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Effect of Goat Manure and Harvesting Age on Growth Performance and Nutrient Composition of Hydroponic Wheatgrass Fodder

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Abstract | Hydroponic wheatgrass (*Triticum aestivum* Linn) production is an alternative to conventional planting, providing a constant supply of green fodder for livestock year-round. It involves growing plants without soil in water or a nutrient-rich solution in a greenhouse. All parts of the hydroponic fodder (leaves, stems, roots, and grain) are fed to livestock by the farmers. This experiment aimed to identify the effect of goat manure liquid fertilizer on growth performance, production yield and proximate composition of all four parts of wheatgrass, including the appropriate day of harvesting. This study used a complete randomised design (CRD) with four treatments in triplicates. Four treatment levels were control (C) without goat manurer; Treatment 1 (T1): 100 g of goat manure per 1 litre of water; Treatment 2 (T2): 200 g of goat manure per 1 litre of water; and Treatment 3 (T3): 300 g of goat manure per 1 litre of water. Fodder plants were planted under a 12-hours photoperiod at room temperatures of 25°C to 30°C. Growth performances and production yields were measured while nutrient compositions were analysed. Plants were harvested on the 8th, 9th and 10th day after planting and separated into four parts (leaf, stem, grain and root). Data were analysed using a two-way approach ANOVA. Results showed that 300 g of goat manure per one litre of water showed higher growth performance and production yield with significantly highest crude protein. In conclusion, 300 g of goat manure can be used as fertilizer in hydroponic forage production.

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Introduction

Livestock farming is an essential industry in Malaysia as it is the population's primary protein source. However, farmers face various constraints in producing green fodder as arable land for grazing is limited. More than 85% of the arable land is used for industrial crop cultivation, such as palm oil and rubber, while the balance is used for food-crop cultivation (Nazmi *et al*., 2022), thus limiting the area for forage production. Sustainable livestock production depends on the availability of quality feed and forage resources. It is also crucial to find an alternative way of planting besides the traditional methods, especially for countries or populations with problems practising traditional agriculture due to soil depletion, infertile soils, climate change or urbanisation. Therefore, soil-less cultivation may be the alternative option to overcome such problems.

Hydroponic is a method of growing plants using a liquid, usually water or liquid nutrient solution, with either the presence or absence of a supporting medium (Yuvaraj and Subramanian, 2020). It is an alternative technology in cultivating livestock fodder as a feed that can provide an effective solution to the shortage of forage. It is very promising for sustainable livestock production in different world regions.

Hydroponics is becoming popular among local farmers due to many reasons. Sharma *et al*. (2018) found that soil-less cultivation is preferable to conventional methods because it requires less material than traditional farming. It can be used efficiently to take pressure off the land and grow green fodder for livestock. Not using soil and pesticides reduces the amount of labour and the hours worked on the farm. In addition, farmers can handle problems like tillering, weeding, and watering. The risk of plant diseases can also be reduced as the hydroponic system allows plants to absorb nutrients directly from the water, thus increasing crop growth, production, and yield. Crops could also be cultivated all year round and not be out of season because they can be grown indoors and not affected by climate change.

In Malaysia, wheatgrass has become popular and widely used for human consumption due to its high level of chlorophyll, nutrients, vitamins, and minerals (Rodríguez *et al*., 2022). People in rural areas have also been using wheatgrass to cure common diseases such as colds, coughs and fevers. Ayurveda's medicinal system also mentions wheatgrass's advantages to humans (Choudary *et al*., 2021). However, it is uncommon for farmers to feed hydroponic fodder to livestock.

There are many benefits of feeding hydroponic fodder to livestock. Salo (2019) shows that dairy cattle fed with hydroponically grown green fodder have high milk yield and good quality. This is because green hydroponic fodder can improve dairy cattle digestibility and provide a better intake of nutrients. Besides that, adding hydroponically grown barley in calf feeding can also affect the calves positively. The barley that acts as a supplement for the calves gives a higher average daily gain than calves without barley supplements (Bari *et al*., 2021).

On the other hand, a study by Rani and Purushothaman (2019) shows that feeding cross-bred calves with hydroponic fodder maize will not have an adverse effect on growth performance and nutrient digestibility. Ebenezer *et al*. (2021) have also proved that supplementing buck kids with hydroponic fodder maize can increase their nutrient digestibility and reproductive performance. These facts prove that hydroponic-grown fodder has a positive effect on livestock animals.

Hydroponic fodder can be grown using tap water or a nutrient solution. The nutrient solution can enhance the crude protein (CP) content of the hydroponics fodder higher than the tap water, possibly due to the uptake of nitrogenous compounds (Dung *et al*., 2010). A study by Mbatha *et al*. (2021) shows that goat manure is the best in increasing nutrient content compared to poultry manure. Dalorima *et al*. (2021) also reported that goat dung gives high concentrations of required nutrients compared to cattle dung and horse manure. Therefore, in this study, goat manure was selected because of its high nitrogen content compared to other fertilizers. To add goat manure to a hydroponic plant, the goat manure must be dissolved in water to form a solution before being administered to the plant.

In the wheatgrass life cycle, maturation occurs on day seven of cultivation. Devi *et al*. (2020) reported that it is best to harvest on this day because it contains the highest crude protein, lower ash content and low crude fat. Crude protein decreases when harvested on the 13th day of cultivation, which means that late harvest is the best for crude fibre. Also, Adhikari *et al.* (2021) recommended harvesting wheatgrass on the ninth day as it had a higher content of phytochemicals. Therefore, this study was conducted to determine the optimal harvesting age of wheatgrass so that the nutritional content of wheatgrass can be maximised.

Materials and Methods

Experimental site

The study was conducted at the F1 building of Universiti Sultan Zainal Abidin (UniSZA), Besut located at latitude and longitude 5.753064809423129, 102.62649231032233. Planting was done in the Agrostology Laboratory, and analysis was performed at the Animal Food Analysis Laboratory.

Experimental design and layout

The experiment was laid out in a factorial arrangement with a completely randomised design with four treatments in triplicates. A total of 36 trays were used with nine trays per treatment. gnSize of each tray was 1728 cm^2 (48 cm × 36 cm) and the entire experiment design is given (Table 1).

Table 1: *Layout of experimental design.*

Control	Treatment 1	Treatment 2	Treatment 3
Replicate 1			
C Ty A	T_1 Ty A	T_2 Ty A	T_3 Ty A
C Ty B	T_1 Ty B	T_2 Ty B	T_3 Ty B
C Ty C	T_1 Ty C	T_2 Ty C	T_3 Ty C
Replicate 2			
C Ty A	T_1 Ty A	T_2 Ty A	T_3 Ty A
C Ty B	T_1 Ty B	T_2 Ty B	T_3 Ty B
C Ty C	T_1 Ty C	T_2 Ty C	T_3 Ty C
Replicate 3			
C Ty A	T_1 Ty A	T_2 Ty A	T_3 Ty A
C Ty B	T_1 Ty B	T_2 Ty B	T_3 Ty B
C Ty C	T_1 Ty C	T_2 Ty C	T_3 Ty C

In each treatment, four concentrations of liquid goat manure fertilizer were administered, which were 0%, 10%, 20% and 30% as control (C), treatment 1 (T1), treatment 2 (T2), treatment 3 (T3) assigned respectively (Hakim and Eko, 2021). Ty: tray.

Liquid fertilizer preparation

Liquid goat manure fertilizer for C, T1, T2, and T3 contained 0 g, 100 g, 200 g and 300 g of goat manure, respectively as shown in Table 2. Goat manure was collected from local livestock farmer and was air dried for 48 hours. Air-dried manure was weighted according to treatment, and grounded into powder form using an electric blender before diluting with one litre of water. All manures were left to sit for 24 hours.

Table 2: *Volume of liquid goat fertilizer.*

Treatments	Volume (g/L)
Control	0
Treatment 1	100
Treatment 2	200
Treatment 3	300

After 24 hours, the nutrient solution of goat manure was strained. The solution was then diluted in 1 litre of nutrient solution to 4 litres of plain water (1:4 ratio). The fertilizer was then administered three times daily in the morning (9.00 am), afternoon (3.00 pm) and evening (9.00 pm). Each treatment received 300 ml of goat fertilizer daily based on 100 ml for each wetting.

Hydroponic system setup

Wheat grains were purchased from a local market and planted in perforated trays that offered proper drainage and airflow with favourable conditions for healthy growth in room temperature (24–30°C) and relative humidity (75%), water spraying (100 ml/tray) three times daily. The planting trays, the laboratory cabinet and the surroundings were cleaned and disinfected before planting.

Planting procedure

Seeds were weighed, using about 70 g of seed per tray. Seeds were washed twice with fresh water while floating seeds (bad seeds that can lead to mould growth) were removed. Seeds were then soaked for 10 hours to absorb moisture and soften the coat, then drained, covered and left for 24 hours to aid germination. When germination occurred, the sprouted seeds were transferred into trays through spreading and watered according to treatments three times daily. Samples were then collected for growth performance and proximate analyses on the 8^{th}, 9^{th} and 10^{th} days.

Data collection on parameters for plant growth performance

Observations on plant height (cm), root length (cm), plant width and plant weight. A meter ruler was used to measure plants' height (cm), width (cm) and root length (cm) manually. The production yield (g) was measured using a weighing scale (Mowa *et al*., 2017). The average for each result was calculated, and data was recorded.

Proximate analysis of organic wheatgrass fodders

The harvested wheatgrasses were separated into four parts: leaves, stems, seeds, and roots. Proximate analysis was carried out according to AOAC (2006). Crude protein (CP), ether extract (EE), crude fibre (CF), ash and moisture were measured in triplicates.

Statistical analysis

All data collected were subjected to a two-way Analysis of Variance (ANOVA) using the OriginPro 2023 software.

Results and Discussion

Growth performance

Plant height, width, root length, and weight of wheatgrass fodder under different treatments and days are shown in Tables 3 and 4.

The effect of liquid fertilizer application and harvesting days on the growth performances of hydroponic wheatgrass is given in Tables 3 and 4. Results showed that days and treatments had a significant effect ($p<0.05$) on growth parameters of wheatgrass fodder. It was observed from both tables that plant height, root length, and width increased with harvesting age, regardless of the treatments applied. On Day 8, all treatments were shown to have the lowest plant height which were 10.1 cm, 13.6 cm, 13.6 cm, and 14.7 cm, respectively. An increase was observed on Day 9: C (12.2 cm), T1(13.9 cm), T2(14.1 cm), T3 (16.5 cm), and likewise on Day 10: C (15.1 cm), T1 (14.7 cm), T2 (14.9 cm), T3 (18.1 cm). There was an increment in the plant width from Day 8 (0.3 cm) to Day 9 (0.4 cm), regardless of the treatment. However, there was no increment on day 10 (0.4 cm). Day 8: C (7.3 cm), T1 (7.8cm), T2 (8.0 cm), and T3 (9.6 cm), were shown to have the lowest root length, compared to Day 9: C, T1, T2, T3 (8.3 cm, 8.7 cm, 9.1 cm, 10.5 cm), and Day 10: C, T1, T2, T3 (10.1 cm, 10.6 cm, 11.6 cm, 12.6 cm), respectively. This indicates that plant height and root length increased with harvesting day regardless of the treatments applied. The continuous increase in height is due to longer harvest time that allowed the plants to use nutrients in the seeds (Bekele *et al*., 2020).

Table 4 shows that root length increased based on treatments applied. The highest growth was observed on Day 10 in which T3 (12.6 cm) with 300g/L of liquid fertilizer showed highest root-length, T2 (11.6 cm) with 200 g/L liquid fertilizer with second-highest root length followed with T1 (10.6 cm) with 100 g/L liquid fertilizer and C (10.1 cm) with 0 g liquid fertilizer. Similar trend was observed on Day 8 and 9 in all treatments and this could be attributed to the differences in composition of liquid fertilizer application. The root is one of the most critical for nutrient absorption, in which phosphorus and

Table 3: *Plant height and width of wheatgrass under different days and treatments.*

	Days/ Plant height				Width			
	C	T1	T2	T3	C	T1	T2	T3
Day 8	$10.1^{d}\pm0.43$	$12.6^{cd}\pm0.52$	$13.6^{c}\pm0.23$	$14.7^{bc}\pm0.36$	$0.3^{b}\pm0$	$0.3^{b}\pm0$	$0.3^{b}\pm0$	$0.3^{b}\pm0$
Day 9	$12.2^{cd}\pm0.22$	$13.9^{c}\pm0.49$	$14.1^{c}\pm0.10$	$16.5^{ab}\pm0.20$	$0.4^{a}\pm0$	$0.4^{a}\pm0$	$0.4^{a}\pm0$	$0.4^{a}\pm0$
Day 10	$15.1^{bc}\pm0.34$	$14.7^{bc}\pm0.73$	$14.9^{bc}\pm0.18$	$18.1^{a}\pm0.32$	$0.4^{a}\pm0$	$0.4^{a}\pm0$	$0.4^{a}\pm0$	$0.4^{a}\pm0$

C = no fertilizer, T1 = 100 g/L liquid fertilizer, T2 = 200 g/L liquid fertilizer, and T3 = 300 g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments ($p<0.05$).

Table 4: *Weight and root length of wheatgrass under different days and treatments.*

	Days/Weight				Root length			
	C	T1	T2	T3	C	T1	T2	T3
Day 8	$250^{g}\pm17.5$	$320^{cdef}\pm14.01$	$279^{efg}\pm1$	$311^{cdef}\pm16.70$	$7.3^{g}\pm0.44$	$7.8^{fg}\pm0.49$	$8.0^{fg}\pm0.56$	$9.6^{cde}\pm0.33$
Day 9	$275^{fg}\pm15.5$	$325^{cde}\pm20.9$	$345^{bc}\pm17.2$	$337^{bcd}\pm26.9$	$8.3^{efg}\pm0.07$	$8.7^{ef}\pm0.30$	$9.1^{def}\pm0.89$	$10.5^{bc}\pm0.41$
Day 10	$296^{def}\pm13.2$	$342^{bcd}\pm13.7$	$382^{ab}\pm4.8$	$392^{a}\pm9.4$	$10.1^{cd}\pm0.43$	$10.6^{bc}\pm0.32$	$11.6^{ab}\pm0.39$	$12.6^{a}\pm0.43$

C = no fertilizer, T1 = 100 g/L liquid fertilizer, T2 = 200 g/L liquid fertilizer, and T3 = 300 g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments ($p<0.05$).

potassium are essential minerals for plant root growth (Sustr *et al*., 2019). As goat manure is known to have higher organic matter, nitrogen, calcium, phosphorus, carbon and minerals than in cattle, chicken and pig manure (Gonzalez *et al*., 2023). Inclusion of N from this manure could have contributed to better growth of root as exhibited by treatments using goat manure compared to control.

In Table 3, it is observed that the highest plant height was in T3 (300 g/L liquid fertilizer) on Day 10 (18.1 cm). In comparison, T3 (300 g/L liquid fertilizer) on Day 9 (16.5 cm) had the second-highest plant height, while C (0g liquid fertilizer) on Day 8 had the lowest growth (10.1 cm). This suggests that high amount of goat manure in T3 (300 g/L liquid fertilizer) increased plant height compared to C (0% liquid fertilizer). Nutrients in the manure solution is responsible in increasing plant height and this suggestion corresponds with Wahyudi *et al*. (2019) that goat manure fertilizer can increase fodder's growth rate and performance. Organic nutrient solution formulated from goat manure positively improved plant growth and yield performance of plants like tomato crop which had provided a feasible and alternative to conventional hydroponics (Mowa *et al*., 2017). Atmaja *et al*. (2019) also stated that goat manure contains relatively high potassium. Potassium aids in the opening and closing of stomata, adequate water consumption, root expansion, plant resilience and increasing the size and quality of plants as observed by Akman *et al*. (2021).

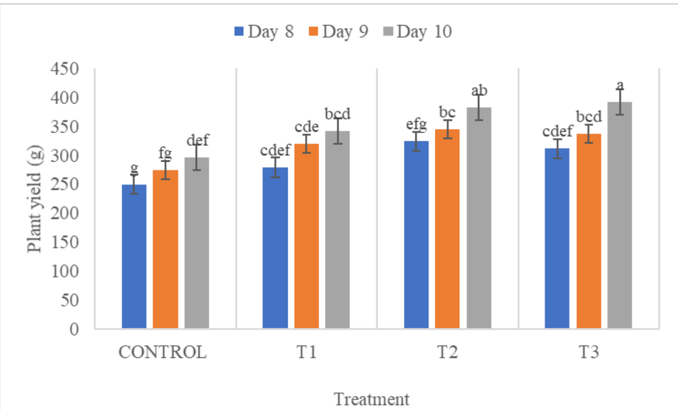

Figure 1: *Comparison of wheatgrass yield in different days and treatments.*

Fodder yield of hydroponics wheatgrass differed between different days and treatments. Figure 1 shows a significant ($p<0.05$) variation in plant yield. There was an increase in fodder yield shown with days and treatment, in which plant yield increased with harvesting age regardless of treatments applied. Thus, on Day 8: C (250 g), T1 (320 g), T2 (279 g), T3 (311 g) produced the lowest plant yield, which increased on Day 9: C (275 g), T1 (325 g), T2 (345 g), T3 (337 g), and Day 10: C (296 g), T1 (432 g), T2 (382 g), T3 (392 g) respectively. This indicates that plant yield increased with harvesting day regardless of the treatments applied. These results also corresponded with a study by Bekele *et al*. (2020) that suggested incremental harvest period increased fresh fodder biomass yield under a hydroponic system.

As indicated in Table 4 too, the highest yield was observed on Day 10: T3 (300 g/L of liquid fertilizer), T2 (200 g/L of liquid fertilizer), and T1 (100 g/L of liquid fertilizer) were (392 g/70 g), (382 g/70 g) and (342 g/70 g), respectively while the lowest was observed in control (0 g liquid fertilizer) on day 8 (250 g/70 g). This indicates that high concentration of goat manures and longer harvesting day could contribute to higher plant yield that conforms to similar observation by Ojeniyi and Adegboyega (2017) on effectiveness of this manure on growth and productivity of okra, Amaranthus, celosia, and maise in Southwestern Nigeria.

Nutrient composition of hydroponic wheatgrass

Protein content: Table 5 shows significant ($p<0.05$) variations in protein content among days and treatments. Results show that Day 10-T3 (300 g/L liquid fertilizer) had the highest CP content in all parts: leaf (44.3%), seed (27.3%), stem (29.3%), and root (20.4%) while C (0 g/L liquid fertilizer) has the lowest CP. This result may be attributed to increased nitrogen (N) content, particularly in wheatgrass leaves when using goat manure as fertilizer. Goat manure is known to have higher organic matter, nitrogen, calcium, phosphorus, carbon and minerals than cattle, chicken and pig manure (Gonzalez *et al*., 2023). Nitrogen serves as a vital source of protein in plants. Due to the nutrient richness of goat manure, including nitrogen, phosphorus, and potassium, the concentration of goat manure fertilizer positively correlates with increased crude protein levels. The nutrient solution enhances the CP content of the hydroponics fodder higher than the tap water, which may be due to the uptake of nitrogenous compounds (Hassen and Dawid, 2022).

Protein content in the leaf reveals a significant difference ($p<0.05$) among treatments. Treatment 3

Table 5: *Protein content of wheatgrass parts under different days and treatments.*

	Leaf				Seed			
Days	**C**	**T1**	**T2**	**T3**	**C**	**T1**	**T2**	**T3**
Day 8	30.9^{g}	36.7^{de}	35.2^{ef}	40.6^{bc}	13.9^{g}	14.3^{fg}	14.9^{def}	19.1^{cde}
Day 9	32.8^{fg}	37.5^{cde}	37.1^{de}	42.5^{ab}	15.3^{efg}	16.7^{efg}	16.5^{bc}	19.9^{ab}
Day 10	31.8^{g}	38.2^{cde}	39.6^{bcd}	44.3^{a}	16.4^{def}	20.7^{cd}	21.9^{ab}	27.3^{a}
SE	0.27	0.30	0.73	0.71	0.38	1.05	1.16	1.37
Stem					Root			
Day 8	18.8^{f}	20.1^{ef}	23.9^{def}	22.6^{c}	12.6^{cd}	12.2^{d}	12.9^{cd}	16.0^{bcd}
Day 9	20.7^{def}	20.9^{d}	25.6^{de}	27.1^{bc}	15.8^{bcd}	17.9^{ab}	19.6^{ab}	19.3^{ab}
Day 10	22.0^{de}	23.9^{bc}	28.2^{b}	29.3^{a}	16.7^{abc}	18.9^{ab}	19.8^{ab}	20.4^{a}
SE	0.49	0.86	0.86	1.10	0.64	1.06	1.24	0.93

C = No fertilizer, T1=100 g/L liquid fertilizer, T2= 200 g/L liquid fertilizer, T3= 300 g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments ($p<0.05$). SE = Standard Error.

Table 6: *Moisture content of wheatgrass parts under different days and treatments.*

	Leaf				Seed			
Days	**C**	**T1**	**T2**	**T3**	**C**	**T1**	**T2**	**T3**
Day 8	19.9^{cd}	10.3^{d}	15.5^{cd}	21.3^{bcd}	12.3^{c}	11.2^{c}	11.9^{c}	12.9^{bc}
Day 9	25.8^{bcd}	19.8^{cd}	22.8^{bcd}	31.5^{abc}	16.7^{abc}	15.4^{abc}	12.7^{c}	14.6^{abc}
Day 10	34.6^{ab}	29.0^{bcd}	30.9^{abc}	38.9^{a}	20.3^{a}	15.6^{abc}	17.0^{abc}	18.7^{ab}
SE	3.01	4.52	2.63	4.41	1.25	0.90	0.97	1.10
Stem					**Root**			
Day 8	3.5^{de}	4.6^{de}	6.9^{bcde}	6.5^{bcde}	7.0^{ab}	6.2^{b}	6.0^{b}	6.3^{b}
Day 9	4.1^{de}	10.9^{abc}	10.4^{abcd}	7.6^{bcde}	7.1^{ab}	7.4^{ab}	7.2^{ab}	6.7^{b}
Day 10	4.4^{cde}	12.6^{ab}	12.8^{ab}	14.1^{a}	7.5^{ab}	9.5^{a}	8.3^{ab}	9.6^{a}
SE	0.17	1.84	1.73	1.47	0.17	0.61	0.48	0.90

C = no fertilizer, T1 = 100g/L liquid fertilizer, T2 = 200g/L liquid fertilizer, T3 = 300g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments ($p<0.05$). SE = Standard Error.

exhibits the optimal concentration of goat manure, followed by T2 (200 g/L liquid fertilizer) and T1 (100 g/L liquid fertilizer). Conversely, the control group demonstrates the least favourable results, with the lowest mean protein content. Results also show an increase in CP content in leaf for control from day 8 (30.9%) to day 9 (32.8%) but a decrease in crude protein on day 10 (31.8%). This trend conforms to a study conducted by Islam *et al*. (2016). This may indicates that Day 9 is the optimum day for CP wheatgrass without fertilizer application.

Moisture content

Moisture content is crucial in maintaining good feed quality, minimising product loss and determining the product's water content (Uyeh *et al*., 2021). Table 6 shows a significant (<0.05) variation in the moisture content among the days and treatments. Results show that Day 10-T3 (30 g/L liquid fertilizer) exhibited the highest moisture content in all parts: Leaf (38.9%), seed (18.7%), stem (14.1%), and root (9.6%) while C (0 g/L liquid fertilizer) had the lowest CP. It is essential to consider that moisture content can be influenced by factors such as nitrogen supplementation and variations in nutrient levels in sprouting grains and goat manure, which are known to be high in organic matter and nitrogen content. In addition, cultivation conditions within hydroponic systems can also impact moisture composition of wheatgrass fodder as suggested by Peter *et al*. (2020). This observation also conforms to a study by Brahlek (2023) that hydroponic systems require significantly less water than soil cultivation, typically 80% to 90% less. As compared to conventional planting, the efficiency of hydroponic plants roots in absorbing water and nutrients from water source contributes to the decreasing trend observed throughout the harvesting period (Fayezizadeh *et al*., 2021). In contrast, soil cultivation necessitates a more significant amount of water due to water loss during movement through the soil and evaporation. Hydroponic systems, on the other hand, avoid encountering these issues, resulting in less effort required to absorb water.

Ether extract

The data in Table 7 shows significant (*p<0.01*) variations in the EE content among days. Results indicate that each treatment group exhibited the highest fat content in a specific part. Day 10-T3 shows the highest fat yield in leaf (9.0%) which may be due to the increase in the amount of chlorophyll and structural lipids during germination (Girma and Gebremariam, 2018). Addition of fertilizer to plants too may contribute to accumulation of lipid in leaf as reported by Gumus *et al.* (2024) that the highest EE was observed in fertilized sprouted barley compared to control without fertilizer.

Day 10-C shows the highest fat in seed (4.3%), stem (6.9%) and root (2.7%). Comparing these findings to a study by Thakur *et al.* (2019), the crude fat content in hydroponically cultivated wheatgrass fodder was approximately 3.49%, while conventional cultivation of wheatgrass showed a fat content of 2.3%. Thakur *et al.* (2019) also reported an average crude fat amount of 5.45 ± 0.212, which aligns with the fat content observed in the stem of this study. The findings indicated that crude fat content increased in all parts of the wheatgrass as the harvesting age increased. These findings aligned with Devi *et al.* (2020) that discovered a significant increase in crude fat content from day 7 to day 13. It is important to note that fat content can vary among different plant parts and treatments as specific fat composition in wheatgrass fodder can affect its nutritional value and potential applications.

Table 7: *Ether extract content of wheatgrass parts under different days and treatments.*

	Leaf				Seed			
Days	**C**	**T1**	**T2**	**T3**	**C**	**T1**	**T2**	**T3**
Day 8	2.4^{bc}	2.3^{bc}	2.3^{bc}	4.9^{b}	2.2^{ab}	1.4^{b}	1.7^{b}	1.4^{b}
Day 9	3.3^{bc}	3.4^{bc}	3.4^{bc}	5.9^{b}	3.6^{ab}	1.6^{b}	1.8^{b}	1.9^{b}
Day 10	5.6^{b}	6.0^{b}	6.0^{b}	9.0^{a}	4.2^{a}	2.2^{ab}	2.9^{ab}	2.9^{ab}
SE	3.01	4.53	2.63	6.44	0.79	0.61	0.47	0.82
Stem					**Root**			
Day 8	4.2^{ab}	0.7^{c}	1.1^{bc}	0.4^{c}	0.1^{c}	0.1^{c}	0.7^{b}	1.2^{ab}
Day 9	5.3^{ab}	2.3^{b}	2.1^{bc}	2.6^{b}	1.2^{ab}	0.1^{c}	0.9b	1.4^{ab}
Day 10	6.9^{a}	2.7^{b}	2.7^{b}	3.1^{b}	2.7^{a}	0.2^{c}	0.9^{b}	1.6^{ab}
SE	0.61	0.23	0.38	0.44	0.74	0.01	0.07	0.10

C = No fertilizer, T1=100 g/L liquid fertilizer, T2= 200 g/L liquid fertilizer, T3= 300 g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments (p<0.01). SE = Standard Error.

Table 8: *Ash content of wheatgrass parts under different days and treatments.*

	Leaf				Seed			
Days	**C**	**T1**	**T2**	**T3**	**C**	**T1**	**T2**	**T3**
Day 8	6.0^{d}	10.9^{abcd}	8.1^{cd}	8.9^{cd}	8.2^{c}	4.9^{bc}	7.9^{bc}	7.9^{bc}
Day 9	9.3^{bcd}	13.0^{abc}	12.6^{abc}	9.9^{abcd}	10.0^{ab}	7.9^{bc}	9.3^{ab}	9.9^{ab}
Day 10	13.1^{abc}	15.4^{ab}	15.5^{a}	11.9^{abcd}	11.9^{a}	10.4^{ab}	9.6^{ab}	11.1^{ab}
SE	1.11	1.66	1.70	0.54	0.74	0.95	0.46	1.94
	Stem				Root			
Day 8	0.1^{c}	0.2^{bc}	0.2^{bc}	0.2^{c}	0.1^{b}	0.03^{b}	0.06^{b}	0.04^{b}
Day 9	0.1^{c}	0.2^{bc}	0.3^{abc}	0.2^{abc}	1.2^{a}	0.05^{b}	0.08^{b}	0.07^{b}
Day 10	0.2^{c}	0.3^{abc}	0.3^{ab}	0.4^{a}	1.4^{a}	0.08^{b}	0.12^{b}	0.15^{b}
SE	0.01	0.02	0.02	0.03	0.22	0.01	0.01	0.02

C = no fertilizer, T1 = 100 g/L liquid fertilizer, T2 = 200 g/L liquid fertilizer, T3 = 300 g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments (p<0.01). SE = Standard Error.

Table 9: *Crude fiber content of wheatgrass parts under different days and treatments.*

	Leaf				Seed			
Days	**C**	**T1**	**T2**	**T3**	**C**	**T1**	**T2**	**T3**
Day 8	36.5^ab	36.8^ab	36.4^ab	46.2^a	21.9^ab	18.8^b	35.7^ab	42.5^a
Day 9	36.7^ab	37.7^ab	42.2^a	48.3^a	22.1^ab	22.1^ab	41.3^a	43.1^a
Day 10	38.3^ab	39.6^ab	45.8^a	48.5^a	22.5^ab	23.4^ab	43.2^a	43.7^a
SE	0.56	0.84	2.72	0.75	0.17	1.36	2.26	0.33
	Stem				**Root**			
Day 8	32.7^ab	26.9^b	31.5^ab	34.6^ab	25.5^b	34.6^ab	34.1^ab	31.3^ab
Day 9	33.9^ab	29.8^b	32.4^ab	35.9^ab	25.7^b	36.5^ab	36.5^ab	34.6^ab
Day 10	34.4^ab	31.6^ab	34.7^ab	42.2^a	25.8^b	41.3^a	41.3^a	43.1^a
SE	0.22	1.39	0.95	2.32	0.08	1.98	2.22	3.53

C = no fertilizer, T1 = 100 g/L liquid fertilizer, T2 = 200 g/L liquid fertilizer, T3 = 300 g/L liquid fertilizer. The subsets in the same column indicate a significant difference between the treatments (p<0.05). SE = Standard Error.

Ash content

Table 8 shows a significant (<0.01) variation in EE content among days. The results indicate that each treatment group exhibited the highest ash content on day 10 in a specific part. The highest ash content found in leaf was T2 (15.5%), control (11.9%) in seed, T3 (3.9%) in stem and control (1.4%) in root. Additionally, the study by Islam *et al.* (2016) reported that the highest ash yield in root was observed on day 10 (3.2%), aligning with the observations in this study. Results from this study too demonstrated that ash contents in all parts increase with day-to-day maturity regardless of treatments applied. The lowest ash content was observed in the leaf on Day 8 with a mean range (6.0 – 8.9%), which increased on Day 9 with a mean range of (9.3 - 13.0%) and on Day 10 with mean range (11.9 – 13.1%). This result corresponds to research by Edgar *et al.* (2017), that explained importance of goat manure in enhancing mineral content of wheatgrass. Absorption of minerals by the roots may be improved if goat manure is diluted with water as Dung *et al.* (2010) suggested that ash content of sprouts increases more if the nutrient solution is used rather than water, which may be due to the absorption of minerals by the roots.

Crude fiber (CF)

Significant differences of crude fibre content in hydroponics wheatgrass were observed during different days and treatments. Table 9 shows a significant (*p<0.05*) variation in CF. There was an increase in CF content shown with days and treatment. The highest yield was observed on Day 10-T3 in all parts: leaf (45.8%), seed (43.7%), stem (34.7%) and root (43.1%), respectively. These yields were comparatively higher that a study by Gumus *et al.* (2024) that recorded highest CF value of 21.54% in sprouted barley with the application of fertilizer and Grigas *et al.* (2024) with approximately 14.1% to 25.9% of CF content in hydroponically cultivated wheatgrass fodder. In this study, CF in leaf was the highest up to 45% which may be due the cultivation conditions, including nutrient composition and growth duration. Growth duration in plants tends to increase with the maturity stages according to Islam *et al.* (2016) that could attribute to the progressive concentration of cell walls as the plant matures.

Conclusions and Recommendations

In conclusion, the optimal harvesting age for hydroponically grown wheatgrass is day 10, with the inclusion of a 30% concentration of goat manure, specifically in treatment three as it has shown better growth performance, leading to better fodder production. The evaluation of wheatgrass harvested on day 10 with the inclusion of treatment 3 (30% concentration of goat manure) was shown to have high crude protein, crude fat, and crude fibre content. This research also shows that all fodder parts (leaf, stem, root and seed) are nutritious. Considering the specific nutritional requirements of different livestock, wheatgrass may emerge as a viable option for animal feed. The hydroponic technique is also recommended due to its ease, efficiency, and time-saving nature. Nevertheless, further studies should be conducted to explore the utilisation of goat manure as a fertilizer for various hydroponically grown fodder.

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Novelty Statement

The study presents a method for maximizing the potential of wheatgrass by determining the optimal harvesting age and enhancing its nutritional content to reduce farmers' reliance on conventional planting for livestock.

Author's Contribution

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Asmad Kari: Provided directions on data analysis, checked results from data analysis and evaluated the manuscript.
Enike Dwi Kusumawati and Wayan Karyasa: Checked results from data analysis and evaluated the manuscript.
Connie Fay Komilus: Supervised the experiments, provided directions on data processing, wrote and evaluated the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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