Communications in Soil Science and Plant Analysis

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lcss20

Whole Forage Barley Crop Quality as Affected by Different Deficit Irrigation and Fertilizing Systems

Saeideh Maleki Farahani [a] & Mohamad Reza Chaichi [b]

[a] Department of Crop Production and Plant Breeding, Faculty of Agricultural Sciences , Shahed University , Tehran , Iran

[b] Department of Crop Production and Plant Breeding, Faculty of Agriculture and Natural Resources , University of Tehran , Tehran , Iran

Accepted author version posted online: 05 Sep 2013.Published online: 28 Oct 2013.

To cite this article: Saeideh Maleki Farahani & Mohamad Reza Chaichi (2013) Whole Forage Barley Crop Quality as Affected by Different Deficit Irrigation and Fertilizing Systems, Communications in Soil Science and Plant Analysis, 44:20, 2961-2973, DOI: 10.1080/00103624.2013.829848

To link to this article: http://dx.doi.org/10.1080/00103624.2013.829848

Communications in Soil Science and Plant Analysis, 44:2961–2973, 2013

ISSN: 0010-3624 print / 1532-2416 online
DOI: 10.1080/00103624.2013.829848

Whole Forage Barley Crop Quality as Affected by Different Deficit Irrigation and Fertilizing Systems

SAEIDEH MALEKI FARAHANI[1] AND MOHAMAD REZA CHAICHI[2]

[1]Department of Crop Production and Plant Breeding, Faculty of Agricultural Sciences, Shahed University, Tehran, Iran
[2]Department of Crop Production and Plant Breeding, Faculty of Agriculture and Natural Resources, University of Tehran, Tehran, Iran

Effects of organic, biological, and chemical fertilizers along with water-deficit regimes were investigated on forage barley in a field experiment during 2007–2008. Irrigation regimes were nonstressed (NS), moderately stressed (MS), and severely stressed (SS) and fertilizer treatments were no fertilizer (NF), phosphorus and nitrogen biofertilizers (BF), chemical fertilizer (CF), vermicompost (VC), chemical fertilizer + vermicompost (CV), and chemical fertilizer + biofertilizer (CB). Water stress reduced leaf/stem ratio and dry-matter digestibility (DMD), but increased crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF). However, the effect of water deficit on DMD, ash, and NDF depended on the fertilizer treatment. In BF and CV, the barley forage had the greatest DMD and least ash and NDF under water-deficit conditions. The integrated fertilizing systems are more reliable than conventional systems to produce high-quality forage barley in arid environments with late water stress or water deficit irrigation system.

Keywords Crop, drought, fertilizer

Introduction

Barley was presumably first used as human food but evolved primarily into a feed, malting, and brewing grain due to the rise in prominence of wheat and rice. In recent times, about two-thirds of the barley crop has been used for feed, one-third for malting, and about 2% for food (Baik and Ullrich 2008). Barley is a versatile feed used throughout the world for a wide variety of livestock species. The increasing scarcity of water for irrigation is becoming the most important problem for producing forage in all arid and semi-arid regions. Barley is also imported and used successfully in temperate and warmer semi-arid regions as a protein and energy source for milking herds (Anderson and Schroeder 1999). Whole-crop cereals as a forage for dairy cows can provide several advantages to the dairy sector. For instance the cereal cropping system can be incorporated into a program of pasture renovation (De Ruiter 1999). It can provide a source of supplementary feed with characteristics of high digestibility and substantial levels of starch (Hargreaves, Hill, and

Received 4 November 2011; accepted 5 August 2012.

Address correspondence to Saeideh Maleki Farahani, Department of Crop Production and Plant Breeding, Faculty of Agricultural Sciences, Shahed University, Tehran, Iran. E-mail: maleki@shahed.ac.ir

Leaver 2009). Cereal crops can be grown in areas where maize silage is limited by climatic conditions (Weller, Cooper, and Dhanoa 1992) or alfalfa production is limited by a short growth season.

Nutrient content of barley can vary somewhat within an ecoregion due to variation in temperature, planting date, soil fertility, rainfall, variety, and other factors. Arid and semi-arid countries in which barley can grow for forage production usually have low soil fertility so it is assumed that production of high-quality and high-quantity forage barley is one of the challenges in these regions. Different fertilizers may have various effects on forage based on the type and application rate. There is evidence that application of chemical fertilizer, especially nitrogen (N) fertilizer, increases crude protein (CP) and digestibility (Peers and Taylor 1976; Jørgensen, Gabert, and Fernández 1999); however, there was no consistent effect on crude fiber (CF) content (Brezink, Santavec, and Tajnsek 2002; Carr, Horsley, and Poland 2004) and ash (Jørgensen, Gabert, and Fernández 1999; Brezink, Santavec, and Tajnsek 2002). Brezink et al (2002) found that integrated application of chemical and animal manure, green manure, and straw plowing did not affect CP and ash. Valja et al (1997) found that soil type had little effect on feeding value of barley whereas plant variety highly affected barley forage quality.

Water stress increases N concentration and protein content in cereals grain (Haberle, Svoboda, and Raimanova 2008). Climate change threatens sustainable production of food and feed for an increasing world population, especially in countries with limited production sources. Adequate healthy forage production for livestock in areas with low soil fertility and water limitation is an essential factor to reach sustainability in agriculture. Finding the water and fertilizing management options to fit requirements in areas with low water availability are necessary to safely use water and fertilizer.

To improve understanding about the interactions between water stress and various fertilizers on whole barley crop as forage, we investigated the effect of organic, chemical, and integrated fertilizers along with deficit irrigation systems in a field experiment on forage quality parameters of barley CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), ASH, and dry-matter digestibility (DMD).

Materials and Methods

Plant Material

Seeds of the barley Turkman used in this experiment were provided by the Seed and Plant Breeding Research Institute, Karaj, Iran.

Field Experiments

Field studies were conducted at the Experimental Farm of the College of Agriculture, University of Tehran, Karaj, Iran (35º 56′ N and 50º 58′ E with an altitude of 1312 m) during the 2006–2007 and the 2007–2008 cropping seasons. The soil was a clay loam with a pH of 8.4 and electrical conductivity (EC) of 1.02 ds m^{-1}. Karaj has an average annual rainfall of 270 mm, and it was about 450 mm for first year of the experiment (2007). However, in the second year (2008), total rainfall was about 680 mm; most of the precipitation was as snow during January and February in 2008 (Table 1).

The experimental design was a split-plot arrangement based on a randomized complete block design with four replications. The barley was sown in 2-m by 5-m plots with 3-m alleys between replications on 17 March 2007 and 1 March 2008 at a rate of 400 seed m^{-2}.

Table 1

Total monthly precipitation, average monthly temperature, average monthly relative humidity, and maximum air temperature (T_{max}) for the period 1 October to 31 July in 2007 and 2008, Karaj, Iran

	Precipitation (mm)		Temperature (°C)		Relative humidity (%)		T_{max} (°C)	
Month	2006–2007	2007–2008	2006–2007	2007–2008	2006–2007	2007–2008	2006–2007	2007–2008
October	71.2	5.5	18.9	17.6	51.0	43	31.0	30.0
November	16.0	33.2	8.4	11.6	61.0	44	22.2	25.0
December	62.9	69.8	1.3	3.6	70.0	64	9.6	16.6
January	45.9	475.2	1.9	−5.7	58.0	76	14.0	6.4
February	44.0	95.0	5.6	1.5	61.2	65.8	14.6	15.0
March	82.2	3.2	7.3	14.7	60.0	34	18.2	37
April	100.4	4.1	14.4	17.7	52.0	34	23.6	33.0
May	13.1	0.0	20.3	22.0	45.0	34	22.4	35.0
June	12.6	0.20	24.3	24.6	38.0	36	38.0	37.0
July	6.8	0.1	27.0	27.8	37.0	34	38.4	39.8

A buffer of 1 m between irrigation treatments in each replication was maintained. The treatments consisted of three irrigation regimes (main plots) and six soil fertilizing systems (subplots). The irrigation treatments were applied at different phenological stages of barley according to the Zadoks scale (Zadoks, Chang, and Konzak 1974) and consisted of no stress (NS, normal irrigation until the end of physiological maturity), moderate stress (MS, ceased irrigation from the beginning of flowering [Zadoks 65] to the beginning of the grain filling stage [Zadoks 70]), and severe stress (SS, ceased irrigation from the beginning of flowering stage to harvest).

The irrigation was performed based on 50% depletion of total available soil water over 30-cm soil depth. The percentage depletion of available soil water in the root zone was estimated by

$$D(\%) = 100 \times \sum \frac{\mathrm{Fc} - \theta}{Fc - Wp}$$

where D is depletion, F_C is the soil moisture at field capacity for the 30-cm layer, θ is the soil moisture in the 30-cm layer, and WP is the soil moisture at the wilting point.

The amount of water applied on each treatment was calculated by

$$I = \frac{(Fc - \theta) \times D \times A}{100}$$

where I is the volume of irrigation water, D is the effective rooting depth, and A is the plot surface area. Each plot was irrigated individually through the furrows. Soil moisture content up to 30 cm of soil depth was measured in all irrigation treatments before reapplying any water to make sure there was 50% depletion of available soil water. Water was provided to experimental plots by an electric pump and three main polyvinyl chloride (PVC) pipes with branches. The amount of water estimated was applied to the furrows and measured by a water meter. The irrigation schedule of irrigation treatments and amount of consumed water are presented in Table 2.

Soil water status was determined gravimetrically. Soil was sampled with an auger at 30-cm depth intervals every 2 days. The soil samples were dried in an oven at 105 °C for 24 h. Then the soil moisture was calculated.

Evapotranspiration (ET) was calculated using

$$ET = P + I - R - D_p \pm \Delta S$$

where ET is crop water consumption (mm), P is rainfall (mm), I is irrigation water (mm), R is surface runoff (mm), D_p is deep percolation (mm), and ΔS is soil water content variation in crop root depth (mm). Therefore, total ET was calculated by summation of all ET during the growing season. In this study, D_p and R_f were assumed to be negligible. Because the slope of each plot was near zero and the amount of irrigation water was only enough to reach to field capacity, it was also assumed that there was no deep percolation.

Fertilizing systems consisted of the following:

1. No fertilizer (control) (NF),
2. Phosphorous and nitrogen biofertilizers (BF),
3. 100% chemical fertilizer (NPK) (based on soil chemical analysis) (CF),
4. Vermicompost (VC) (applied 5 t/ha),
5. 50% chemical fertilizer (NPK) + 50% vermicompost (2.5 t/ha) (CV), and finally
6. 50% chemical fertilizer (NPK) + biofertilizer (CB).

Table 2
Number of irrigations and amount of water applied per irrigation plots after starting water regimes

Year	Irrigation regimes	Fertilizing system	Number of irrigations	Total amount of applied water (mm)
2007	NS	NF	8	242.61
		NB	8	248.00
		VC	8	240.00
		CV	8	293.59
		CB	8	316.08
		CF	8	330.98
	MS	NF	6	261.67
		NB	6	258.00
		VC	6	252.00
		CV	6	283.33
		CB	6	265.28
		CF	6	278.61
	SS	NF	5	285.00
		NB	5	275.00
		VC	5	260.00
		CV	5	319.44
		CB	5	324.07
		CF	5	335.65
2008	NS	NF	9	272.94
		NB	9	279.00
		VC	9	270.00
		CV	9	330.29
		CB	9	355.59
		CF	9	372.35
	MS	NF	7	305.28
		NB	7	301.00
		VC	7	294.00
		CV	7	330.56
		CB	7	309.49
		CF	7	325.05
	SS	NF	6	342.00
		NB	6	330.00
		VC	6	312.00
		CV	6	383.33
		CB	6	388.89
		CF	6	402.78

Systems were assigned to the subplots. Fertilizer characteristics are presented in Table 3.

Application of chemical fertilizer was performed based on soil analysis. The amounts of N, P, and K applied were 105 kg N ha^{-1}, 32 kg P_2O_5 ha^{-1}, and 170 kg K_2O ha^{-1}, respectively. All P (triple superphosphate), K (K_2SO_4), and organic fertilizers were applied to the soil during seedbed preparation (as basal fertilizers), whereas one half of N (urea)

Table 3
Characteristics of applied fertilizers in 2007 and 2008 growing seasons

Fertilizer \ Parameter	Organic carbon (%)	pH	EC (dS/m)	P (mg/kg)	N (mg/kg)	K (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Fe (mg/kg)
Chemical fertilizer (CF)				460000	460000	500000				
Vermicompost (VC)	22.2	8.4	6.705	547.5	22950	4729	30.562	156.75	74.925	1666.5

Notes. Nitrogen and phosphorous biofertilizers were complexes of different free living nitrogen-fixing and phosphorus-solubilizing bacteria including *Azosprillium* and *Azetobacter* as nitrogen-fixing bacteria and *Bacillus lentus* and *Pseudomonas putida* as phosphorus-solubilizing bacteria.

was applied during the seedbed preparation period (as basal fertilizer) and the rest as top-dressing during the tillering stage. Biofertilizer (BF) was a complex of different free living N-fixing (Nitroxin™) and P-solubilizing (Barvar 2™) bacteria.

Nitroxin was liquid and applied as 2 L/ha according to the instructions. The effective gradients of the biological P fertilizer were comprised of two bacteria strains of p5 (*Bacillus lentus*) and P13 (*Pseudomonas potida*) with 10^8 cfu (colony-forming units), which have been screened from soil bacteria populations. The medium of the fertilizer was some kind of sugarcane perlite. The bacteria strain P5 (*Bacillus lentus*) dissolves P from soil mineral compounds while P13 (*Pseudomonas potida*) separates P from soil organic compounds by exerting a variety of phosphotase enzymes. The synergic effect of these two bacteria reduces the soil pH along with increasing of P availability.

At the soft dough stage (Zadoks 84) plants were harvested from the two central rows of each plot. Feed samples were weighed, dried at 70 °C for 48 h, and ground to pass through a 1-mm sieve. Agronomic characteristics such as L/S ratio and dry matter (DM) were measured. For forage quality assessment the oven-dried samples were analyzed by near infrared reflectance spectroscopy (Inframatic 8620 feed analyzer) (Perten, U.S.) for parameters such as DMD, CP, ADF, ash, CF, and NDF.

Statistical Analysis

Data were statistically analyzed separately for each production year by analysis of variance (ANOVA) using MSTATC (Michigan State University, East Lansing, Mich.) and SAS (SAS Institute, Cary, N.C.) programs. Homogeneity of error variances was tested using Bartlett's chi square. Because the χ^2 was not significant, a combined analysis of the data was performed for 2 years. Data from 108 forage samples (i.e, 2 years × 3 replicates × 3 irrigation regimes × 6 fertilizers) were analyzed using the GLM procedures of SAS. The following model was used for combined analyses within the context of the split-plot design:

$$\text{Y} = \text{year, rep(year), irrigation, irrigation} \times \text{year, rep} \times \text{irrigation(year), fertilizer,}$$

$$\text{fertilizer} \times \text{year, fertilizer} \times \text{irrigation, irrigation} \times \text{fertilizer} \times \text{year}$$

Duncan's test ($P < 0.05$) was used to compare means within and among treatments and interactions when the respective F-test was significant ($P < 0.05$). A tendency to significance was accepted at $P < 0.05$.

Results

The leaf-to-stem ratio of barley was significantly influenced by all factors ($P < 0.05$), except for fertilizing systems (Table 4). The L/S varied from 0.16 for CF under SS water stress in 2008 to 0.63 in CF under NS in 2007 (Table 4). The mean L/S was greater under well irrigation (NS) than water stress conditions (MS and SS) in both years.

The DM was significantly ($P < 0.01$) affected by all treatments and their interactions (Table 5). Barley had high DM (11266.66 kg ha^{-1}) in CF under SS in 2007 but low DM was generally recorded in BF (3800 kg ha^{-1}) under MS in 2008. The mean DM was greater in 2007 (8473.9 kg ha^{-1}) than the drier year of 2008 (7158.1 kg ha^{-1}). The effects of all factors and their interactions except for year × irrigation system were significant on DMD ($P < 0.01$). The DMD of barley was greater in treatments fertilized with BF under NS water condition and lower in treatments fertilized with CF under SS (severe stress) water conditions. Water stress caused a significant decrease in DMD; however, it was greater in 2007 than in 2008. The DMD of treatments fertilized with biofertilizers (BF and CB) were high (56.2 and 53.52%) and it was low in CF (37.97%) (fertilized only with chemical fertilizer).

The CP was significantly influenced by all factors ($P < 0.01$), except for year. Crude protein content varied from 13.12% in CB under SS in 2007 to 7.43% in NF under MS in 2008. Crude protein content was more in NS and SS than MS water conditions, and treatments that were fertilized with chemical fertilizer had more CP than other fertilizing treatments. The ADF was significantly ($P < 0.01$) affected by all treatments and their interactions. The ADF varied from 45.17% in VC under SS in 2008 to 28.37% in BF under NS in 2007. Water stress increased both ADF and NDF content; however, it was not significant on NDF. The mean ADF and NDF were less (34.10 and 53.48%, respectively) in 2007 than 2008 (40.08 and 57.39%). Ash content was not significantly affected by year, irrigation, and fertilizing system. Interactions of year and fertilizing systems by irrigation systems were significant ($P < 0.05$ and 0.01) on ash content. Ash content increased with water stress in NF, VC, and CB treatments. However, in BF, CV, and CF treatments, ash content followed a decreasing trend as drought stress increased (Figure 1). Crude fiber was not significantly influenced by irrigation system the same as ash. The crude fiber content was low in 2008 compared to 2007. Water stress and fertilizing system had no significant effects on crude fiber. However, plants receiving organic fertilizers (BF and VC) produced less fiber under water-stress conditions compared to other treatments in 2008.

Discussion

Application of different fertilizing regimes will have a long-term effect on these parameters. This research was not able to investigate this important environmental aspect because of limitations in time and budget. However, good correlation between the results clearly shows the response of whole forage of barley to environmental parameters in this context.

The L/S was adversely affected by water stress and decreased as water stress intensity increased. This reaction was more pronounced because of higher temperature and less relative humidity during the generative growth stage in 2008. Water stress did not significantly reduce L/S in treatments that received biological fertilizer (BF and CB); however, in other treatments, especially CF, less leaf was produced in water-stress treatments. It seems that application of CF is most beneficial for plant growth only if adequate volume of water is available (Day, Lawlor, and Day 1987).

Table 4
Effects of year, fertilizer, and irrigation regimes on forage characteristics of whole barley crop

Year	Irrigation regimes	Fertilizing system	L/S	DM (kg/ha)	DMD (%)	CP (%)	ADF (%)	CF (%)	NDF (%)
2007	NS	NF	0.29	8175	47.51	8.94	37.13	43.41	54.98
		NB	0.37	10100	56.2	9.64	28.37	41.96	47.84
		VC	0.59	7475	49.64	10.58	34.1	43.65	53.96
		CV	0.41	6400	51.40	7.98	32.45	45.08	52.82
		CB	0.34	9665	53.52	9.35	29.87	44.36	51.85
		CF	0.63	7365	46.09	7.79	37.51	42.26	57.48
	MS	NF	0.38	8866	48.14	8.59	35.03	44.18	52.68
		NB	0.32	7733	47.56	9.39	35.82	43.43	54.32
		VC	0.37	7011	46.39	9.77	35.49	41.54	54.56
		CV	0.29	8333	51.48	8.00	31.65	44.18	47.23
		CB	0.32	7273	49.58	9.21	35.54	44.26	55.22
		CF	0.36	9815	42.41	10.34	30.62	42.25	50.66
	SS	NF	0.36	8666	51.34	11.12	32.2	40.76	50.18
		NB	0.44	8133	52.31	11.97	35.22	43.86	54.26
		VC	0.27	8750	48.82	10.89	33.73	43.01	53.93
		CV	0.29	8550	53.84	10.12	34.30	42.06	54.00
		CB	0.37	8950	48.90	13.12	35.71	42.92	55.88
		CF	0.41	11266	40.89	11.06	39.07	41.87	60.82
2008	NS	NF	0.43	6466	46.27	8.03	38.67	37.46	54.53
		NB	0.21	9240	46.62	8.48	36.29	37.01	51.17
		VC	0.19	9300	45.64	8.71	37.00	39.57	56.62
		CV	0.4	7306.	46.87	10.83	37.25	38.91	52.41
		CB	0.3	8437.	45.04	11.36	37.12	37.03	61.46
		CF	0.25	8300	46.19	12.84	37.16	37.00	60.37
	MS	NF	0.2	5911	44.03	7.43	40.08	39.88	58.59
		NB	0.21	3800	44.5	9.26	40.30	39.91	64.97
		VC	0.38	5516	41.67	8.42	42.41	38.85	64.88
		CV	0.18	6300	39.13	7.79	41.84	38.48	54.65
		CB	0.23	7510	42.35	7.77	43.69	36.67	52.55
		CF	0.27	6700	42.39	9.38	43.55	37.96	55.47
	SS	NF	0.17	6833	44.91	9.86	43.56	39.32	68.2
		NB	0.18	6800	45.78	8.91	34.46	36.98	60.87
		VC	0.18	6524	38.85	8.37	45.17	37.77	63.14
		CV	0.2	10400	38.17	8.83	44.03	41.94	50.66
		CB	0.2	5800	45.72	9.48	34.26	39.68	52.29
		CF	0.16	7700	37.97	9.53	44.67	37.90	50.26
		LSD	0.11	1392	3.60	1.05	2.69	2.49	4.91

Notes. NS, nonstress: normal irrigation until the end of the plant physiological maturity; MS, medium stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70); SS, severe stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity); NF, no fertilization; BF, phosphate and nitrogenous biofertilizer; VC, vermicompos;, CV, 50% chemical fertilizer including NPK + 50% vermicompost; CB, 50% chemical fertilizer including NPK + 50% biofertilizer; CF, 100% chemical fertilizer; L/S, leaf-to-stem ratio; DM, dry matter; DMD, dry-matter digestibility; CP, crude protein; ADF, acid detergent fibre; CF, crude fiber; and NDF, neutral detergent fiber.

Table 5

Mean squares for quantitative and qualitative characteristics of whole forage barley as affected by irrigation and fertilizing systems from 2007 to 2008 in Karaj, Iran

Source of variation	DF	L/S	DM	DMD	CP	ADF	ASH	CF	NDF
Year (Y)	1	0.67**	62325573.18**	1158.85**	3.65^{NS}	966.34**	1.57^{NS}	570.49**	413.00**
Irrigation system (IS)	2	0.13**	20346902.64**	977.39**	16.69**	92.36**	0.33^{NS}	1.13^{NS}	22.62^{NS}
Y × IS	2	0.01*	15841551.07**	28.38^{NS}	34.15**	34.99**	2.17*	10.37*	31.66^{NS}
Fertilizing system (FS)	5	0.01^{NS}	3899440.88**	38.12**	3.77**	33.33**	0.30^{NS}	6.74*	70.45**
Y × FS	5	0.027**	5407537.72**	23.76**	4.93**	11.29**	0.16^{NS}	3.24^{NS}	67.39**
IS × FS	10	0.01**	9790857.18**	20.25**	3.43**	23.41**	0.77**	3.72^{NS}	57.02**
Y × IS × FS	10	0.04**	5232561.88**	22.91**	4.79**	36.00**	0.37^{NS}	6.14**	75.87**
Coefficient of variation (%)		26.18	12.67	4.72	6.65	4.45	7.43	3.74	5.42

**Significance level $P < 0.01$.
*Significance level $P < 0.05$.
Notes. NS, not significant; L/S, leaf-to-stem ratio; DM, dry matter; DMD, dry-matter digestibility; CP, crude protein; WSC, water-soluble carbohydrate; ADF, acid detergent fiber; CF, crude fiber; and NDF, neutral detergent fiber.

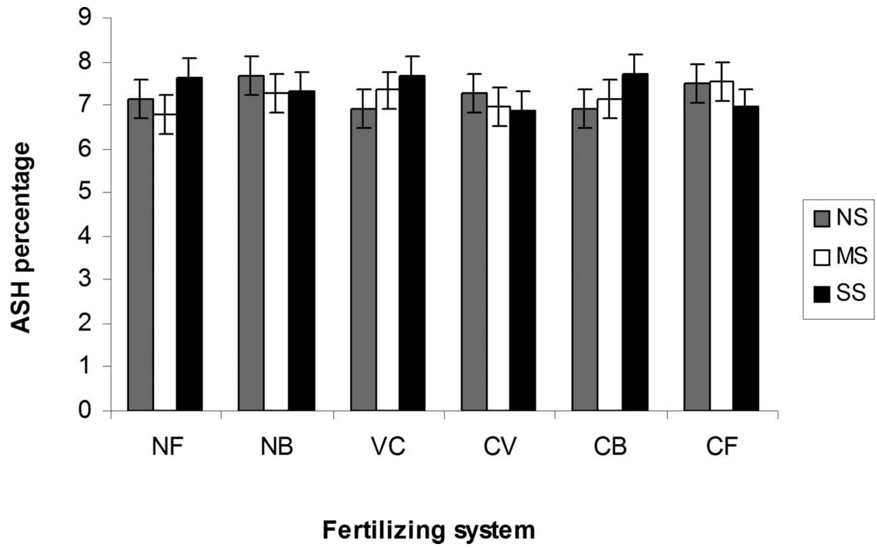

Figure 1. Interaction effect of irrigation regimes and fertilizing systems on ASH percentage. NS, no stress: normal irrigation until the end of the plant physiological maturity; MS, medium stress: ceased irrigation from the beginning of flowering (Zadoks 65) to the initiation of seed filling stage (Zadoks 70); SS, severe stress: ceased irrigation from the initiation of flowering stage (Zadoks 65) to the end of the physiological maturity; NF, no fertilizing; BF, phosphate and nitrogenous biofertilizer; VC, vermicompost; CV, 50% chemical fertilizer including NPK + 50% vermicompost; CB, 50% chemical fertilizer including NPK + 50% biofertilizer; and CF, 100% chemical fertilizer. Bars indicate LSD.

The DM produced under well irrigation treatments (NS) that received biological fertilizer was high; however, under water stress these treatments showed a remarkable decrease. In other fertilizing treatments the dry matter under SS was more than under MS or NS. Because of the more favorable weather conditions (less temperature and more relative humidity) during generative growth stage in 2007, the increase in dry matter due to fertilizer treatments was more than 2008. Even CF treatment was more effective in 2007 than 2008. These results could be explained by more snow during winter and early spring in 2008, which probably caused more mineral leaching and provided with less nutrients in the rhizosphere during the second year's growing season. However, application of integrated (CB) fertilizer as well as vermicompost caused slow release of nutrients and less mineral leaching, which provided with more nutrients for plant growth. More dry-matter production under water stress can be a way to drought avoidance. Wardlaw (1971) found that water stress in 7 days after anthesis increased the rate of cell division and grain development. Thus dry-matter increase can be related to faster grain filling in early days after stress.

Water stress caused a decrease in DMD; however, different fertilizing systems differed in their adverse effects on DMD under water-stress conditions. Treatments receiving VC as well as treatments receiving BF did not show significant decrease in DMD. However, plants in CF treatments showed significant decrease in DMD under drought stress in both years. These results showed that the barely response to biological fertilizers depends upon weather condition and the biological fertilizers have the ability to modify adverse water stress effects on barely forage yield. Peers and Taylor (1976) have described that increase in N content tended to increase the DMD. The decrease in DMD with water stress is consistent with results of Safari et al.'s (2011) study conducted in rainy, mid-dry, and late-dry seasons. According to Tainton (1999), forages containing digestible organic matter coefficients of less than 0.45, 0.45–0.55, and more than 0.55 are of poor, low, and medium nutritional quality, respectively; thus, forages fertilized with only CF in the present study were of poor digestibility especially under SS water conditions, whereas forages fertilized with chemical along with biofertizer (CB) and only biofertilizer had low to medium nutritional values.

Crude protein increment with increase in stress severity in 2007 is in agreement with the results reported by Savin and Nicolas (1996), Ozturk and Aydin (2004), and Haberel, Svoboda, and Raimanova (2008), who found that water stress causes N concentration increase. However, treatments under normal irrigation had more CP than water-stressed treatments, whereas treatments under SS showed more CP than MS treatments in 2008. The decrease in protein content with water stress is consistent with previous studies conducted in areas with distinct wet and dry seasons (Hassen et al., 2007; Safari et al. 2011)]. Plants that were fully or partially fertilized with chemical fertilizer (CF, CB, and CV) in 2008 had more CP under normal irrigation, which it is in agreement with results of Brezink, Santavec, and Tajnsek (2002), who demonstrated that N increment increased CP of barley forage.

The ADF increased with water stress in both years except for treatments fertilized with biofertilizer under SS condition. Brandt and Mølgaard (2001) described that carbohydrate content decreased when P level was high in plants. Thus, the greater P content in integrated and bilogical fertilizer (BF and CB) could explain why treatments receiving P-solubilizing bacteria tend to have lower ADF values.

A significant increase in ADF under water-stress conditions shows that it is more susceptible to water deficit than NDF, so more lignin could have been made under water-stress conditions. Greater ADF and NDF in 2008 compared to 2007 could be explained by greater temperatures during March to May in 2008 compared to the same period in 2007. From these results it is clear that ADF and NDF increase in dry areas with greater temperatures. High fiber content and low DMD is in agreement with the findings in other studies by Safari et al. (2011).

Jørgensen, Gabert, and Fernández (1999) have demonstrated that ash content is adversely influenced by greater N availability, which supports the results obtained in this research for BF, CV, and CF fertilizing treatments.

Conclusion

According to our forage quality analysis, greater ADF and NDF and lower DMD and L/S ratio in response to water stress and higher temperature could cause a decline in barley forage quality and palatability in the future as a consequence of climate change. However, application of biofertilizers alone or with chemical fertilizers are promising for modifying the adverse effect of water stress on forage quality because these fertilizing systems increased DMD and decreased ADF and NDF under water-deficit irrigation. These fertilizers are less expensive than chemical fertilizer as Nitroxin and Barvar 2 (prices are \$4 and \$5/ha, though 50 kg urea fertilizer costs \$13), and applying them is easier than applying chemical fertilizer. Irrigation of barley plants only to flowering stage can reduce water consumption without detrimental effect on forage yield and quality. Because of lower digestibility and greater ADF content in forages fertilized with chemical fertilizer, it is recommended to substitute it in barley forage production systems by integrated, organic, and biological fertilizers.

Acknowledgment

The authors express their full appreciation to the University of Tehran, Iran, for technical, moral, and financial support, which made this project possible.

References

Anderson, V., and J. W. Schroeder. 1999. *Feeding barley to dairy cattle* (EB-72). North Dakota State University.

Baik, B. K., and S. E. Ullrich. 2008. Barley for food: Characteristics, improvement, and renewed interest. *Journal of Cereal Science* 48:233–242.

Brandt, K., and J. P. Mølgaard. 2001. Organic agriculture: Does it enhance or reduce the nutritional value of plant foods? *Journal of Science of Food and Agriculture* 81:924–931.

Brezink, B. C., I. Santavec, and A. Tajnsek. 2002. Management system and mineral nitrogen rate impact on the barley grain composition and its nutritional value for ruminants. *Rostlinna Vyroba* 48:463–470.

Carr, P. M., R. D. Horsley, and W. Poland. 2004. Barley, oat, and cereal–pea mixtures as dryland forages in northern great plains. *Agronomy Journal* 96:677–684.

Day, W., D. Lawlor, and A. Day. 1987. The effect on barley yield and water use in two contrasting years. *Irrigation Science* 8:115–130.

De Ruiter, J. M. 1999. Yield and quality of barley (*Hordeum vulgare* L. 'Valetta') in response to irrigation and nitrogen fertilization. *New Zealand Journal of Crop and Horticultural Science* 27:307–317.

Haberle, J., P. Svoboda, and I. Raimanova. 2008. The effect of post-anthesis water supply on grain nitrogen concentration and grain nitrogen yield of winter wheat. *Plant Soil and Environment* 54:304–312.

Hargreaves, A., J. Hill, and J. D. Leaver. 2009. Effect of stage of growth on the chemical composition, nutritive value, and ensilability of whole-crop barley. *Animal Feed Science and Technology* 152:50–61.

Hassen, A., N. F. G. Rethman, W. A. Van Niekerk, and T. J. Tjelele. 2007. Influence of season/year and species on chemical composition and in vitro digestibility of five Indigofera accessions. *Animal Feed Science and Technology* 92:149–158.

Jørgensen, H., V. M. Gabert, and J. A. Fernández. 1999. Influence of nitrogen fertilization on the nutritional value of high-lysine barley determined in growing pigs. *Animal Feed Science and Technology* 79:79–91.

Ozturk, A., and F. Aydin. 2004. Effect of water stress at various growth stages on some quality characteristics of winter wheat. *Journal of Agronomy and Crop Science* 190:93–99.

Peers, D. G., and A. G. Taylor. 1976. The influence of the variety of barley and level of nitrogen fertilization on the digestibility and metabolisable energy value of barley meal in the pig. *Journal of the Science of Food and Agriculture* 28:602–606.

Safari, J., D. E. Mushi, G. C. Kifaro, L. A. Mtenga, and L. O. Eik. 2011. Seasonal variation in chemical composition of native forages, grazing behavior, and some blood metabolites of small East African goats in a semi-arid area of Tanzania. *Animal Feed Science and Technology* 164:62–70.

Savin, R., and M. E. Nicolas. 1996. Effects of short periods of drought and high temperature on grain growth and starch accumulation of two malting barley cultivars. *Australian Journal of Plant Physiology* 23:201–210.

Tainton, N. 1999. *Veld management in South Africa*. Pietermaritzburg: University of Natal Press.

Valja, J., K. Suomi, T. Alaviuhkola, and T. Mela. 1997. Effects of variety, soil type, and nitrogen fertilizer supply on the nutritive value of barley for growing pigs. *Agricultural and Food Science in Finland* 4:295–303.

Wardlaw, I. F. 1971. The early stages of grain development in wheat: response to water stress in a single variety. *Australian Journal of Biological Science* 24:1047–1055.

Weller, R. F., A. Cooper, and M. S. Dhanoa. 1992. The national whole-crop cereals survey. In *Whole-crop cereals*, ed. B. A. Stark and J. M. Wilkinson, 137–156. Canterbury, UK: Chalcombe.

Zadoks, J. C., T. T. Chang, and C. F. Konzak. 1974. A decimal code for the growth stages of cereals. *Weed Research* 14:415–421.