53±7.11^{ab}	46.33±0.72^{ab}
CV	3.66	2.82	1.76	2.47	2.55	4.90
MSD	0.08	0.07	NS	1.96	1.53	3.26
			Cutting management			
C_0: No Cut	0.00	1.86±0.02^{a}	0.00	57.45±0.43^{a}	0.00	49.23±0.71^{a}
C_1: Cut at 45 DAS	2.31±0.02^{a}	1.71±0.02^{c}	63.55±0.20^{a}	54.13±0.34^{b}	59.42±0.31^{a}	43.73±0.56^{b}
C_2: Cut at 55 DAS	2.14±0.02^{b}	1.78±0.03^{b}	61.45±0.29^{b}	55.55±0.31^{b}	56.18±0.43^{b}	46.09±0.52^{b}
C_3: Cut at 65 DAS	2.02±0.02^{c}	1.86±0.03^{a}	60.75±0.40^{b}	57.34±0.63^{a}	54.65±0.56^{c}	49.04±1.05^{a}
CV	2.41	1.83	1.75	2.58	2.52	5.10
MSD	0.04	0.03	0.91	1.63	1.20	2.70
			Varieties × Cutting management			
CV	2.41	1.83	1.75	2.58	2.52	5.10
MSD	0.12	NS	NS	NS	3.33	NS

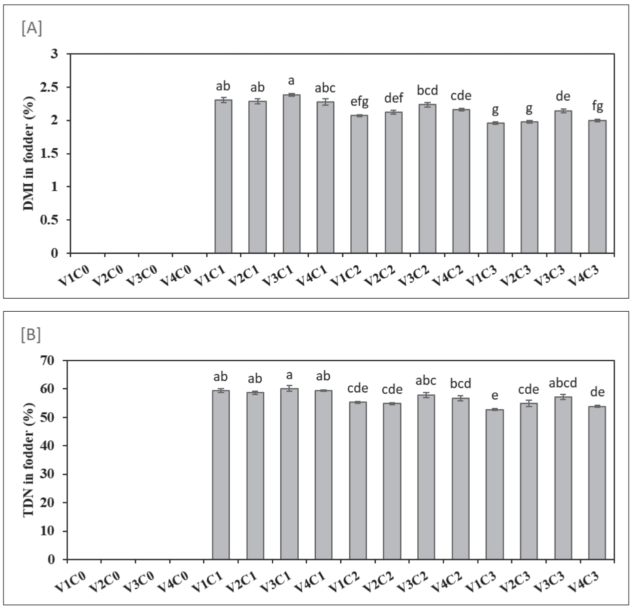


Fig. 3. Effect of interaction between different varieties and cutting management on dry matter intake (DMI) [A] and total digestible nutrient content [B] in fodder oat

These outcomes align with earlier research that identifies certain oat varieties as better suited for higher digestibility and nutrient intake due to their reduced fiber content and higher nutrient availability (S. Singh *et al*., 2019). Conversely, HFO-114, which recorded the lowest DMI, DMD, and TDN, may exhibit structural or compositional traits that reduce its digestibility. This reflects observations where high-fiber content oats, despite higher yields, are associated with reduced feed efficiency (Bhilare & Josh, 2007). JHO-851 consistently displayed superior energy values, including the highest NEL, RFV, and RFQ in both fodder and straw. Cutting at 45 DAS maximized these energy metrics, aligning with studies that associate early harvest with increased metabolizable energy and digestible nutrient content (S. Singh *et al*. 2019).

Cutting at 45 DAS significantly improved fodder quality, with the highest DMI (2.31%), DMD (63.55%), and TDN (59.42%). Early cutting maintains higher protein content and minimizes lignin development, enhancing digestibility and energy intake (Tiwana & Singh, 2012). In straw, leaving the crop uncut until grain harvest preserved maximum DMI (1.89%), DMD (57.45%), and TDN (49.23%).

The cutting practice also influenced the energy measures significantly; for instance, in straw, leaving the crop uncut maximized energy retention with notable NEL (1.24 MJ kg^{-1}), DE (2.73 MJ kg^{-1}), and ME (2.24 MJ kg^{-1}) values (Table 6 and Figure 4). The significant interactions between JHO-851 and cutting at 45 DAS for DMI and TDN highlight the optimized combination for superior feed quality. This variety, combined with early cutting, recorded the highest NEL (0.86 MJ kg^{-1}), RFV (118.12), and RFQ (116.52), surpassing other combinations and demonstrating its ideal adaptation for high-energy and digestibility yields (Verma *et al*. 2023).

Overall, the study clearly demonstrated that both oat varietal selection and cutting management exert a strong and interactive influence on fodder yield, nutritional

Table 6. Effect of different varieties and cutting management on Net energy of lactation, relative feed value, relative feed quality, digestible energy and metabolizable energy content of fodder oat

Treatments	NEL		RFV		RFQ		DE		ME	
	Fodder	Straw	Fodder	Straw	Fodder	Straw	Fodder	Straw	Fodder	Straw
Varieties										
V_1: HFO-114	0.37 ± 0.08^{b}	1.16 ± 0.01^{b}	75.41 ± 12.80^{b}	73.85 ± 1.34^{b}	72.11 ± 12.35^{b}	63.64 ± 1.65^{b}	2.17±0.36	2.62 ± 0.02^{b}	1.78±0.30	2.15 ± 0.01^{b}
V_2: HFO-607	0.40 ± 0.08^{b}	1.21 ± 0.02^{ab}	76.35 ± 12.89^{b}	78.12 ± 1.71^{b}	72.94 ± 12.37^{b}	69.36 ± 2.19^{b}	2.18±0.36	2.69 ± 0.02^{ab}	1.79±0.27	2.21 ± 0.02^{ab}
V_3: JHO-851	0.54 ± 0.10^{a}	1.24 ± 0.02^{a}	82.41 ± 13.83^{a}	86.88 ± 1.64^{a}	80.32 ± 13.53^{a}	77.96 ± 2.27^{a}	2.22±0.37	2.72 ± 0.03^{a}	1.82±0.21	2.24 ± 0.02^{a}
V_4: Kent	0.43 ± 0.09^{ab}	1.18 ± 0.01^{ab}	77.25 ± 13.04^{b}	75.65 ± 1.38^{b}	74.35 ± 12.62^{b}	66.06 ± 1.68^{b}	2.19±0.37	2.65 ± 0.02^{ab}	1.80±0.32	2.18 ± 0.02^{ab}
CV	22.03	3.91	3.13	5.00	5.09	7.45	1.60	2.22	1.60	2.22
MSD	0.13	0.06	3.44	5.55	5.39	7.29	NS	0.08	NS	0.06
Cutting management										
C_0: No Cut	0.00	1.24 ± 0.01^{a}	0.00	83.04 ± 1.32^{a}	0.00	74.66 ± 1.59^{a}	0.00	2.73 ± 0.02^{a}	0.00	2.24 ± 0.01^{a}
C_1: Cut at 45 DAS	0.81 ± 0.02^{a}	1.13 ± 0.01^{b}	113.91 ± 1.11^{a}	71.95 ± 1.68^{c}	111.72 ± 1.09^{a}	61.04 ± 1.85^{c}	2.99 ± 0.01^{a}	2.59 ± 0.01^{b}	2.45 ± 0.01^{a}	2.12 ± 0.02^{b}
C_2: Cut at 55 DAS	0.51 ± 0.04^{b}	1.18 ± 0.01^{b}	102.02 ± 1.37^{b}	76.65 ± 1.55^{b}	97.87 ± 1.59^{b}	66.76 ± 1.71^{b}	2.90 ± 0.04^{b}	2.65 ± 0.01^{b}	$2.38\pm0.0.02^{b}$	2.17 ± 0.02^{b}
C_3: Cut at 65 DAS	0.40 ± 0.05^{c}	1.24 ± 0.02^{a}	95.14 ± 1.49^{c}	82.56 ± 1.92^{a}	89.83 ± 1.82^{c}	74.15 ± 2.45^{a}	2.87 ± 0.02^{b}	2.72 ± 0.03^{a}	2.36 ± 0.02^{b}	2.24 ± 0.04^{a}
CV	19.28	4.07	3.07	3.55	3.41	6.09	1.59	2.32	1.59	2.32
MSD	0.09	0.05	2.69	3.15	2.87	4.75	0.03	0.06	0.03	0.05
Varieties × Cutting management										
CV	19.28	4.07	3.07	3.55	3.41	6.09	1.59	2.32	1.59	2.32
MSD	0.25	NS	7.42	NS	7.94	NS	NS	NS	NS	NS

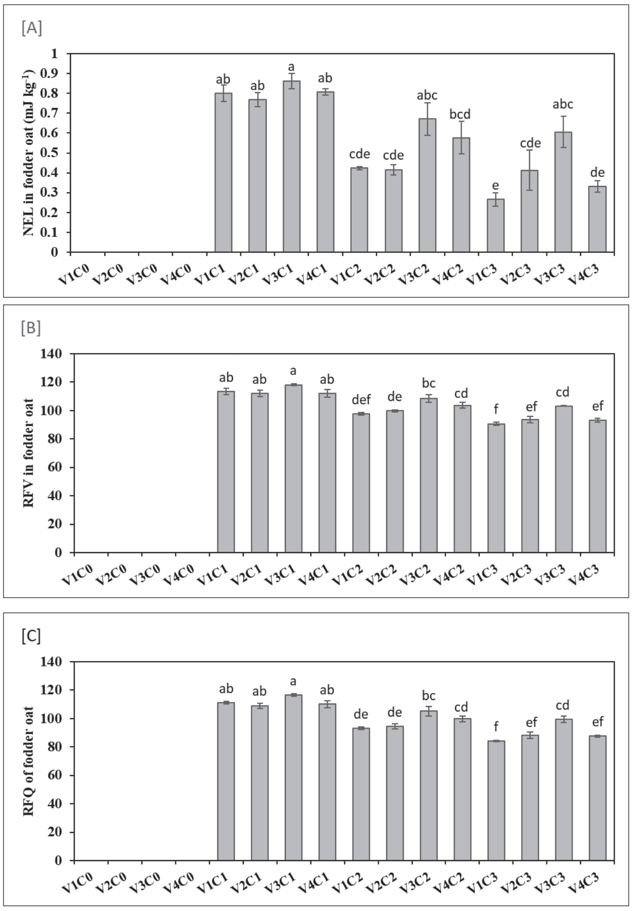


Fig. 4 Effect of interaction between different varieties and cutting management on net energy of lactation (NEL) [A], relative feed value (RFV)[B] and relative feed quality (RFQ)[C] in fodder Oat

composition, and energy-related feed value parameters. Among the tested combinations, JHO-851 harvested at 45 days after sowing (DAS) consistently recorded higher crude protein content, improved digestibility, and superior energy indices, indicating a favorable balance between biomass quality and intake potential. This combination is therefore well suited for high-quality fodder production aimed at improving animal nutrition and feed efficiency, and may be confidently recommended to farmers under irrigated rabi conditions. The findings are expected to be applicable to regions with comparable agro-climatic conditions, soil fertility status, and management practices, though validation under rainfed or stress-prone environments is warranted.

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