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EFFECT OF DIFFERENT IRRIGATION REGIMES AND ZEOLITE APPLICATION ON YIELD AND QUALITY OF SILAGE CORN HYBRIDS

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KEYWORDS

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Zeolite

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Corn

ABSTRACT

Present study was carried out to evaluate the effects of irrigation regimes and zeolite on the yield and quality parameters of silage corn hybrids. Study was conducted at Seed and Plant Improvement Institute in Karaj, Iran during 2013. The experiment was arranged in a three-replicated split-split plot based on randomized complete blocks design (RCBD) including three irrigation regimes as main plots (irrigation after 70, 100 and 130 mm evaporation from standard class A evaporation pan), two levels of zeolite as sub plots (0, 10 ton/ha) and three hybrids of silage corn (KSC704, KSC705 and KSC720) as sub sub-plot. Results of this study indicated that increasing water stress from optimum irrigation (Ir₇₀) to moderate (Ir₁₀₀) and low irrigation (Ir₁₃₀) caused 25 and 37% reduction in forage dry matter yield but no significant difference was reported in protein yield. Moreover, application of zeolite have significant effect on forage yield and also have significant effect on protein yield ($P < 0.01$). Forage quality parameters including water soluble carbohydrates, crude protein, acid detergent fiber and neutral detergent fiber increased and dry matter digestibility reduced when there was limited irrigation imposition. Among the tested corn seed hybrids KSC704 hybrid produced the highest dry forage yield and in terms of protein yield, no significant difference was reported between KSC720. KSC705 hybrid had the lowest acid detergent fiber and neutral detergent fiber and the highest dry matter digestibility.

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1 Introduction

In present scenario drought became a worldwide problem and most of the applied researches are based on the drought resistance sustainable crop production (Kojić et al., 2012). Demand of water for irrigation continuously increasing while a drastic reduction was reported in the availability of water, condition became more critical under arid and semi-arid environmental conditions (Rostamza et al., 2011). Alternative forage sources which can grow under these extreme conditions could be utilized to cope with the declining water availability (Marsalis & Bean, 2010). Approximately, seventy three (73) percent of Iranian agricultural production area has arid and semi-arid climatic conditions (Abarghouei et al., 2011). Therefore, effective alternative management strategies are required for the efficient uses of water. Among the available information, retaining soil moisture and preventing substantial loss of water by the use of zeolite was used by researchers (Mumpton, 1999; Armandpisheh et al., 2009; Ahmed et al., 2010). Zeolites are hydrated aluminosilicates of alkaline with open three-dimensional structure and are able to lose or gain water reversibly and exchange extra framework cations, both without crystal structure changes (Mumpton, 1999). Zeolites can act as water moderators and can absorb up to 55% water of their own weight, later on this water released slowly as per plant water demand (Pisarovic et al., 2003).

Further, Ahmed et al. (2010) and Polat et al. (2004) also reported that Zeolites can enhance the better utilization of NPK nutrition and play an important role in the plant growth. Krutilina et al. (2000) also reported a significant effect of zeolite on the improvement of biomass production and rate of photosynthesis in maize and barley crops. Similarly, Keshavarz & Farahbakhsh, (2012) reported that under the drought conditions application of zeolite increased the yield of millet crop. Also, similar type of improvement was reported in rapeseed (Valadabadi et al., 2010) and *Lathyrus sativus* (Pirzad & Mohammadzade, 2014).

Forage crops play an important role in supplying energy and protein to livestock (Eskandari et al., 2009). In breeding of forage crops, increase of yield and forage quality are the main factors which play prominent role in the introduction of new varieties. Forages with good quality should have high dry matter yield, energy, digestibility and low fiber for optimal fermentation in the silo and storage. Silage corn have almost all these features, except the high protein content and this phenomenon make it better than other forage plants (Curran & Posch, 1999). Various researchers reported the scarcity of irrigation water may cause reduction in dry matter yield of forage crops (Vasilakoglou et al., 2011; Keshavarz & Farahbakhsh, 2012; Jahanzad et al., 2013). Knowledge about the influence of drought on nutritive quality of forage plants is inconsistent and limited. Some studied like Jahanzad et al. (2013) reported that drought condition may cause reduction in NDF and ADF concentration while it can improve the

concentration of CP, DMD, WSC and DMD in forage sorghum cultivars. Similar type of findings was reported by Newman (2014) under drought stress conditions. Further, Xu & Lascano (2007) reported that drought stress reduced the silo quality.

Compared to well-watered treatments, the silage produced from drought stressed plants had higher CP, ADF, NDF, lignin contents and lower total digestible nutrients and starch. Limited informations are available with concern to the integrated effects of irrigation and application of zeolite on yield and forage quality of silage corn. KSC704 is currently the most common hybrid of silage corn in Iran. However, newly released hybrids, KSC720 and KSC705, have been also introduced to eliminate the probable problems concerning with a single corn planting in the country. The objective of this study was to determine the effect of zeolite on yield and quality of three silage corn hybrids (KSC704, KSC705 and KSC720) under normal and stress conditions.

2 Materials and Methods

The experiment was conducted at the experimental field of Seed and Plant Improvement Institute, Karaj, Iran (35°47'N, 50° 55' W, altitude 1254.5 m) during 2013. Study area has an average of 150-160 dry days in a year and coming in the hot and dry Mediterranean climate zones. The experiment was arranged in split-split-plot with three replicates by following randomized complete blocks (RCBD) design. Three irrigation regimes including Ir₇₀ (optimum irrigation -irrigation when evaporation reached 70 mm, using evaporation pan class "A"), Ir₁₀₀ (moderate) and Ir₁₃₀(low irrigation) were used as main plots. While, two levels of zeolite (0, 10 ton/ha) were used as sub- plots and also three hybrids of silage corn (KSC704, KSC705 and KSC720) were considered as sub-sub-plots.

The experiments were carried out in a clay-loam soil. Important physical and chemical properties of soil based on soil test results are presented in Table 1 and on the basis of these results dose of fertilizers application were determined. To determine the physical and chemical properties of soil at experimental field, 15 soil samples were randomly collected from 0-30 and 30-60 cm depth. Samples were carefully mixed together and turned into a single sample and were transferred to the laboratory. Physicochemical properties of the collected soil samples were determined by method described by Hesse (1971) and have been shown in Table 1. Distance between rows and plants per row were considered 75 and 15.5 cm, respectively (85000 plants. ha⁻¹). Each sub sub-plot included 4 rows with spacing of 0.75 m and length of 6 m. Irrigation regimes were applied when plants were completely established with 6 to 8 leaves, by average. Plots were irrigated when evaporation reached the considered amount for each irrigation regimes (70, 100, and 130 mm evaporation from the surface of the class A evaporation pan). In order to determine the water volume for irrigation, a soil sample was collected from each plot in depth of root development region before irrigation.

Table 1 Selected properties of the soil at the experimental site.

Soil depth (cm)	Total N (%)	P (mg/kg)	K (mg/kg)	OC (%)	PH	EC (ds/m)	ρ_b	F.C (%)	Clay (%)	Silt (%)	Sand (%)	Soil texture
0-30	0.08	10.4	380	0.80	7.4	1.20	1.39	26.7	31	36	33	Clay loam
30-60	0.06	9.2	334	0.64	7.5	1.60	1.42	28.1	-	-	-	-

OC: organic carbon, F.C: field capacity, ρ_b : soil bulk density

The samples were kept in 80°C oven for 24 hours. The weight of soil moisture content was determined by the method given by Azizi & Mahrokh, 2012 where moisture content was calculated by using equations 1 and the volume of water needed for irrigation was determined by using equations 2 and 3.

Moisture content in soil (Θ_m) = wet soil weight (gr) - dry soil weight (gr)/ dry soil weight(gr)1

$H = \rho_b (\Theta.F.C - \Theta_m) D$ 2

$V = H \times A$ 3

Where H is water height in the plot; ρ_b is soil bulk density; $\Theta.F.C$ is the moisture level at field capacity; Θ_m is plot moisture at irrigation time; D is the root development depth in different growth stages and V is the irrigation water volume needed for each plot and A is the plot area (18 m²).

10 plants were randomly selected from each plot to determine dry forage yield. Then, the samples were dried in an oven at 70°C for 72 h, and dry matter yield per unit area was measured. Forage quality parameters was measured including crude protein (CP), water soluble carbohydrate (WSC), acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter digestibility (DMD) and ASH. Near infrared reflectance spectroscopy (NIRS) method described by Jafari et al (2003) was used for quality analysis. Dried samples were ground through the 0.1 mm screen of a cyclone mill and scanned using a near-infrared reflectance spectroscopy (NIRS, Informatics Perten 8600 Feed Analyzer) at wavelengths ranging from 500 to 2400 nm. Protein yield was calculated by multiplying dry matter yield to crude protein content and all values are given in % on dry matter basis. Data were analyzed using the analysis of variance (ANOVA) and general linear model (GLM) procedures of SAS (SAS Institute, 2003). Effects were considered significant at P-values ≤ 0.05 in the F-test. Duncan multiple range test was conducted for comparison of means.

3 Results and Discussion

3.1 Forage dry matter

Dry matter yield was significantly affected ($P < 0.01$) by different irrigation regimes (Table 2), among various tested irrigation regimes, highest dry matter yield (15939 kg. ha⁻¹) was obtained from normal irrigation regime (I_{70}) while the lowest dry forage yield (10036 kg. ha⁻¹) was observed at low

irrigation level (I_{130}). Irrigation regime, I_{70} has shorter irrigation intervals than I_{100} and I_{130} and it produced 25 and 37% higher forage dry matter than the rest two, respectively. Kramer & Boyer (1995) suggested that when soil water ratio is not enough to facilitate nutrient uptake by roots, plants face difficulty in absorbing essential elements such as nitrogen and phosphorus for their normal growth which caused reduction in final yield. This statement justified the results obtained in present study. Further, various researchers reported that impaired mitosis, cell elongation and expansion result reduced plant height, leaf area and crop growth under drought stress (Nonami, 1998; Kaya et al., 2006; Hussain et al., 2008).

Now, in these days it is well established that reduced dry matter yield of forage is associated with drought stress (Marsalis et al., 2009; Marsalis & Bean, 2010; Rostamza et al., 2011; Jahanzad et al., 2013). Result of this study suggested that use of zeolite increased dry forage yield ($P < 0.01$) by 20% from 11202 kg. ha⁻¹ to 14106 kg. ha⁻¹ (Table 3). According to Torkashvand & Shadparvar (2013) application of zeolite could be beneficial with respect to increased water holding capacity of soil. Similarly, Ahmed et al. (2010) suggested that zeolite application not only increase the uptake of N,P,K but also increase the efficiency of their use by plants. Valadabadi et al. (2010) reported significant improvement in the yield of rapeseed by the application of Zeolite under drought stress. Similar type of improvement was reported by Najafinezhad et al. (2014) in corn crop. These results are in accordance with the findings of present study. While Turk et al. (2006) reported contradictory results when they tested the effect of Zeolite on the yield of Alfalfa crops. Corn hybrids also differed significantly ($P < 0.01$) in terms of forage dry matter (Table 2) and corn hybrid KSC704 produced the highest dry forage yield (14330 kg. ha⁻¹) and contained 10 and 25% higher forage dry matter than KSC720 and KSC705, respectively (Table 3). Interaction between various treatments has no significant effect on dry forage yield.

3.2 Forage quality

3.2.1 Crude protein

Crude protein content which is one of the most important factors in forage quality (Wang & Frei, 2011) has been significantly affected ($P < 0.01$) by irrigation levels, zeolite application and corn cultivars (Table 2). In present study it was reported that less irrigation led to a progressive rise in CP content.

Table 2 Analysis of variance of silage corn hybrids traits under irrigation treatments and zeolite.

S.O.V	df	Yield (kg ha ⁻¹)	WSC (%)	CP (%)	Protein yield (kg ha ⁻¹)	ADF (%)	NDF (%)	DMD (%)
Replication	2	53744014 *	0.675 ^{ns}	0.208 ^{ns}	380159*	8.81 ^{ns}	14.28 ^{ns}	3.58 ^{ns}
Irrigation	2	162850877**	120.21**	41.35**	65994 ^{ns}	249.85**	586.58*	402.3**
E(a)	4	3833548	3.025	0.410	36997	11.75	51.19	3.61
Zeolite	1	113822281**	17.17 ^{ns}	15.01**	245522**	10.15 ^{ns}	187.60 ^{ns}	14.23 ^{ns}
Irrigation* zeolite	2	319077 ^{ns}	8.229 ^{ns}	2.51*	18114 ^{ns}	20.54 ^{ns}	30.82 ^{ns}	6.49 ^{ns}
E(b)	6	490398	6.36	0.372	7628	6.25	37.39	6.33
Hybrid	2	58719385**	85.05**	11.64**	918926**	23.95*	82.18**	120.0**
Irrigation* Hybrid	4	597206 ^{ns}	6.95**	0.473 ^{ns}	17387 ^{ns}	13.29 ^{ns}	35.34*	9.25 ^{ns}
Zeolite* Hybrid	2	447291 ^{ns}	4.05 ^{ns}	0.0222 ^{ns}	5483 ^{ns}	0.28 ^{ns}	12.51 ^{ns}	6.92 ^{ns}
Irrigation*Zeolite* Hybrid	4	752988 ^{ns}	2.67 ^{ns}	0.132 ^{ns}	4403 ^{ns}	4.93 ^{ns}	10.81 ^{ns}	6.54 ^{ns}
E(c)	24	2797962	1.403	0.215	30937	5.56	10.90	4.49
C.V	-	13.21	4.35	5.37	16.59	9.10	7.44	3.17

ns - Non significant, * and ** significant at P<0.05 and P<0.01, respectively.

Various researchers reported that water deficit intensifies forage CP content as a result of nitrogen accumulation (Pessarakli et al., 2005; Haberle et al., 2008) and accumulation of protein metabolites such as proline in leaves (Pelleschi et al., 1997). Further, the negative effects of drought stress on dry matter accumulation have been suggested by many researchers as a main factor related to higher protein concentrations (Gooding et al., 2003; Asseng & Milroy, 2006; Weightman et al., 2008).

These results are in agreement with the findings of this study. However, Dwivedi et al. (1996) have reported lower protein concentration under drought stress. Significant interactions between irrigation levels and zeolite application were also reported in this study (P < 0.05). Zeolite reduced the negative effect of drought stress in mild (Ir₁₀₀) and severe stress (Ir₁₃₀) condition and increase the crude protein content but this improvement in crude protein content are not significantly

differ that the normal irrigation condition (Ir₇₀) (Table 4). Huang & Petrovic(1994) suggested that zeolite can improve the water retention capacity of the soil and decreased severity of drought stress, in this manner findings of this study are in agreement with these researchers. The hybrids also had significant differences (P < 0.01) in crude protein content (Table 1). At corn hybrid level, highest CP content (9.4%) was observed in KSC720 hybrid (Table 3).

3.2.2 Protein yield

Protein yield combines the total biomass produced and forage CP content. Unlike CP, protein yield showed no significant difference as intervals of irrigation increased, it could be explained by higher forage dry matter yield and lower protein content at Ir₇₀ compared with Ir₁₀₀ and Ir₁₃₀ irrigation regimes (Table 3).

Table 3 Effect of irrigation regime, zeolite and hybrid on yield and quality traits of silage corn.

Forage quality parameters		Yield (kg ha ⁻¹)	WSC (%)	CP (%)	Protein yield (kg ha ⁻¹)	NDF (%)	ADF (%)	DMD (%)
Irrigation regime	Ir ₇₀	15939 ^a	24.8 ^c	7.0 ^c	1120 ^a	39.8 ^b	22.1 ^c	71.3 ^a
	Ir ₁₀₀	11986 ^b	26.9 ^b	8.9 ^b	1062 ^a	42.4 ^b	26.0 ^b	66.7 ^b
	Ir ₁₃₀	10036 ^c	29.9 ^a	10.0 ^a	999 ^a	50.7 ^a	29.5 ^a	61.9 ^c
L.S.		**	**	**	ns	*	**	**
Zeolite	Z ₀	11202 ^b	27.8 ^a	9.1 ^a	993 ^b	42.5 ^a	25.4 ^a	67.1 ^a
	Z ₁	14330 ^a	26.7 ^a	8.1 ^b	1128 ^a	46.2 ^a	26.3 ^a	66.1 ^a
L.S.		**	ns	**	**	Ns	ns	ns
hybrid	KSC704	14330 ^a	29.3 ^a	8.7 ^b	1216 ^a	45.0 ^a	26.7 ^a	65.7 ^b
	KSC705	10741 ^c	25.0 ^c	7.8 ^c	801 ^b	41.9 ^b	24.6 ^b	69.5 ^a
	KSC720	12891 ^b	27.4 ^b	9.4 ^a	1164 ^a	46.1 ^a	26.4 ^a	64.6 ^b
L.S		**	**	**	**	**	*	**

Means in the same column followed by letters differ significantly at P < 0.05; Ir₇₀, Ir₁₀₀, and Ir₁₃₀ represent high, moderate, and low irrigation levels; Z₀ and Z₁ represent consumption 0 and 10 ton per hectare, respectively; L.S.: level of significance; * P < 0.05; ** P < 0.01; Non-significant (ns) effect of interaction.

Table 4 Effects of irrigation regime and zeolite interaction on yield and quality traits of silage corn.

Irrigation regime	Zeolite	Yield (kg ha ⁻¹)	CP (%)	Protein yield (kg ha ⁻¹)	WSC (%)	DMD (%)	NDF (%)	ADF (%)
Ir₇₀	Z ₀	14640 ^b	7.1 ^d	1052 ^b	25.4 ^{bc}	71.7 ^a	39.1 ^c	20.4 ^c
	Z ₁	17238 ^a	6.8 ^d	1187 ^a	24.2 ^b	71.0 ^a	40.5 ^{bc}	23.8 ^b
Ir₁₀₀	Z ₀	10442 ^c	9.8 ^b	1026 ^b	28.2 ^{ab}	66.7 ^b	40.8 ^{bc}	26.2 ^b
	Z ₁	13530 ^c	8.0 ^c	1098 ^{ab}	25.7 ^{bc}	66.8 ^b	44.1 ^{bc}	25.9 ^b
Ir₁₃₀	Z ₀	8523 ^f	10.5 ^a	899 ^c	29.8 ^a	63.0 ^c	47.5 ^{ab}	29.7 ^a
	Z ₁	11548 ^d	9.5 ^b	1098 ^{ab}	30.1 ^a	60.7 ^c	54.0 ^{ab}	29.3 ^a
L.S.		ns	*	ns	ns	ns	ns	ns

Means in the same column followed by letters differ significantly at $P < 0.05$; Ir₇₀, Ir₁₀₀, and Ir₁₃₀ represent high, moderate, and low irrigation levels; Z₀ and Z₁ represent consumption 0 and 10 ton per hectare, respectively; L.S.: level of significance; * $P < 0.05$; ** $P < 0.01$; Non-significant (ns) effect of interaction.

Similar types of findings was reported by Jahanzad et al (2013) and Asay et al (2002), these researchers reported that drought stress reduced dry matter yield and increased protein content in sorghum forage and tall fescue, respectively. However in their study the reduction amount of dry matter was very high and finally the protein yield reduced significantly when limited irrigation was imposed. Although zeolite did not have any significant effect on crude protein content, here also application of zeolite caused some increases in protein yield ($P < 0.01$) but also did not show any significant difference (Table 2). Similar, type of findings was Najafinezhad et al. (2014) and Nasri et al. (2012) reported by using zeolite, these researchers find some increase in protein yield of maize and sorghum. Hybrids had significant differences in crude protein content ($P < 0.01$) and KSC720 shows superiority in terms of protein yield on KSC704 and KSC705 (Table 3).

3.2.3 Water-soluble carbohydrates

Water soluble carbohydrates represent the most important source of energy in the finished diet (Coleman & Moore, 2003)

and have positive influence on fodder intake and are important for an efficient utilization of dietary N (Küchenmeister et al., 2013). WSC content was significantly ($P < 0.01$) affected by irrigation levels and cultivars as shown in Table 2. In this experiment, less irrigation led to a progressive rise in WSC content (Table 3). Significant increases in WSC content under drought stress may be because of osmotic adjustments of plants (DaCosta & Huang, 2006; Nakayama et al., 2007), reduction in starch formation (Bethke et al., 2009) and due to the inhibition in the activity of the enzyme starch synthase which resulting in impeded conversion of sugars to starch (Wang & Frei, 2011).

According to Buxton (1996) rate of photosynthesis usually less affected by drought as compared to the rate of respiration and growth and this may be a possible reason of increasing digestible soluble sugars in plants. Hybrids had significant difference ($P < 0.01$) on WSC content (Table 2). Among three hybrids, highest WSC content was observed in KSC704 hybrid (Table 3). Also, WSC content was influenced ($P < 0.01$) by the interaction of irrigation regime and hybrid (Table 2).

Table 5 Effects of irrigation regime and hybrid interaction on yield and quality traits of silage corn.

Irrigation regime	Hybrid	Yield (kg ha ⁻¹)	CP (%)	Protein yield (kg ha ⁻¹)	WSC (%)	NDF (%)	ADF (%)	DMD (%)
Ir₇₀	KSC 704	17740 ^a	7.2 ^e	1274 ^a	27.3 ^d	40.6 ^{de}	22.2 ^{ef}	71.7 ^{ab}
	KSC705	13828 ^b	6.3 ^f	873 ^{cd}	22.6 ^f	36.8 ^e	20.2 ^f	73.2 ^a
	KSC720	16249 ^a	7.5 ^{de}	1212 ^{ab}	24.5 ^e	42.0 ^{cd}	23.8 ^{de}	69.1 ^c
Ir₁₀₀	KSC 704	13445 ^{bc}	8.8 ^c	1183 ^{ab}	29.3 ^{bc}	45.7 ^{bc}	26.3 ^{cd}	65.4 ^d
	KSC705	10007 ^{de}	7.9 ^d	771 ^d	23.5 ^{ef}	39.3 ^{de}	26.3 ^{cd}	69.3 ^{bc}
	KSC720	12507 ^{bc}	10.0 ^b	1232 ^{ab}	28.0 ^{cd}	42.2 ^{cd}	25.5 ^{cd}	65.4 ^d
Ir₁₃₀	KSC 704	11804 ^{cd}	10.1 ^{ab}	1189 ^{ab}	31.4 ^a	48.6 ^b	31.6 ^a	60.1 ^e
	KSC705	8387 ^e	9.2 ^c	759 ^d	28.8 ^{bc}	49.7 ^b	27.2 ^{bc}	66.1 ^d
	KSC720	9916 ^{de}	10.6 ^a	1047 ^{bc}	29.6 ^b	54.0 ^a	29.8 ^{ab}	59.4 ^e
L.S.		ns	ns	ns	**	*	ns	Ns

Means in the same column followed by letters differ significantly at $P < 0.05$; Ir₇₀, Ir₁₀₀, and Ir₁₃₀ represent high, moderate, and low irrigation levels; Z₀ and Z₁ represent consumption 0 and 10 ton per hectare, respectively; L.S.: level of significance; * $P < 0.05$; ** $P < 0.01$; Non-significant (ns) effect of interaction.

Table 6 Effects of zeolite and hybrid interaction on yield and quality traits of silage corn.

Zeolite	Hybrid	Yield (kg ha ⁻¹)	CP (%)	Protein yield	WSC (%)	NDF (%)	ADF (%)	DMD (%)
Z₀	KSC 704	12755 ^b	9.2 ^b	1145 ^{ab}	30.0 ^a	44.0 ^b	26.4 ^a	66.3 ^c
	KSC705	9467 ^c	8.3 ^c	752 ^c	25.0 ^d	39.9 ^c	24.0 ^b	70.7 ^a
	KSC720	11384 ^b	9.9 ^a	1080 ^b	28.3 ^b	43.5 ^b	25.9 ^{ab}	64.5 ^c
Z₁	KSC 704	15904 ^a	8.2 ^c	1286 ^a	28.7 ^b	45.9 ^{ab}	27.0 ^a	65.2 ^c
	KSC705	12015 ^b	7.2 ^d	850 ^c	24.9 ^d	44.0 ^b	25.1 ^{ab}	68.4 ^b
	KSC720	14398 ^a	8.9 ^b	1247 ^{ab}	26.4 ^c	48.6 ^{ab}	26.8 ^a	64.8 ^c
L.S.		ns	ns	ns	Ns	ns	ns	ns

Means in the same column followed by letters differ significantly at $P < 0.05$; Ir₇₀, Ir₁₀₀, and Ir₁₃₀ represent high, moderate, and low irrigation levels; Z₀ and Z₁ represent consumption 0 and 10 ton per hectare, respectively; L.S.: level of significance; * $P < 0.05$; ** $P < 0.01$; Non-significant (ns) effect of interaction.

While in hybrids KSC704 and KSC720, mild stress increased the WSC content significantly, but in hybrid KSC705 the mild stress did not have significant effect on water-soluble carbohydrates. In combination also, highest WSC content (31.4%) was observed in the combination of Ir₁₃₀ and KSC704 hybrid (Table 5).

3.2.4 Acid detergent fiber & neutral detergent fiber

Acid detergent fiber (cellulose and lignin) and neutral detergent fiber (hemicelluloses, cellulose, and lignin) are considered to be two important characteristics of forage quality (Caballero et al., 1995; Assefa & Ledin, 2001). High quality forages have low concentrations of both NDF and ADF. According to the results of variance analysis, irrigation treatments had a significant effect on ADF and NDF concentrations of forage. Both ADF and NDF follow an incremental trend as interval irrigation increased (Table 3). Newman (2014) reported an association between the improvement of corn plant ADF and NDF content and drought stress. Similarly, Xu & Lascano (2007) reported that drought stress increased concentrations of both NDF and ADF forage by reducing the share of grain and ear in corn. Contradictory finding was reported by Küchenmeister et al. (2013) when they studied the effect of drought condition on ADF and NDF content of forage legumes; they found that drought stress reduced NDF and ADF concentration for forage legumes.

Further, in this study it was reported that ADF and NDF content was not affected by using zeolite (Table 2) but significant difference was reported in the value of ADF and NDF content in case of tested cultivars ($P < 0.05$). Among various tested cultivars, lowest ADF and NDF content was reported from the KSC705 cultivar and KSC704 and KSC720 cultivars showed superiority over this (Table 6). Also, forage NDF content was influenced by the interaction of irrigation regime and hybrid ($P < 0.05$). The highest NDF content (54%) was observed in combination of irrigation treatment Ir₁₃₀ and KSC720 hybrid while the lowest NDF content was reported from the combination of treatment Ir₁₀₀ and KSC705 hybrid (36.8%) (Table 5).

3.2.5 Dry matter digestibility

Improving the digestibility of forage is an important objective of breeding programs because high digestibility, improves forage intake and efficiency of conversion of nutrients by livestock. According, Coleman & Moore (2003) dry matter digestibility represents digestible energy. In this study, forage DMD significantly influenced by irrigation level and hybrid (Table 2). Opposite to ADF and NDF concentrations, forage DMD declined significantly ($P < 0.01$) as the interval of irrigation increased (Table 3). It could be due to increase of ADF concentration at higher interval of irrigation and negative correlation of DMD with ADF and NDF accumulation. Negative correlation between DMD and hemicelluloses has already been reported by various researcher in several similar studies (Theander & Westerlund, 1986; Hatfield, 1993; Contreras-Govea et al., 2009). Further, Wilson & Ng (1975) observed a better water status in maturing plants alleviated the extent of digestibility decrease in senescing leaves and stems. Study also suggested that application of Zeolite had no significant effect on DMD forage (Table 2). Further, hybrids had significant difference ($P < 0.01$) on DMD content (Table 2). The highest DMD concentration (69.5%) was recorded for KSC705 (Table 3). It would be due to the lower content of ADF in this hybrid compared with KSC704 and KSC720.

Conclusion

Results of study revealed a noticeable effect of water deficiency on the production of forage and all three selected cultivars had highest forage production at the Ir₇₀ irrigation regime. Under such experimental conditions, irrigation levels seemed to be a more influential factor compared to zeolite with regards to most forage quality and quantity parameters. Zeolite increased forage and protein yield under different irrigation regimes but it did not show any significant effect on rest of the studied forage quality parameters. Therefore, considering the water shortage in the country and importance of silage corn as a forage plant, application of zeolite can be useful to save more water that leads to produce more yields. Overall, KSC704 hybrid showed superiority over the rest two hybrids

due to greater forage dry matter production and higher protein yield. On the other hand, KSC705 produced more desirable forage in terms of some forage quality parameters.

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Abbreviations

Ir ₇₀	- Optimum irrigation Levels (at 70 mm evaporation)
Ir ₁₀₀	- Moderate irrigation Levels (at 100 mm evaporation)
Ir ₁₃₀	- Low irrigation Levels (at 130 mm evaporation)
CP	- Crude protein
WSC	- Water soluble carbohydrate
ADF	- Acid detergent fiber
NDF	- Neutral detergent fiber
DMD	- Dry matter digestibility

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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