Turkish Journal of Agriculture - Food Science and Technology, 14(7): 1992-1998, 2026
DOI: https://doi.org/10.24925/turjaf.v14i7.1992-1998.8903

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effects of Organomineral and Chemical Fertilizers on Forage Quality of Wheat Hay

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ARTICLE INFO

Research Article

Received : 14.03.2026
Accepted : 06.04.2026

Keywords:

Wheat hay
Organomineral fertilizer
Chemical fertilizer
Crude protein
NDF

ABSTRACT

Sustainable fertilization is critical for modern agriculture. While wheat grain production is well-studied, the quality of wheat hay-a vital livestock feed-is often overlooked. Organomineral fertilizers (OMFs) are proposed as a sustainable alternative to conventional chemical fertilizers, but their comprehensive impact on hay quality is not well understood. This study aimed to investigate the trade-offs in wheat hay quality resulting from different organomineral and chemical fertilization strategies. A field experiment was conducted using a randomized complete block design with a factorial arrangement. Treatments included four fertilizer types (two chemical: 20-20-0, 15-15-15; and two organomineral: (16-15-0-OM, 12-15-5-OM) and three nitrogen (N) doses (0, 160, and 240 kg ha^{-1}). A comprehensive analysis of wheat hay was performed, including crude protein (CP), neutral and acid detergent fiber (NDF, ADF), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), and energy content (SE, ME). The results revealed a significant trade-off between protein content and forage digestibility. The organomineral fertilizer (12-15-5-OM) produced hay with the highest CP content (up to 8.10%), an effect that was significantly enhanced at the highest N dose. Conversely, the balanced chemical fertilizer (15-15-15) yielded the highest overall forage quality, characterized by the lowest NDF and ADF content, and consequently the highest RFV and metabolizable energy. Increasing N application consistently increased hay CP but decreased its digestibility and energy value across all fertilizer types. We conclude that the optimal fertilizer strategy for wheat is goal-dependent. OMFs are superior for maximizing the protein content of hay, making it a valuable protein supplement. In contrast, balanced chemical fertilizers are more effective for producing highly digestible, energy-rich forage. These findings highlight the necessity of a tailored, objective-driven approach to nutrient management in integrated crop-livestock systems.

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Introduction

Global population growth necessitates a continuous increase in food production, placing immense pressure on agricultural systems worldwide. Wheat (*Triticum aestivum* L.) is a cornerstone of global food security, providing a significant portion of the daily caloric and protein intake for billions of people (Chachar et al., 2024). The agricultural intensification practices of the last century, largely dependent on the extensive use of synthetic chemical fertilizers, have been instrumental in meeting the rising demand for wheat (Sekhon, 2014). These fertilizers provide essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) in readily available forms, leading to substantial increases in crop yields (Trenkel, 2010; Asadu et al., 2020).

However, the long-term and often injudicious application of chemical fertilizers has raised significant environmental and agronomic concerns (Tilman et al., 2002; Chen et al., 2018; Kumar et al., 2019). These include the contamination of ground and surface waters through nitrate leaching and phosphate runoff, increased greenhouse gas emissions, and a decline in soil health due to the depletion of soil organic matter (SOM) (Tilman et al., 2002; Büyük et al., 2016; Chen et al., 2018; Pahalvi et al., 2021). In many agricultural regions, including Turkey, a significant percentage of soils are characterized by low SOM content, high pH, and high lime content (Eyüpoğlu, 1999; Saltalı et al., 2024). Under these conditions, the efficiency of applied chemical fertilizers is significantly reduced; nitrogen is lost to the atmosphere via

volatilization, and phosphorus is rapidly fixed into forms unavailable to plants (Yurdakul and Usta, 2023; Saltalı ve Nedirli, 2021). This not only represents an economic loss for the farmer but also exacerbates the environmental burden of agriculture. In addition to its role as a staple grain, wheat also serves as a valuable alternative forage crop, particularly under rainfed and semi-arid conditions where traditional forage resources are limited. The cultivation of wheat for green forage contributes significantly to livestock feeding programs, providing an early-season source of high-quality herbage with considerable protein and digestible fiber content. As global and regional feed deficits continue to challenge mixed crop-livestock systems, the use of wheat as a dual-purpose crop-harvested both for forage and grain-has gained increasing importance. Thus, improving the yield and nutritive quality of wheat forage, alongside grain production, represents a strategic pathway toward more resilient and efficient agricultural systems.

To address these challenges, sustainable agricultural practices that enhance nutrient use efficiency while preserving soil health are urgently needed. In this context, organomineral fertilizers (OMFs) have emerged as a promising alternative. OMFs are produced by combining mineral nutrients with organic materials, such as leonardite, biochar, compost, or animal manure (de Morais et al., 2023; Llovet et al., 2023). This combination offers a dual benefit: providing essential nutrients for plant growth while simultaneously replenishing soil organic matter (Chojnacka and Baltrusaitis, 2025). The organic component in OMFs can improve soil physical, chemical, and biological properties. Furthermore, the humic substances within the organic matrix can chelate mineral nutrients, protecting them from fixation and leaching, and facilitating a slow, sustained release that better matches the crop's nutrient uptake pattern (Melito et al., 2023; Cotta et al., 2023).

Previous studies have demonstrated the potential of OMFs to improve crop performance (Erdal, 2018; Badiane et al., 2023). For instance, research on wheat has shown that OMF applications can lead to higher grain yield and protein content compared to conventional chemical fertilizers alone (Tejada et al., 2005; Çelebi and Ağırağaç, 2022; Bilir et al., 2024; Vedat et al., 2024). These benefits are often attributed to the improved nutrient availability and enhanced soil conditions fostered by the organic component.

Despite these findings, a significant knowledge gap remains regarding the comprehensive effects of OMFs on the overall quality of the wheat plant, particularly the hay, which is a critical feed resource for livestock in many farming systems. Forage quality is determined by factors such as protein content, fiber components (NDF and ADF), digestibility, and energy content (Metabolic and Digestible Energy). While increasing grain yield and protein is a primary goal, optimizing the nutritional value of the crop residue can provide significant added value for integrated crop-livestock systems. It is currently unclear whether a trade-off exists between maximizing grain-focused parameters and enhancing forage quality, and how the choice of fertilizer type-organomineral versus chemical-influences this relationship.

Therefore, the objective of this study was to conduct a comprehensive comparison of the effects of two different chemical fertilizers and two organomineral fertilizers, applied at three different nitrogen rates, on wheat. The study aimed to evaluate not only grain yield and quality (protein content) but also the detailed forage quality parameters of the wheat hay, including crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), and energy values (SE, ME).

Materials and Methods

Site Description, Soil Properties, and Climate

The field experiment was conducted at the experimental farm of the Faculty of Agriculture, Kahramanmaraş Sütçü İmam University, during the 2018-2019 wheat growing season (Figure 1). The experimental area is in a region with a typical Mediterranean climate, characterized by hot, dry summers, cool and rainy winters. Climatic data for the growing season, including monthly average temperature (°C) and total precipitation (mm), were recorded from a meteorological station adjacent to the experimental site (Table 1). Before the experiment, composite soil samples were collected from the experimental area at a depth of 0-30 cm for the determination of physicochemical properties. The soil was characterized as clayey in texture, with a slightly alkaline pH (7.62), low in organic matter content (%1.8), less calcareous $CaCO_3$ (%2.1), and having insufficient levels of available phosphorus (P; 8.3 ppm) and Zinc (Zn; 0.45 ppm) (Bilir et al., 2024).

Experimental Design and Treatments

The experiment was laid out as a randomized complete block design (RCBD) with a factorial arrangement of treatments, replicated three times. The two factors were:

1. Fertilizer Type (Factor A): Four different fertilizer types were used.

   F1 (Chemical): 20-20-0
   F2 (Chemical): 15-15-15
   F3 (Organomineral): 16-15-0 + % 15 Organic Matter (OM)
   F4 (Organomineral): 12-15-5 + % 15 Organic Matter (OM)

2. Nitrogen Dose (Factor B): Three different nitrogen (N) application rates were tested.
3.

   N1: 0 kg N ha^{-1} (Control)
   N2: 160 kg N ha^{-1} (16 kg N da^{-1})
   N3: 240 kg N ha^{-1} (24 kg N da^{-1})

The combination of these factors resulted in 12 treatments per block. The total number of experimental plots was 36. Each plot had dimensions of 5 m × 1.2 m = 6 m^2.

Each plot consisted of 6 rows with 20 cm row spacing and a 5 m row length. At harvest, 0,5 m from the top and bottom of each plot, and the side rows, were excluded as borders. The remaining central 3.2 m^2 area was manually harvested for analysis.

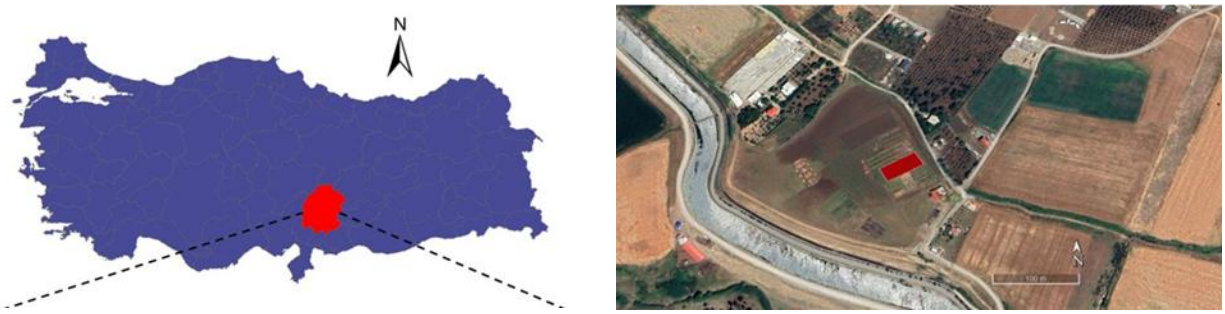

Figure 1. Representation of the research area on Google Earth

Table 1. Monthly Mean Temperature, Total Precipitation, and Relative Humidity in Kahramanmaraş (2018-2019 and Long-term Average)

Months	Temperature (°C) (2018-2019)	Temperature (°C) (Long-term)	Precipitation (mm) (2018-2019)	Precipitation (mm) (Long-term)	Relative Humidity (%) (2018-2019)	Relative Humidity (%) (Long-term)
November	12.06	11.7	81.7	49.2	63.4	59.8
December	8.05	6.7	127.0	226.4	70.8	68.3
January	5.44	4.9	130.0	265.8	70.3	68.3
February	7.39	6.5	109.9	111.6	66.7	64.9
March	10.84	10.7	96.3	143.4	60.6	58.7
April	14.16	15.5	72.8	32.2	58.0	56.4
May	23.01	20.3	41.9	3.6	54.7	48.6
June	27.15	25.2	7.40	5.2	49.2	41.3
Total/Avg.	13.51	12.68	667.0			

Crop Management and Fertilizer Application

A common bread wheat (*Triticum aestivum* L.) cultivar Adana-99, was sown in November 2018 at a seeding rate of 550 grain per m^2.

All phosphorus (P) and potassium (K) required by the treatments, along with the organic matter component of the organomineral fertilizers, were applied to the soil at the time of sowing. For the nitrogen applications, a split application method was used. Urea (46% N) and organomineral fertilizer (26% Nitrogen + OM) were used as top fertilizer. Half of the total nitrogen for the N2 and N3 doses was applied at sowing, and the remaining half was applied at the tillering stage (Zadoks GS21-23). The control plots (N1) received no nitrogen fertilizer. Weed and pest control were managed according to standard local agronomic practices for wheat cultivation.

Data Collection and Laboratory Analyses

At physiological maturity, plant height (PH) was measured from the soil surface to the tip of the spike (excluding awns) on 10 randomly selected plants from the central rows of each plot. Wheat forage samples were obtained by reaping the wheat with a sickle during the milking period. Then, green forage samples from each plot were dried in a 70°C forced-air oven for 48 hours. The dried samples were then ground to pass through a 1-mm sieve and stored for forage quality analysis.

The following parameters were analyzed:

Crude Protein (CP): The total nitrogen (N) content of the hay samples was determined using the Kjeldahl method (AOAC, 1990). The crude protein content was calculated by multiplying the N percentage by a factor of 6.25.

Fiber Analysis: Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) contents were determined using the ANKOM Fiber Analyzer according to the methods described by Van Soest et al., (1991).

Calculated Forage Quality Parameters: Based on the fiber analysis results, several key forage quality indices were calculated using standard equations (Rohweder et al., 1978):

Digestible Dry Matter (DDM, %) = 88.9 – (0.779 × %ADF)
Dry Matter Intake (DMI, % of body weight) = 120 / %NDF
Relative Feed Value (RFV) = (DDM × DMI) / 1.29

Energy Values: Digestible energy (DE) and metabolic energy (ME) results were determined by the calculations given below.

DE= 0.27 + 0.0428 x (% DDM) (Fonnesbeck et al., 1984)
ME= 0.821 x DE (Mcal kg^{-1}) (Khalil et al., 1986)

Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using the PROC ANOVA procedure of the SAS System software (SAS Institute Inc., Cary, NC, USA). The analysis was performed according to the factorial experimental design in a randomized complete block. When the F-test indicated statistically significant differences ($p \leq 0.05$), the treatment means were separated and compared using Duncan's Multiple Range Test.

Results

The analysis of variance (ANOVA) revealed that the main effects of fertilizer type and nitrogen dose, as well as their interaction (Fertilizer × Dose), had statistically significant effects on most of the investigated wheat hay quality parameters. A summary of the mean squares and significance levels from the ANOVA is presented in Table 2. The mean values for the main effects of fertilizer type and nitrogen dose are shown in Table 3.

Table 2. Summary of Analysis of Variance (Mean Squares) for Measured Parameters of Wheat Hay

Source of Variation	Replication (Block)	Fertilizer (F)	Dose (D)	F × D Interaction	Error	CV (%)
df	2	3	2	6	22	
Plant Height (PH)	2381.90**	48.18**	16.40ns	13.85ns	9.57	3.25
Crude Protein (CP)	0.02**	2.01**	1.88**	0.32**	0.02	1.88
Crude Ash (ASH)	0.15**	3.00**	8.97**	0.46**	0.11	5.57
NDF	0.48ns	39.89**	26.11**	4.67**	1.46	2.24
ADF	1.25ns	7.86**	60.39**	5.64**	1.65	4.36
DDM (SKM)	0.76ns	4.78**	1.82ns	15.06**	1	1.52
DMI (KMA)	0.00ns	0.07**	0.01**	0.02**	0.003	2.62
RFV	13.64ns	316.50**	51.23ns	168.43**	19.65	3.89
SE	0.00ns	0.01ns	0.01ns	0.03**	0.002	1.39
ME	0.00ns	0.01ns	0.00ns	0.02**	0.001	1.38

**, $P \leq 0.01$; ns, nonsignificant.

Table 3. Main Effects of Fertilizer Type and Nitrogen Dose on Wheat Hay Quality Parameters

Treatments	PH (cm)	CP (%)	ASH (%)	NDF (%)	ADF (%)	DDM (%)	DMI (%)	RFV	SE (Mcal kg^{-1})	ME (Mcal $kg^{-1)}$
F1 (20-20-0)	96.9a	6.13d	5.78c	55.3a	30.49a	65.15b	2.17c	109.6c	3.06a	2.51a
F2 (15-15-15)	97.5a	6.62b	6.22b	51.17c	28.26c	66.89a	2.35a	122.1a	3.13a	2.57a
F3 (16-15-0-OM)	92.8b	6.46c	5.44d	53.68b	29.33b	66.05ab	2.24b	114.5b	3.10a	2.54a
F4 (12-15-5-OM)	93.8b	7.25a	6.78a	55.86a	29.78ab	65.70b	2.15c	109.5c	3.08a	2.53a
N1 (0 kg ha^{-1})	95.0a	6.29c	5.12c	52.37b	27.13c	66.35a	2.26a	116.3a	3.11a	2.55a
N2 (160 kg ha^{-1})	96.5a	6.51b	6.21b	54.42a	29.66b	65.58a	2.22b	113.0a	3.08a	2.53a
N3 (240 kg ha^{-1})	94.2a	7.05a	6.83a	55.23a	31.60a	65.92a	2.20b	112.5a	3.09a	2.54a

Plant Height (PH)

Fertilizer type had a significant effect on plant height (P=0.0083), whereas the effects of nitrogen dose and the Fertilizer × Dose interaction were not significant (Table 2). Fertilizer type significantly affected plant height ($p<0.01$), with F1 and F2 producing taller plants than F3 and F4. However, the effect of nitrogen doses and the Fertilizer × Dose interaction were not statistically significant ($p>0.05$). (Table3).

Crude Protein (CP) and Crude Ash (ASH)

The main effects of fertilizer type, nitrogen dose, and their interaction were all highly significant ($P<0.0001$) for both crude protein and crude ash content of the wheat hay (Table 2).

For crude protein (CP), the highest content was obtained from the F4 (12-15-5-OM) organomineral fertilizer, which was statistically superior to all other treatments. The lowest CP content was recorded in the F1 (20-20-0) chemical fertilizer treatment. Crude protein content increased significantly with each increment in nitrogen application rate, with the N3 (240 kg N ha^{-1}) dose yielding the highest values (Table 3).

Similarly, the highest crude ash (ASH) content was observed in the F4 (12-15-5-OM) treatment. Increasing nitrogen doses also led to a significant increase in the crude ash content of the hay.

Fiber Components (NDF and ADF)

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were significantly influenced by fertilizer type, nitrogen dose, and their interaction (Table 2).

The lowest NDF and ADF contents, which indicate higher forage quality, were consistently recorded in the F2 (15-15-15) chemical fertilizer treatment. Conversely, the highest NDF content was observed in the F4 (12-15-5-OM) and F1 (20-20-0) treatments, while the highest ADF content was found in the F1 (20-20-0) treatment (Table 3). Nitrogen application significantly increased both NDF and ADF contents compared to the control (N1), with the highest fiber values generally observed at the highest N dose (N3).

Forage Quality Indices (DDM, DMI, and RFV)

Digestible Dry Matter (DDM), Dry Matter Intake (DMI), and Relative Feed Value (RFV) were all significantly affected by the main factors and their interaction (Table 2).

Consistent with the fiber analysis results, the highest values for DDM, DMI, and RFV were all obtained from the F2 (15-15-15) chemical fertilizer treatment ($p<0.01$). However, according to the ANOVA results, the main effect of nitrogen doses on DDM and RFV was statistically insignificant ($p>0.05$). While nitrogen application showed a numerical downward trend in these indices, the differences were not sufficient to be statistically validated (Table 3).

Increasing nitrogen application from 0 to 160 and 240 kg ha^{-1} led to a numerical decrease in DDM and RFV, indicating a negative impact of high N rates on forage digestibility and overall quality.

Energy Values (SE and ME)

The digestible energy (DE) and metabolizable energy (ME) of the wheat hay were significantly influenced by the Fertilizer × Dose interaction ($p<0.01$). However, the main effects of fertilizer type and nitrogen dose alone were not statistically significant ($p>0.05$). This indicates that the energy content of the hay is determined by the specific combination of fertilizer type and nitrogen level rather than the nitrogen dose independently (Table2). Mirroring the results of the forage quality indices, the highest SE and ME

values were found in hay from plots fertilized with F2 (15-15-15). The lowest energy values were associated with the F1 (20-20-0) fertilizer. Nitrogen application generally resulted in a decrease in the energy content of the hay compared to the unfertilized control.

Means within a column for each main factor followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p \leq 0.05$).

Discussion

The findings of this study reveal a complex and significant relationship between fertilizer strategy and the multifaceted quality of wheat hay. Our results clearly demonstrate that the choice between organomineral and conventional chemical fertilizers involves a critical trade-off between enhancing the protein content versus optimizing the digestibility and energy value of the forage (Moore and Hatfield, 1994; López-Bellido et al., 2005).

The Trade-Off: Crude Protein vs. Forage Digestibility

The most striking finding of this research is the opposing effect of different fertilizer types on crude protein (CP) and fiber components (NDF, ADF). The organomineral fertilizer F4 (12-15-5-OM) produced hay with the highest crude protein content, significantly outperforming all other treatments, especially at the highest nitrogen dose. This aligns with previous research suggesting that the organic matter in OMFs, particularly humic substances, can enhance nitrogen use efficiency. These substances may reduce nitrogen losses through leaching and volatilization and promote a slow, sustained release of N, leading to greater N uptake and assimilation into proteins later in the plant's life cycle (Chen et al., 2004). The superior performance of F4 over F3 could also be attributed to its balanced nutrient profile, including potassium (K), which plays a vital role in enzyme activation and protein synthesis (Marschner, 2012).

Conversely, the very same treatments that excelled in protein content (F4 and F1) produced hay with the highest concentrations of NDF and ADF (Table 3). High fiber content is directly associated with lower digestibility and reduced feed intake by livestock. Consequently, the forage quality indices that depend on fiber content-namely DDM, DMI, and RFV-were lowest in these treatments (Van Soest, 1994). This suggests that while organomineral fertilizers promote nitrogen assimilation for protein, they may also stimulate the synthesis of structural carbohydrates (cellulose, hemicellulose), leading to more lignified and less digestible plant tissue (Moore and Hatfield, 1994).

In stark contrast, the chemical fertilizer F2 (15-15-15) consistently produced hay with the lowest NDF and ADF content, and consequently, the highest DDM, DMI, RFV, and energy values (SE, ME). This indicates that a balanced and readily available supply of N, P, and K, as provided by the 15-15-15 formulation, fosters a type of plant growth that results in less structural fiber and higher overall forage quality (Fageria, 2001). This finding is of great practical importance for farmers in mixed crop-livestock systems, where hay quality is as economically relevant as grain yield. The F2 treatment, while not producing the highest protein levels, yielded a forage that is more palatable, more digestible, and energetically richer for ruminant animals.

The Role of Nitrogen Dose and Its Interaction with Fertilizer Type

As expected, increasing nitrogen application rates significantly boosted the crude protein content of the hay across all fertilizer types. This is a well-documented phenomenon, as nitrogen is a fundamental component of amino acids, the building blocks of protein. Regarding nitrogen application, while higher doses significantly increased the crude protein (CP) content, their impact on

overall digestibility (DDM) and relative feed value (RFV) remained statistically insignificant ($p>0.05$). This suggests that for wheat hay quality, selecting a balanced fertilizer type (like F2) is more critical for maintaining high energy and digestibility than the amount of nitrogen applied within the studied ranges). This can be attributed to the "dilution effect," were rapid, N-fueled biomass accumulation results in a higher proportion of structural cell wall material relative to more digestible cell contents (Lemaire et al., 2008).

The significant Fertilizer × Dose interaction observed for most parameters highlights that the response to nitrogen is not uniform across fertilizer types. The most dramatic interaction was seen in crude protein, where the superiority of the organomineral fertilizer F4 became overwhelmingly evident at the highest N dose (N3), reaching an average of 7.05%. This suggests a synergistic effect: the organic component of F4 likely improved the plant's ability to utilize the high level of applied nitrogen, converting it into protein more efficiently than the chemical fertilizers could (Diacono and Montemurro, 2010). This finding challenges the conventional wisdom that high N rates alone are sufficient for high protein and underscores the importance of the fertilizer's carrier and composition (Sebilo et al., 2013).

Implications for Sustainable Agriculture and Crop Management

The results of this study have profound implications for fertilizer management strategies. They suggest that there is no single "best" fertilizer, but rather an optimal choice depending on the farmer's primary objective.

For Maximizing Forage Quality: A farmer whose primary goal is to produce high-quality, highly digestible hay for livestock feed would benefit most from using a balanced chemical fertilizer like 15-15-15 a finding that is consistent with the work of Wang et al., (2013).

For Maximizing Protein Content: A farmer aiming to produce a protein-rich supplement, or operating in a system where hay protein commands a premium, would achieve the best results with an organomineral fertilizer rich in organic matter and balanced with potassium, like the 12-15-5-OM formulation, especially when combined with higher nitrogen rates as has also been demonstrated by Nardi et al., (2002).

This research fills a critical gap in the literature by moving beyond simple yield metrics to provide a holistic assessment of fertilizer impacts on the entire plant system. The demonstrated trade-off between protein and digestibility is a key concept that should be integrated into agronomic recommendations (Grote et al., 2021; Erenstein et. al., 2022). Future research could explore the economic implications of these trade-offs, analyzing whether the premium for high-protein hay outweighs the benefits of higher digestibility in specific livestock production scenarios.

Conclusion

This study conclusively demonstrates that fertilizer selection has a profound and differential impact on the quality parameters of wheat hay, presenting a clear trade-off between nutritional components. The application of organomineral fertilizers, particularly a formulation containing 12% N, 15% P_2O_5, 5% K_2O, and % 15 organic matter, was the most effective strategy for maximizing the crude protein content of the hay. This effect was especially pronounced at higher nitrogen application rates, indicating a synergistic relationship between the organic component and nitrogen utilization.

Conversely, a balanced N-P-K chemical fertilizer (15-15-15) was unequivocally superior in enhancing the forage quality of the hay. This treatment resulted in significantly lower fiber content (NDF and ADF), which translated into higher digestible dry matter, greater potential dry matter intake, a superior relative feed value (RFV), and higher energy content (SE and ME).

Our findings challenge the notion of a single "best" fertilization strategy. Instead, the optimal choice is dependent on the specific production goals of the agricultural system. For integrated crop-livestock systems where high-quality, digestible forage is paramount, a balanced chemical fertilizer offers a distinct advantage. For systems aiming to produce protein-rich biomass or amend soils with organic matter, organomineral fertilizers are the more effective choice. These results underscore the necessity of a goal-oriented approach to nutrient management, enabling farmers to tailor their fertilization strategies to achieve specific quality outcomes beyond grain yield alone.

Conflict of Interest

The authors confirm there are no conflicts of interest associated with this study.

Artificial Intelligence Declaration

The authors declare that no generative artificial intelligence tools were used at any stage of the preparation of this manuscript, including the writing, editing, or refinement of the text, or the creation of any images, figures, graphics, tables, or related titles.

Funding Statement

This research received no funds.

Author Contributions

Zekeriya Kara; Ömer Süha Uslu; K.S; Conceptualization, Zekeriya Kara; Methodology, Ömer Süha Uslu; Zekeriya Kara; Formal analysis, Zekeriya Kara; Ömer Süha Uslu; Kadir Saltalı; Original draft preparation and writing. All authors have read and agreed to the published version of the manuscript

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