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Comparison of the fodder yield, nutritive value and cost of triticale and vetch mixtures under hydroponic condition

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ABSTRACT

This study aimed to determine the effects of different ratios of triticale and vetch seeds and the use of fertilizer on fodder yield, nutritive value, and the cost of grown fodder. The treatments included five ratios of triticale seeds to vetch seeds at 100:0, 90:10, 80:20, 70:30, and 0:100 (V0, V10, V20, V30, and V100, respectively) and a fertilizer treatment (with [+] or without [-] fertilizer). Considering yield performance, differences were found among treatments, with the highest yield (21.78 kg fresh weight m^{-2}) for V0+ treatment and the lowest (18.48 kg fresh weight m^{-2}) for V100- treatment. With increasing proportions of vetch seeds, ash, the content of crude protein, and acid detergent fiber increased linearly, whereas neutral detergent fiber and nitrogen-free extract decreased linearly. The content crude fiber was lowest (8.43%) for V0+ and highest (10.26%) for V100+ fodders, respectively. The highest neutral detergent fiber was observed for V0- fodder, while V100- fodder revealed the lowest neutral detergent fiber. Acid detergent fiber was lowest for V0+ fodder compared with all other treatments. The nitrogen-free extract content in V0+ fodder was gradually higher than that of other fodders. The fodder's energy value was significantly different among the treatments. The study results showed that the seed cost was the highest in the V0+ fodder to produce one kg fresh fodder. The higher expense for one kg CP and one unit of energy (MJ kg^{-1}) was obtained in V0- fodder as well. Taking those factors into account, the most profitable fodder seems to be vetch fodder grown individually or in combination with triticale (V30).

Introduction

The hydroponic system allows for the growth of plants without soil (31). It can be employed for green fodder production in a hygienic environment without the use of chemicals such as herbicides, insecticides, and fungicides. First discovered in 1860 in England and referred to as "Nutriculture," it emerged as an alternative to conventional agriculture. Agricultural and livestock businesses have been utilizing soilless agriculture equipment to maximize productivity (18, 33). A hydroponic production chamber for green fodder is a closed system where environmental parameters, including temperature, humidity, lighting values (1000 to 1500 microwatts cm^{-2}), pH, and electrical conductivity (EC) values of water, and the irrigation system, can be adjusted to desired values. These parameters are essential for faster and healthier plant growth (18). Hydroponic systems or incubation rooms do not require soil or nutrient mediums for green fodder growth. Optimal temperature, humidity, and light are necessary for improved germination, making green feed production much more manageable (22, 33). After germination, the roots interlock, forming a carpet-like structure, with stems reaching a height of 21-24 cm in 7-9 days, producing 7-9 times more fresh green fodder than the initial seed weight (31, 33). Soil-planted crops demand more time, tools, labor, and extensive field areas, and their growth can be affected by climate change. Utilizing hydroponic systems provides a simple solution for producing grass fodder in a few days to meet ruminant nutritional needs (31). Some researchers have reported that the nutritional values of hydroponically grown green fodder are higher after 7 days of growth (2, 30). As fiber increases, energy levels and organic matter content decrease linearly after 7-8 days from planting (14, 15, 20). Throughout the sprouting process, the conversion of starch to sugar alters the nutritive value of fodder, resulting in an increase in ash and crude protein content, a decrease in dry matter content, and starch levels (29). Factors such as fertilization, temperature, seed quality, moisture, and seed density can influence the quality and yield of green fodder (31). It is worth noting that fungal and mold proliferation may occur due to the high water content of green fodder produced in hydroponic systems (31). On the other hand, there could be a challenge in using green fodder with low dry matter content for animal nutrition (17). While barley is commonly used in hydroponic systems (12-14, 21), studies on the nutritional values and plant heights of green fodders produced from other crops, such as sorghum, wheat (4), or oats (17), exist. However, few studies have focused on the comparison of green fodder performance of triticale and vetch seeding in a hydroponic system, and limited data is available on their nutritive value. Therefore, the aim of the study was to compare the fodder yield, nutritive value, and cost of triticale and vetch mixtures seeded in different ratios in a hydroponic system.

Materials and Methods

The experiment was conducted in a stainless steel hydroponic chamber at the Agriculture, Livestock, and Food Research and Application Center of Burdur (Southern Turkey, 30° 53' E, 36° 53' N and 950 m above sea level) Turkey in 2020. The intensive hydroponic system was constructed using a steel stand with dimensions of 2.80 m × 9 m × 7 m (H × L × W), equipped with seven shelves having a total capacity of 196 polyethylene trays (70 × 30 × 5 cm; 0.21 m^2). Hydroponic conditions were maintained with a temperature of 18-19 °C, relative humidity of 60%, a lighting time of 12 hours using yellow-colored lights, and irrigation every 2 hours for 90 seconds throughout the research period. The growing period lasted for 7 days after seed planting. The production chamber, trays, irrigation system, and necessary tools were sterilized with 10 % formaldehyde before planting. To mitigate the risk of mold formation, 50 ml of sodium hypochlorite (%20) was added to the irrigation water daily. Tap water was used for irrigation.

Triticale and vetch seeds were mixed at ratios of 100%:0%, 90%:10%, 80%:20%, 70%:30%, and 0%:100% (V0, V10, V20, V30, and V100, respectively). The experiment followed a completely randomized design with a 5 × 2 factorial treatment arrangement (five seed ratio treatments and two fertilizer treatments, with (+) and without (-)), with four replications. A total of 40 trays (five seed treatments x two fertilizer treatments x four replicates) were used in the hydroponic chamber. Liquid fertilizer NPK 8% N (1/8 Ammonium N, 1/8 Nitrate N, and 6/8 Urea N), 4% P_2O_5, and 3% K_2O (8:4:3) was applied at the rate of 10 ml into each tray per day, and each treatment received 350 ml of liquid fertilizer during the study. Seeds were pre-soaked in water separately for 24 hours to clean them from impurities, straw, etc., and to accelerate germination. In this study, seeds absorbed an average of 70% of their weight in water before planting, with an average of 1.7 kg of seed applied per tray (17). The dry seeding rate applied was approximately 1000 g per tray before soaking. The trays were placed on the shelves of the hydroponic chamber and allowed to grow for 7 days. At the end of the study, all trays were weighed to determine fresh weight (FW) and dry weight (DW) of fodder. The obtained dry fodder (kg) was divided by dry seed (kg) to determine the fodder produced (kg) per one kg dry seed (df/ds).

Feed samples were analyzed based on the AOAC (7) method for dry matter (DM, method 934.01), ash (method 942.05), ether extract (EE, method 920.39), and N (method 954.01) contents. ADF, NDF, and CF content were determined following the ANKOM (Ankom200 fiber analyzer, Ankom Technology Corp., Fairport, NY) methods. Non-fibrous carbohydrates (NFC =100 - (%NDF + %CP + %EE + %Ash) and nitrogen free extract (NFE= 100 - (%CF + %EE + %CP + %Ash) were calculated according to the standards of the National Research Council equation. The energy value of fodder was calculated according to Kirchgessner and Kellner (23) and MAFF (24). The unit production cost was calculated by using seeds and fertilizer expenses in the produced fodder under the same conditions, essentially dividing the seed plus fertilizer cost ($) by the produced fodder (kg ha^{-1}). $1 US Dollar is equal to 13.80 Turkish lira.

Statistical Analysis: A two-way ANOVA was applied using general linear model procedures of SPSS 22 (19) to compare fodder yield, nutritive value, and production cost of green fodder across treatments. Significant differences between means were calculated using the Tukey HSD test at α=0.05. The data were analyzed by independent-samples t-test to compare the nutritive value of both crop seed and their fodder.

Results

The effect of fertilizer and treatments on the FW (kg per tray) was significant (P<0.001). The highest FW (kg m^{-2}) was obtained by V0+ and V10+, while the lowest value was observed for V100- and V100+ (P<0.001). There was a significant treatment and fertilizer interaction for df/ds

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(P<0.05) and DM loss (P<0.01). The df/ds ratio ranged from 0.90 to 1.06 among all treatment groups. The dry fodder per unit dry seed (df/ds) was highest for V100+. The highest DM loss was observed in V20+, while the highest DM recovery was in V100+ (Table 1).

The nutritive values of green fodder are listed in Table 2. The content of crude protein (CP), ether extract (EE), and nitrogen-free extract (NFE) was significantly affected by seed ratio treatments, fertilizer addition, and their interaction (P<0.001). The fodders treated with

Table 1. Fodder yield from different ratios of triticale and vetch seeds with or without fertilizer grown in a hydroponic system.

Parameters[1]	F[2]	Treatments[3] (%)					SEM[4]	Impact[5]		
		V0	V10	V20	V30	V100		T	F	T×F
FW, kg/tray	-	4.52^{a}	4.48^{a}	4.46^{a}	4.50^{a}	3.89^{b}	0.02	***	***	ns
	+	4.57^{a}	4.53^{a}	4.51^{a}	4.54^{a}	3.95^{b}				
DW, kg/tray	-	0.85	0.90	0.88	0.91	0.87	0.03	ns	ns	ns
	+	0.94	0.89	0.84	0.89	0.99				
FW, kg m^{-2}	-	21.51^{a}	21.35^{a}	21.26^{a}	21.43^{a}	18.48^{b}	0.09	***	***	ns
	+	21.78^{a}	21.58^{a}	21.49^{a}	21.63^{a}	18.79^{b}				
DW, kg m^{-2}	-	4.00	4.30	4.18	4.35	4.19	0.15	ns	ns	ns
	+	4.49	4.24	4.01	4.24	4.71				
df/ds; kg/kg	-	0.91	0.97	0.94	0.98	0.94	0.04	ns	ns	*
	+	1.02	0.96	0.90	0.96	1.06				
DMloss, %	-	9.05-	2.75-	5.58-	1.97-	6.07-	2.20	ns	ns	**
	+	1.96+	4.12-	9.50-	4.28+	6.26+				

ns: not significant; *P<0.05; **P<0.01; ***P<0.001
[1]FW: Fresh weight, DW: Dry weight, df/ds: Dry fodder kg per dry seed kg, DMloss: Dry matter losses
[2]Fertilizer addition; 8 ml N (1 ml Ammonium N, 1 ml Nitrate N and 6 ml Urea N), 4 ml P_2O_5 and 3 ml K_2O each tray/per day
[3]Triticale and vetch was mixed at a ratio of 100:0 (V0), 90:10 (V10), 80:20 (V20), 70:30 (V30), and 0:100 (V100)
[4]SEM: Standard error mean
[5]T: Treatments, F: Fertilizer, T×F: The interaction between treatments × fertilizer

Table 2. Nutritive value of fodder from different ratios of triticale and vetch seed with or without fertilizer grown in a hydroponic system (DM basis, %).

Parameters[1]	F[2]	Treatments[3] (%)					SEM[4]	Impact[5]		
		V0	V10	V20	V30	V100		T	F	T×F
DM%	-	18.60	20.10	19.70	20.30	22.49	0.69	ns	***	*
	+	20.60	19.60	18.50	19.60	24.99				
Ash%	-	2.16^{c}	2.18^{c}	2.25^{bc}	2.40^{b}	3.00^{a}	0.05	***	ns	***
	+	1.98^{d}	2.19^{cd}	2.36^{bc}	2.52^{b}	3.15^{a}				
CP%	-	13.74^{c}	14.47^{bc}	14.49^{bc}	15.30^{b}	21.34^{a}	0.31	***	**	***
	+	11.94^{d}	14.29^{c}	16.20^{b}	17.03^{b}	22.86^{a}				
EE%	-	1.94^{ab}	1.86^{ab}	1.60^{b}	2.27^{a}	1.66^{b}	0.14	***	***	**
	+	2.51^{ab}	2.96^{a}	1.69^{c}	2.31^{abc}	1.84^{bc}				
CF%	-	8.97	9.04	9.38	9.12	8.99	0.39	ns	*	ns
	+	8.43	9.83	10.17	10.18	10.26				
ADF%	-	11.01^{b}	11.15^{b}	12.74^{ab}	13.56^{b}	14.16^{a}	0.53	***	ns	ns
	+	10.58	11.99	13.10	13.11	13.26				
NDF%	-	26.78^{a}	24.39^{ab}	25.91^{ab}	23.92^{b}	17.03^{c}	0.07	***	ns	ns
	+	24.68^{a}	25.00^{a}	24.21^{a}	22.96^{a}	18.65^{b}				
NFE%	-	73.12^{a}	72.51^{a}	72.33^{a}	70.91^{a}	63.48^{b}	0.68	***	*	**
	+	75.23^{a}	70.72^{b}	69.64^{b}	67.92^{b}	63.41^{c}				
NFC%	-	55.31	57.13	55.75	56.11	55.28	0.59	ns	ns	ns
	+	58.92	55.51	55.42	55.13	55.03				

ns: not significant; *P<0.05; **P<0.01; ***P<0.001
[1]DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, ADF: Acid detergent fiber, NDF: Neutral detergent fiber, NFE: Nitrogen free extract, NFC: Non-fiber carbohydrate
[2]Fertilizer
[3]Triticale and vetch was mixed at a ratio of 100:0 (V0), 90:10 (V10), 80:20 (V20), 70:30 (V30), and 0:100 (V100)
[4]SEM: Standard error mean
[5]T: Treatments, F: Fertilizer, T×F: The interaction between treatments × fertilizer

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fertilizer had higher means of CP (16.46 vs. 15.86% DM) and means of EE (2.26 vs. 1.87% DM) but a lower concentration of means of NFE (69.37 vs. 70.44% DM) compared with fodders without fertilizer. A non-significant effect (P>0.05) of the treatment was observed on the DM, CF, and NFC. Lower fodder DM, on average, was observed in fodders without fertilizer than in fodders with fertilizer, but the differences were not significant (20.23 vs. 20.65; P=0.927). The highest CF content was found in V100+ fodder, and the lowest was in V0+ fodder. There was a significant increase in the ash content (P<0.001) with V100+ fodder having the highest ash content among treatments. Neither fertilizer addition nor the interaction of seed ratio and fertilizer affected ADF and NDF content (P>0.05). However, an effect of seed ratio on ADF (P<0.001) and NDF (P<0.001) contents was observed, with ADF increasing and NDF decreasing with a greater vetch seed ratio. The fodder energy content had a remarkable response, with the highest and lowest energy contents obtained from V0+ fodder and V100- fodder, respectively (Table 3).

Applied treatments and fertilizer addition showed a significant effect on the production cost of dry fodder (DF-c), fresh fodder (FF-c) without fertilizer, ranging from 0.249 to 0.431 and 0.056 to 0.080 $ for one kg fodder production fodder, respectively (Table 4). The production cost per kg of protein (CP-c) and per energy unit (ME-c) increased with the addition of fertilizer. When comparing the nutritive values of fodder and seed, the green fodder had higher CP and fiber value than its seeds, which had higher significantly NFE and NFC content (Table 5).

Table 3. Energy content of fodder from different ratios of triticale and vetch seed with or without fertilizer grown in a hydroponic system (DM basis, %).

Parameters[1]	F[2]	Treatments[3] (MJ/kg)					SEM[4]	Impact[5]		
		V0	V10	V20	V30	V100		T	F	T×F
ME_{CF}	-	12.51	12.50	12.45	12.33	12.29	0.06	ns	*	ns
	+	12.59	12.38	12.33	12.49	12.45				
ME_{ADF}	-	13.05[a]	13.03[a]	12.79[ab]	12.67[b]	12.58[b]	0.09	***	ns	ns
	+	13.11	12.90	12.74	12.73	12.90				
ME_{CF+ADF}	-	12.87[a]	12.84[a]	12.50[b]	12.27[bc]	12.11[c]	0.09	***	**	**
	+	12.91	12.73	12.50	12.50	12.77				
ME_{MAFF}	-	12.93[a]	12.91[a]	12.82[a]	12.78[a]	12.41[b]	0.05	***	*	***
	+	13.15[a]	13.03[a]	12.72[b]	12.92[b]	12.71[b]				

ns: not significant; *P<0.05; **P<0.01; ***P<0.001; ME_{CF}: calculated by using crude fiber ME_{CF+ADF}: Calculated by using crude fiber and acid detergent fiber; ME_{ADF}: Calculated by using acid detergent fiber: Calculated by Ministry of Agriculture, Forestry and Fisheries (ME_{MAFF}, MJ/kg DM = 0.12%CP + 0.31%EE + 0.05%CF + 0.14%NFE).
[1]ME: Metabolic energy, MJ kg^{-1}
[2]Fertilizer
[3]Triticale and vetch was mixed at a ratio of 100:0 (V0), 90:10 (V10), 80:20 (V20), 70:30 (V30), and 0:100 (V100)
[4]SEM: Standard error mean
[5]T: Treatments, F: Fertilizer, T×F: The interaction between treatments ×fertilizer

Table 4. Economic analyses of fodder production cost.

Parameters[1]	F[2]	Treatments[3] (%)					SEM[4]	Impact[5]		
		V0	V10	V20	V30	V100		T	F	T×F
DF-c	-	0.431[a]	0.388[ab]	0.380[b]	0.351[b]	0.249[c]	0.07	**	*	ns
	+	0.537[a]	0.555[a]	0.565[a]	0.518[a]	0.362[b]				
FF-c	-	0.080[a]	0.077[b]	0.074[c]	0.071[d]	0.056[e]	0.01	**	**	ns
	+	0.110[a]	0.102[d]	0.105[c]	0.108[b]	0.091[e]				
CP-c	-	0.066[a]	0.056[b]	0.055[b]	0.048[c]	0.025[d]	0.02	*	*	**
	+	0.095[a]	0.082[b]	0.073[bc]	0.064[c]	0.033[d]				
ME-c	-	0.033[a]	0.031[ab]	0.028[b]	0.030[b]	0.019[c]	0.01	*	**	ns
	+	0.043[a]	0.041[a]	0.042[a]	0.041[a]	0.029[b]				

ns: not significant; *P<0.05; **P<0.01; ***P<0.001
[1]DF-c: Production cost of dry fodder ($/kg ha^{-1}), FF-c: Production cost of fresh fodder ($/kg ha^{-1}), CP-c: Cost of producing one kg of protein ($/kg ha^{-1}), ME-c: Cost of producing one unit of energy ($/MJ ha^{-1}) by calculated using ADF content of fodder
[2]Fertilizer
[3]Triticale and vetch was mixed at a ratio of 100:0 (V0), 90:10 (V10), 80:20 (V20), 70:30 (V30), and 0:100 (V100)
[4]SEM: Standard error mean
[5]T: Treatments, F: Fertilizer, T×F: The interaction between treatments × fertilizer

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Table 5. The comparison of the nutritive value of triticale and vetch seeds and their fodder (DM basis, g kg^{-1}).

Parameters[1]	Nutritive value[2]								
	DM	Ash	CP	EE	CF	ADF	NDF	NFE	NFC
TS	928.9	19.1	103.7	10.3	37.7	55.2	140.8	829.4	726.5
TF	186.0	22.5	137.4	19.4	89.7	110.1	267.8	730.1	553.8
P-value	***	ns	**	**	*	***	***	***	***
VS	931.3	29.1	197.1	15.2	50.6	103.0	159.6	707.1	599.0
VF	224.9	30.0	213.4	16.7	89.9	141.6	172.0	650.0	568.0
P-value	***	ns	**	*	***	***	***	**	***

ns: not significant; *P<0.05; **P<0.01; ***P<0.001

[1]TS: Triticale seeds, TF: Triticale fodder (V0-without fertilizers), VS: Vetch seeds, VF: Vetch fodder (V100-without fertilizers)

[2]DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, ADF: Acid detergent fiber, NDF: Neutral detergent fiber, NFE: Nitrogen free extract, NFC: Non-fiber carbohydrate.

Discussion and Conclusion

The inadequacy of good quality roughage in Türkiye has prompted the development of alternative methods. An alternative to conventional agriculture is the use of the hydroponic system, which allows the production of green fodder throughout the year irrespective of the climate changes (27). After 7 days of harvesting, the highest FW in V0+ fodder and DW in V100+ fodder were recorded at 4.57 and 0.99 kg per tray. The lowest FW and DW (kg m^{-2}) were obtained for V100- and V0- fodder, respectively. Higher DW was mainly due to the higher DM content in V100+ fodder. Özdemir and Temür (28) stated that a barley and vetch mix produced the lowest fresh yield but also produced the highest DM yield due to the mix having a higher DM concentration. The outcome of the present research agrees with those of Al-Karaki and Al-Momani (5), who reported that the FW of barley fodder ranged from 3.74 to 6.0 kg per kg of barley seeds. Gümüş and Bayır (17) showed that oat fodder had lower FW than barley-oat fodder. The DW of fodder ranged from 4.00 to 4.49 kg m^{-2}. Our study was comparable to those reported by Emam (12) and Assefa et al. (6), who obtained 7-8 kg of dry barley fodder and 4.58-6.63 kg of dry maize fodder per m^{-2}. Lower fodder FW, on average, was observed in fodders without fertilizer compared to those with fertilizer, but the differences were small (21.38 vs. 21.62 kg m^{-2}). The winter term generally lasts for 5 months in Türkiye, depending on topography (9). Assuming that quality fresh forage cannot be produced during winter, if fodder was produced in 7-day harvest cycles over 5 months using the current hydroponic chamber (41.16 m^2 of total trays), then about 17 tons of fresh triticale or triticale + vetch mixed fodder could be produced. A low level of DM in green fodder may limit its use for animal nutrition (3). However, it is worth pointing out that high-moisture forage such as pasture, silage, haylage, fodder, etc., have been consistently used in the ration as forage regardless of their DM content (17). The recommended (10, 32) optimal DM content of rations should be more than 45% and less than 60%. As higher DM content can reduce the ration intakes by dairy cattle (8). The present study showed that the fodder DM content was the highest (24.99%) for V100+ fodder and the lowest (18.5%) for V20+ fodder. Almost similar results were also found by researchers evaluating barley or oat fodder (12, 17). The reduction seen in DM content in V20 treatment along with an increase in DM loss is explained by the fact that the increment of germination of fodder results in a greater conversion of seeds and greater shoot height and root length. The results of our previous studies showed that the highest mean shoot height and root length value of fodder were recorded for V20 (3).

Regarding the nutritive value of fodder, the ash content increased for all treatments compared to the initial seeds. Similar results were obtained by Saidi and Omar (30) and Emam (12). The former stated that the ash content in the fodder was improved by using hydroponic production, while the latter stated that the ash content ranged from 2.27 to 3.43%. The reason for the increased ash content might be enhanced by root mineral uptake (26). Fazaeli et al. (13) suggested that the calcium, iron, and zinc content of fodder were significantly higher than that of original seeds, and it could be associated with higher ash content also due to the concentrating effect of the starch and sugars for growth, while the minerals are not lost. As expected, the highest CP content was found for V100+ (22.86%), probably due to its seeds having higher CP content than the other seeds and the addition of nitrogen increasing the protein content. The mean CP content in the fodder of V30+, V20+, V10+, and V0+ treatments were stated on level 17.03%, 16.2%, 14.29%, and 11.94% respectively. Our findings were in line with the results of Fazaeli et al. (14) who found that the CP content of barley fodder ranged from 13.7% to 14.5%. Contrary to the current study, Saidi and Omar (30) showed CP was 19.8% in barley fodder. It is worth stating that the findings were inconsistent possibly due to differences in research conditions, seed type, seed quality, addition of liquid fertilizer, and harvesting time. A study by Akbağ et al. (2) reported the effects of harvesting time on fodder CP, with CP slightly higher at day 13 (17.6%) than at day 7 (17.1%), but lower than at day 10 (18.2%). One possible reason for higher protein content in the fodder might be the greater photosynthesis ability of young sprout and its higher DM losses (33). The results of El-Morsy et al. (11) indicated that an increased CP is associated with the positive effect of germination on enzyme activity, which leads to changes in the amino acid profile. Adding fertilizers, especially nitrate and ammonium, can improve the CP content of the fodder (16). In the current study, the fodders treated with fertilizer had a higher concentration of CP (16.46 vs. 15.86% DM) compared with fodders without fertilizer. The highest ether extract (EE) value was recorded in V10+ (2.96%) fodder, followed by V0+ (2.51%), V30+ (2.31%), V100+ (1.84%), and V20+ (1.69%) fodder in the current study. Gümüş and Bayır (17) found that the EE values of barley fodder and oat fodder were 3.22% and 5.23% of DM, respectively. However, ether extract of hydroponic fodder increases due to the increment of structural lipids and chlorophyll as the plant grows (16). Regarding the structural carbohydrates of fodder, it was expected that the CF, ADF, and NDF content of fodder would be higher compared to its seeds. The highest CF value was found as 10.26% of DM in V100+ fodder and the lowest was as 8.43% of DM in V0+ fodder. Emam (12) found that CF values of barley fodder ranged from 8.13 to 12.4% of DM which is similar to our results. These results are also in agreement with Fazaeli et al. (13), who reported that CF, ADF, and NDF content are increased, but NFC contents decrease in fodder compared to the seeds. For the fodder ADF, the highest value was found for V30- (13.56% of DM) and the lowest value was found as V0+ (10.58% of DM). Al-Karaki and Al-Monami (5) also obtained similar findings for barley fodder with the authors stating the fodder had better quality than alfalfa hay in terms of their use in animal nutrition. Fazaeli et al. (14) reported that structural carbohydrates increased due to late harvesting time. The mean value of NDF (14) with barley fodder ranged from 31.25% to 35.40% which is higher than the current study's range (17.03 - 26.78% of DM). Saidi and Omar (30) reported that the NDF content was 3.5 times higher in barley fodder compared to barley seeds which is greater than differences between fodder and seed in the current study. Also, fodder energy content was affected by seed ratios regardless of calculation methods with slightly lower energy contents as vetch seed share increased. Emam (12) stated that green fodder is highly digested by ruminant animals and has a greater protein and metabolic energy content. Afzalinia and Karimi (1) showed that the barley cultivar Behrokh had the highest energy productivity compared to the other cultivar due to its lower energy use during the growth process. As indicated by Girma and Gebremariam (16) during germination, the plant converts starch into sugars during respiration and therefore, a decreased energy content in fodder is expected as compared to grains.

Regarding the cost of production, V100- fodders had the lowest cost to produce one kg dry or fresh fodder among the groups. Assefa et al. (6) found that the cost of dry and fresh barley fodder ranged from \$31.06 to \$42.54 and \$4.55 and \$6.90 per 100 kg fodder, respectively. In the current study, the lowest (\$0.025) and highest (\$0.095) seed cost for the production of one kg CP of dry fodder was obtained for V100- and V0+ fodders. Compared to the present study, a lower cost per unit CP was found for pasture grass produced in a hydroponic chamber (6). The seed cost for energy production (ME/MJ) ranged from \$0.019 and \$0.043. Our results were in line with the results of Assefa et al. (6) who showed that energy pasture grass hay costs were \$0.02 per MJ/ME.

In conclusion, the mixing of vetch seeds with triticale apparently changed the nutritive value of fodder and increased the DM, CP, CF, and ADF. The current results confirmed that the addition of vetch seeds can effectively decrease the FW of fodder. The highest DM loss was recorded in V20+ fodder with a value of 9.5%. The DM gain was observed in V0+ and V100+ fodder with fertilizer. The cost of dry fodder in the fertilized group was higher compared to the non-fertilized group. Further studies are required to investigate the use of hydroponic systems to produce green fodder from various seeds and mixture ratios in a hydroponic chamber taking into account economic efficiency.

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Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contributions

Experimental design was created by MA and HG. Samples were collected by MA and HG led the manuscript writing. All authors have contributed to the revision of the manuscript.

Ethical Statement

This study does not present any ethical concerns.

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