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Chapter 8

Comparative Production and Nutritional Evaluation of Hydroponically Grown Wheat and Maize Fodder with Conventional Fodder

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Abstract

The present study was conducted to evaluate the production efficiency and nutritive value of hydroponically grown wheat and maize fodders in comparison with conventionally produced fodders. The study included two treatments; hydroponic wheat (T_1) and hydroponic maize (T_2) and their respective field-grown (FP) controls. Seven trials were carried out over a 15-day growth period from germination to harvest. Results revealed that hydroponic wheat and maize produced 4.72 kg and 5.60 kg fodder per kg seed, representing 43-47 % higher yields than field-grown fodders. Crude protein content increased to 16.54 % and 18.13 % for hydroponic wheat and maize, respectively, while mineral (Ca, P) content also improved significantly. The economic analysis showed higher benefit–cost ratios (1.57 and 1.60) for hydroponic systems. Hydroponic maize demonstrated had higher biomass yield, nutritive composition, and mineral content over hydroponic wheat, making it a more efficient and nutrient-rich fodder source under hydroponic conditions. The study concludes that hydroponic fodder production is a sustainable and economically viable method for producing nutrient-rich green fodder year-round.

Keywords: Hydroponics, Wheat fodder, Maize fodder, Nutritive value, Fodder yield, Benefit–cost ratio.

1. Introduction

Forage constitutes a fundamental component of livestock feed, supplying essential nutrients necessary for optimal growth, reproduction, and milk production in ruminants. However, in recent years, the availability of quality forages has been declining due to increasing climatic variability, limited water resources, and shrinking arable land [1]. Traditional forage production systems are further constrained by prolonged crop growth periods, high dependency on fertilizers and manure, and competition for cultivable land with food crops [2]. These multidimensional challenges collectively threaten the sustainability and efficiency of conventional forage-based feeding systems.

To overcome these limitations and ensure the continuous supply of fresh green fodder, innovative and sustainable production technologies are being explored worldwide. Among these, hydroponic fodder production a soil-less cultivation technique utilizing water and nutrient solutions has gained significant attention [3]. This system allows the production of 7 to 10 kilograms of green fodder from a single kilogram of grain within a short growth period of 7 to 10 days, irrespective of seasonal fluctuations [4]. Hydroponic systems are resource-efficient; requiring less water and land compared to conventional cultivation, while also producing fodder with higher digestibility and reduced risk of soil-borne contamination [5].

Despite its advantages, the economic viability and productivity of hydroponic fodder systems depend on several factors, including grain type, germination rate, soaking duration, nutrient formulation, water quality, and management practices [6]. Therefore, comprehensive evaluation of production performance and nutritive composition of hydroponically produced fodder compared to conventional methods is essential to determine its practical feasibility for livestock farmers.

The present study was undertaken to compare the yield performance and nutritive value of hydroponically grown wheat and maize fodder with their conventionally cultivated counterparts. The findings aim to provide practical insights into enhancing year-round fodder availability through sustainable and climate-resilient technologies, thereby improving livestock productivity and farm profitability.

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2. Material and methods

2.1. Experimental design

The study was conducted as an on-farm trial as technology validation at seven locations in Begusarai, Bihar (India) during October and November, when the ambient temperature ranged between 24°C and 32°C (https://www.weatherapi.com). It included two hydroponic treatments T_1: hydroponic wheat and T_2: hydroponic maize and their respective conventional (field-produced) controls (FP). Each trial lasted 15 days from germination to harvest and was repeated three times for reproducibility.

2.2. Hydroponic system setup, seed preparation and harvesting

A simple hydroponic fodder unit was established using plastic trays (dimension: 22 × 16 inches) designed with drainage holes to allow proper water flow and aeration. The system was installed under a shaded structure to prevent direct sunlight while maintaining sufficient light intensity for growth. High-quality seeds of maize (Zea mays; variety: Rajendra Hybrid Makka-4) and wheat (Triticum aestivum; variety: HD-2967) were procured from KVK, Begusarai. Seeds were washed, cleaned, and soaked in clean water for 12 hours, followed by 24 hours of sprouting under moist cloth conditions. Seeds of maize and wheat were evenly spread in a single layer across the hydroponics trays. Water was supplied manually using a fine-spray watering can two to three times daily to keep the seeds moist without causing waterlogging. No soil or chemical fertilizers were used. Each Fodder was harvested on the 15^{th} day after sowing. The entire mat (shoot and root) was collected and weighed for yield estimation. Representative composite samples from the three trials were oven-dried at $100 \pm 5^{\circ}C$ and subjected to proximate analysis for nutrient composition.

Figure 1: Recording of Physical Parameters

2.3. Analytical methods

Chemical analysis was performed in Animal Nutrition Laboratory, Bihar Animal Science University, Patna as the standard procedures of the [7] for determining crude protein (CP), ether extract (EE), crude fiber (CF), total ash, acid-insoluble ash, calcium, and phosphorus. Yield and benefit–cost ratio (B:C) were calculated to assess productivity and economic efficiency.

3. Results and discussion

3.1. Physical parameters

Hydroponic fodders recorded significantly higher yields and plant heights compared to field-grown fodders Table 1. Hydroponic wheat yielded 4.72 kg fodder per kg seed, while hydroponic maize produced 5.60 kg, representing increases of 43.17% and 47.14%, respectively, over conventional methods. Plant height also higher under hydroponic conditions, with wheat and maize reaching 17.84 cm and 20.10 cm respectively, compared to 11.36 cm and 16.15 cm under field production. Fodder yield per unit area increased to 0.16 kg/ft² in wheat and 0.19 kg/ft² in maize under hydroponics, confirming efficient space utilization. Our findings are in agreement with those of [8, 9] who reported higher biomass yield (kg) in hydroponically grown maize compared to conventionally grown maize fodder.

The B:C ratio was significantly higher in hydroponic systems (1.57 for wheat, 1.60 for maize) compared to conventional methods (0.39 and 0.55), indicating economic viability. [10] also reported that the production cost was lower compared to that of conventional fodder. The higher yields and growth rates under hydroponic conditions may be attributed to continuous water and nutrient availability, improved root aeration, and the absence of soil-borne stresses, resulting in better nutrient uptake and biomass accumulation.

3.2. Nutritive value

Hydroponic fodders showed higher nutritive composition as compare to conventional fodder Table 1. Crude protein content showed a substantial increase in hydroponically grown fodders, reaching 16.54% in hydroponic wheat and 18.13% in hydroponic maize, compared to 14.88% and 16.90%, respectively, in conventionally grown fodders. This increase reflects enhanced nutrient mobilization and utilization during the germination process, where enzymatic activities convert stored nutrients into more bioavailable forms required for seedling development. Similarly, the ether extract content was higher by approximately 36% in hydroponic fodders, indicating a greater concentration of lipids that contribute to the overall energy density of the feed. Higher ether extract not only enhances the energy value but also improves palatability, making the fodder more appealing to livestock.

The crude fiber content in hydroponically grown fodders remained within the optimal range, suggesting balanced structural development of plant tissues. This ensures good rumen function and digestibility, providing sufficient roughage without compromising nutrient availability.

A marked reduction in total ash and acid-insoluble ash was also observed, confirming the absence of soil contamination in hydroponically produced fodder. The cleaner nature of the feed results in higher nutritional purity and reduces the risk of ingesting undesirable materials.

Furthermore, the mineral composition of hydroponic fodders improved significantly, with calcium and phosphorus concentrations increasing by 55–80% compared to conventional fodders. This enhancement is likely due to better nutrient absorption from the hydroponic nutrient solution, contributing to stronger bone development, improved metabolic functions, and overall animal health.

This improvement indicates superior nutrient bioavailability in hydroponic systems, where minerals remain in a readily soluble form and are continuously available to the developing seedlings. The absence of soil further prevents nutrient fixation and losses, allowing efficient uptake of essential elements through the root system. Consequently, the resulting fodder is richer in bioavailable minerals, which are crucial for bone development, metabolic functions, and overall livestock productivity. Our findings are in line with those of [9], who reported a higher nutritive value (on % DM basis) in hydroponically grown maize fodder compared to conventionally grown maize fodder.

3.3. Comparative evaluation

Hydroponic Maize vs. Hydroponic Wheat

Table 1: Physical and Nutritive value of Conventional and Hydroponic Fodders

S.N.	Attributes	Wheat (FP)	Maize (FP)	Hydroponics wheat (T_1)	Hydroponics maize (T_2)
1.0	**Physical parameters**				
1.1	Fodder (kg)/kg seed	1.90	2.96	4.72	5.60
1.2	Height (cm)	11.36	16.15	17.84	20.10
1.3	Fodder (kg)/ft^2	0.065	0.10	0.16	0.19
1.4	B:C ratio	0.39	0.55	1.57	1.60
2.0	**Nutritive value (% DM basis)**				
2.1	Crude protein	14.88	16.90	16.54	18.13
2.2	Ether extract	1.40	1.60	2.20	2.50
2.3	Crude fiber	5.30	6.90	5.60	7.40
2.4	Total ash	8.04	7.97	3.80	2.80
2.5	Acid insoluble ash	3.81	3.23	0.92	0.69
2.6	Calcium	0.23	0.32	0.52	0.74
2.7	Phosphorus	0.11	0.12	0.39	0.58

FP = Field Produced, DM = Dry Matter, B:C Ratio = Benefit Cost Ratio

Physical parameters

Hydroponic maize produced 18.6% more fodder per unit seed than hydroponic wheat, indicating better biomass conversion efficiency. Hydroponic maize plants were about 13% taller, reflecting stronger vegetative growth. Hydroponic maize yielded 24% more fodder per unit area, showing higher productivity and space utilization. Both had similar economic returns, but maize had a slightly higher benefit–cost ratio, indicating marginally greater profitability.

Nutritive value (on DM basis)

Hydroponic maize showed about 9.6% higher protein, implying superior amino acid synthesis and nutrient mobilization during germination. Hydroponic maize had about 13.6% higher fat content, suggesting greater energy density and improved palatability. Maize exhibited 32% higher fiber, which may aid rumen function but slightly reduce digestibility if excessive.

Wheat showed higher total ash, possibly due to greater mineral accumulation or residue; maize had lower ash, indicating cleaner biomass. Maize had 25% lower AIA, confirming lesser contamination and higher purity. Maize showed a 42% higher calcium level, beneficial for bone health and milk production. Maize recorded about 49% higher phosphorus, enhancing energy metabolism and skeletal strength.

Between the two crops, hydroponic maize outperformed wheat in both yield and nutritive parameters. It showed higher crude protein, ether extract, and mineral content, making it a superior option for livestock feeding. However, both hydroponic fodders provided substantial improvement in yield and quality compared with traditional methods.

4. Conclusions

The study demonstrates that hydroponic fodder production offers substantial advantages over conventional field-grown systems in terms of yield, nutrient content, and economic returns. Hydroponic maize showed the best overall performance, producing the highest crude protein (18.13%), energy (EE 2.5%), and mineral content with a favorable benefit–cost ratio (1.60). Hydroponic maize demonstrated clear advantages over hydroponic wheat in terms of biomass yield, nutritive composition, and mineral enrichment, making it a more efficient and nutrient-rich fodder source under hydroponic conditions. Hydroponic wheat, while slightly lower in yield and nutrients, still represents a high-quality, soil-free green fodder suitable for balanced livestock feeding. Hydroponic systems thus represent a sustainable and climate-resilient solution for ensuring year-round availability of high-quality green fodder, particularly in regions with limited land and water resources.

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