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Effects of Drought Stress on the Quantitative and Qualitative Yield of Forage Faba Bean Varieties (*Vicia faba* L.)

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ABSTRACT

Faba bean (*Vicia faba* L.) is important source of food and feed worldwide and provides a range of advantages in crop rotations. However, faba bean is susceptible to water stress, which limits its yield potential in Water deficit coditions. This study aimed to evaluate the effects of drought stress on the quantitative and qualitative yield of forage faba bean genotypes in autumn cultivation, which is considered a strategy for adapting to drought and climate change. This study was conducted in Gorgan Agricultural Research Station, Iran over two crop years (2022-2023 and 2023-2024). A randomized complete block design with three replications was employed to investigate the effects of drought stress on both the quantitative and qualitative forage yield of new faba bean varieties under autumn cultivation. Accordingly, nine new faba bean lines along with two control varieties of Mehta (low tannin) and Shadan (high tannin) were compared and evaluated under two environmental conditions: drought stress after flowering and normal irrigation. The combined analysis of variance indicated significant interaction effects between treatments and the measured traits. Specifically, the interaction between year and environment in both the optimal irrigation and drought stress conditions revealed that the highest fresh forage yields (37294 kg/ha and 18382 kg/ha, respectively) and dry forage yields (5948 kg/ha and 5523 kg/ha) were observed under normal irrigation and drought stress environments, respectively. The interaction between environment and variety, as well as the triple interaction of environment × variety × year, demonstrated that the WRB1-5 genotype, Shadan variety, and BPL4104 genotype yielded the highest fresh and dry forage yields in both environments. In terms of forage quality, the S2008-0330 genotype had the highest percentage of non-acid detergent insoluble fiber (NDF) (33.97%) under optimal irrigation, while the FLIP03-07FB genotype exhibited the highest NDF percentage (16.15%) under drought stress. The results indicate that drought stress after the flowering stage reduced both fresh and dry forage yields and increased ADF, CF, and NDF values across all varieties. However, the BPL4104 and WRB1-5 genotypes consistently outperformed other genotypes in both environments, suggesting that these genotypes are more resilient to drought stress while maintaining higher forage yields. Therefore, they could be considered potential candidates for cultivation in drought-prone areas.

Keywords: faba bean, irrigation, stress, fresh forage, dry forage, protein.

INTRODUCTION

The faba bean (*Vicia faba* L.) is a nutritionally valuable legume, characterized by its high content of phosphorus, calcium, iron, and protein (approximately 20-25%) and phytochemicals (Yahia et al., 2013). It holds a significant role in crop rotation systems, agricultural cropping patterns, and as a staple in household diets (Koepke and Nemecek, 2016; Sheikh and Feyzbakhsh 2019). Furthermore, this crop plays a pivotal role in achieving sustainable agricultural systems and biological fixation of atmospheric nitrogen through symbiosis (Karkanis et al., 2018; Tadele, 2019; Mansouri Vajari et al., 2024). Globally, the broad bean is cultivated on approximately 2.51 million hectares of agricultural land, with a total production of

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4.92 million tons. The crop's yield ranges from 1 to 6 tons of grain per hectare, depending on environmental conditions and management practices. China leads global faba bean production, contributing 53% of the total output, followed by Ethiopia at 11%. Iran ranks 12th globally in this crop’s cultivation and production (Souri et al., 2020; Memari et al., 2021; Mollaali et al., 2023). The insufficient focus on enhancing the quantity and quality of forage crops has resulted in a persistent shortage of protein sources. Given the growing global demand for food and livestock products, alongside the seasonal scarcity of forage and water during the summer, it is imperative for producers to prioritize the provision of fall forage to address these challenges effectively (Javanmard et al. 2015; Saberi 2018). The expansion of forage crop cultivation and their integration into crop rotation systems is of significant importance. Forage plants not only contribute to meeting the demand for animal feed but also play a crucial role in reducing soil erosion, improving soil structure, and enabling the productive use of low-yield areas. These benefits collectively support the achievement of sustainable agricultural objectives (Shahvardi et al., 2023). Feyzbakhsh (2020) conducted an experiment comparing faba beans (*Vicia faba* L.), cowpeas (*Vigna unguiculata*), and vetch (*Vicia spp.*), reporting that faba beans produced higher forage yield and quality compared to the other two species. Additionally, faba beans were found to be more suitable for livestock feeding due to their superior harvesting characteristics, including their stability during harvest and compatibility with mechanized equipment such as choppers and silage machines.

In the northern regions of Iran, including Gorgan, precipitation during autumn and winter is generally adequate, providing sufficient moisture for plant growth and development. However, during spring, these areas often experience reduced precipitation, leading to end-of-season drought stress. To enhance forage quality, it is essential to reduce the content of acid-detergent insoluble fiber (cellulose and lignin) and non-acid detergent insoluble fiber (hemicellulose) while increasing crude protein levels (Stolts and Nadeau, 2014; Piri et al., 2018). The cultivation of forage beans generates substantial biomass, making it a suitable and recommended choice for forage production (Feizbakhsh, 2020). Grain yield has been reported to depend on several yield components, including the number of branches per plant, the number of pods per plant, the number of grains per Irrigation significantly influenced the number of side branches, the number of pods per plant, and grain yield at the 1% level, as well as soybean dry matter yield at the 5% level (Mousavi et al., 2014). Besides, a two-year study on the quantitative and qualitative yields of annual forage legumes cultivated in autumn across Mazandaran, Golestan, and Lorestan provinces revealed that the Mehta variety of faba bean produced the highest digestible dry matter. Additionally, the Barkat, Feyz, Shadan, and Mehta varieties exhibited the lowest levels of acid detergent insoluble fiber and neutral detergent insoluble fiber (Alizadeh, 2019; Qotbi et al., 2021). Water is a critical factor in plant growth and development, making it the most significant constraint on crop yield (Amiri et al., 2023; Feyzbakhsh et al., 2015). In an experiment, 16 faba bean genotypes were evaluated under normal irrigation and drought stress conditions, revealing that humid climates are optimal for faba bean cultivation. Moreover, the flowering and mid-podding stages were identified as the most critical periods for irrigation (Boshagh et al., 2018). Drought stress negatively impacts plant photosynthesis by reducing leaf area and accelerating leaf senescence, leading to decreased dry matter production, yield, and yield components (Bista et al., 2018; Nakhzari Moghaddam et al., 2019). Similarly, drought stress during the flowering stage of chickpea (*Cicer arietinum* L.) and soybean (*Glycine max* L.) resulted in reductions in grain weight, grain number, pod number, plant height, and lateral branch number. However, it was associated with an increase in protein content (Nawabpour et al., 2016).

Considering the increasing prevalence of drought and the rising demand for forage in recent years, along with the findings from research conducted in Golestan province and other regions of Iran, the present study was undertaken to identify suitable faba bean lines or varieties that can tolerate drought stress in the climatic conditions of Gorgan.

MATERIAL AND METHODS

Experimental area and design

This experiment was conducted at the Agricultural Research Station (Iraqi Mahalle), Gorgan, Iran (36°54'N, 54°25'E, 5.5 m above sea level), over two crop years (2022-2023 and 2023-2024). In this study, nine new faba bean lines, along with two control varieties (Mehta variety has alow tanninand Shadan variety with high tannin content), were compared and evaluated under two distinct environmental conditions: a drought stress environment (irrigation interruption after the flowering stage) and a non-stress environment (optimal irrigation). The experiment was conducted in a randomized complete block design with three replications, focusing on the evaluation of forage quantity and quality. The lines included in this experiment were selected from the superior lines of preliminary faba bean experiments conducted at the Golestan Education, Agriculture, and Natural Resources Research Center. The crops were sown on November 15 in both years of the study. Each experimental unit consisted of four rows, with a row spacing of 60 cm, a length of 6 m, and a plant spacing of 8 cm within the row.

Drought stress application and fertilization

In the non-stress environment, irrigation was applied four times at key growth stages (sowing, pre-flowering, beginning of flowering, and seed filling) based on weather conditions and the plant's water requirements, ensuring that the plants did not experience drought stress. In contrast, in the stress environment, no irrigation was provided from the beginning of flowering (March 15) until the end of the growing season. A wooden scaffold was constructed around the drought-stress environment, and, based on the weather forecast, nylon was stretched over the scaffold immediately before rainfall to prevent rainwater from entering the stress area.

Before the experiment, soil samples were collected from soil layers of 0-20 cm, 20-40 cm, and 40-60 cm to determine the physical and chemical properties of the soil at the experimental site. These samples were then analyzed at the soil laboratory of the Agricultural Research, Education, and Extension Center of Golestan Province (Table 1). Results revealed that the soil texture was classified as silty clay loam. Based on the soil test results, base fertilizers, including triple superphosphate (150 kg/ha) and urea (50 kg/ha), were applied to the soil before planting on November 25 (Table 1).

Table 1. Characteristics of the soil sample at the test site (depth 0-20, 20-40 and 40-60 cm)

Soil characteristics	Sampling depth		
	0-20 (cm)	20-40 (cm)	40-60 (cm)
EC (dS/m)	1.35	1.27	1.42
(pH)	7.2	7.3	7.3
(% Oc)	1.5	1.1	0.6
(% Total nitrogen)	0.15	0.11	0.06
Absorbable phosphorus (mg/kg)	8.6	4.8	2
Absorbable potassium (mg/kg)	333	220	108
(clay %)	28	30	34
(silt %)	54	52	52
(sand %)	18	18	14
soil texture	Silty clay loam		

Table 2. Pedigree of investigated cultivars and lines

Line number	Family tree	origin
1	S2008-96	ICARDA
2	ILB1266*ZV1269-1509-39	ICARDA
3	S2008-034	ICARDA
4	BPL4104	ICARDA
5	WRB1-3	ICARDA
6	S2009-167	ICARDA
7	S2008-0330	ICARDA
8	FLIP03-07FB	ICARDA
9	WRB1-5	ICARDA
10	Mahta	Iran
11	Shadan	Iran

Harvesting and measurement

From planting to harvest, detailed measurements were recorded during agricultural operations, including plant height, number of branches, number of pods, pod fresh weight, stem and leaf fresh weight, pod dry weight, stem and leaf dry weight, protein percentage, and the percentages of acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude fiber (CF) at different growth stages. Agricultural operations, such as planting, weed control, and pest management, were carried out consistently across all treatments. At harvest time (May), the faba bean plants were at the soft-grain pulp stage (R8). During harvest, two marginal rows and a 1-meter section from both the beginning and end of the two middle rows were excluded, and the fresh forage yield was measured. Additionally, 10 plants were selected as samples, and their plant height, number of lateral branches, and number of pods per plant were recorded. Five plants were randomly chosen from each plot, dried in an oven at 65°C for 72 hours, and then sent to the laboratory. The protein percentage, crude fiber percentage, and the percentages of ADF and NDF were measured using a Near-Infrared Reflectance (NIR) device.

Data analysis

Data analysis of variance was conducted using SAS version 9.1 statistical software. Besides, mean comparisons were performed using the least significant difference (LSD) method at the 5% significance level. Figures were generated using Excel software.

Climatic conditions

Table 3 presents meteorological data during the two-year bean growing period and its comparison with long-term meteorological statistics. According to this table, no uncontrolled weather phenomena occurred during the crop growing period.

Table 3. Average monthly temperature of minimum, maximum and total rainfall in crop year 2022-2024 compared to 20 year statistics in Gorgan

Month	Total rainfall (mm)		Average	Average maximum temperature (°C)		Average	Average minimum temperature (°C)		Average
	2022-2023	2023-2024	20 years old	2022-2023	2023-2024	20 years old	2022-2023	2023-2024	20 years old
August	85.9	49.8	54.5	22.2	25.7	20.8	10.2	12.7	10.1
July	28.4	48.3	51.4	16.4	17.5	15.2	6	6.7	5.5
December	9.3	43.8	45.5	13.8	17.5	11.4	1	5.2	3.1
November	29.1	75	50.9	14.2	15.2	12.4	1	4.3	2.7
October	11.3	43.9	56.1	20.3	13.8	14.5	7.4	3.9	4.7
March	33.1	19.4	46.8	23.3	20.9	18.8	9.2	9	8.5
February	95.9	66.3	51.6	27.4	26.1	24.4	14.3	14.4	13.6
January	29.1	9.5	22.2	34	32.9	30.2	20.8	19.5	18.4
Total	322	296.8	379	0	0	0	0	0	0

Source: General Department of Meteorology of Golestan Province - Gorgan Meteorological Station.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) results indicated that the main effects of year and environment on plant height were statistically significant at the 1% level (Table 4). The ANOVA results for the number of branches showed that the environment effect, the interaction effect of year × environment, the effect of variety, the interaction effect of environment × variety, and the triple interaction effect of year × drought stress × variety were all statistically significant at the 1% level. The ANOVA result showed that the main effects of year and drought stress. Besides, the double interaction of year × environment, year × variety, environment × variety, and the triple effect of year × environment × variety on the pod number were significant at 1% level. The main effects of year, environment effect (normal and drought stress), variety, the double interaction effect of year × environment, environment × variety, and triple effect of year × environment × variety on the fresh forage yield were significant at 1% probability level. ANOVA analysis showed that the main effects of year, environment, variety, and the double interaction of year × drought stress, drought stress × variety, and triple effect of year × environment × variety on dry forage yield trait were significant at the 1% level. According to ANOVA results, the main effect of environment and variety on protein percentage was significant at 1% (Table 4). According to ANOVA results, the main effects of year, environment, and variety on Acid detergent insoluble fiber (ADF) were significant at a 1% level (Table 4). The ANOVA results of the year, variety, environment, and year × environment interaction on CF were statistically significant at 1%. Non-acid detergent insoluble fiber (NDF) was significantly affected by the main effects of year, environment, variety, and the triple interaction of year × environment × variety, at 1% (Table 4).

Table 4. Mean squares of the effect of year, normal irrigation environment, drought stress environment and cultivar on forage quality traits (protein percentage, ADF; NDF; CF)

ANOVA	DF	Plant height (cm)	Number of branches	Pod number	Fresh forage yield	Dry forage yield	Protein percentage	Acid detergent insoluble fiber	Neutral detergent fiber	Crude fiber
Year	1	5436.200**	0.221ns	96.564**	266969415.608**	14942013.726**	1.002ns	675.017**	51.938**	941.869**
Location	1	7312.926**	39.710**	1932.773**	8744699493.538**	39788554.732**	27.546**	70.547**	263.219**	341.128**
YL	1	0.246ns	3.869**	73.801**	228927000.971**	4974060.658**	0.182ns	3.502ns	8.451ns	54.735**
R (LY)	8	702.381	0.546	14.942	68011643.52	3823058.961	9.534	18.374	9.251	82.37
Factor A	10	160.160ns	0.928**	18.991**	92114354.278**	3816901.342**	11.863**	176.642**	2030.733**	43.557**
YA	10	122.333ns	0.621*	9.305**	10993452.356ns	629189.505ns	1.306ns	6.329ns	9.240ns	3.352ns
LA	10	159.819ns	0.698**	12.222**	29928438.879**	1402242.341**	0.740ns	7.836ns	9.443ns	5.258ns
YLA2	10	32.689ns	0.981**	10.585**	24017832.300**	1511201.914**	1.048ns	8.273ns	23.585**	5.034ns
Error	80	89.827	0.258	2.938	8951504.066	509992.191	1.107	7.666	6.22	3.946
CV (%)		10.2	16.1	17.1	11.3	12.8	7.37	10.03	7.75	6.64

$^{*,\ **,\ ns}$ are significant at the five, one percent and non-significant levels, respectively.

Plant height

The mean comparison of plant height revealed that the highest plant height (100.2 cm) was observed in the irrigated environment, while the lowest value (85.3 cm) was recorded in the drought-stress environment. However, no significant difference was found between the two environments (Table 5). Besides, plant height across years revealed that the highest value (99.19 cm) was recorded in the second year, while the lowest plant height (86.35 cm) occurred in the first year. No significant difference was observed between the two years (Table 5). A decrease in plant height was observed in the drought stress environment, which may indicate that the plant reached its maximum height before flowering, and subsequent irrigation after flowering slightly affected this parameter. Siddiqui et al. (2015) and Eshraqinejad et al. (2021) also found that drought stress led to a reduction in plant height, while irrigation increased plant height. Behrouzi et al. (2021) also reported that drought stress reduced plant height due to a decrease in cell mass, cell enlargement, cell division, and photosynthesis. Moreover, Memari et al. (2022) stated that a reduction in available water, particularly during the early flowering period in faba beans, diminishes vegetative growth and shortens the reproductive growth period, indirectly negatively affecting plant height. The decrease in plant height due to moisture stress is influenced by the growth stage at which the stress occurs. Water stress during the early stages of development can have a more pronounced effect on reducing plant height.

Branches number

The mean comparison for the interaction effect of year × environment in the first year showed that the highest number of branches (3.9) was observed in the favorable irrigation environment, while the lowest (2.4) was found in the drought stress environment, which was higher than in the second year (Table 6). The results for the interaction effect of year × variety indicated that, in the first year, the lowest number of branches (2.7) was observed in the Mehta genotype, while the highest number of branches (3.7) was recorded in the BPL4104 genotype 4 (Figure 1). Besides, the interaction effect of drought stress × variety on this parameter in the optimal irrigation environment showed that the highest value (4.7) belonged to the BPL4104 genotype, while the lowest one (3.05) was recorded by the S2008-033 genotype. In the drought stress environment, the highest number of branches (2.9) was observed in the Mehta variety, while the lowest (2.3) was found in the S2008-033, S2009-167, and S2008-034 genotypes (Table 8). The triple interaction effect of year × drought stress × variety under optimal irrigation conditions, in both the first and second years, showed that the WRB1-3 genotype and the BPL4104 genotype had the highest number of lateral branches (4.86 and 4.83, respectively). In the drought-stress environment during the first year, the Shadan variety exhibited a higher number of branches (3.03), while the S2008-034 genotype had the lowest number of branches (1.8) compared to the second year (Table 9). In this experiment, the number of branches was higher in the optimal irrigation environment, as maintaining adequate soil moisture during growth prevented the plant from experiencing drought stress. This facilitated increased vegetative growth, which in turn resulted in a higher number of branches. Jamali et al. (2021) stated that irrigation, through its effects on soil moisture and the length of the growth period, probably influenced nutrient absorption by the plant, leading to an increase in the number of branches. Conversely, drought stress resulted in a decrease in the number of lateral branches. The significant reduction in the number of branches per plant was attributed to disrupted photosynthesis caused by water scarcity, which led to a decrease in the production of photosynthetic materials needed for the growth of plant parts. As a result, the plant was unable to reach its genetic potential in terms of branch number (Estanbulluoglu et al., 2010; Ziaei et al., 2016).

Pod number

The mean comparison of the year × drought interaction in the second year showed that the higher pod number (13.94) was obtained in the favorable irrigation environment, while a lower value (7.79) was recorded in the drought stress conditions (Table 6). Besides, year × variety interaction in the second year compared to the first year revealed that the highest pod number (13.46) was related to the BPL4104 genotype, whereas the lowest one (9.16) was associated with the S2008-033 genotype (Figure 2). The analysis of the stress × variety interaction revealed that the BPL4104 genotype produced the highest number of pods (17.75) under normal environmental conditions, whereas the S2008-033 genotype exhibited the lowest value (9.51). On the other hand, the WRB1-3 genotype demonstrated the highest pod number (7.13) (Table 8), under drought stress conditions. Furthermore, the triple interaction of year × drought stress × variety indicated that in the optimal irrigation environment (non-stress conditions) during the second year, the BPL4104 genotype recorded the highest mean number of pods (18.93).

In contrast, under drought stress conditions, the highest pod yield (9.03) was associated with the S2008-96 genotype, while the Shadan variety had the lowest value of the mentioned parameter (7.03) (Table 9). The results indicated that the BPL4104 genotype produced a greater number of pods than other varieties under irrigated conditions, with lower pod shedding observed in this genotype. Under drought stress conditions, the highest pod number was recorded in the S2008-96 and FLIP03-07FB genotypes. Irrigation significantly increased this parameter across different faba bean varieties, whereas drought stress during early reproductive development caused a marked reduction in pod numbers (Sanchez-Reinoso et al., 2020; Memmari et al., 2021). The reduction in pod numbers under drought stress can be attributed to its impact on the synthesis and distribution of photosynthetic materials. Stress conditions led to the shedding of flowers and pods, as well as a decrease in fertile flowers, resulting in a reduced number of pods (Soureshjani et al., 2019; Safari et al., 2023). In the current study, it is likely that flower and pod shedding, along with reduced flower fertility under stress conditions, contributed to the observed decrease in pod numbers, which aligns with the findings of Ghaedi et al. (2020). Drought stress had the greatest impact on pod number during the flowering stage and also affected pod formation during the pod growth stage. This reduction can be attributed to the reduced vegetative growth period and the accelerated transition to the reproductive stage under drought conditions (Chianeh et al., 2016).

Fresh forage yield

The mean comparison of year × environment in the second year revealed that the optimal irrigation environment produced the highest fresh forage yield (37,294 kg/ha), whereas the drought stress environment resulted in the lowest fresh forage yield (18,382 kg/ha) (Table 6). The interaction effect of environment × variety indicated that under optimal irrigation conditions, the BPL4104 genotype achieved the highest fresh forage yield (40620 kg/ha), while the lowest yields were recorded for the S2008-033 and S2008-034 genotypes. In the drought stress environment, the WRB1-5 genotype produced the highest fresh forage yield (21629 kg/ha), whereas the S2008-96 genotype showed the lowest yield (15583 kg/ha) (Table 8). Besides, the triple interaction effect of year × environment × variety in the second year under optimal irrigation conditions demonstrated that the BPL4104 genotype had the highest fresh forage yield (44910 kg/ha). Under drought stress conditions, the highest fresh forage yield (22370 kg/ha) was observed in the WRB1-5 genotype, while the lowest yield (16200 kg/ha) was associated with the S2008-034 genotype (Table 9). On the other hand, fresh forage yield across different forage sorghum genotypes under varying irrigation levels demonstrated that increased irrigation significantly enhanced fresh forage yield. This increase was attributed to improvements in plant height, branch number, and pod number (Kagatay and Ali, 2022). Similarly, Sheikh and Chekani (2020) and Jamali et al. (2021) reported that irrigation increased the fresh weight of stems and leaves, thereby contributing to higher fresh forage yield. Behrouzi et al. (2021) highlighted the significant impact of irrigation on corn fresh forage yield under different irrigation treatments, with the highest yield (82.5 tons/ha) recorded under optimal irrigation and the lowest yield (30.1 tons/ha) observed under drought stress conditions. Drought stress negatively affected fresh forage yield by impairing the photosynthetic activity of plants (Nakhzari Moghaddam et al., 2019; Song et al., 2019).

In the current study, the observed reduction in fresh forage yield under stress conditions was associated with declines in plant height, branch number, pod number, pod weight, and stem and leaf weight. These findings are consistent with those reported by.

Dry forage yield

According to mean comparison results, year × environment interaction in the second year showed that in the optimal irrigation environment, the highest dry forage yield (6234 kg/ha) was observed. Whereas, the lowest value (4463 kg/ha) was observed in the first year under the drought stress environment (Table 6). The environment × variety interaction indicated that under optimal irrigation conditions, the highest dry forage yield (7450 kg/ha) was achieved by the WRB1-5 genotype, followed by the Shadan variety, which produced 7040 kg/ha and was statistically comparable. In contrast, the lowest dry forage yield (5234 kg/ha) was recorded for the WRB1-3 genotype. Under drought stress conditions, the FLIP03-07FB genotype exhibited the highest dry forage yield (5771 kg/ha), with the BPL4104 genotype closely following at 5,673 kg/ha. The lowest dry forage yield under drought stress (4082 kg/ha) was observed in the S2008-033 genotype (Table 8). Besides, the triple interaction of year × environment × variety in the second year revealed that under optimal irrigation conditions, the WRB1-5 genotype produced the highest dry forage yield (7602 kg/ha). Under drought stress conditions, the highest yield (6691 kg/ha) was recorded for the BPL4104 genotype, whereas the S2008-033 variety exhibited the lowest yield (4563 kg/ha) (Table 9). Drought stress reduces cell turgor pressure, resulting in decreased water retention within cells, reduced cell volume, and consequently, a decline in dry forage yield (Eshraqinejad et al., 2021). Vendruscolo et al. (2007) reported that increased temperatures at the end of the growing season adversely affected fava bean growth, reducing the duration of all growth stages. This reduction in growth stages led to a decline in yield traits and yield components, ultimately decreasing dry forage yield, consistent with the findings of this study. Irrigation promoted pod formation and increased seed number, whereas drought stress during early reproductive development caused flower and pod shedding, resulting in reduced dry forage yield (Safari et al., 2023). Kagatay and Ali (2022) demonstrated that irrigation enhanced the leaf area and the green parts of the plant, facilitating the transfer of greater photosynthetic and assimilated materials, which contributed to increased dry forage yield. Similarly, Wasaya et al. (2021) observed in a study with three irrigation treatments in Islamabad, Pakistan, that increasing drought stress significantly reduced shoot weight and forage dry weight. The decline in total dry weight yield due to irrigation deficits aligns with the results reported by Daneshvar Rad (2021) and Palash et al. (2021).

Protein percentage

Mean comparison results in two environments, optimal irrigation, and drought stress, showed that the protein percentage increased by the highest value (14.72%) in the drought stress environment, while the lowest one was obtained (13.81%) in the optimal irrigation environment (without stress) (Table 5). Besides, the analysis of protein percentage in the studied varieties revealed that the FLIP03-07FB and BPL4104 genotypes exhibited the highest protein percentage (15.52%), whereas the S2008-033 genotype had the lowest protein percentage (12.75%) (Table 7). Variations in protein percentage have been reported by other researchers. For instance, Ghotbi et al. (2021) found that the Barakat, Shadan, and Feyz varieties contained 14.62%, 14.93%, and 16.06% forage protein, respectively. Similarly, Ghaedi et al. (2020) reported that among several bean varieties, the Sadri variety exhibited the highest protein percentage (23.9%), while the KS-21193 variety had the lowest (19.9%). Under stress conditions, stomatal closure leads to reduced carbon fixation and diminished nitrogen remobilization from leaves to seeds, contributing to an increase in protein percentage. Eskandari et al. (2019) and

Nematollahi et al. (2019) observed that irrigation reduced protein percentage, whereas drought stress increased it. However, drought stress also decreases total protein content due to reduced protein synthesis. This phenomenon can be attributed to the disruption in the transport of photosynthetic assimilates under drought stress, resulting in fewer carbohydrates being transferred to the seeds. Consequently, as stress intensifies, the protein percentage increases while the total protein amount decreases (Nawabpour et al., 2016; Ozmen, 2017). Farhadi et al. (2021) concluded that increasing protein content improves the qualitative performance of forage, underscoring the importance of optimizing conditions to balance protein synthesis and yield.

Acid detergent insoluble fiber (ADF)

The effect of the year on ADF percentage showed that in the first year, ADF was 25.35%, whereas in the second year, it increased to 29.87%. This increase was attributed to reduced rainfall in the second year compared to the first (Figure 3). A comparison of ADF percentages across environments revealed that ADF was higher under drought stress (28.34%) compared to optimal irrigation conditions (26.88%) (Table 5). Among the studied varieties, the S2008-033 genotype exhibited the highest ADF percentage (34.58%), while the BPL4104 genotype had the lowest (23.49%) (Table 7). Keten and Degirmenci (2020) found that drought stress significantly increased ADF by 59.2%, whereas irrigation reduced ADF by 54.4% in forage sorghum. The reduction in ADF under irrigation improved forage quality, while drought stress caused forage to become dry and woody due to increased ADF content (Nematollahi et al., 2019; Oner and Guneş, 2019). Furthermore, Piri et al. (2018), Ghotbi et al. (2021), and Tucak et al. (2023) reported that lower levels of cell wall components without hemicellulose (ADF) enhance digestibility and improve forage quality, emphasizing the importance of managing environmental conditions to optimize forage nutritive value.

Crude fiber (CF)

The mean comparison of year × environment interaction showed that, in the first year, the optimal irrigation environment resulted in the lowest crude fiber percentage (26.29%), while the drought stress had the highest crude fiber percentage (28.22%). In the second year, the stressed environment exhibited the highest crude fiber percentage (34.84%), whereas the optimal irrigation environment had the lowest (30.34%) (Table 6). The analysis of crude fiber percentages among the studied varieties indicated that the Shadan variety had the highest crude fiber content (33.5%), while the BPL4104 genotype exhibited the lowest (26.67%) (Table 7). These results suggest that the Shadan variety has lower forage quality compared to the BPL4104 genotype due to its higher crude fiber content. Similarly, Alizadeh (2019) reported that under drought stress conditions, annual forage plants such as vegetables, clover, forage peas, safflower, forage rapeseed, and oil mustard displayed variability in crude fiber content. Among faba bean varieties, Mehta, Shadan, and Barakat had the lowest crude fiber percentages of 25.4%, 26.91%, and 27.15%, respectively. Similarly, Eskandari et al. (2019) and Nour et al. (2022) and observed that drought stress increased crude fiber percentage, while irrigation reduced it. This reduction in crude fiber was associated with improved forage quality. Furthermore, studies by Bhattarai et al. (2020) and Kaplan et al. (2019) demonstrated that drought stress conditions reduce the leaf-to-stem ratio in forage sorghum, thereby increasing fiber content. In contrast, irrigation improved forage quality by increasing the leaf-to-stem ratio and reducing stem proportion per plant.

Non-acid detergent insoluble fiber (NDF)

The NDF represents the cell wall content of forage, and its reduction enhances the forage's nutritional value. Analysis of year effects on NDF revealed that the lowest NDF percentage (31.57%) occurred in the first year, while the second year exhibited the highest NDF (32.82%) (Figure 3). Comparing environmental impacts, the normal irrigation environment produced the lowest NDF (30.78%), and the drought-stress environment resulted in the highest NDF (33.61%) (Table 5). Among the studied varieties, the Shadan variety displayed the highest NDF percentage (39.53%), while the S2009-167 genotype had the lowest (26.52%) (Table 7). This indicates lower forage quality in the Shadan variety due to its higher cell wall content. Examining the triple interaction of year × environment × variety, the second year under optimal irrigation revealed that the S2008-033 genotype had the highest NDF percentage (36.57%), followed by the Shadan variety with 33.47%. In the drought-stress environment of the second year, the S2008-033 genotype again had the highest NDF (33.36%), while the FLIP03-07FB variety recorded the lowest percentage (4.25%) (Table 9). These findings align with Alizadeh (2019) and Stolts and Nadeau (2014), who reported that drought stress increased NDF, reflecting greater cell wall content, which reduced forage intake by livestock due to its indigestibility. Azari-Nasrabad and Moghri Fariz (2020) and Behrouzi et al. (2021) noted that irrigation decreased NDF, enhancing forage digestibility. Similarly, Ozmen (2017) concluded that drought stress increased NDF due to a higher stem-to-leaf ratio, which contributes to reduced forage quality under stress conditions.

Table 5. Comparison of the average effect of environment on plant height, protein percentage, and insoluble fiber in acidic and non-acidic detergent

Location	Plant height (cm)	Protein percentage (CP%)	Acid detergent insoluble fiber (ADF%)	Neutral detergent fiber (NDF%)
optimal irrigation	100.218a	13.814b	26.88b	30.786b
drought stress	85.332b	14.727a	28.342a	33.611a

Numbers that have at least one letter in common in each column do not have a significant difference at the 5% level

Table 6. Comparison of the mean interaction effect of year × environment on the traits of number of branches, number of pods, fresh forage yield, dry forage yield and crude fiber

Year	Location	Number of branches	Pod number	Fresh forage yield (kg/ha)	Dry forage yield (kg/ha)	Crude fiber (CF%)
2022-2023	optimal irrigation	3.903a	13.733a	31816.403b	5948.739a	26.291b
2023-2024	drought stress	2.464c	4.585c	18171.715c	4463.506b	28.218b
2022-2023	optimal irrigation	3.479b	13.948a	37294.545a	6234.452a	30.345ab
2023-2024	drought stress	2.724c	7.791b	18382.152c	5523.585ab	34.848a

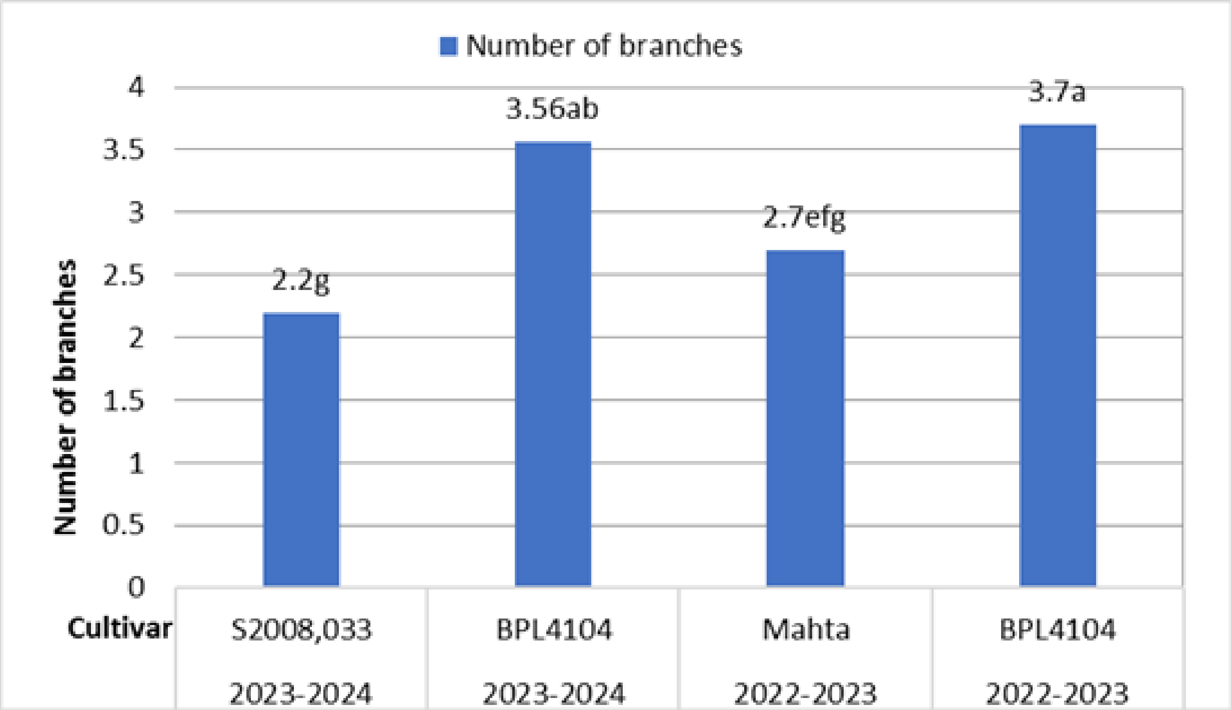
Numbers that have at least one letter in common in each column do not have a significant difference at the 5% level

Table 7. Comparison of the average effect of number on the traits of protein percentage, acid and non-acid detergent insoluble fiber, and crude fiber

Cultivar	Protein percentage (CP%)	Acid detergent insoluble fiber (ADF%)	Neutral detergent fiber (NDF%)	Crude fiber (CF%)
s2008-96	13.475de	25.89ef	29.01e	30.07b
ilb1266*zv1269-1509-39	14.35cd	26.77de	32.58cd	31.05bc
s2008-034	13.68de	29.5bc	35.43b	29.46cd
BPL4104	15.52a	23.49f	29.2e	26.67f
WRB1-3	14.54bc	30.18b	30.83de	31.59b
S2009,167	13.16ef	24.25f	26.52f	29.61cd
S2008,033	12.75f	34.58a	38.28a	31.28b
FLIP03-07FB	15.52a	23.52f	30.5e	28.83de
WRB1-5	15.27ab	24.73ef	28.96e	27.63ef
Mahta	15.09abc	27.59cd	33.33c	29.51cd
Shadan	13.61de	33.22a	39.53a	33.5a

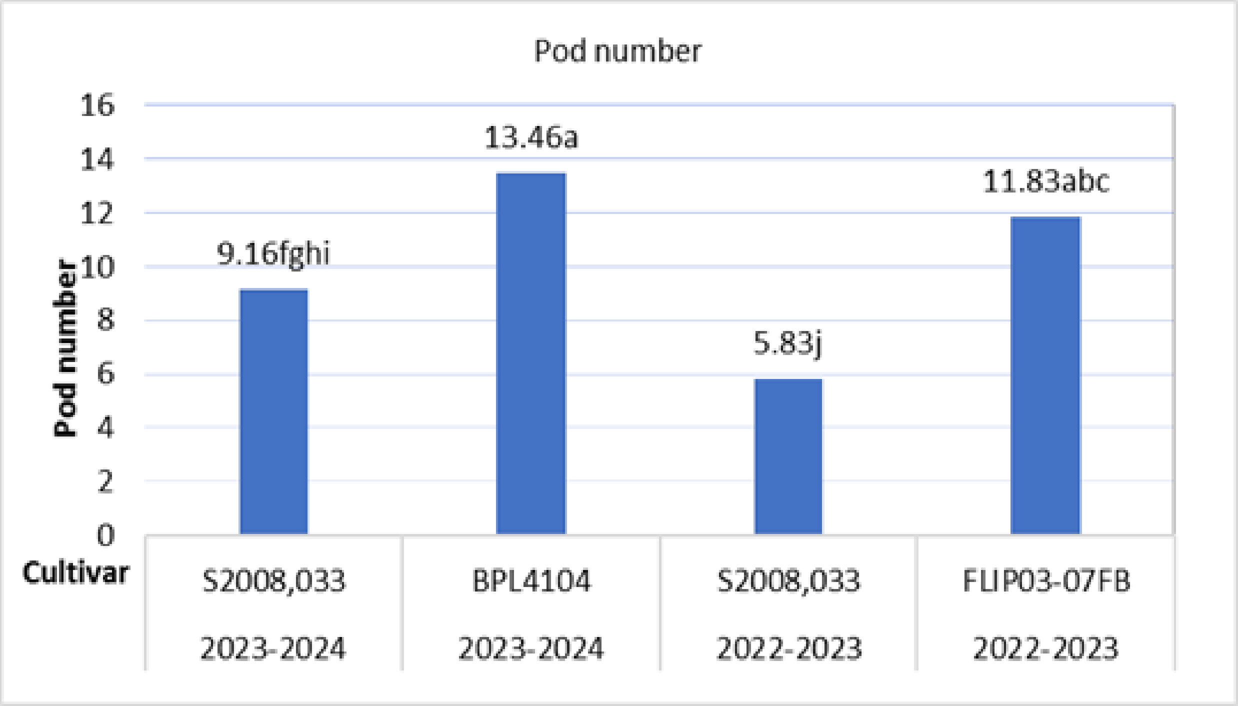
Numbers that have at least one letter in common in each column do not have a significant difference at the 5% level

Figure 1. Comparison of the mean interaction effect of year × cultivar on the number of branches



Numbers that have at least one letter in common in a column do not have a significant difference at the 5% level.

Figure 2. Comparison of the mean interaction effect of year × variety on pod number



Numbers that have at least one letter in common in a column do not have a significant difference at the 5% level.

Table 8. Comparison of the mean interaction effect of environment × cultivar on the traits of number of branches, number of pods, fresh forage yield, and forage dry weight

Location	Cultivar	Number of branches	Pod number	Fresh forage yield (kg/ha)	Dry forage yield (kg/ha)
optimal irrigation	s2008-96	3.417bcd	13.167cde	31216.667def	5257.133efgh
	ilb1266*zv1269-1509-39	3.750bc	11.433ef	31433.333def	5413.083efgh
	s2008-034	3.767b	12.333de	29016.667f	5672.200defg
	BPL4104	4.700a	17.750a	40620a	6410.883bcd
	WRB1-3	3.767b	15.183b	36102.766bc	5234.833efgh
	S2009,167	3.167cde	13.817bcd	32535.550dc	5393.017efgh
	S2008,033	3.050def	9.517f	29966.667ef	5973.950cde
	FLIP03-07FB	3.983b	15.033bc	39300ab	6409.883bcd
	WRB1-5	3.900b	14.683bc	38999.700ab	7450.833a
	Mahta	3.133def	13.833bcd	33973.600cd	6751.233abc
	Shadan	3.967b	15.500b	36945.267bc	7040.500ab
drought stress	s2008-96	2.600efgh	6.317g	15583.333k	5143.383fghi
	ilb1266*zv1269-1509-39	2.600efgh	6.217g	16731.483ijk	4712.133hig
	s2008-034	2.317h	5.400g	17935.183hijk	4692.883hig
	BPL4104	2.600efgh	6.067g	19694.450ghi	5673.767defg
	WRB1-3	2.567fgh	7.133g	16462.950igk	4921.450ghi
	S2009,167	2.350gh	6.233g	16027.783jk	4384.100ig
	S2008,033	2.350gh	5.483g	17666.667hijk	4082.317j
	FLIP03-07FB	2.667efgh	6.917g	19120.367ghij	5771.500def
	WRB1-5	2.683efgh	5.717g	21629.617g	5451.783efgh
	Mahta	2.933defg	6.217g	19833.333ghi	4873.250ghij
	Shadan	2.867defgh	6.367g	20361.100gh	5222.433efgh

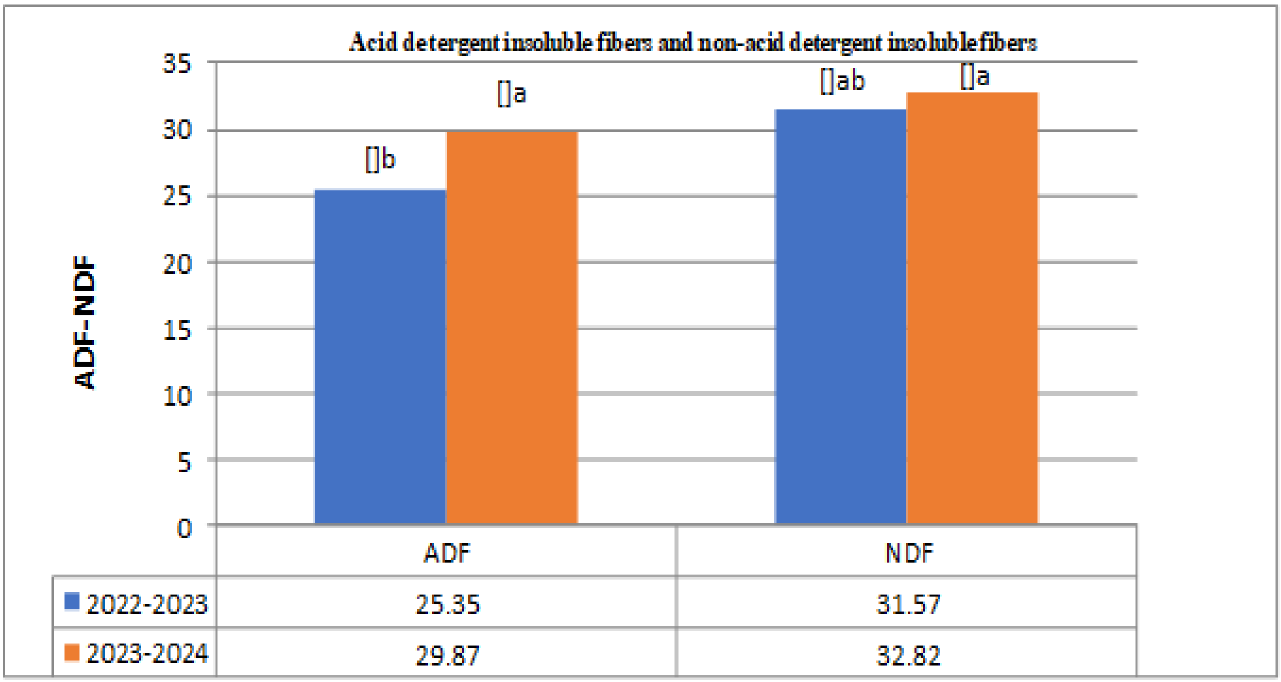
Numbers that have at least one letter in common in each column do not have a significant difference at the 5% level.

Table 9. Comparison of the mean interaction effect of year × environment × cultivar on the traits of number of branches, number of pods, fresh pod weight, fresh forage yield, dry forage yield, and non-acid detergent insoluble fiber

Year	Location	Cultivar	Number of branches	Pod number	Fresh forage yield (kg/ha)	Dry forage yield (kg/ha)	Neutral detergent fiber (NDF%)
2022-2023	optimal irrigation	S2008-96	3.433fghijkl	13fgh	28330j	4792jklmnopqr	22.6lmnop
		ILB1266*ZV1269-1509-39	3.833cdefg	11.53hi	26670jk	4904jklmnopqr	25.53ijklmn
		S2008-034	4cdef	12gh	27330j	5871defghij	26.6hijklm
		BPL4104	4.567abc	16.57abcd	36330def	7026abcd	19.33p
		WRB1-3	4.867a	16bcde	37410cdef	4187pqrs	29.07efghi
		S2009-167	3.667defgh	16.77abcd	31400ghij	4656klmnopqrs	19.47p
		S2008-0330	3.9cdef	8.233klmn	26670jk	6140bcdefghi	31.37cdefg
		FLIP03-07FB	4.333abcd	17.2abc	36670def	6480abcdefg	20.83op
		WRB1-5	3.5efghijk	14.77cdefg	34770defgh	7300ab	21.1nop
		Mahta	2.933hijklmnop	12.67fgh	28680ij	6804abcde	24.5jklmno
		Shadan	3.9cdef	12.33fgh	35720defg	7276abc	32.2abcdef
	drought stress	S2008-96	2.5nopqr	3.6r	14670opq	4676klmnopqrs	23.73klmnop
		ILB1266*ZV1269-1509-39	2.367opqr	5.1opqr	15890nopq	3808rs	23.73klmnop
		S2008-034	1.8r	3.667r	19670lmn	4394opqrs	27.8fghijk
		BPL4104	2.9hijklmnop	4.133qr	22330kl	4656klmnopqrs	22.17mnop
		WRB1-3	2.367opqr	5.8mnopqr	14440pq	4925jklmnopqr	29.07efghi
		S2009-167	1.933qr	3.9qr	14000q	4132pqrs	22.93lmnop
		S2008-0330	2.333opqr	3.433r	18000lmnopq	3601s	34.07abcd
		FLIP03-07FB	2.567mnopqr	6.467lmnopq	19330lmno	5220hijklmnop	22.3mnop
		WRB1-5	2.667lmnopq	4.1qr	20890lm	4619mnopqrs	22.6lmnop
		Mahta	2.633lmnopq	4.533pqr	20000lmn	4004qrs	24.5jklmno
		Shadan	3.033ghijklmno	5.7nopqr	20670lmn	5063ijklmnopq	32.2abcdef
2023-2024	optimal irrigation	S2008-96	3.4fghijkl	13.33efgh	34100efgh	5722efghijklmn	28.13fghijk
		ILB1266*ZV1269-1509-39	3.667defgh	11.33hij	36200defg	5922defghij	27ghijkl
		S2008-034	3.533defghij	12.67fgh	30700hij	5473ghijklmno	31.63cdef
		BPL4104	4.833ab	18.93a	44910a	5796efghijkl	24.27jklmno
		WRB1-3	2.667lmnopq	14.37defg	34800defgh	6283bcdefgh	33abcde
		S2009-167	2.667lmnopq	10.87hijk	33670efgh	6130cdefghi	25.3ijklmno
		S2008-0330	2.2pqr	10.8hijk	33270fghi	5808efghijk	36.57a
		FLIP03-07FB	3.633defghi	12.87fgh	41930abc	6340bcdefgh	25.53ijklmn
		WRB1-5	4.3abcde	14.6cdefg	43230ab	7602a	26.93ghijkl
		Mahta	3.333fghijklm	15cdef	39270bcd	6698abcdef	26.93ghijkl
		Shadan	4.033bcdef	18.67ab	38170cde	6805abcde	33.47abcde
	drought stress	S2008-96	2.7klmnopq	9.033ijkl	16500mnopq	5611fghijklmn	29.1efghi
		ILB1266*ZV1269-1509-39	2.833ijklmnop	7.333lmno	17570lmnopq	5616fghijklmn	30.8cdefgh
		S2008-034	2.833ijklmnop	7.133lmnop	16200mnopq	4992ijklmnopq	31.97bcdef
		BPL4104	2.3opqr	8lmn	17060mnopq	6691abcdef	28.2fghijk
		WRB1-3	2.767jklmnop	8.467klmn	18480lmnopq	4918jklmnopqr	29.6defghi
		S2009-167	2.767jklmnop	8.567jklm	18060lmnopq	4636lmnopqrs	29.3efghi
		S2008-0330	2.367opqr	7.533lmno	17330mnopq	4563nopqrs	36.33ab
		FLIP03-07FB	2.767jklmnop	7.367lmno	18910lmnop	6323bcdefgh	25.4ijklmn
		WRB1-5	2.7klmnopq	7.333lmno	22370kl	6285bcdefgh	28.3fghij
		Mahta	3.233fghijklmn	7.9lmn	19670lmn	5743efghijklm	34.43abc
		Shadan	2.7klmnopq	7.033lmnop	20060lmn	5382ghijklmno	35abc

Numbers that have at least one letter in common in each column do not have a significant difference at the 5% level

Figure 3. Comparison of the average effect of the year on fibers insoluble in acidic detergent and fibers insoluble in non-acidic detergent



Numbers that have at least one letter in common in a column do not have a significant difference at the 5% level

CONCLUSIONS

Drought stress after the flowering stage reduces the quantitative and qualitative yield of forage. Identifying drought-resistant varieties toward the end of the season is crucial for improving faba bean production under water-limited conditions. The results of this study indicate that in both non-stressed (normal irrigation) and stressed (drought) environments, the genotypes BPL4104 and WRB1-5 exhibited the highest fresh and dry forage yields, along with the lowest percentages of ADF, CF, and NDF. Based on these results, it is recommended that the cultivation and further development of the BPL4104 and WRB1-5 genotypes be pursued, following compatibility and adaptability tests for local conditions.

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REFERENCES

Alizadeh, K., 2019. *The annual forage crops under dryland conditions. A review*. Iranian Journal of Dryland Agriculture, 8(1): 95-113. https://doi.org/10.22092/idaj.2019.124675.245

Amiri, S.R., Ziaei, S.M., Zakeri, N., 2023. *Managing drought risk on lentil using deficit irrigation in arid zones*. Romanian Agricultural Research, 40: 483-489. https://doi.org/10.59665/rar4045

Azari-Nasrabad, A., and Moghri Fariz, A., 2020. *The effect of irrigation regimes on the performance and efficiency of water use of sorghum forage of speedfed variety in South Khorasan province*. Fodder and Animal Feed Promotional Magazine, 14: 68-74.

Behrouzi, D., Dayant, M., Majidi, A., Mirhadi, M.J., Shirkhani, A., 2021. *Effect of deficit irrigation, fertilizers and vermicompost on forage maize (Zea mays L.)*. Journal of Agricultural Agriculture, 24(4): 1071-1084. http://doi.org/10.22059/jci.2021.328509.2594

Bhattarai, B., Singh, S., West, C.P., Ritchie, G.L., Trostle, C.L., 2020. *Effect of deficit irrigation on physiology and forage yield of forage sorghum, pearl millet, and corn*. Crop Science, 60: 2167-2179. https://doi.org/10.1002/csc2.20171

Bista, D., Heckathorn, S., Jayawardena, D., Mishra, S., Boldt, J., 2018. *Effects of drought on nutrient uptake and the levels of nutrient-uptake proteins in roots of drought-sensitive and-tolerant grasses*. Planta, 7(2): 28. https://doi. org/10.3390/plants7020028

Boshagh, B., Astraki, H., Pezashkipour, P., 2018. *Evaluation of faba bean genotypes using drought tolerance indices and multivariate statistical methods*. Journal of Crop Breeding, 10(2): 1- 9. http://dx.doi:10.29252/jcb.10.27.1

Chianeh, R., Rahimi, A., Sheikh, F., Maheji, M., 2016. *The response of some agricultural characteristics of faba beans to biofertilizers under low stress conditions of Vicia faba L*. Agricultural Plant Production Journal, 10(4): 107-120. https://doi.org/10.22069/EJCP.2018.12238.1943

Daneshvar Rad, R., Heidari Sharifabad, H., Torabi, M., Azizinejad, R., Salemi, H.R., Heidari Soltanabadi, M., 2021. *Impact of drought stress on biochemical responses, energy, and water productivity on maize forage (Zea mays L.)*. SN Applied Sciences, 3, 834. https://doi.org/10.1007/s42452-021-04813

Eshraqinejad, M., Alavi Sini, S.M., Ayin, A., 2021. *Examining and comparing the performance of grass sorghum genotypes under moisture stress conditions in the southern region of Kerman*. Environmental Stresses in Crop Sciences, 15(1): 31-41. http://dx.doi.org/10.22077/escs.2020.3860.1931

Eskandari, H, Alizadeh-Amraie, A., Kazemi, K., 2019. *Effect of drought stress caused by partial root zone irrigation on water use efficiency and grain yield of maize (Zea mays L.) and mung bean (Vigna radiata L.) in different intercropping planting patterns*. Environmental Stresses in Crop Sciences, 12(1): 29-40. https://doi.org/10.22077/escs.2018.1133.1233

Estanbulluoglu, A., Arslan, B., Gocmen, E., Gezer, E., Pasa, C., 2010. *Effects of deficit irrigation regimes on the yield and growth of oil seed rape (Brassica napus L)*. Biosystem Enginiering, 105(3): 388-394. https://doi.org/10.1016/j.biosystemseng.2009.12.010

Farhadi, A., Paknejad, F., Gol Zardi, F., Ilkabi, M.N., Agha Yari, F., 2021. *Investigating the yield characteristics, forage quality, and water use efficiency of forage sorghum (Sorghum bicolor) in response to different levels of drought and nitrogen stress*. Environmental Stresses in Agricultural Sciences, 15(4): 865-879. http://dx.doi.org/10.22077/escs.2021.4115.1971

Feyzbakhsh, M.T., 2020. *Comparison of quantitative and qualitative forage yield of vetch, kholer and broad bean forage plants in the climatic conditions of Gorgan*. Forage and Animal Feed Promotional Magazine, 4(1): 48-55.

Feyzbakhsh M.T, Kamkar, B., Mokhtarpour, H., Asadi, M.E. 2015. *Effect of soil water management and different sowing dates on maize yield and water use efficiency under drip irrigation system*. Archive of Agronomy and Soil Sciences, 16(11): 1581-1592. https://doi.org/10.1080/03650340.2015.1019345

Ghaedi, R., Razmjoo, J., GholamiZali, A., 2020. *Effect of irrigation regimes on yield, yield components and seed quality of different pinto bean (Phaseolus vulgaris) genotypes*. Journal of Crop Production and Processing, 11: 1-18. https://doi:10.47176/jcpp.11.2.23942

Jamali, S., Ansari, H., Zeynodin, S.M., 2021. *Investigation of the effect of irrigation water quality and harvesting time on the yield and yield components of forage sorghum (Sorghum bicolor L.)*. Journal of Water and Soil Science, 25(1): 231-241. http://dx.doi.org/10.47176/jwss.25.1.35826

Javanmard, A., Mohamadi-Nasab, A.D., Javanshir, A., Moghaddam, M., Janmohammadi, H., Nasiri, Y., Shekari, F., 2015. *Evaluation of maize neutral detergent fiber (NDF), acid detergent fiber (ADF), total digestible nutrients (TDN) dry matter intake (DMI) and net energy for lactation (NEL) in intercropping*. Journal of Crop Production and Processing, 4(14): 175-190. http://jcpp.iut.ac.ir/article-1-2278-en.html

Kagatay, R., and Ali, M., 2022. *Determination of Forage Yield and Some Quality Characteristics of Silage Sorghum Genotypes at Different Water Stress Levels*. Selcuk Journal of Agriculture and Food Sciences, 36(1): 1-7. https://doi.org/10.15316/SJAFS.2022.001

Kaplan, M., Kara, K., Unlukara, A., Kale, H., Buyukkilic Beyzi, S., Varol, I.S., Kizilsimsek, M., Kamalak, A., 2019. *Water deficit and nitrogen affects yield and feed value of sorghum sudangrass silage*. Agricultural Water Management, 218: 30-36. https://doi.org/10.1016/j.agwat.2019.03.021

Karkanis, A., Ntatsi, G., Lepse, L., Fernandez, J.A., Vagen, I.M., Rewald, B., Alsiņa, I., Kronberga, A., Balliu, A., Olle, M., Bodner, G., Dubova, L., Rosa, E., Savvas, D., 2018. *Faba bean cultivation, revealing novel managing practices for more sustainable and competitive European cropping systems*. Frontier in Plant Science, 9: 1115. http://dx. doi:10.3389/fpls.2018.01115

Keten, M., and Degirmenci, H., 2020. *Farklı sulama seviyeleri altında yetiştirilen ikinci urun silajlık mısır ve sorgum bitkilerinin yaprak su potansiyellerinin karşılaştırılması*. ISPEC Journal of Agricultural Sciences, 4(4): 865-874.

Kopke, U., and Nemecek, T., 2016. *Ecological services of faba bean*. Field Crops Research, 115: 217-233. https://doi.org/10.1016/j.fcr.2009.10.012

Mansouri Vajari, M.R., Zainali, A., Soltani, A., Torabi, B., Nebandani, A.R., 2024. *Estimation and analysis of bean grain yield gap in Golestan province using CPA method*. Tehran University Press, 26(2): 331-348. https://doi.org/10.22059/jci.2024.364740.2844

Memari, M., Dadashi, M.R., Sheikh, F., Ajamnoruzi, H., 2021. *Evaluation of drought stress tolerance in some faba bean genotypes using drought tolerance indices and biochemical compounds*. Journal of Crop Production and Processing, 11(2): 121-139. http://dx.doi.org/10.47176/jcpp.11.2.3591

Memari, M., Dadashi, M.R., Sheikh, F., Ajamnoruzi, H., 2022. *Evaluation of drought stress tolerance in some faba bean genotypes using drought tolerance indices*. Romanian Agricultural Research, 39: 35-43. https://doi.org/10.59665/rar3904

Mollaali, E., Dadashi, M.R., Sheikh, F., Ajamnorozi, H., Feyzbakhsh, M.T., 2023. *Evaluating the Waterlogging Tolerance of Faba Bean Genotypes at Different Growth Stages under Field Conditions*. Romanian Agricultural Research, 40: 239-249. https://doi.org/10.59665/rar4023

Mousavi, S.A., Khaledian, M., Ashrafzadeh, A., Rakhsar, R., 2014. *The effect of limited irrigation in the sensitive stages of growth on increasing the performance and water productivity of three soybean genotypes in Rasht region*. Journal of Water Research in Agriculture, 29(4): 433-446. http://dx.doi.org/10.22092/JWRA.2016.105811

Nakhzari Moghaddam, A., Samsami, A.N., Rahemi Karizaki, A., Gholinezhad, E., 2019. *Effect of irrigation on physiological traits and seed yield of soybean under inoculation with mycorrhiza fungi and rhizobium bacteria*. Environmental Stresses Crop Sciences, 13(2): 413-423. http://dx.doi.org/10.22077/escs.2019.2131.1531

Nawabpour, S., Hazarjaribi, A., Mazandarani, A., 2016. *Investigating the effect of drought stress on important agricultural traits and the amount of protein and seed oil in soybean genotypes*. Environmental Stresses in Agricultural Sciences, 10(4): 491-503. http://dx.doi.org/10.22077/escs.2017.61.1021

Nematollahi, D., Eisvand, H.R., Modaerrs-Sanavy, S.A.M., Akbari, N., Ismaili, A., 2019. *Effects of low irrigation on yield quantity and quality of clover species under high input management conditions*. Iranian Journal of Field Crop Science, 51(3): 47-57. http://dx.doi.org/10.22059/IJFCS.2019.251696.654444

Nour, R., Sanchez-Ballesta, M.T., Badri, M., 2022. *Influence of drought and heat stresses in fodder legumes productivity and nutritive value*. Journal of Oasis Agriculture and Sustainable Development. https://doi.org/10.56027/JOASD.092023

Oner, F., and Guneş, A., 2019. *Determination of silage yield and quality characteristics of some maize (Zea mays L.) varieties*. Journal of Tekirdag Agricultural Faculty, 16: 42-50. https://doi.org/10.33462/jotaf.516865

Ozmen, S., 2017. *Bingol koşullarında farklı sorgum turlerinin ot verimi ve kalite ozelliklerinin belirlenmesi*. Master thesis, Bingol Universitesi, Fen Bilimleri Enstitusu.

Palash, M., Bafkar, A., Farhadi Bansouleh, B., Ghobadi, M., 2021. *Effects of deficit irrigationon, quantity, quality characteristics and water productivity in grain maize (KSC 706) in Kermanshah*, Advanced Technologies in Water Efficiency, 1: 68-88. (In Persian) https://doi.org/10.22126/ATWE.2021.6686.1003

Piri, H., Ansari, H., Parsa, M., 2018. *The interaction effect of salinity, drought and harvesting dates on yield, quality and efficiency of forage sorghum in subsurface drip irrigation (Case study: sistan plain)*. Irrigation Sciences and Engineering, 41(1): 99-114. https://doi.org/10.22055/JISE.2018.13454

Qotbi, V., Sheikh, F., Feyzbaksh, M.T., Shahverdi, M., Sarparast, M., Asadi, H., Moghaddam, A., 2021. *The comparison of qualitative and quantitative yield of annual forage legumes in autumn cultivation*. Scientific Research Journal of Agricultural Knowledge and Sustainable Production, 23(3): 81-95. https://doi.org/10.22034/SAPS.2021.46092.2684

Sabri, A.R., 2018. *Investigating the performance and morphological traits of some new forage products and forgotten forage plants in Golestan province*. Journal Applied Researches of Plant Ecophysiology, 6(2): 45-57. https://doi.org/10.22092/AJ.2022.352836.1518

Safari, M.R., Dadashi, M.R., Faraj, A., Armin, M., 2023. *Effect of biofertilizer and drought stress on quantitative and qualitative traits in some winter rapeseed (Brassica napus L.) cultivars*. Romanian Agricultural Research, 40: 403-415. https://doi.org/10.59665/rar4038

Sanchez-Reinoso, A.D., Ligarerreto-Moreno, G.A., Restrepo-Díaz, H., 2020. *Evaluation of drought indices to identify tolerant genotypes in common bean bush (Phaseolus vulgaris L.*). J. Integration. Agriculture, 19: 99-107. https://doi.org/10.1016/S2095-3119(19)62620-1

Shahvardi, M., Nasrollahi, M., Chegny, A.R., Cheshmeh Noor, M., Asterisk, H., 2023. *The effect of irrigation regimes and planting dates on forage yield of safflower (Lathyrus sativus L.) genotypes*. Crop Plant Sciences of Iran, 54(3): 110-117. http://dx.doi.org/10.22059/IJFCS.2023.352981.654973

Sheikh, F., and Feyzbakhsh, M.T., 2019. *Faba bean, cultivation, crop husbandry and harvest*. *Nashre, Amoozesh, e, Keshavarzi*. Agricultural Research, Education and Extension Organization, Iran. (In Persian)

Sheikh, F., and Chekani, A., 2020. *Comparison of forage and grain yield of faba bean cultivars suitable for livestock feed and poultry diets*. Fodder and Animal Feed Promotional Magazine, 2(1): 70-77.

Siddiqui, M.H., Al-Khaishany, M.Y., Al-Qutami, M.A., Al-Whaibi, M.H., Grover, A., Ali, H.M., Al-Wahibi, M.S., Bukhari, N.A., 2015. *Response of different genotypes of faba bean plant to drought stress*. International Journal of Molecular Sciences, 16: 102214-102227. https://doi.org/10.3390/ijms160510214

Song, L., Jin, J., He, J., 2019. *Effects of severe water stress on Maize growth processes in the field*. Sustainability, 11: 1-18.

Soureshjani, H.K., Nezami, A., Kafi, M., Tadayon, M., 2019. *Responses of two common bean*

(Phaseolusvulgaris) genotypes to deficit irrigation. Agriculture Water Manag., 213: 270-279. https://doi.org/10.1016/j.agwat.2018.09.038

Souri, S., Amirnia, R., Rezaei Chianeh, A., Sheikh, F., 2020. *Evaluation of yield and yield components of different faba bean cultivars (Vicia faba L.) in mixed cultivation with triticale (Tritico secale L.)*. Journal of Agricultural Ecology, 12(1): 143-159. https://doi.org/10.22067/JAG.V12I1.81918

Stolts, E., and Nadeau, E., 2014. *Effect of intercropping on yield, weed incidence, forage quality, soil residual N in organically grown forage maize and faba bean*. Field Crops Research, 169: 21-29. https://doi.org/10.1016/j.fcr.2014.09.004

Tadele, S.M., 2019. *Breeding achievements of faba bean (Vicia faba L.) and its impact in the livelihood of Ethiopian farmers*. International Journal of Agriculture and Biosciences, 8(5): 263-269. https://www.researchgate.net/publication/341867375

Tucak, M., Cupic, T., Horvat, D., Ravlic, M., Krizmanic, G., Macesic, D., Znidarsic, T., Meglic, V., 2023. *Changes in agronomic and forage nutritive values of red clover in response to different devel opment stage*. Romanian Agricultural Research, 40: 215-224. https://doi.org/10.59665/rar4021

Vendruscolo, A.C.G., Schuster, I., Pileggi, M., Scapim, C.A., Molinari, H.B., 2007. *Stress, induced synthesis of proline confers tolerance to water deficit in transgenic wheat*. Journal of Plant Physiology, 164(10): 1367-1376. https://doi.org/10.1016/j.jplph.2007.05.001

Wasaya, A., Affan, M., Ahmad Yasir, T., Atiqueur, R., Mubeen, K., Rehman, H.U., Ali, M., Nawaz, F., Galal, A., Iqbal, M.A., 2021. *Foliar potassium sulfate application improved photosynthetic characteristics water relations and seedling growth of dought-stressed maize*. Atmosphere (Mdpi), 12(6), 663. https://doi.org/10.3390/atmos12060663

Yahia, Y., Elfalleh, W., Thlili, N., Hannachi, H., Loumerem, M., Ferchichi, A., 2013. *Phytochemical contents and antioxidant activities of some Tunisian faba bean populations*. Romanian Agricultural Research, 30: 65-74.

Ziaei, S.M., Khazaei, H.R., Nizami, A., 2016. *Investigating the effect of different levels of irrigation on morphophysiological and biochemical characteristics in five mung bean genotypes*. Scientific Research Quarterly Journal of Crop Physiology, 9(34): 5-21. https://www.sid.ir/FileServer/JF/26213963401