Effects of limited irrigation, on yield and yield components of different fodder maize cultivars in a saline condition

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Abstract: Water shortage is one of the most important limiting factors, which results in yield loss of crops, in arid and semi-arid regions, all around the world. In Iran, maize production, is significantly affected by drought. An investigation was carried out to find the effect of drought on yield, and yield components of fodder maize in a saline condition during 2018-2019 growing season. A split plot experiment based on randomized complete blocks design, with four replications was conducted in Abbas-Abad research station of Mashhad, Khorasan-Razavi province, Iran. Main plots belonged to three irrigation treatments (providing 100, 80 and 60 percent of water requirement as I1, I2 and I3 respectively), and sub plots belonged to four different cultivars of fodder maize (single cross hybrids KSC703, KSC704, KSC705 and KSC706). Fodder yield and ear diameter significantly affected by drought stress ($p<0.01$). Kernel rows, kernel number per row and ear length didn't affect by drought. Comparison of means, showed that the highest (41.1 ton/ha) and the lowest (29 ton/ha) fodder yield, belonged to cultivar ksc 703 at I1 and ksc705 at I3 irrigation level, respectively. The highest (28) and the lowest (23) Kernel number per row was produced at I1 and I3, respectively. The highest fodder yield belonged to hybrid No. 703, while 100 percent of water requirement was provided.

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Introduction

Maize (*Zea mays* L.), is a crop with the highest yield potential among cereals (Muthukumar et. al., 2015). After wheat, maize is in the second place, in respect of area under cultivation (Zeidan et. al., 2006). Maize is consuming as a staple food by millions of people globally. It uses for feeding livestock and poultry as well (Campos et. al., 2004). Drought stress, during growing stages of plants, is one of the most important limiting factors of producing crops in arid regions (Harrison et. al., 2014). The effect of drought is depended on developmental stage of plant, plant cultivar, planting method, soil quality, drought intensity and other environmental situations (Sepehr et. al., 2002). Maize water requirement during growing season, is related to the selected cultivar and weather circumstances and is ranged between 6000 to 12000 m^3, in short and long season cultivars, respectively. Maize water requirement is low in the early growth stages but it enhances by producing more leaves. The most sensible stage of maize growth to drought, are pollination and fertilization (Smith and Betran, 2004). Maize is the most sensible plant to the environmental stresses, among all C4 crops. Water shortage, during vegetative stage, effects on some important developmental features like an thesis, silking, beginning and ending of kernel filling, nitrogen reduction and protein synthesis, as well as leaf and stem growth (cakir, 2004).

Some researches revealed that, drought stress before anthesis, results in 15.1 to 22.1 percent of maize yield losses. Yield loss rate is related to different characteristics of various cultivars, stress intensity and the time of drought induction (Osborne et. al., 2002). Water shortage, results in reducing carbon dioxide concentration in chloroplast due to stomatal closure and finally decreases photosynthesis rate. Root and stalk growth and leaf area index decreases by drought stress, too (Huner and Hopkins, 2008).

In arid and semi-arid regions, soil salinity is a secondary limiting factor of crop stable production. Salinity results in lower water uptake due to high osmotic pressure. Besides it effects on seed germination and plant growth, via ion toxicity (Farooq et. al., 2008; Jiang et. al., 2016). Aliu et. al., (2015), reported that the concentration of chlorophyll a, chlorophyll b and carotenoids in the maize plantlet, significantly decreased, applying 100 and 200 millimolar sodium chloride solutions. El Sayed (2011), stated that chlorophyll a, chlorophyll b, total chlorophyll content and carotenoid concentration, significantly decreased by salinity increment. Leaf water content (RWC) is a physiological trait which widely uses to estimate osmotic tolerance in plants (Cechin et. al., 2010). Tolerate cultivars, overcome high transpiration rate by the abiliety of higher water uptake which results in high RWC percentage (Chen et. al., 2010). A positive correlation was reported between RWC, kernel yield and photosynthesis rate (Kaymakanova et. al., 2008). Salinity results in higher absorption of Na^+ and Cl^- and low absorption of K^+ and Ca^{+2}. It results in higher Na^+/K^+ and Na^+ / Ca^{+2} ratios, too. Lower potassium content at saline condition may be the result of the competition between sodium and potassium in connecting to membrane transporters (Gaber et. al., 2010). Ashraf et. al., (2009) described that, high concentration of sodium in the root medium, has antagonistic effect on potassium absorption. Ion toxicity in saline condition is due to replacing sodium instead of potassium in biochemical reactions. It results in structural changes and disruption of protein action (El Sayed et. al., 2011).

Maize is widely planted in Abbas-Abad, and the region is exposed to drought and saline stresses. This study was performed to investigate the effect of diminished irrigation on yield, yield components and some physiological characteristics of fodder maize, in a saline condition**.**

Materials and methods:

An investigation was performed to estimate drought tolerance in some fodder maize cultivars, during 2018-2019 growing seasons. The study was conducted in Abbas-Abad livestock breeding station of north-east of Iran. The station is located in Tangalshur, 20 km south-east of Mashhad, with a 36° 16 N latitude and 59° 38 E longitude, 985 m altitude above the sea level. A split plot experiment based on randomized complete blocks design, with four replications and 48 plots was conducted. Main plots belonged to three irrigation treatments (providing 100, 80 and 60 percent of water requirement as I1, I2 and I3 respectively), and sub plots belonged to four different cultivars of fodder maize (single cross hybrids KSC703, KSC704, KSC705 and KSC706). In order to preparing the soil, the first plowing was done deeply, in the autumn. The field was ploughed for the second time, just before planting, in the spring and finally disk harrowed. Planting was done by early June. Four rows was planted in each plot. Row spacing was 75 cm and seed spacing on each row was 15 cm. Planting density was 90000 plants per hectare. Seeds were planted on hills. Soil electrical conductivity (EC) of saturated paste extract was measured in two depth: 0-30 and 30- 60 cm. In order to estimate the soil properties, samples sent to the Soil and Water Research Center of Mashhad, Iran.

Kernel number per row, row number per ear, pant height, total leaves number and stalk diameter was measured on ten random plants in each plot. In order to measure the fodder yield, middle rows of each plot, was harvested, separately. Two marginal rows of each plot and two plants of the beginning and end of each row, were removed before harvesting. The plants harvested, ears and vegetative parts were weighted separately. Five random plants from each plot were weighted and then oven dried in 80° C for 72 hours, in order to determine the fresh and dry weight of each treatment. Data were analyzed, using MSTATC. Comparison of means were conducted using Duncan’s multiple range test.

Results and discussions

Analysis of variance showed that, total fresh fodder yield was significantly affected by drought stress ($p<0.01$) (table 1). Comparison of means revealed that the highest (39.2 ton/ha) and lowest (30.8 ton/ha) fresh fodder yield produced by preparing 100 (I1) and 60 (I3) percent of water requirement, respectively (table 2). Fodder yield didn’t affected by cultivars significantly (table 1). Comparison of means showed that the highest (36.7 ton/ha) and lowest (36.4 ton/ha) yield produced by single cross KSC703 and KSC704 respectively (table 3). Fodder yield didn’t affect by interaction between irrigation and cultivar. Comparison of means showed that, the highest (41.1 ton/ha) and lowest (39 ton/ha) produced by KSC703 in I1 irrigation treatment and KSC705 in I3, respectively (table 4). At the first stages of plant growth, many leaf meristems are produced by each plant. In an ideal environmental situation, all meristems have the ability to become a true leaf. But environmental stresses cause them to die which results in less leaf per plant and low leaf area index as well (Kuchaki and Sarmadnia, 2003). Cakir (2004), reported that, leaf area index, decreased in low water stress durations, due to diminished leaf production and accelerated leaf senescence. Besides low leaf area, drought results in low cell volume due to diminished turgor pressure and low water content in cells, which consequence by low fodder production. Number of cells and the ability of each cell to preserve water is different in various cultivars. Plant mass, is determined by these two factors.

Kernel row per ear

Kernel row per ear, didn't affected by irrigation level, cultivar and interaction between them (table 1). Comparison of means showed that the highest (14 per ear) and lowest (13 per ear) kernel per ear produced at I1 and I3, respectively (table 2). In respect of cultivars, the highest (13.9 per ear) produced by KSC705, KSC706 while the lowest (13.2 per ear) kernel rows, produced by KSC704 (table 3). The highest (14 per ear) and the lowest (12 per ear) kernel row number produced by KSC704 at I1 and KSC704 at I3 respectively (table 4). The effects of drought, on yield and yield components of maize was studied by Ghahfarokhi et. al. (2004). Results showed that, kernel rows per ear and thousand kernel weight, didn't affected by drought.

Kernel number per row

Results showed that kernel number per row, didn't affected by irrigation level, cultivar and interaction between them (table 1). Comparison of means showed that the highest (28 per row) and lowest (23 per row) kernel per row produced at I1 and I3, respectively (table 2). The highest (27 per row) and lowest (24 per row) kernel per row, produced by KSC706 and KSC703 respectively (table 3). The highest (29.3 per row) and lowest (20 per row) kernel per row produced by KSC704 at I1 and S.C. 703 at I3 respectively (table 4). Growth and development of reproductive organs, severely, affect by soil low water content, which results in lower kernel production per row. Higher kernel production, in I1 treatment, may be the result of short anthesis- silking interval (ASI) and high fertilization rate. Westgate and Boyer (1989) reported that, kernel number per row decreased by ASI durations above eight days. Lake of corn ear fill is another results of ASI above eight days.

Ear length

Ear length didn't affect by irrigation levels, cultivars and interaction between them (table 1).). Comparison of means showed that the highest (133cm) and lowest (124 cm) ear length produced at I1 and I3, respectively. There was no significant difference between I2 and I3 in respect of ear length (table 2).). The highest (134 cm) and lowest (107 cm) ear length produced by KSC703 at I1 and KSC703 at I3 respectively (table 4). Ear length is controlled by both genotype and environmental situations in maize. Fodder quality is positively correlated with kernel yield. The higher ear length, results in more kernel number per ear which produces higher kernel yield and enhances fodder quality. Drought stress and water shortage, results in less photosynthesis rate and decreased plant growth due to lower leaf water content, lower stomatal conductivity and diminished CO2 fixation. Ear length and ovule fertilization is negatively correlated with drought stress, especially during reproductive organs differentiation (Westgate and Boyer, 1986).

Ear diameter

Ear diameter, significantly affected by irrigation levels ($P<0.05$) and cultivars ($p<0.01$) but it didn't affect by interaction between treatments (table 1). Comparison of means showed that, the highest (46 mm) and lowest (43 mm) ear diameter produced by I1 and I3, respectively (table 2). The highest (44 mm) and the lowest (42 mm) ear diameter observed for KSC703 and KSC706 respectively (table 3)

Table 1: The results of the analysis of variance of yield and yield components of different maize cultivars as affected by drought

Source of variances	Degree of freedom	Fodder yield	Kernel row per ear	Kernel number per row	Ear diameter	Ear length
Block	3	129.42*	1.24ns	37.30ns	11.24ns	353.53ns
Droght stress	2	292.36**	2.308ns	100.62ns	39.54*	1314.36ns
Main plot error	6	42.89	0.663	29.47	2.46	265.79
cultivar	3	20.34ns	0.789ns	30.20ns	27.28**	102.11ns
cultivar ×drought stress	6	14.62ns	1.172ns	8.69ns	1.41ns	82.911ns
Sub plot error	27	18.94	1.324	20.62	4.14	145.65
CV%		12.27	8.38	17.59	4.57	9.74

* and ** significant at 5 and 1% probability levels respectively

n.s: not significant

Table 2: mean comparison of fodder maize yield and yield components at different irrigation levels

Drought stress	Fodder yield Ton/ha	Kernel rows per ear	Kernel number per row	Ear diameter mm	Ear length cm
Preparing 100 percent of water requirement (I1)	39.26a	14.12a	28.40a	46.28a	133.6a
Preparing 80 percent of water requirement (I2)	36.24ab	13.72a	25.50a	44.23b	124.2a
Preparing 60 percent of water requirement (I3)	30.83b	13.36a	23.40a	43.19b	127.9a

In each column, means with the same letters are not significantly different

Table 3: mean comparison of yield and yield components of different cultivars of fodder maize

Cultivars	Fodder yield Ton/ha	Kernel rows per ear	Kernel number per row	Ear diameter mm	Ear length cm
KSC703	36.7a	13.7a	24.3a	44.44b	121.6a
KSC704	36.4a	13.2a	26.0a	44.28b	124.3a
KSC705	34.5a	13.9a	25.3a	46.60a	121.9a
KSC706	34.1a	13.9a	27.4a	42.96b	127.9a

In each column, means with the same letters are not significantly different

Table 4: mean comparison of yield and yield components of different cultivars of fodder maize at different irrigation levels

Drought stress	Cultivar	Fodder yield Ton/ha	Kernel rows per ear	Kernel number per row	Ear diameter mm	Ear length cm
Preparing 100 percent of water requirement (I1)	KSC703	41.12a	13.5a	27.4a	45.7a	134.5a
	KSC704	40.50ab	14.4a	29.2a	46.8a	133.3a
	KSC705	40.22ab	14.4a	27.8a	47.6a	128.3a
	KSC706	37.52abc	14.0a	29.0a	44.8a	138.4a
Preparing 80 percent of water requirement (I2)	KSC703	36.75abcd	13.8a	25.6a	44.1a	122.1a
	KSC704	36.52abcd	12.8a	24.0a	43.4a	117.7a
	KSC705	35.22abcd	14.3a	25.4a	46.6a	122.5a
	KSC706	34.17abcd	13.9a	27.1a	42.6a	127.4a
Preparing 60 percent of water requirement (I3)	KSC703	32.90bcd	13.7a	20.1a	43.4a	108.1a
	KSC704	31.55cd	12.9a	24.6a	42.5a	121.9a
	KSC705	29.57cd	12.0a	22.7a	45.4a	114.8a
	KSC706	29.30d	13.8a	26.2a	41.3a	117.8a

In each column, means with the same letters are not significantly different

Conclusion

Results showed that, maize yield decreased in drought conditions. All studied cultivars showed a negative reaction to the water shortage. All measured characteristics adversely affected by drought stress. Among the studied cultivars, single cross 704, showed the higher yield and yield components. The highest area under cultivation belongs to this cultivar in the region, at the study time.

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