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Original Research

Forage Yield and Nutritive Values of Selected Improved Barley Varieties under Hydroponic System

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Abstract

The study aimed to assess the nutritional value and biomass yields of hydroponically grown improved barley using a completely randomized design. The cultivars HB-1307, HB-1965, and HB-1966 were grown hydroponically for twelve days, with watering intervals of two, three, and four hours. The study found no correlation between watering intervals and yield or fodder production characteristics in fodder harvested six, eight, ten, and twelve days after sowing. Barley cultivars' harvest dates significantly impacted their forage output, with the highest DMY yield on the sixth day. The biomass yield was also influenced by the variety of barley cultivars (p<0.05), with HB-1307 producing the highest amount (21.3 tonnes/ha) and HB-1966 second with 18.6 ns/ha. A notable effect on the nutritional composition and in-vitro digestibility of DM (IVDMD) of the fodder was the variation in barley types and harvesting dates (p<0.01). Longer harvesting dates were associated with a significant increase (p<.0001) in crude protein (CP) and cell wall contents (NDF, ADF, and ADL), with the lowest amounts achieved by the non-sprouted grain. Research indicates that HB-1307, an improved barley variety, yields the highest quality feed, with maximum yield achieved on the twelfth day of harvesting using hydroponically grown green fodder.

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INTRODUCTION

Approximately 85% of livestock keepers worldwide are located in SSA nations, and the socioeconomic development of SSA is significantly influenced by livestock production (Erdaw, 2023). According to Yigezu (2022), Ethiopia is one of the sub-Saharan African nations that uses mixed agriculture, or systems that combine the production of crops and animals. The country has approximately 65 million cattle, 40 million sheep, 51 million goats, 8 million camels, 49 million poultry, and 6.52 million beehives, according to the CSA (2021) report. Livestock is essential to the nation's ability to export goods like hides, skins, and live animals and generate foreign cash (CSA, 2017). According to Shapiro et al. (2017), the sector accounts for roughly 21% of the country's GDP, 49% of the GDP from agriculture, and 37–87% of family incomes (Behnke and Metaferia, 2011; Gebremariam et al., 2010). Additionally, it offers animal products like meat, milk, eggs, cheese, butter, and honey that provide people with the energy and animal proteins they need to improve their nutritional state. Shapiro et al. (2017) estimate that the industry contributes between 21% and 49% of the nation's GDP, which originates from agriculture, and between 37 and 87% of family earnings (Behnke and Metaferia, 2011; Gebremariam et al., 2010). It also provides animal goods that help people feel better nutritionally, such as meat, milk, eggs, cheese, butter, and honey. These products provide people with energy and animal proteins.

The primary cause of the nation's major livestock productivity bottleneck is the lack of feed, both in terms of quantity and quality (Duguma and Janssens, 2021). Increased feed prices contributed between 60 and 70 percent of the cost of producing livestock in Ethiopia (Yosef et al., 2022). The lack of feed in cities and metropolitan areas is a severe issue. This is due to the fact that the majority of Ethiopia's rural youth are moving to the country's cities and towns for a variety of reasons, including the need for education, employment opportunities, and future residency. These elements helped to hasten the rise of the urban population, which in turn raised food demand in areas where conventional forage production is challenging owing to a lack of available land. In these circumstances, it is crucial to look for alternative methods of producing fodder, such as hydroponics.

Many forage crops can be produced as green fodder using hydroponic technology in a clean, chemical-free environment without the use of fungicides, insecticides, herbicides, or artificial growth boosters (Al-Hashmi, 2008). Arable land is not necessary for the short development time (7–12 days) of hydroponically generated fodder (Al-Karaki, 2011). Rich in proteins, fibre, vitamins, and minerals, it has a high feed quality (Lorenz, 1980). In addition to its many other unique qualities, the hydroponic system is one of the most significant agricultural methods used today for the production of green fodder in many nations, particularly in metropolitan settings where there is a significant scarcity of both land and water (Al-Momani, 2010).

While a wide variety of tiny grains, including cereals and pulses, can be grown in hydroponic systems, barley is the most widely grown and least expensive cereal crop. Additionally, the enhanced barley varieties employed in this experiment were selected for hydroponic fodder producers due to their high grain yield and widespread availability in farmer's stocks and various research centres. Therefore, the purpose of this study was to assess how different watering schedules, varietals, and harvesting dates affected the biomass production and nutritional qualities of particular modified barley varieties grown in hydroponic systems.

MATERIALS AND METHODS

Site of experimentation

In western Ethiopia, at Wollega University, the study was carried out. The distance between the university and Addis Ababa is 328 kilometers west. 10° 0' 0" N latitude and 37° 30' 0" E longitude are its geographic coordinates. The area's average air temperature is 21°C, while the average indoor temperature in the laundry house is 28°C with an 83% humidity level. The lowest and largest amounts of rainfall recorded in the area are roughly 1376 mm and 2037 mm, respectively (Zemadim, 2011).

Tray and shelf arrangements

Plastic-made trays were bought from the Nekemte town open market. The bottoms of the trays were evenly perforated to create holes so that extra water could drain away during watering. Inside the lath house shade, sturdy metal shelves were set up to accommodate tray arrangements. In the lath home, three shelves were built side by side at comparable heights. The shelves were installed so that proper light and air entry could be provided by drainage and an adequate ventilation system. Subsequently, the trays containing hydroponically grown barley seeds were positioned on the shelves in accordance with the appropriate designs chosen.

Seed collection, preparation, and germination

The enhanced Holeta Agricultural Research Centre barley cultivars, HB-1307, HB-1965, and HB-1966, were acquired. For appropriate storage and germination, the seeds were sun-dried for a day to eliminate moisture. Normal seeds were chosen after the contaminants were physically cleansed. The seeds were weighed and then thoroughly cleaned with fresh water. For twelve hours, the seeds were submerged in fresh water. The seeds were taken out after 12 hours and given an hour to air out (Al-Hashmi, 2008). This breathing period promotes healthy seed germination. Following a period of breathing, the seeds were arranged on trays so that the density attained matched the seed rate of 4.5 kg/m^2 (Al-Hashmi, 2008).

Agronomic data collection and management

Seeding rate

The weight of pure seeds used on each tray prior to the commencement of watering is known as the seeding rate. First, the empty tray's weight was determined (W1). Next, unadulterated barley seeds were placed on the tray and weighed once again (W2). The seeds' weight was calculated as the difference between W2-W1.

Seeding date

The day that every variety of barley was ready and placed on the tray.

Germination date

The date that new plants emerge from seeds following a period of hibernation is known as the germination date. In this experiment, there was hardly any variation in the timing of germination across the several types of barley. On the second day, all types began to germinate, and on the fourth day, the process was finished.

Plant height during harvest

Using a clear glass ruler, the plant's height (measured in centimetres) was recorded at the conclusion of the 12th day of sprouted barley growth. Ten plants were chosen at random from four different sections of the tray, and their heights were measured for this purpose. The average height was then noted.

Weight of leaf in grammes

The weight of all the fodder in the tray was measured first during harvesting (W_1). After that, the sections of the leaves were cut with a razor blade, and the tray and root were weighed once more (W_2). The difference between W_1 and W_2 was used to calculate the fresh leaf's weight.

Weight of the root

Following leaf removal, the weight of the tray plus the root together, less the weight of the tray, was the weight of the root.

Leaf to root ratio

This indicates how leafy or nutrient-dense the hydroponically grown fodder is, even if both the roots and the leaves are edible. To compute this, divide the total weight of the leaves by the total weight of the roots.

Total yield of fodder

By adding the weight of the fodder and tray together, the total weight of the green fodder harvested was determined. At planting time, tray weight was noted for each treatment. The weight of the fodder and tray less the weight of the tray was the total fresh weight of the fodder.

Every tray was documented with the following information during harvest time. The ratio of produced green fodder to root weight and the total fresh and dry matter yield of the fodder were calculated. At harvest, representative fresh plant samples weighing about 150 grammes were obtained from each tray. The samples were dried for 48 hours at 105°C in a forced air draft oven, and the DM yield was calculated (James, 2008).

$$DM\ yield\left({}^{t}/_{ha}\right) = \frac{(10 \times TFW \times SSDW)}{(HA \times SSFW)}$$

Where: 10 = constant for conversion of yields in kg/m^2 to tone/ha;TFW = total fresh weight from harvesting area (kg);SSDW = sub-sample dry weight (g); HA = harvest area (m^2), and SSFW = sub-sample fresh weight (g)

Designs and treatments

There were two trials conducted, but not at the same time. The purpose of the first experiment was to assess the impact of watering intervals on enhanced barley varieties. Watering intervals of two, three, and four hours were delivered manually using a watering can and tap water for 30 seconds per tray for a period of twelve days. In the second experiment, the fodder of the same enhanced barley varieties was harvested on days six, eight, ten, and twelve following planting. Watering intervals of four hours were chosen to ensure optimal biomass yield and nutritional properties. Equal weights of composite samples of the varieties were utilised to investigate the effects of harvesting dates on nutritive values and fodder yields, with the exception of the effect of varieties on fodder yield and nutritive values. Since the experiment was conducted in a greenhouse, all other variables were taken to be under control. To investigate the impacts of the varieties' harvesting date and watering intervals, completely randomised design (CRD) was used.

Examining Chemicals

The Holeta Agricultural Research Centre (HARC) assessed the results of the chemical examination of the fodder samples. The fodder samples were dried in an air-drafted oven at

60°C for 48 hours to ascertain the partial dry matter (DM) of each variety of barley (Fazaeli et al., 2012). The samples were dried, sieved to a 1 mm pore size, and then kept for chemical analysis and in-vitro DM digestibility testing (Hande et al., 2014). The DM and ash contents were analysed using the AOAC (2000) methods. The crude protein (CP) was calculated as N×6.25, and the nitrogen (N) concentration was determined using the Micro Kjeldahl method. Using the methods of Van Soest et al. (1991), the amounts of acid detergent lignin (ADL), neutral detergent fibre (NDF), and acid detergent fibre (ADF) were determined.

In vitro DM digestibility

Similar to the chemical study, in vitro DM digestibility was carried out at HARC. The two-stage Tilley and Terry (1963) approach was modified by Van Soest et al. (1991) to investigate the in-vitro DM digestibility of barley hydroponic samples. To replicate true digestibility, neutral detergent extraction was used in place of the second stage, which calls for Rumen liquor-pepsin digesting.

Analytical Statistics

A General Linear Model (GLM) approach of the statistical analysis system (SAS, 2008) version 9.2 was used to analyse the data on biomass yield and yield related components, chemical compositions, and in vitro DM digestibility. At $\alpha=0.05$, the Duncan's Multiple Range Test (DMRT) was utilised for the mean comparison. The experimental model that was employed was;

$$Y_{ij} = \mu + t_i + e_{ij}$$

Where, μ= the overall mean; t_i= the i^{th} effect of watering intervals and harvesting dates; e_{ij}= the error term

RESULTS AND DISCUSSION

Effect of watering intervals on fodder yield and yield related components

With the exception of plant height, all other parameters examined and the dry matter yield (DMY) of the hydroponic barley fodder were unaffected by watering intervals ($P>0.05$) (Table 1). The average DMY for two-, three-, and four-hour watering intervals was 18.12, 18.93, and 19.58 tons/ha, respectively. When the watering interval was lengthened, the fodder yield was comparatively best gathered. The DMY values for sprouted barley were less than the seed weight at all watering intervals. The study's observation of a reduction in dry matter output during sprouting is consistent with the findings of Fazaeli et al. (2012), who reported a decrease of dry matter yield in barley hydroponic fodder. According to Chavan and Kadam (1989), DMY is also lost during germination as a result of the increased metabolic activity of sprouting seeds, which is powered by the partial oxidation and breakdown of the seed's starch. On the other hand, the fact that the averages of DMY against watering intervals did not differ statistically could indicate that the root weight predominated over the leaf weight in all treatments. This was due to the fact that the watering intervals had an impact ($P<0.05$) on plant height, which impacts the fodder's above-root performance.

For two-hour, three-hour, and four-hour watering intervals, the mean plant height values were 12.88, 14.16, and 14.88 cm, respectively. The results indicated that the lowest mean value (12.889 cm) was recorded at the two-hour watering interval of a day, and the greatest mean value (14.88 cm) was obtained at four hours. The increased frequency of watering that encouraged leaching was primarily responsible for the lowest mean DMY value measured for a two-hour watering period. Because roots account for the majority of the fodder yield in this study, plant height appears to have contributed less to the overall DMY.

At 4-hour watering intervals, the best mean dry leaf harvest (2.61t/ha) was observed. This could be the result of less frequent watering intervals and condensed leaching, which limit plant growth. The average dried root weight for watering intervals of two hours, three hours, and four hours was 17.72, 17.39, and 15.50 tons/ha, respectively. The findings were consistent with those of Mesfin et al. (2020), who reported decreased root weight as watering intervals increased for various maize varieties under hydroponic systems in similar environments. The average dried root weight decreased as watering intervals increased.

The leaf to root ratio (LRR) range of 0.09 to 0.18 suggests that only a portion of the overall fodder yield—between 9 and 18%—comes from the leaves. Furthermore, it demonstrates that the root portion of the overall mass has a significant influence on the amount of fodder generated and the nutritional values in the current study. The green section of these fodders, known as the leaf region, is where the concentration of vital elements that are beneficial to animals is anticipated. But even though it appears vigorous when growing (as observed), its dry matter contribution is less than that of its root weight. Researchers must pay attention to this in order to improve the herbage DMY of the hydroponic fodder through additional experiments.

Table 1

Effect of watering intervals on biomass yield of improved barley varieties

Parameters	2 hours	3 hours	4 hours	SEM	P-value
Seed weight (t/ha)	25.78	25.78	25.78	0.19571	1.0000
Plant height (cm)	12.88^{b}	14.16^{ab}	14.88^{a}	0.41644	0.0461
Fresh yields (t/ha)	81.33	93.84	89.34	3.69116	0.1939
Root weight (t/ha)	17.72	17.39	15.50	0.94978	0.2590
Leaf weight (t/ha)	1.85	1.54	2.61	0.21714	0.3662
LRR (t/ha)	0.11^{ab}	0.09^{b}	0.18^{a}	0.017118	0.1469
DMY (t/ha)	18.12	18.93	19.58	0.94746	0.3607

Biomass Yield of Improved Barley Varieties on Different Harvesting Dates

Variations in harvesting dates had a significant (P<0.05) impact on the dry matter yield (DMY) and yield-related components of enhanced barley varieties (Table 2). On the sixth, eighth, tenth, and twelfth days of harvesting, the average DMY was 27.95, 26.74, 26.04, and 19.01 tons/ha, respectively.

It has been demonstrated that in this hydroponic system, a later harvest date led to a lower DMY. The fresh biomass yield on the twelfth day of harvesting was 4.4 times higher than the fodder DMY. This outcome was consistent with the findings of Fazaelil et al. (2011), who reported that as the harvesting date is extended, the DM content of fodder decreases. Contrary to its DMY, the fodder's greater fresh yield with longer harvesting times indicates that the moisture content rose as the herbage grew.

In addition to the metabolic loss of nutrients in the seed, the decreasing trend in DMY of the feed during the longer growth period of the plants indicates that nitrogen is a particularly limiting nutrient in this instance. This is because the barley varieties used in this study have stomata that allow them to absorb carbon from the air, one of the macronutrients needed for growth. As mentioned in the methods section, they also receive watering intervals every four hours. The barley types did not receive adequate nitrogen, one of the essential nutrients for vegetative growth, because the system was hydroponic and soil was not used in this instance. This would have allowed DMY to be sustained at least as much as its seed weight. N is one of the primary elements of the living plant's chlorophyll structure (Amin, 2022). The amount of chlorophyll in a plant is a key factor in regulating how quickly it photosynapses and produces (Amin, 2022). This was corroborated by Britz et al. (2023), who found that higher nitrogen fertiliser levels promoted the growth of plants' roots, shoots, and branches. Furthermore, the study's barley grain nitrogen percentage (composition) was 2.16% (table 2), which was insufficient to maintain the fodder's ideal DMY in a hydroponic system. According to other researchers (Luis et al., 2021), the kinds utilised in this study had a nitrogen composition of 1.06%, which is less than that of the same element. Even on field crop farms where some soil nitrogen is available, about 46–92 kg/ha of nitrogen is sprayed for the production of barley crops (Kedir and Aliyi, 2021). It is a fact that a higher rate of nitrogen may be needed in a hydroponic system where the soil is not used for plant growth to promote greater vegetative growth and a higher yield of feed.

On the sixth, eighth, tenth, and twelfth days of harvesting, the average plant heights were 4.40, 6.83, 9.28, and 12.16 cm, respectively. It showed that longer harvesting intervals led to an increase in plant height, with the tallest plants being those cut on the twelfth day. The current study's motivation to measure plant height stemmed from the possibility that it may have positively impacted feed DMY. The apparent outcome, however, did not match the reality. The cause was that as the plants grew, the herbage (sprouted) portion's metabolic needs increased and the nutrient in the seed portion was more fully utilised. As a result, the DMY of the fodder declined as harvest dates approached. It was clear that enhanced plant leaf output was the outcome of a prolonged harvesting date. This indicates that even though the date of harvesting rose, photosynthesis persisted and plant leaf growth maintained, but DMY remained lower than that of the seed.

The lowest mean value of dry root weight was observed on the twelfth day, and the root dry matter production declined with increasing harvest time. Given that the leaf-to-root ratio (LRR) is the ratio of plant leaf to plant root, the plant with the higher plant LRR was the one that was harvested after 12 days because as harvesting time increased, the root weight decreased relative to the leaf weight.

Table 2

Effect of harvesting dates on biomass yield of improved barley varieties

Parameters	6^{th} day	8^{th} day	10^{th} day	12^{th} day	SEM	P-value
Grain weight (t/ha)	25.78	25.78	25.78	25.78	0.1687	1.0000
DMY (t/ha)	24.35^{a}	24.24^{a}	24.04^{a}	19.01^{b}	0.9223	0.0003
Plant height (cm)	4.40^{d}	6.83^{c}	9.28^{b}	12.16^{a}	0.6198	0.0001
Fresh yield (t/ha)	59.23^{b}	78.19^{a}	82.40^{a}	83.76^{a}	3.2067	0.0001
Root weight(t/ha)	34.17^{a}	26.54^{b}	25.25^{b}	18.70^{c}	1.0606	0.0001
Leaf weight (t/ha)	0.30^{c}	0.79^{bc}	1.22^{ab}	1.40^{a}	0.1181	0.0242
LRR (t/ha)	0.009^{c}	0.030^{bc}	0.047^{b}	0.074^{a}	0.0058	0.0015

LRR = leaf to root ratio; DMY = Dry matter yield of hydroponic fodder; SEM = Standard error mean; tons/ha= tone per hectare; cm = centimeter; a b c = Means with different superscript letters within rows differ at p<0.05.

Varieties Affected Biomass Yield of Improved Barley under Hydroponic System

Table 3 shows the impact of several types on improved barley's yield and the components connected to yield. The majority of the parameters examined showed no significant difference (P>0.05) between the enhanced barley varieties. For HB-1307, HB-1965, and HB-1966, the average yields of green fodder are 98.27, 75.91, and 90.33 tons/ha, respectively. The results of this experiment showed that HB-1307 had the highest green fodder yield (98.27 t/ha), followed by HB-1966, and HB-1965 had the lowest output. This could be because different cultivars have different individual grain sizes, which affect the nutrients that sustain the growth of the herbage portion. The current results' mean ratio of fresh green fodder to original seed weight (3.4 times) is less than that of Al-Karaki's (2010) report, which identified barley hydroponic green fodder as an alternative technique for conserving water in arid regions eight times. The environmental conditions in which the experiment was conducted may have had an impact on the outcome. One possible explanation for the variations in yield could be the utilisation of distinct barley cultivars for hydroponically produced feed. The yield of dry matter in the fodder did not exhibit any significant variations (p>0.05) across the treatments, and the final weight was lower than the seed's initial weight. This indicates that there were some dry matter losses. The majority of other researchers (Dung et al., 2005; Fazaeli et al., 2012; Putnam et al., 2013; Sneath and McIntosh, 2003) also found similar numbers, indicating that after sprouting for 6-7 days of growth, respiration was the primary cause of the 7–47% loss in DM from the initial seed.

Figure 1: Plant growth in days

In one production cycle, the height of the barley seedlings in this study varied from 12.33 cm to 15.55 cm, with the HB-1307 variety having the tallest barley seedlings. The current study's height was lower than Mooney's (2005) and Reddy's (2014) studies, which reported receiving 20–30 cm of hydroponically grown feed in 6–8 days. This resulted from many factors influencing the hydroponic fodder growth that was used to manage the experiment (El-Deeba et al., 2009; Jeton, 2016). Compared to HB-1965 and HB-1966, the variety HB-1307 has a greater mean dry leaf weight value. For HB-1307, HB-1965, and HB-1966, the average leaf weights were 2.67, 1.17, and 2.16 tons/ha, respectively.

The dry root weight did not significantly differ across treatments ($p>0.05$). The average root weights for HB-1307, HB-1965, and HB-1966 were 18.63, 15.53, and 16.46 tons/ha, in that order. Similar changes in root and leaf weights were seen with LRR. The cultivar HB-1307 performed better overall across all criteria examined, which may be explained by its bigger grain.

Table 3

Effect of varieties on fodder biomass yield of different improved barleys

Parameters	HB-1307	HB-1965	HB-1966	SEM	P-value
Seed weight (t/ha)	25.78	25.78	25.78	0.19571	1.0000
Plant height (cm)	15.55[a]	12.33[c]	14.05[b]	0.41644	0.0006
Fresh yield (t/ha)	98.27[a]	75.91[b]	90.33[ab]	3.69116	0.0200
Root weight (t/ha)	18.63	15.53	16.46	0.94978	0.1847
Leaf weight (t/ha)	2.67[a]	1.17[b]	2.16[a]	0.21714	0.0623
LRR (t/ha)	0.16	0.08	0.14	0.017118	0.2131
DMY (t/ha)	21.30[a]	16.70[b]	18.63[ab]	0.94746	0.0143

LRR = leaf to root ratio; DMY = Dry matter yield; SEM = Standard error mean; tons/ha= tone per hectare; cm = centimeter; a b c = Means with different superscript letters within rows differ at $p<0.05$.

Nutritive Value of Improved Barley Varieties under Hydroponic System

Table 4 displays the chemical composition and in vitro dry matter (DM) digestibility of enhanced barley varieties produced hydroponically, as well as the corresponding grain variety. The findings demonstrated a substantial difference (p<0001) in all chemical parameters between barley grain and sprouted barley feed. Barley grain had the highest average DM content (94.2%) whereas sprouted fodder had the lowest average DM content (91.93%). The findings demonstrated that, in comparison to barley fodder grown in grains, hydroponically grown barley fodder had a reduced DM concentration. This was consistent with the findings of Morgan et al. (1992), who said that losses in DM content were brought about by the germination process. The DM levels of the barley types cultivated hydroponically in the current study ranged from 91.86 to 92.05%, which was consistent with the results of Emam et al. (2018), who reported 91.22 to 92.37% DM of barley hydroponic fodder.

The hydroponically produced barley varieties exhibited considerably (p<.0001) greater crude protein (CP) levels than their grain. The average values for barley grain and sprouted barley of HB-1307, HB-1965, and HB-1966 were 13.42%, 18.53%, 18.53%, and 16.85%, respectively. This shows that when modified barley grains sprout, the fodder's CP content rises relative to the grain. Comparable to other researchers' results (Sneath and McIntosh, 2003), where the CP ranged from 11.38 to 24 percent, were the CP contents obtained in this investigation. Additionally, it was comparable to the Fazaeli et al. (2012) research, in which the CP varied from 14.9% to 24.9%. However, it was higher than the findings of Morgan et al. (1992), who reported that in a hydroponic method of producing barley fodder, the CP content grew from 10.8 percent at day 4 to 14.9 percent at day 8.

It was, nevertheless, greater than the findings of Al-Ajmi et al. (2009) and Snow et al. (2008), who reported hydroponic barley fodder yields of 14% and 16.13%, respectively. The longer sprouting time was responsible for the larger losses in dry weight and increasing trend in protein content, and this increase in percent CP content may be related to the loss of carbohydrates through respiration during germination (Chavan and Kadam, 1989).

The average results ranged from 5.37 to 6.10%, with the ash contents of fodder from hydroponically grown barley types being greater (p<.0001) than its grain. The current study's findings, which show that green fodder has more ash than the original barley grain, are consistent with the findings of Fazaeli et al. (2012). According to Morgan et al. (1992), changes in the ash content happen quickly starting on day 4, which coincides with the root's (radicle's) expansion and permits the uptake of minerals. In the current experiment, the average ash concentration (5.8%) exceeded the results of Intissar and Eshtayeh (2004), who found that 3.6% of the barley feed was hydroponically grown.

Improved barley varieties grown hydroponically had significantly (p<.0001) higher cell wall contents (NDF and ADF) and lignin (ADL) than original grains. The NDF averages for barley grain and hydroponically grown fodder of HB-1307, HB-1965, and HB-1966 were 31.38%, 45.83%, 43.25%, and 46.53%, respectively. This suggested that barley grains might be sprouted to boost the fodder's fibre content. The outcome corroborated Lorenz's (1980) findings, which found that grain sprouting enhanced crude fibre content. The current NDF concentration of the sprouted fodder, however, was greater than what Fazaeli et al. (2012) found, which showed that the NDF content of hydroponic barley fodder was 35.40%. Feeds with NDF values less than 45% are categorised as high-quality fodder, feeds with values between 45% and 65% are categorised as medium, and feeds with values above 65% are classified as low-quality fodder, according to Singh and Oosting (1992). According to the current study, the variety HB-1965's NDF content, which was below 45%, satisfies the high-quality forage requirements; the remaining varieties fell into the medium-quality classifications. This demonstrates that significant animal consumption was anticipated from the hydroponic barley fodder produced in the current study.

For hydroponically grown barley types, the ADF values in the current study varied from 19.04 to 21.84%; these values were greater than those found by Fazaelil et al. (2012), who reported 17.15%. The enhanced barley grain and hydroponically grown fodder of HB-1307, HB-1965, and HB-1966 had mean values for ADL of 2.62%, 8.04%, 6.84%, and 8.60%, respectively. The outcome demonstrated that barley types grown hydroponically have higher ADL values. The outcome is consistent with the research done by Emam et al. (2018), who found that hydroponic green fodder barley considerably increased ADL values when compared to original barley seeds.

The IVDMD of barley types cultivated hydroponically in the current investigation was considerably (P<.0001) lower than its initial grain. This might be the result of the barley grain growing into hydroponic fodder, which increases the cell wall and ADL contents. The outcome is consistent with the findings of Peer and Leeson's (1985) study, which showed that sprouting grains' DM digestibility significantly decreased during the course of a 7–8-day growth cycle. The results of Mansbridge and Gooch (1985), Grigor'ev et al. (1986), and Cuddeford (1989), who reported 72–76% on the in-vitro digestibility of hydroponically grown barley at 6–8 day growing periods, are less than the mean value of IVDMD range 62.55 – 65.78% in the current study.

Table 4

Effect of varieties on chemical composition and in vitro DM digestibility of selected improved barley varieties under hydroponic systems

Parameters	Grain	HB-1307	HB-1965	HB-1966	SEM	P-value
DM (%)	94.24[a]	91.86[b]	91.87[b]	92.05[b]	0.20108	0.0001
Ash (%)	4.00[b]	6.10[a]	5.37[a]	5.92[a]	0.19377	0.0001
CP (%)	13.42[b]	18.53[a]	18.53[a]	16.85[a]	0.46339	0.0001
NDF (%)	31.38[c]	45.83[ab]	43.25[b]	46.53[a]	1.14116	0.0001
ADF (%)	12.42[b]	21.43[a]	19.40[a]	21.84[a]	0.78308	0.0001
ADL (%)	2.62[c]	8.04[ab]	6.84[b]	8.60[a]	0.48175	0.0001
IVDMD (%)	82.53[a]	62.88[b]	65.78[b]	62.55[b]	1.61400	0.0001

DM = Dry matter; CP = crude protein; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; ADL = Acid detergent lignin; IVDMD = In-vitro dry matter digestibility; SEM = Standard error means; a b c Means followed by different superscript letters within treatments differ at p<0.05

Harvesting Date Affected Nutritive Values of Improved Barley Varieties Fodders under Hydroponic Systems

Table 5 displays the results of the evaluation of the modified barley grain's chemical composition and in-vitro DM digestibility as well as that of the hydroponically grown fodder. The findings demonstrated that the harvesting date had an impact on every nutritive value parameter examined (P<0.0001). Extended harvesting times resulted in a significant (P<.0001) increase in the CP content of the cultivars. The current result was consistent with Flynn et al. (1986) report, which reported that the CP content gradually increases with longer growth time.

For the original barley seed and its fodder gathered on the twelfth day, the mean DM values were dramatically (p<.0001) reduced from 94.24% to 91.11%. The outcome concurs with the research conducted by Fazeli et al. (2012), which indicated that the DM content of seeds decreases as they sprout.

With an increasing harvest date, barley variety fodder's ash content rose. The outcome supported the findings of Naik et al. (2012), who found that the ash content of the seeds rose as they sprouted.

The hydroponically grown barley cultivars exhibited a considerable (p<.0001) increase in cell wall contents (NDF, ADF, and ADL) as the harvesting date advanced.

Similar findings for cell wall accumulation, including elevated mean values for NDF, ADF, and ADL as a result of longer growth duration, were reported by Hoffman et al. (2003). Additionally, it corroborated the results of Fazeli et al. (2012) and Naik et al. (2012), who found that the components of the plant's cell wall grew as the harvest period progressed.

Table 5

Harvesting dates affected the nutritive values of improved barley varieties

Parameters	Grain	6^{th} day	8^{th} day	10^{th} day	12^{th} day	SEM	P-value
DM (%)	94.24^a	93.09^b	92.59^c	92.08^d	91.11^e	0.1676	0.0001
Ash (%)	4.003^b	5.235^a	5.485^a	5.838^a	6.085^a	0.1674	0.0001
CP (%)	13.52^c	16.18^b	16.43^b	17.14^b	20.35^a	0.3977	0.0001
NDF (%)	31.38^c	42.23^b	42.48^b	46.27^a	46.88^a	0.9627	0.0001
ADF (%)	12.43^c	17.91^b	18.16^b	21.05^a	23.47^a	0.6777	0.0001
ADL (%)	2.62^c	5.673^b	5.923^b	8.373^a	9.193^a	0.3997	0.0001
IVDMD (%)	82.54^a	74.05^b	71.35^c	69.50^d	67.36^e	1.3623	0.0001

DM = Dry matter; CP = crude protein; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; ADL = Acid detergent lignin; IVDMD = In-vitro dry matter digestibility; SEM = Standard error means; a b c Means followed by different superscript letters within treatments differ at p<0.05

In the current investigation, the IVDMD for the original seed and sprouted barley harvested on the 12th day, respectively, decreased dramatically (p<.0001) from 82.53% to 57.36%. In a similar vein, Peer and Leeson (1985) also reported that sprouting grains' DM digestibility gradually decreased over the course of a 7–8-day development cycle.

CONCLUSIONS

For all barley varieties grown in a hydroponic system, the greatest biomass yield was obtained with a 4-hour watering interval. Out of all the types that were employed in this study, HB-1307 demonstrated greater fodder yield and associated yield components. The most nutrient-dense fodder was the HB-1965 barley variety, as shown by its chemical composition and IVDMD values, which were produced in a hydroponic environment. The ideal time to harvest barley varieties for hydroponic fodder output was found to be on the twelfth harvesting date. When compared to its grain equivalent, barley types that were sprouting produced the highest levels of CP, ash, and cell wall components (NDF, ADF, and ADL). Harvesting in short days, before the 12th day, is beneficial for better IVDMD results. This, however, restricts the fodder's hydroponic herbage output.

RECOMMENDATION

It would be crucial if more research was done to figure out how to address the issue of the hydroponic fodder's decreased dry matter yield in comparison to its grain counterpart.

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DECLARATION

The authors declare that there is no any conflicting interest.

DATA AVAILABILITY

Data used for this study are available from the corresponding author for reasonable issues.

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