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Simulated Grazing (Clipping) Affected Growth and Nutritional Quality of Barley, Rye, and Wheat in an Arid Climate

Irshad Ahmad[1] · **Hua Wang**[1] · **Muhammad Kamran**[1] · **Khushnuma Ikram**[2] · **Fujiang Hou**[1]

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Abstract

Deficit and unpredictable precipitation in arid regions can result in lower yield and nutritional quality of barley, rye, and wheat. Therefore, improving yield and nutritional quality of barley, rye, and wheat is important for livestock production in arid regions. We investigated the effect of simulated grazing (clipping) and no simulated grazing (no clipping) treatments on the growth and nutritional quality of barley, rye, and wheat in an arid region. Simulated grazing (clipping) treatment reduced number of tillers m^{-2} in barley and wheat, and increased in rye before second and third simulated grazing. In no simulated grazing (no clipping) treatment, the highest dry matter yield was recorded in barley (8543 and 8802 kg ha^{-1}), followed by wheat (6712 and 6895 kg ha^{-1}) and lowest in rye (3465 and 3657 kg ha^{-1}) before fourth simulated grazing. In simulated grazing (clipping) treatment, the highest dry matter yield was recorded in rye (2624 and 2941 kg ha^{-1}), followed by barley (2243 and 2454 kg ha^{-1}) and lowest in wheat (1667 and 1760 kg ha^{-1}) before second simulated grazing. Simulated grazing (clipping) treatment improved barley, rye, and wheat crude protein content (by 18.9%, 35.6%, and 2.5%, respectively), ether extract content (by 0.2%, 13.5%, and 4.8%), and crude ash content (by 7.2%, 6.4%, and 1.8%), while reduced neutral detergent fiber content (by 9.5%, 16.4%, and 6.7%) and acid detergent fiber content (by 20.2%, 26.9%, and 6.0%) compared with the no simulated grazing (no clipping) treatment. In arid regions, simulated grazing (clipping) is the best strategy to improve the nutritional quality of barley, rye, and wheat. Simulated grazing (clipping) of barley, rye, and wheat at different time intervals will provide high quality feed for livestock and will improve livestock husbandry in arid regions. For large scale assessment of simulated grazing (clipping) impact on growth and nutritional quality of barley, rye, and wheat more research for different climates, soil, and agronomic management would be required.

Keywords Arid region · Barley · Nutritional quality · Rye · Simulated grazing · Wheat

Introduction

Precipitation serve as the main water source for crops growth and development in arid and semi-arid areas (Ali et al. 2017; Ahmad et al. 2019; Jia et al. 2021). However, the deficit and unpredictable precipitation in these regions lead to drought stress and thus inhibit crops growth and development and sometimes complete failure of the crops (Ren et al. 2008, 2010; Nazari et al. 2019, 2020). In arid and semi-arid regions, the overall strategy used by the farmers is the cultivation of annual forage crops to efficiently utilize the deficit and erratic precipitation (Delogu et al. 2002; Ahmad et al. 2022). Dry-land farming is crucial for food and livestock production in the Loess Plateau of China (Yang et al. 2021). However, due to climatic change and increase in human population the dry-land farming faces various challenges such as the deficit and erratic precipitation and limited economic

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✉ Irshad Ahmad
irshad88@aup.edu.pk

✉ Fujiang Hou
cyhoufj@lzu.edu.cn

[1] State Key Laboratory of Grassland Agro-Ecosystems, Key Laboratory of Grassland Livestock Industry Innovation, Ministry of Agriculture and Rural Affairs, Engineering Research Center of Grassland Industry, Ministry of Education, College of Pastoral Agriculture Science and Technology, Lanzhou University, Lanzhou 730020, People's Republic of China

[2] Department of Biotechnology, Abdul Wali Khan University Mardan, Mardan 23200, Pakistan

resources (Deng et al. 2021). In these regions, livestock production could improve the income of farmers (Komarek et al. 2012; Hu et al. 2019a). However, in these regions the forage availability is a critical issue for livestock production (Yang et al. 2021; Kamran et al. 2022). Feed shortage in China is increasing due to rapid development of livestock husbandry and therefore it is crucial to improve feed production (Ning et al. 2022). The lack of forage per farmer in this region is two tons per year (Niu and Nan 2012), which negatively affect livestock husbandry and farmers income (Hou et al. 2008; Tian et al. 2012). Therefore, improving forage productivity is important for livestock production in arid regions.

Grasslands cover an area of 40% of the terrestrial surface and provide forage for ruminants, soil and water conservation and other important ecosystem services (Hopkins and Wilkins 2006; Hu et al. 2019b; Zhao et al. 2020). Grasslands are an important part of agriculture and the proportion of grassland in agriculture indirectly reflects the degree of development of a country livestock husbandry (Zhao et al. 2020). However, grasslands are degrading day by day due to over-grazing, climate change and improper management and it is challenging to provide sufficient and quality feed for livestock production (Deng et al. 2017; Van Zanten et al. 2018; Wang et al. 2019a; Huang et al. 2021), which results in large dependency on the imports of livestock products (Wang et al. 2019a, b). China has 400 million hectares of grassland area, however, about 31.8% of the grasslands in China are in the state of degradation (Sui and Zhou 2013; Li 2017; Li et al. 2018). Therefore, improving sown forage productivity and quality is important in order to improve the livestock husbandry. Countries with developed animal husbandry mainly rely on the development of grass industry to solve the feed problem. Animal husbandry in the USA accounts for about 60% of agriculture, 70% in Germany, 57% in France, and 65% in Canada. In China, the animal husbandry accounts for about 30% of agriculture which is far below the average level of developed countries (Hou 2013). Therefore, improving yield and nutritional quality of barley, rye, and wheat crops are important for livestock production.

Barley, wheat, and rye are the most important crops for forage and food production in arid and semi-arid regions (Royo et al. 1997; Zeleke 2019; Xu et al. 2020). The wider planting area, large total output, and their many uses indicate that they have strong adaptability to many complex habitats, multi-functionality to meet the needs of human life and are important for the stability and evolution of the agricultural system (Hou and Xu 2010). Wheat is an important rainfed crop in this region having a planting area of more than four million hectares per year (Li et al. 2017; Yang et al. 2021). Besides wheat, barley and rye are also planted in these regions for forage production. Forage yield is one of the foundations of cultivated grassland research and is the main indicator of the essential connection between forage and the environment, and is also a comprehensive expression of community structure and function (Zhang et al. 2013; Yang et al. 2021). Nutritional quality of forages is related to the availability and content of essential nutrients for consuming animals (Van Saun 2013). Quality of forages determines the utilization efficiency, digestion and absorption, energy intake, nutrient acquisition and affects the quality of livestock products (Richman et al. 2015). Improving nutritional quality of forages is crucial for livestock production (McDonald et al. 2021). Crude protein content, neutral detergent fiber content, acid detergent fiber content, ether extract content, and crude ash content are the commonly used indexes to determine the quality of forages (Ahmad et al. 2022). The higher the crude protein content in forages, the higher will be the nutritional quality of forages (Yang et al. 2021). Neutral detergent fiber is used for potential feed intake, and higher neutral detergent fiber content in forages the worse will be the nutritional quality, whereas acid detergent fiber is used for the digestibility, and higher the acid detergent fiber content in forages, the lower will be the nutritional quality (Rotger et al. 2006). Ether extract content is also an important indicator of forages quality (Ahmad et al. 2022). The quality of forage is the most critical factor affecting animal health and production performance. Studies have shown that if the protein content of forage ingested by livestock is less than 7%, the microorganisms in the rumen will not be able to effectively decompose the ingested food resulting in livestock weight loss (Charmley 2001). Therefore, improving forages nutritional quality is important for livestock production.

The research related to the effect of simulated grazing (clipping) and no simulated grazing (no clipping) on the growth and nutritional quality of barley, rye, and wheat is limited, especially under deficit and erratic precipitation conditions (arid regions). In the present experiment, we carried out a detailed study on the effects of simulated grazing (clipping) and no simulated grazing (no clipping) on the growth and nutritional quality of barley, wheat, and rye in an arid region. The result of the current research provides important insights regarding improving the nutritional quality of barley, rye, and wheat in arid regions.

Materials and Methods

Experimental Site Description

The field experiment was carried out in Linze Grassland Agricultural Experimental Station of Lanzhou University (39°15′N, 100°02′E, 1390 m *a.s.l*) Linze County, Zhangye City, Gansu Province China during 2012 and 2013. The experimental area belongs to temperate continental desert steppe climate, having the characteristics of deficit precipitation, heavy winds, and extreme cold in winter. The annual rainfall at the experimental site was 118.4 mm, the annual average evaporation was 1830.4 mm, and the average temperature was 7.7 °C, whereas the average sunshine duration was 3026 h per year. The soil of the experimental site is saline soil. The type of agriculture system in the experimental site is extensive crop-livestock integrated production system (Hou et al. 2008). Precipitation and temperature during 2012 and 2013 growth season at the experimental site was measured with an automatic weather station and has been presented in Fig. 1.

Experimental Design, Treatments, and Field Management

The experimental design used was factorial design having four replications. There were two factors in the experiment, and factor A was triticeae crops, i.e., barley (B), rye (R), and wheat (W), and factor B was no simulated grazing or no clipping (G_0) and simulated grazing or clipping (G). There were six treatments in the experiment and the treatment combinations comprised of BG_0, RG_0, WG_0, BG, RG, and WG. Each plot was 35 m^2 (7 m × 5 m) with a plot to plot distance of 0.5 m. The inter replication distance was maintained at 1 m. The inter row spacing was 20 cm. Recommended dose (150 kg ha^{-1}) of nitrogen and phosphorus were applied to all the experimental plots at the time of sowing. During both years, sowing was carried out on 28th March at recommended seed rates. After sowing barley, rye, and wheat crops, the growth period was observed. Simulated grazing (clipping) was carried out on 13th May, 3rd June, 23th June, and 13th July during 2012 and 2013 growth seasons. In simulated grazing (clipping) treatment, the plants were cut at 10 cm at each cutting (clipping) stage. Due to low and erratic precipitation, we applied two times irrigation (100 mm) at 20 days after sowing (DAS) and at 40 DAS to all the treatments during both growth seasons. All other agronomic practices were uniformly applied to all treatments during both growth seasons.

Sampling and Measurements

Plant Height (cm)

Plant height of barley, rye, and wheat in simulated grazing (clipping) and in no simulated grazing (no clipping) treatment was measured on randomly selected 20 plants per replication in central rows by avoiding side rows. The plant height of barley, rye, and wheat was measured from ground level to tip of the plant. The plant height of barley, rye, and wheat was measured at 46 DAS (before first simulated grazing or clipping), 67 DAS (before second simulated grazing or clipping), 87 DAS (before third simulated grazing or clipping), and at 107 DAS (before fourth simulated grazing or clipping). The plant height of barley, rye, and wheat was measured with a measuring tape.

Number of Tillers m^{-2}

Number of tillers m^{-2} in barley, rye, and wheat in simulated grazing (clipping) and in no simulated grazing (no clipping) treatment was counted on one square meter area at three different locations in each plot. Number of tillers m^{-2} in barley, rye, and wheat was measured on 46 DAS (before first simulated grazing or clipping), 67 DAS (before second simulated grazing or clipping), 87 DAS (before third simulated grazing or clipping), and at 107 DAS (before fourth simulated grazing or clipping).

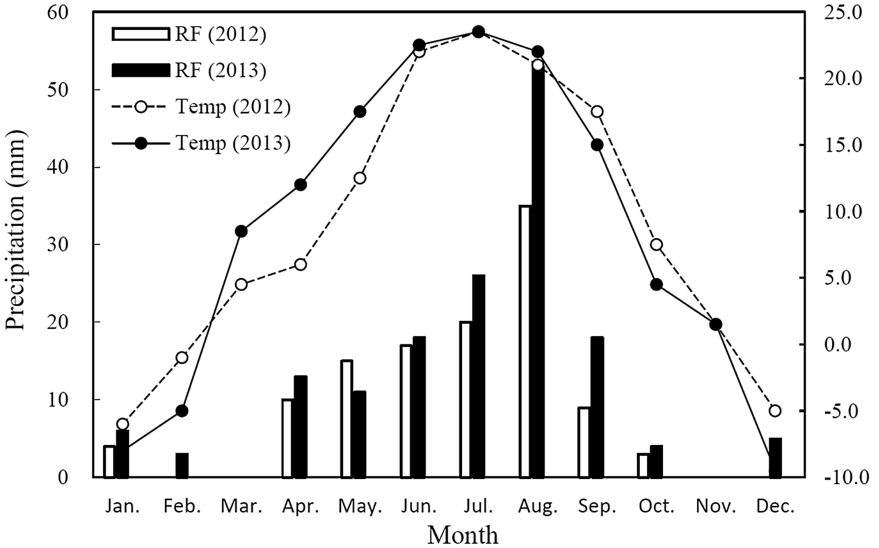

Fig. 1 Mean temperature (°C) and precipitation (mm) during 2012 and 2013 at the experimental site

Dry Matter Yield (kg ha^{-1})

Dry matter yield of barley, rye, and wheat in simulated grazing (clipping) and in no simulated grazing (no clipping) treatment was measured on one square meter area at three different locations in each replication. Dry matter yield of barley, rye, and wheat was determined on 46 DAS (before first simulated grazing or clipping), 67 DAS (before second simulated grazing or clipping), 87 DAS (before third simulated grazing or clipping), and at 107 DAS (before fourth simulated grazing or clipping). Barley, rye, and wheat plants in simulated grazing (clipping) and in no simulated grazing (no clipping) treatment was cut at 10 cm above ground level. The samples were placed in an oven and dried at 105 °C for 1 h and then at 75 °C until constant weight (Ren et al. 2008). The dry matter yield of barley, rye, and wheat was expressed in kg ha^{-1}.

Nutritional Quality Determination

Nutritional quality of barley, rye, and wheat in simulated grazing (clipping) and in no simulated grazing (no clipping) treatment was determined at 46 DAS (before first simulated grazing or clipping), 67 DAS (before second simulated grazing or clipping), 87 DAS (before third simulated grazing or clipping), and at 107 DAS (before fourth simulated grazing or clipping). Thirty plants of barley, rye, and wheat in each replication at different locations in central rows by avoiding side rows were sampled at 46, 67, 87, and at 107 DAS. The plant samples were oven dried at 65 °C for 48 h until constant weight (Lloveras and Iglesias 2001). The plant samples were crushed and passed through a 1 mm sieve. The samples were stored until their subsequent analysis.

Crude Protein Content (%)

Nitrogen content in barley, rye, and wheat samples was determined by using K9840 automatic Kjeldahl nitrogen analyzer (Nelson and Sommers 1973). Crude protein content (%) was calculated according to Lloveras and Iglesias (2001) as follows;

$$\text{Crude protein content}(\%) = \text{Total nitrogen content} \times 6.25$$

Neutral Detergent Fiber Content (%)

Neutral detergent fiber content in barley, rye, and wheat samples was measured using ANKOM fiber technique. The instrument used was ANKOM A200 fiber analyzer (Van Soest et al. 1991; Robinson et al. 1999).

Acid Detergent Fiber Content (%)

Acid detergent fiber content in barley, rye, and wheat samples was measured using ANKOM fiber technique. The instrument used was ANKOM A200 fiber analyzer (Van Soest et al. 1991; Robinson et al. 1999).

Ether Extract Content (%)

Ether extract content in barley, rye, and wheat samples was measured by using ANKOM AXT15i automatic fat analyzer (AOAC 2000).

Crude Ash Content (%)

Crude ash content in barley, rye, and wheat samples was measured by high temperature burning method by using TM-O91OP muffle furnace (AOAC 1990).

Statistical Analysis

Analysis of variance was determined by using SPSS 17.0. The data obtained from each sampling event was analyzed separately. Mean comparisons were determined with least significant difference test (LSD test) at $P \leq 0.05$.

Results

Plant Height

Plant height of barley, rye, and wheat was affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 1). The effect of triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) and the interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on plant height at 67, 87, and 107 DAS were significant (Table 1S). At 46 DAS, triticeae crops (barley, rye, and wheat) significantly affected plant height, whereas simulated grazing (clipping) or no simulated grazing (no clipping) and the interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) was non-significant. Plant height was higher in 2013 compared with the 2012. In no simulated grazing (no clipping) treatment plant height of triticeae crops (barley, rye, and wheat) increased from 46 DAS and reached to its maximum at 107 DAS. In simulated grazing (clipping) treatment plant height of barley and rye gradually increased and

Table 1 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on the plant height (PH) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	PH (cm) (46 DAS)	PH (cm) (67 DAS)	PH (cm) (87 DAS)	PH (cm) (107 DAS)
2012	B	G_0	17.8bc	35.3c	65.4b	73.2b
	R	G_0	18.4ab	48.5a	104.5a	113.4a
	W	G_0	18.3ab	24.7e	54.7c	68.4c
	B	G	17.6c	28.4d	35.4e	32.6d
	R	G	18.5a	43.7b	37.3d	18.6f
	W	G	18.2ab	25.8e	23.2f	25.4e
	Average	B	17.7b	31.9b	50.4b	52.9b
		R	18.4a	46.1a	70.9a	66.0a
		W	18.2a	25.2c	38.9c	46.9c
		G_0	18.2a	36.2a	74.8a	85.0a
		G	18.1a	32.6b	32.0b	25.5b
2013	B	G_0	19.2ab	37.5c	70.4b	79.1b
	R	G_0	19.7a	52.3a	110.3a	124.3a
	W	G_0	19.5ab	27.4e	59.4c	73.2c
	B	G	19.1b	30.6d	38.3d	35.3d
	R	G	19.6ab	46.4b	39.7d	20.3f
	W	G	19.4ab	27.8e	25.3e	26.5e
	Average	B	19.1b	34.1b	54.4b	57.2b
		R	19.7a	49.3a	75.0a	72.3a
		W	19.4ab	27.6c	42.4c	49.8c
		G_0	19.3a	39.0a	80.0a	92.2a
		G	19.4a	34.9b	34.4b	27.4b

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

reached to its maximum at 87 DAS and then decreased at 107 DAS, whereas plant height of wheat was higher at 67 DAS, decreased at 87 DAS, and again increased at 107 DAS. In no simulated grazing (no clipping) treatment maximum plant height was recorded in rye. In simulated grazing (clipping) treatment maximum plant height was recorded in rye at 46, 67, and 87 DAS and at 107 DAS in barley. Simulated grazing (clipping) significantly decreased plant height of triticeae crops (barley, rye, and wheat) compared with the no simulated grazing (no clipping). Mean based on 2012 and 2013 and four growth stages result showed that BG_0, RG_0 and WG_0 reduced plant height by 20.1, 43.4, and 19.3 cm compared with the BG, RG, and WG.

Numbers of Tillers m^{-2}

Number of tillers m^{-2} of triticeae crops (barley, rye, and wheat) were affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 2). During 2012 growth season, the effect of triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) and the interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no grazing (no clipping) on the number of tillers m^{-2} at 67, 87, and 107 DAS were significant (Table 2S). During 2013 growth season, the effect of triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) and the interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on the number of tillers m^{-2} at 87 and 107 DAS was significant, whereas at 67 DAS the number of tillers m^{-2} was significantly affected by triticeae crops (barley, rye, and wheat) and the interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping). At 46 DAS, triticeae crops (barley, rye, and wheat) significantly affected the number of tillers m^{-2} during both growth seasons. Numbers of tillers m^{-2} were higher in 2013 growth season compared with the 2012 growth season. In no simulated grazing (no clipping) treatment, number of tillers m^{-2} of barley and wheat gradually increased and reached to its maximum at 87 DAS and then decline at 107, whereas the number of tillers m^{-2} of rye was higher at 46 DAS and then gradually decreased at 67 and 87 DAS and again increased at 107 DAS. In simulated grazing (clipping) treatment, number of tillers m^{-2} of barley reached

Table 2 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on number of tillers m^{-2} of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	Tillers m^{-2} (46 DAS)	Tillers m^{-2} (67 DAS)	Tillers m^{-2} (87 DAS)	Tillers m^{-2} (107 DAS)
2012	B	G_0	143bc	173a	187b	148a
	R	G_0	136e	89e	64f	88c
	W	G_0	148ab	178a	237a	118b
	B	G	142cd	163b	141d	37f
	R	G	137de	102d	76e	60e
	W	G	150a	153c	180c	78d
	Average	B	142b	168a	164b	93b
		R	137c	95b	70c	74c
		W	149a	166a	209a	98a
		G_0	142a	147a	163a	119a
		G	143a	139b	132b	58b
2013	B	G_0	151b	182a	199b	160a
	R	G_0	146c	100e	72f	100c
	W	G_0	157a	185a	248a	130b
	B	G	152b	177b	150d	45f
	R	G	144c	120d	85e	70e
	W	G	158a	166c	194c	90d
	Average	B	151b	179a	174b	103b
		R	145c	110c	78c	85c
		W	157a	175b	221a	110a
		G_0	151a	156a	173a	130a
		G	151a	154a	143b	68b

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

to its maximum at 67 DAS and then gradually decreased, the number of tillers m^{-2} of rye was highest at 46 DAS and then showed a decreasing trend, whereas the number of tillers m^{-2} of wheat reached to its maximum at 87 DAS and then decreased at 107 DAS. In no simulated grazing (no clipping) treatment, maximum number of tillers m^{-2} at 46, 67, and 87 DAS were recorded in wheat, whereas at 107 DAS in barley. In simulated grazing (clipping) treatment, maximum number of tillers m^{-2} at 46, 87, and 107 DAS were recorded in wheat, whereas at 67 DAS in barley. In simulated grazing (clipping) treatment rye has higher number of tillers m^{-2} at 67 and 87 DAS compared with the no simulated grazing (no clipping) treatment. Mean of two growth seasons and four growth stages data depicted that BG and WG reduced the number of tillers m^{-2} by 42 and 29 compared with the BG$_0$ and WG$_0$, whereas RG$_0$ and RG has the same number of tillers m^{-2}.

Dry Matter Yield

Dry matter yield of triticeae crops (barley, rye, and wheat) was affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 3). The effect of triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) and the interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on the dry matter yield at 67, 87, and 107 DAS was significant (Table 3S). At 46 DAS, triticeae crops (barley, rye, and wheat) significantly affected the dry matter yield. Dry matter yield of triticeae crops (barley, rye, and wheat) were higher in 2013 growth season compared with the 2012 growth season. In no simulated grazing (no clipping) treatment dry matter yield showed an increasing trend and reached to its maximum at 107 DAS. In simulated grazing (clipping) treatment dry matter yield reached to its maximum at 67 DAS and then gradually decreased. In no simulated grazing (no clipping) treatment maximum dry matter yield was recorded in barley. In simulated grazing (clipping) treatment maximum dry matter yield at 46 DAS was recorded in barley, at 67 DAS in rye, whereas at 87 and 107 DAS in wheat. Simulated grazing (clipping) significantly reduced dry matter yield of triticeae crops (barley, rye, and wheat) compared with the no simulated grazing (no clipping). Mean of two growth seasons and four stages data depicted that BG$_0$, RG$_0$ and WG$_0$ treatments reduced dry

Table 3 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on the dry matter yield (DMY) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	DMY (kg ha^{-1}) (46 DAS)	DMY (kg ha^{-1}) (67 DAS)	DMY (kg ha^{-1}) (87 DAS)	DMY (kg ha^{-1}) (107 DAS)
2012	B	G_0	332a	2892a	6986a	8543a
	R	G_0	318b	2743b	3256c	3465c
	W	G_0	301c	1532f	6654b	6712b
	B	G	334a	2243d	923e	376e
	R	G	317b	2624c	345f	301e
	W	G	302c	1667e	1088d	845d
	Average	B	333a	2567b	3954a	4459a
		R	318b	2683a	1801c	1883c
		W	302c	1599c	3871b	3779b
		G_0	317a	2389a	5632a	6240a
		G	318a	2178b	785b	507b
2013	B	G_0	345a	3170a	7243a	8802a
	R	G_0	332b	3023b	3435c	3657c
	W	G_0	315c	1654e	6826b	6895b
	B	G	342a	2454c	1002e	408e
	R	G	334b	2941b	400f	321f
	W	G	313c	1760d	1165d	976d
	Average	B	343a	2812b	4123a	4605a
		R	333b	2982a	1917c	1989c
		W	314c	1707c	3995b	3935b
		G_0	331a	2616a	5835a	6451a
		G	330a	2385b	855b	568b

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

matter yield by 3779 kg ha^{-1}, 1581 kg ha^{-1} and 2847 kg ha^{-1} compared with the BG, RG, and WG.

Nutritional Quality

Crude Protein Content (%)

Crude protein content of triticeae crops (barley, rye, and wheat) were affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 4). The effect of triticeae crops (barley, rye, and wheat) at 46, 67, 87, and 107 DAS and simulated grazing (clipping) or no simulated grazing (no clipping) at 67, 87, and 107 DAS on crude protein content was significant (Table 4S). The interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on the crude protein content at 87 and 107 DAS was significant. Crude protein content was lower in 2012 growth season and higher in 2013 growth season. In no simulated grazing (no clipping) treatment crude protein content was higher at 46 DAS and then gradually decreased until 107 DAS. In simulated grazing (clipping) treatment crude protein content of barley and rye was higher at 46 DAS and then gradually decreased, whereas the crude protein content of wheat increased a little from 46 to 67 DAS, and then decreased until 107 DAS. In no simulated grazing (no clipping) treatment maximum crude protein content at 46 DAS was recorded in barley and at 67, 87, and 107 DAS in wheat. In simulated grazing (clipping) treatment maximum crude protein content at 46 and 87 DAS were recorded in barley and at 67 and 107 DAS in wheat. Simulated grazing (clipping) significantly improved the crude protein content of barley and rye at all growth stages compared with the no simulated grazing (no clipping). In wheat simulated grazing (clipping) improved crude protein content except at 87 DAS, where the crude protein content of simulated grazing (clipping) was lower compared with the no simulated grazing (no clipping). Mean of two growth seasons and four growth stages data depicted that treatments BG, RG, and WG increased crude protein content by 18.9%, 35.6%, and 2.5% compared with the BG_0, RG_0 and WG_0.

Neutral Detergent Fiber Content (%)

Neutral detergent fiber content of triticeae crops (barley, rye, and wheat) was affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 5). The

Table 4 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on the crude protein content (CP, %) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	CP (%) (46 DAS)	CP (%) (67 DAS)	CP (%) (87 DAS)	CP (%) (107 DAS)
2012	B	G_0	26.93a	19.34d	14.34d	4.45d
	R	G_0	23.12c	15.98e	7.13e	2.98e
	W	G_0	25.34b	23.65b	22.03a	7.45c
	B	G	27.01a	22.01c	17.04b	11.76a
	R	G	23.09c	18.02d	15.32c	9.87b
	W	G	25.38b	25.87a	16.86b	12.52a
	Average	B	26.97a	20.68b	15.69b	8.11b
		R	23.10c	17.00c	11.22c	6.43c
		W	25.36b	24.76a	19.44a	9.98a
		G_0	25.13a	19.66b	14.50b	4.96b
		G	25.16a	21.97a	16.41a	11.38a
2013	B	G_0	27.83a	21.32d	16.32c	5.23d
	R	G_0	24.66b	17.43f	8.23d	3.23e
	W	G_0	26.75a	25.32b	23.43a	8.54c
	B	G	27.68a	23.70c	18.74b	13.45a
	R	G	24.37b	19.49e	17.98b	11.23b
	W	G	26.84a	27.05a	18.05b	13.94a
	Average	B	27.76a	22.51b	17.53b	9.34b
		R	24.51b	18.46c	13.10c	7.23c
		W	26.79a	26.18a	20.74a	11.24a
		G_0	26.41a	21.36b	15.99b	5.67b
		G	26.30a	23.41a	18.26a	12.87a

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

effect of triticeae crops (barley, rye, and wheat) on neutral detergent fiber content at all growth stages and simulated grazing (clipping) or no simulated grazing (no clipping) at 67, 87, and 107 DAS was significant (Table 5S). The interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on the neutral detergent fiber content at 46 and 67 DAS were non-significant and significant at 87 and 107 DAS. Neutral detergent fiber content was higher in 2012 growth season and lower in 2013 growth season. In simulated grazing (clipping) and no simulated grazing (no clipping) treatment neutral detergent fiber content gradually increased from 46 and reached to its maximum at 107 DAS during both growth seasons. In no simulated grazing (no clipping) treatment maximum neutral detergent fiber content was recorded in rye and lower in wheat. In simulated grazing (clipping) treatment maximum neutral detergent fiber content at 46 and 67 DAS was recorded in rye and at 87 and 107 DAS in barley. Simulated grazing (clipping) significantly reduced neutral detergent fiber content of barley and rye at all growth stages compared with the no simulated grazing (no clipping). In wheat simulated grazing (clipping) reduced the neutral detergent fiber content except at 87 DAS, where the neutral detergent fiber content in simulated grazing (clipping) was higher compared with the no simulated grazing (no clipping). Mean of two growth seasons and four growth stages data showed treatments BG, RG, and WG reduced the neutral detergent fiber content by 9.5%, 16.4%, and 6.7% compared with the BG_0, RG_0 and WG_0.

Acid Detergent Fiber Content (%)

Acid detergent fiber content of triticeae crops (barley, rye, and wheat) was affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 6). The effect of triticeae crops (barley, rye, and wheat) on acid detergent fiber content at all growth stages and simulated grazing (clipping) or no simulated grazing (no clipping) at 67, 87, and 107 DAS was significant (Table 6S). The interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on acid detergent fiber content at 87 and 107 DAS was significant. Acid detergent fiber content was lower in 2013 growth season and was higher in 2012 growth season.

Table 5 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on the neutral detergent fiber content (NDF, %) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	NDF (%) (46 DAS)	NDF (%) (67 DAS)	NDF (%) (87 DAS)	NDF (%) (107 DAS)
2012	B	G_0	39.34ab	43.56bc	62.67b	74.02b
	R	G_0	40.34a	46.56a	67.45a	78.09a
	W	G_0	38.05b	41.56d	53.12e	69.45c
	B	G	39.28ab	42.34cd	58.76c	61.23d
	R	G	40.37a	44.89b	55.34d	59.34e
	W	G	38.02b	39.54e	54.03de	57.07f
	Average	B	39.31a	42.95b	60.71a	67.63a
		R	40.35a	45.72a	61.39a	68.72a
		W	38.03b	40.55c	53.57b	63.26b
		G_0	39.24a	43.89a	61.08a	73.86a
		G	39.22a	42.26b	56.04b	59.21b
2013	B	G_0	38.11b	41.46bc	60.23b	71.95b
	R	G_0	39.40a	44.63a	64.34a	76.06a
	W	G_0	37.03b	39.45de	50.34e	67.33c
	B	G	38.05b	40.23cd	55.34c	58.58d
	R	G	39.50a	42.56b	53.34d	57.23e
	W	G	37.21b	38.34e	52.01de	55.14f
	Average	B	38.08b	40.84b	57.78a	65.23b
		R	39.45a	43.58a	58.84a	66.64a
		W	37.12c	38.89c	51.17b	61.23c
		G_0	38.12a	41.84a	58.30a	71.78a
		G	38.25a	40.37b	53.56b	56.98b

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

In no simulated grazing (no clipping) treatment acid detergent fiber content was higher at 46 DAS, decreased at 67 DAS, and then showed an increasing trend until 107 DAS. In simulated grazing (clipping) treatment acid detergent fiber content in rye and in wheat was higher at 46 DAS, decreased at 67 DAS, and then showed an increasing trend until 107 DAS, whereas in barley the acid detergent fiber content was higher at 46 DAS, decreased at 67 DAS, again increased at 87 DAS, and then decrease at 107 DAS. In no simulated grazing (no clipping) treatment maximum acid detergent fiber content was recorded in rye. In simulated grazing (clipping) treatment maximum acid detergent fiber content at 46 DAS and 67 DAS was recorded in rye and at 87 DAS and 107 DAS in wheat. Simulated grazing (clipping) significantly reduced acid detergent fiber content of barley and rye at all growth stages compared with the no simulated grazing (no clipping). In wheat simulated grazing (clipping) reduced acid detergent fiber content except at 87 DAS, where acid detergent fiber content of simulated grazing (clipping) was higher compared with the no simulated grazing (no clipping). Mean of two growth seasons and four growth stages data depicted that treatments BG, RG, and WG reduced acid detergent fiber content by 20.2%, 26.9%, and 6.0% compared with the BG_0, RG_0, and WG_0.

Ether Extract Content (%)

Ether extract content of triticeae crops (barley, rye, and wheat) was affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 7). The effect of triticeae crops (barley, rye, and wheat) on ether extract content during both growth season was significant (Table 7S). The effect of simulated grazing (clipping) or no simulated grazing (no clipping) on ether extract content at 67 DAS, 87 DAS, and at 107 DAS during 2012 growth season, and at 87 DAS and at 107 DAS during 2013 growth season was significant. The interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on ether extract content at 67, 87, and at 107 DAS was significant. Ether extract content was lower in 2012 growth season and higher in 2013 growth season. In no simulated grazing (no clipping) treatment ether extract content in barley was lower at 46 DAS, increased at 67 DAS, and then decreased until 107 DAS. In simulated

Table 6 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on acid detergent fiber content (ADF, %) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	ADF (%) (46 DAS)	ADF (%) (67 DAS)	ADF (%) (87 DAS)	ADF (%) (107 DAS)
2012	B	G_0	33.03ab	24.43cd	32.05b	44.04b
	R	G_0	34.54a	26.76a	35.04a	47.54a
	W	G_0	32.03ab	25.10bc	27.05de	42.03c
	B	G	33.14ab	23.34d	28.04d	26.04f
	R	G	34.43a	25.89ab	26.04c	28.45e
	W	G	32.10b	23.87cd	29.45c	34.05d
	Average	B	33.08b	23.88b	30.04a	35.04b
		R	34.49a	26.32a	30.54a	37.99a
		W	32.06b	24.49b	28.25b	38.04a
		G_0	33.20a	25.43a	31.38a	44.53a
		G	33.22a	24.37b	27.84b	29.51b
2013	B	G_0	31.76a	22.12bcd	30.43b	41.43b
	R	G_0	32.23a	24.23a	33.65a	46.76a
	W	G_0	30.07b	22.53bc	25.34de	40.99b
	B	G	31.80a	21.29d	26.54cd	25.45d
	R	G	32.11a	23.08ab	24.65e	26.65d
	W	G	30.13b	21.68cd	27.54c	32.45c
	Average	B	31.78a	21.70b	28.49a	33.44b
		R	32.17a	23.65a	29.15a	36.70a
		W	30.10b	22.11b	26.44b	36.72a
		G_0	31.35a	22.96a	29.81a	43.06a
		G	31.34a	22.01b	26.24b	28.18b

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

grazing (clipping) treatment ether extract content in barley was same at 46 and 67 DAS and then decreased until 107 DAS. In no simulated grazing (no clipping) treatment ether extract content in rye was higher at 46 DAS, decreased at 67 DAS, again increased at 87 DAS, and then decreased at 107 DAS. In simulated grazing (clipping) treatment ether extract content in rye reached to its maximum at 87 DAS and then decreased at 107 DAS. In simulated grazing (clipping) and no simulated grazing (no clipping) treatment ether extract content in wheat gradually increased and reached to its maximum at 87 DAS and then decreased at 107 DAS. In no simulated grazing (no clipping) treatment maximum ether extract content at 46 DAS and 67 DAS was recorded in barley and at 87 DAS and 107 DAS in wheat. In simulated grazing (clipping) treatment maximum ether extract content at 46 DAS was recorded in barley and at 67, 87, and at 107 DAS in wheat. Simulated grazing (clipping) improved ether extract content of barley at 46, 87, and 107 DAS, in rye at 67, 87, and at 107 DAS and in wheat at 67 and at 107 DAS. Mean based on two growth seasons and four growth stages result showed that treatments BG, RG, and WG increased ether extract content by 0.2%, 13.5%, and 4.8% compared with the BG_0, RG_0, and WG_0.

Crude Ash Content (%)

Crude ash content of triticeae crops (barley, rye, and wheat) was affected by simulated grazing (clipping) and no simulated grazing (no clipping) (Table 8). The effects of triticeae crops (barley, rye, and wheat) on crude ash content at all growth stages during both growth seasons were significant. The effect of simulated grazing (clipping) or no simulated grazing (no clipping) on crude ash content at 67, 87, and at 107 DAS during both growth season was significant (Table 8S). The interaction between triticeae crops (barley, rye, and wheat) and simulated grazing (clipping) or no simulated grazing (no clipping) on crude ash content at 67 and 87 DAS during 2012 growth season, and at 67, 87, and at 107 DAS during 2013 growth season was significant. Crude ash content was higher in 2012 and was lower in 2013. In no simulated grazing (no clipping) treatment crude ash content of barley and wheat was higher at 46 DAS, decreased at 67 DAS, again increased at 87 DAS, and then decreased at 107 DAS, whereas the crude

Table 7 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on ether extract content (EE, %) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	EE (%) (46 DAS)	EE (%) (67 DAS)	EE (%) (87 DAS)	EE (%) (107 DAS)
2012	B	G_0	3.54a	4.23b	3.32d	2.53e
	R	G_0	3.23b	3.06e	3.18d	3.05d
	W	G_0	2.90c	4.09b	5.10a	4.01b
	B	G	3.56a	3.56c	3.50c	3.06d
	R	G	3.20b	3.34d	3.98b	3.75c
	W	G	2.88c	4.87a	4.97a	4.28a
	Average	B	3.55a	3.89b	3.41c	2.80c
		R	3.21b	3.20c	3.58b	3.40b
		W	2.89c	4.48a	5.03a	4.14a
		G_0	3.22a	3.79b	3.86b	3.20b
		G	3.21a	3.92a	4.15a	3.70a
2013	B	G_0	3.83a	4.64b	3.52de	2.74e
	R	G_0	3.72a	3.31d	3.42e	3.31d
	W	G_0	3.05b	4.46b	5.48a	4.23b
	B	G	3.80a	3.87c	3.72d	3.34d
	R	G	3.75a	3.54d	4.42c	3.85c
	W	G	3.03b	5.21a	5.24b	4.43a
	Average	B	3.81a	4.26b	3.62c	3.04c
		R	3.73a	3.42c	3.92b	3.58b
		W	3.04b	4.83a	5.36a	4.33a
		G_0	3.53a	4.14a	4.14b	3.42b
		G	3.52a	4.21a	4.46a	3.87a

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

ash content of rye was higher at 46 DAS and then showed a decreasing until 107 DAS. In simulated grazing (clipping) treatment crude ash content of barley and rye was lower at 46 DAS, increased at 67 DAS, and then showed a decreasing trend until 107 DAS, whereas the crude ash content of wheat was higher at 46 DAS, decreased at 67 DAS, again increased at 87 DAS, and then decreased at 107 DAS. In no simulated grazing (no clipping) treatment maximum crude ash content at 46 DAS was recorded in barley, whereas at 67, 87, and at 107 DAS in wheat. In simulated grazing (clipping) treatment maximum crude ash content at 46 and 67 DAS was recorded in barley, whereas at 87 and at 107 DAS in wheat. Simulated grazing (clipping) improved the crude ash content of triticeae crops (barley, rye, and wheat). Mean of two growth seasons and four growth stages data showed that treatments BG, RG, and WG improved crude ash content by 7.2%, 6.4%, and 1.8% compared with the BG_0, RG_0 and WG_0.

Discussion

Deficit and erratic precipitation in arid and semi-arid regions inhibit crops growth and development and results in lower crops productivity (Xu et al. 2020; Jia et al. 2021). Furthermore, the low and erratic precipitation also result in lower forage production and nutritional quality and thus negatively affect livestock husbandry and farmers' income in arid and semi-arid regions (Ahmad et al. 2022; Kamran et al. 2022). Moreover, the low and erratic precipitation in arid and semi-arid regions also leads to drought stress (Ali et al. 2017; Ahmad et al. 2019). Therefore, improving moisture stress tolerance is important for the crop growth and development (Nazari et al. 2018). The natural grasslands are degrading due to climatic change and poor management (Deng et al. 2017; Van Zanten et al. 2018).

Table 8 Effect of simulated grazing (clipping) and no simulated grazing (no clipping) on crude ash content (CA, %) of triticeae crops at 46 (before first simulated grazing or clipping), 67 (before second simulated grazing or clipping), 87 (before third simulated grazing or clipping), and at 107 (before fourth simulated grazing or clipping) days after sowing (DAS) during 2012 and 2013

Year	Triticeae crops	Grazing	CA (%) (46 DAS)	CA (%) (67 DAS)	CA (%) (87 DAS)	CA (%) (107 DAS)
2012	B	G_0	17.65a	15.87c	16.45b	13.65c
	R	G_0	16.34b	12.81d	10.76d	10.06e
	W	G_0	17.23ab	16.45bc	18.76a	17.45b
	B	G	17.63a	18.56a	17.21b	14.08c
	R	G	16.32b	17.23b	15.34c	12.04d
	W	G	17.26ab	16.23c	19.23a	18.63a
	Average	B	17.64a	17.21a	16.83b	13.86b
		R	16.33b	15.01c	13.05c	11.05c
		W	17.25a	16.34b	19.00a	18.04a
		G_0	17.07a	15.04b	15.32b	13.72b
		G	17.07a	17.34a	17.26a	14.91a
2013	B	G_0	16.69a	14.60c	14.73c	12.04cd
	R	G_0	15.88b	11.32d	9.72e	9.34e
	W	G_0	16.43ab	16.21b	17.21ab	16.05b
	B	G	16.73a	17.21a	16.65b	12.32c
	R	G	15.93b	16.23b	14.06d	11.54d
	W	G	16.38ab	16.06b	17.41a	17.05a
	Average	B	16.71a	15.91a	15.69b	12.18b
		R	15.90b	13.77b	11.89c	10.44c
		W	16.41ab	16.13a	17.31a	16.55a
		G_0	16.33a	14.04b	13.88b	12.48b
		G	16.35a	16.50a	16.04a	13.64a

Values are means of four replicates and different lowercase letters within a column indicate significant differences at $P \leq 0.05$ (LSD test)

B barley, *R* rye, *W* wheat, G_o no simulated grazing (no clipping), *G* simulated grazing (clipping)

Therefore, cultivating forage crops and improving their yield and nutritional quality could improve the livestock production and food security in arid regions (Yang et al. 2021; Ning et al. 2022). Our results suggested that the growth and nutritional quality of barley, rye, and wheat was affected by low and erratic precipitation during 2012 and 2013. The mean annual precipitation during 2012 and 2013 was 113 mm and 157 mm, respectively (Fig. 1). During both growth seasons, the maximum dry matter yield in no simulated grazing (no clipping) was recorded in barley, followed by wheat and lowest in rye at 107 DAS whereas, in simulated grazing (clipping), the highest dry matter yield was recorded in rye, followed by barley and lowest in wheat at 67 DAS. The lower dry matter yields were attributed to lower precipitation during both years. Barley was adopted to lower precipitation and therefore resulted in higher dry matter yield compared with the rye and wheat under no simulated grazing (no clipping) condition.

Simulated grazing is an important strategy for sown pastures which can increase the utilization rate of forages (Yang et al. 2021). Cutting forage crops at different intervals can change the distribution and deposition of forage nutrition, promote forage growth and also affect the forage yield and nutritional quality (Li et al. 2022; Ning et al. 2022). Number and frequency of simulated grazing depends on the regeneration characteristics of forages, soil fertility, climatic conditions, and cultivation conditions. In regions, where the growing season is long and the water and fertilizer conditions are good, forages with strong regenerability can generally be grazed multiple times (Li et al. 2022). Our results suggested that simulated grazing (clipping) and no simulated grazing (no clipping) significantly affected plant height, number of tillers m^{-2}, and dry matter yield of barley, rye, and wheat. Simulated grazing (clipping) significantly reduced plant height of barley, rye, and wheat. Simulated grazing (clipping) reduced the number of tillers m^{-2} in barley and wheat and increased in rye before second and third simulated grazing. In no simulated grazing (no clipping) treatment, the highest dry matter yield was recorded in barley (8543 and 8802 kg ha^{-1}), followed by wheat (6712 and 6895 kg ha^{-1}), and lowest in rye (3465 and 3657 kg ha^{-1}) at 107 DAS, whereas in simulated grazing (clipping) treatment, the highest dry matter yield was recorded in rye (2624 and 2941 kg ha^{-1}), followed by barley (2243 and 2454 kg ha^{-1}), and lowest in wheat (1667 and 1760 kg ha^{-1}) before second simulated grazing (67 DAS). Li et al. (2022) also reported that simulated grazing (clipping) reduced the dry matter yield. Our results showed that plant height was reduced with repeated cuttings, and the number of tillers m^{-2} in barley and wheat were also reduced under simulated grazing (clipping) and increased in rye before second and third simulated grazing. Previous research suggested that the lower yield under simulated grazing conditions also attributed to lower number of spikes m^{-2} (Brignall et al. 1988). Kilcher (1982) depicted that under poor climatic and soil fertility conditions the yield was lower when grazing was carried out at vegetative stage.

Improving forage nutritional quality is important for livestock production (Yang et al. 2021; Kamran et al. 2022). Li et al. (2022) suggested that simulated grazing can improve the nutritional quality. Our results suggested that simulated grazing (clipping) and no simulated grazing (no clipping) significantly affected the nutritional quality of barley, rye, and wheat at different growth stages. Simulated grazing (clipping) maintained the nutritional quality of barley, rye, and wheat at high level. Mean based on two growth seasons and four growth stages results suggested that simulated grazing (clipping) improved the barley, rye, and wheat crude protein content (by 18.9%, 35.6%, and 2.5%, respectively), ether extract content (by 0.2%, 13.5%, and 4.8%), and crude ash content (by 7.2%, 6.4%, and 1.8%), while reduced neutral detergent fiber content (by 9.5%, 16.4%, and 6.7%) and acid detergent fiber content (by 20.2%, 26.9%, and 6.0%) compared with the no simulated grazing (no clipping). Yang et al. (2021) also showed that cutting can improve the nutritional quality of wheat. In addition to the chemical composition, the in vitro digestibility of forages can be a good indicator of the forage value. Nutritional quality and digestibility can indicate how the forage is absorbed by the animals (Richman et al. 2015). The growth and development stage of forage is the most important factor that affects the nutrients content and nutritional value of forage (Ahmad et al. 2022). In arid regions, simulated grazing (clipping) is an important strategy to improve the nutritional quality of barley, rye, and wheat.

Conclusion

Simulated grazing (clipping) and no simulated grazing (no clipping) affected the growth and nutritional quality of triticeae crops (barley, rye, and wheat) in an arid climate. Simulated grazing (clipping) reduced plant height of barley, rye, and wheat, and number of tillers m^{-2} in barley and wheat compared with the no simulated grazing (no clipping). Simulated grazing (clipping) reduced dry matter yield of triticeae crops (barley, rye, and wheat), and in no simulated grazing (no clipping) the highest dry matter yield was recorded in barley (8543 and 8802 kg ha^{-1}), followed by wheat (6712 and 6895 kg ha^{-1}) and lowest in rye (3465 and 3657 kg ha^{-1}) at 107 DAS, whereas in simulated grazing (clipping) the highest dry matter yield was recorded in rye (2624 and 2941 kg ha^{-1}), followed by barley (2243 and 2454 kg ha^{-1}), and lowest in wheat (1667 and 1760 kg ha^{-1}) at 67 DAS. Simulated grazing (clipping) improved barley, rye, and wheat crude protein content (by 18.9%, 35.6%, and 2.5%, respectively), ether extract content (by 0.2%, 13.5%, and 4.8%), and crude ash content (by 7.2%, 6.4%, and 1.8%), while reduced neutral detergent fiber content (by 9.5%, 16.4%, and 6.7%) and acid detergent fiber content (by 20.2%, 26.9%, and 6.0%). In arid regions, simulated grazing (clipping) is an important strategy to improve nutritional quality of barley, rye, and wheat. The findings of the present study are important for improving the nutritional quality of barley, rye, and wheat crops and to provide high quality feed for livestock production in arid regions. More research in different climates, soil, and agronomic management would be necessary to study the impact of simulated grazing (clipping) on growth and nutritional quality of barley, rye and wheat.

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Declarations

Conflict of interest The authors have no conflict of interest.

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