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Effect of Drought Stress on Some Morphological, Physiological and Agronomic Traits in Various Foliage Corn Hybrids

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Abstract: In order to study the effect of drought stress on yield and some morphological and physiological traits in 14 new corn (*Zea mays* L.) forage hybrids, an experiment was designed. A split-plot layout within randomized complete block design with three replications was performed at Karaj Seed and Plant Improvement Institute Research farm in 2009. The main plots were three levels of irrigation; normal, mild stress and severe stress (irrigation after 70, 100 and 130 mm cumulative evaporation from Class A pan evaporation respectively,) and subplots included 14 hybrid corn. In this experiment, dry and fresh forage yield, number of leaves, leaf area index, leaf chlorophyll, ear dry weight, leaf dry weight, shoot dry weight, leaf to stem ratio (dry) and plant height were considered. The results showed significant difference for plant height, leaf to stem ratio (dry), dry forage yield hybrids ($P<0.05$) and the number of leaves, leaf area index, dry weight per ear ($P<0.01$), while among the studied hybrids no significant difference was observed for leaf dry weight and shoot dry weight. Also, all traits except number of leaves showed a significant difference ($P<0.01$) to drought stress. Increment of irrigation from normal to severe stress reduced dry and fresh forage yield (44% and 27% respectively).

Key words: Corn · Drought stress · Hybrid · Dry forage · Fresh forage

INTRODUCTION

Drought stress is considered one of the most common factors of limiting plant growth in arid and semiarid regions [1]. The impression of water deficit is the main factor limiting maize (*Zea mays* L.) production in arid and semiarid regions. Forage maize is an important crop as to silage the whole harvested plant [2]. The digestibility of leaves is higher than stems and by the increment of leaf to stem ratio, its forage quality increases [3]. Lauer and Cussicunqui [4] stated that the most effective energy factor of silage maize is the grain to forage ratio. Grains contain a large amount of highly digestible starch [5], more protein and lower levels of cell wall carbohydrate and higher digestibility [2]. Grains energy is 80% higher than forages. Roth and Lauer [5] reported that most hybrids with a high ratio of grain to forage are suitable and are recommended. Song and Dai [6] studied the effect of drought stress on corn growth and development and reported that drought stress prevents the growth and development of corn female flowers. Also height, diameter, dry and fresh weight reduce by water deficit. Cakir [7] reported that water stress during different corn growth stages decreases yield in different degrees of intensity. The decrease of yield depends on both stress severity and plant growth stage. Rezaverdinejad *et al*. [8] by applying low irrigation treatments at different growth stages of forage corn in Karaj (Iran) reported that drought stress at vegetative and flowering stages compared to normal irrigation reduced yield by 28% and 29% respectively. Pandey *et al*. [9] reported that deficit irrigation at early vegetative growth, slightly decrease leaf area index, plant height, plant growth rate and dry matter in corn.

In order to study the effect of drought stress on yield and some morphological and physiological traits in 14 new corn (*Zea mays* L.) forage hybrids, an experiment was conducted at Karaj Seed and Plant Improvement Institute Research farm in 2009.

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Table 1: Hybrids used as sub factors

Number	Hybrid
1	K47/2-2-1-4-1-1-1×MO17
2	K3653/2×K19
3	K3653/2×MO17
4	KSC700
5	KSC704
6	KSC720
7	KLM76004/3-2-1-1-1-1-1-1×K3545/6
8	K74/2-2-1-2-1-1-1-1×K3545/6
9	K47/2-2-1-2-2-1-1-1×K3544/1
10	KL M76004/3-2-1-1-1-1-1-1×K3544/1
11	K47/2-2-1-2-1-1-1-1×K3544/1
12	K47/3-1-2-7-1-1-1×MO17
13	KLM77029/8-1-2-3-2-3×MO17
14	KLM76005/2-3-1-1-1-1×MO17

MATERIALS AND METHODS

This research was conducted at Karaj Seed and Plant Improvement Institute research farm in 2009 with 50°, 55′ eastern latitude and 35°, 47′ northern longitude with an elevation of 1254 meters above sea level. The soil texture of the research site was loam-clay with a pH of 7.5 and the Electrical Capacity (EC) was 0.7 dsm^{-1}. The statistical design was a split-plot layout within randomized complete block design with three replications. The factors in this study were three levels of irrigation as main factor, including S1 = Normal irrigation (irrigation after 70 mm evaporation from Class A evaporation pan), S2 = mild stress (irrigation after 100 mm evaporation from Class A evaporation pan) and S3 = severe stress (irrigation after 130 mm evaporation from Class A evaporation pan) and 14 late corn foliage hybrids were designated in sub plots as mentioned in Table 1.

Cultivation pattern in each plot was 3 lines each 7m in length and seeds were cultivated 75cm (75000 plant/ha) apart on the lines. In order to prevent irrigation confliction, two rows at the beginning and end of each main plot was considered marginal rows and were not cultivated. Amount of fertilizer application was based on soil test. 400 kg/ha urea fertilizer was applied, half before cultivation and the other half at 6-7 leaf stage. Suitable herbicide application was used for weed control. Irrigation time was determined using daily evaporation rate of class A pan evaporation. To determine the volume of water per irrigation, a sample from each plot from the depth of root development was prepared before irrigation. The samples were kept in 80°C oven for 24 hours. The weight of soil moisture content was calculated and the volume of water per irrigation was determined by using equations 1 and 2.

1: $H = \rho b\,(\theta_{F.C} - \theta_m)\,D$

2: $V = H \times A$

Where H is the water height in the plot, ρb is soil bulk density, $\theta_{F.C}$ is the moisture level at field capacity, θ_m is plot moisture mass desired at irrigation time, D is the root development depth, V is the volume of irrigation water in the plot and A is the plot area. From each plot 10 plants were randomly selected to determine traits such as dry forage yield per hectare, fresh forage yield per hectare, plant height, leaf number, leaf area index, leaf chlorophyll, dry ear weight, dry leaves weight, dry stem weight and the ratio of dry leaf to dry stem. Statistical analysis of variance was calculated by using SAS software version 9.1 and Duncan multiple range test was used for means comparison.

RESULTS AND DISCUSSIONS

Dry Foliage Yield: Evaluation of dry forage showed significant difference for various irrigation and hybrid treatments ($P<0.01$ and $P<0.05$ respectively) but the interaction between irrigation and hybrids did not show any significant difference (Table 2). This indicated that the hybrids used in this study showed similar reaction to applied stress conditions. Means comparison of different irrigation treatments showed that the highest dry forage yield (17871 kg ha^{-1}) was obtained from the treatment of irrigation after 70 mm evaporation while irrigations after 100 and 130 mm evaporation produced 15381 and 9862 kg ha^{-1} dry forage yield, respectively which had 14% and 45% decrease respectively compared to irrigation after 70 mm (Table 3). This difference could be due to hybrids low ability in the uptake, transport and food construction during water shortages which reduce plant dry matter accumulation. Dry weight loss and reduce of photosynthetic materials due to water limitation have also been reported by other researchers such as Kisman [10] and Osborne *et al*. [11]. The increment of dry mater is because of higher use of light due to expansion of leaf area under normal irrigation (irrigation after 70 mm evaporation) condition. Lak *et al*. [12] also emphasized that reduction in plant dry matter production under irrigation after 130 mm evaporation due to the negative impact of drought stress on ear dry weight (51% reduction) because in corn, cob is an important component of the plant. Scarisbrick and Daniels [13] showed that 20% of total dry matter weight could be reduced because of drought stress during flowering period. According to hybrids mean comparison (Table 4),

Table 2: Analysis of variance of corn hybrids traits under irrigation treatments

S.O.V	df	Dry foliage yield	Fresh foliage yield	Leaves number	Leaf area index	Leaf chlorophyll	Ear dry weight	Leaf dry weight	Shoot dry weight	Leaf to stem ratio (dry)	Plant height
Replication	2	52928023**	207188917**	3.175*	0.585*	31.655^{ns}	109020.097*	11907.814**	163598.171**	919.130**	887.505^{ns}
Irrigation	2	705763464**	1714231975**	0.529^{ns}	2.297**	403.715**	2173347.101**	72612.977**	951182.469**	4242.750**	34780.836**
E(a)	4	36014993	207135392	2.649	0.186	218.675	27180.610	3170.086	89151.118	593.559	2403.490
Hybrid	13	17116088*	21705734^{ns}	7.629**	0.629**	61.749*	91988.054**	1708.161^{ns}	28933.702^{ns}	198.153*	389.513*
H*I	26	8764874^{ns}	16500941^{ns}	0.623^{ns}	0.113^{ns}	9.189^{ns}	37005.434^{ns}	1299.885^{ns}	12825.704^{ns}	97.033^{ns}	128.590^{ns}
E(b)	78	7733934	16625611	0.732	0.138	20.973	29474.058	1172.904	17334.171	88.830	171.279
CV (%)	-	19.350	9.941	6.198	10.137	16.602	26.092	14.054	28.678	15.462	8.588

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

Table 3: Means Comparison of different irrigation treatments

Irrigation treatments	Dry foliage yield (kgha^{-1})	Fresh foliage yield (kgh^{-1})	Leaves number	Leaf area index	Leaf chlorophyll	Ear dry weight (g)	Leaves dry weight (g)	Shoot dry weight (gr)	Leaf to stem ratio (dry)	Plant height (cm)
Irrigation after 70 mm of evaporation	17871.8^{a}	47372.8^{a}	13.936^{a}	3.884^{a}	31.137^{a}	892.86^{a}	273.804^{a}	532.08^{a}	54.223^{b}	178.540^{a}
Irrigation after 100 mm of evaporation	15381.8^{b}	41086.6^{b}	13.746^{a}	3.693^{b}	26.185^{b}	642.36^{b}	260.997^{a}	559.17^{a}	56.140^{b}	157.074^{b}
Irrigation after 130 mm of evaporation	9862.1^{c}	34596^{c}	13.738^{a}	3.419^{c}	25.429^{b}	438.71^{c}	196.241^{b}	286.03^{b}	72.510^{a}	121.561^{c}

Means with the same letter in each column have no significant difference (P<0.05).

Table 4: Means Comparison of various hybrids

Hybrid	Dry foliage yield (kg.ha^{-1})	Fresh foliage yield (kg.h^{-1})	Leaves number	Leaf area index	Leaf chlorophyll	Ear dry weight (g)	Leaves dry weight (g)	Shoot dry weight (g)	Leaf to stem ratio (dry)	Plant height (cm)
1	14821 a	40135 ab	13/963 cde	3/809 ab	29/146 ab	737/38 abc	235/96 abc	443/88 abc	61/752 ab	154/144 abcde
2	13372 ab	43426 a	11/852 g	3/307 cde	32/592 a	572/29 bcd	230/92 abc	420/13 bc	60/130 abc	147/211 bcde
3	13970 a	38719 b	12/629 fg	3/264 de	25/640 bc	683/29 abc	233/25 abc	407 bc	62/961 ab	158/839 abc
4	15565 a	39107 ab	14/963 ab	4/069 a	23/960 c	771/54 a	252/75 abc	461 abc	68/159 a	161/717 a
5	13805 ab	40014 ab	13/629 de	3/849 ab	29/836 ab	598/04 abcd	249/74 abc	443/96 abc	65/041 ab	145/550 cde
6	14901 a	41379 ab	13/556 de	3/967 ab	25/796 bc	552/63 cd	268/13 a	588/08 a	50/962 c	152/994 abcde
7	15392 a	42439 ab	14/074 cde	3/901 ab	25/965 bc	728/38 abc	254/17 abc	480/83 abc	59/825 abc	160/450 ab
8	16377 a	42911 ab	13/593 de	3/656 bc	28/043 abc	769/58 a	260/54 ab	522/13 ab	57/280 bc	159/794 abc
9	13300 ab	41288 ab	14/741 abc	3/706 ab	25/712 bc	563/08 cd	248/50 abc	448/50 abc	65/303 ab	150/028 abcde
10	10930 b	43414 a	15/370 a	3/566 bcd	25/867 bc	435/29 d	223/96 bc	354/54 c	67/311 ab	142/861 e
11	13474 ab	39952 ab	13/407 def	3/176 e	32/561 a	639/54 abc	220/04 c	421 bc	56/856 bc	144/167 de
12	14772 a	39660 ab	14/037 cde	3/642 bcd	27/876 abc	728/33 abc	239/17 abc	447/33 abc	62/212 ab	145/983 bcde
13	15867 a	40537 ab	14/333 bcd	3/711 ab	27/025 bc	728/33 abc	249/33 abc	515/42 ab	58/069 abc	151/722 abcde
14	14661 a	41278 ab	13/148 ef	3/687 abc	26/156 bc	754/46 ab	245/08 abc	473/50 abc	57/545 bc	158/022 abcd

Means with the same letter in each column have no significant difference (P<0.05).

hybrids 1, 3, 4, 6, 7, 8, 12, 13 and 14 had the highest total dry weight per hectare (14821, 13970, 15565, 14901, 15392, 16377, 14772, 15867 and 14661 kg ha^{-1} respectively). High forage yield in these hybrids were due to their long-term growth which had more time for production and accumulation of plant materials. Also hybrid 10 had the lowest total dry weight per plant (10930 kg ha^{-1}). It is reported that hybrids with longer growth period produce more dry matter [14].

Fresh Foliage Yield: Effect of different irrigation treatments showed significant difference on fresh forage yield (P<0.01) while different hybrids and the interaction between different irrigation treatments and hybrids were not significant (Table 2). Means comparison of different irrigation treatments showed that the highest fresh forage yield (47372 kg ha^{-1}) was obtained with irrigation after 70 mm evaporation, while irrigation after 100 mm and 130 mm evaporation produced a mean of 41086 and 34596 kg ha^{-1}, respectively with a 13 and 27% decrement compared to irrigation after 70 mm evaporation,respectively (Table 3). Lower yield in treatments under drought stress indicated that if a lack of soil moisture passes a certain level, plant performance was decreased significantly. Other studies, Osborne *et al*. [11], Kramer [15], Levitt [16] and Wilson [17] reported a significant reduction of fresh forage yield under drought conditions. Hybrids mean comparison (Table 4) of fresh forage yield showed that the highest forage yield was obtained in hybrids 2 and 10 (43426 and 43414 kg ha^{-1} respectively), while hybrid 3 had the lowest forage yield (38719 kg ha^{-1}).

Leaf Number: A significant difference (P<0.01) was observed for leaves number among the hybrids, while effects of different irrigation treatments and the interaction between different irrigation treatments and hybrids did not show any significant difference (Table 2). As this trait is not affected by environmental conditions, it is not expected to be affected by different irrigation treatments (Table 3). In the early growth stages of corn plants, leaves are formed under more desirable conditions but under poor growth conditions and environmental stress early formed leaves will die [18]. Mean comparison of hybrids showed that hybrid number 10 had the highest number of leaves (15) and hybrid 2 had the lowest (11) (Table 4). Albert [19] reported that corn late varieties maintain their green leaves longer than others after starting seed production therefore leaves in late varieties dries later than early varieties. This is the main reasons for higher photosynthesis and yielding in late varieties or hybrids.

Leaf Area Index: According to Table 2, drought stress and hybrids showed significant difference (P<0.01) on leaf area index (LAI). Due to means comparison (Table 3), increase in drought stress decreased leaf area index. Other researchers, such as Nouri azhar and Ehsanzadeh [20], Saberali *et al*. [21], Pandey *et al*. [9] also reported significant reduction in LAI during drought stress. Ritchie [22] also reported no difference of LAI between plants irrigated normally and plants under drought stress condition during growth season but the only difference in LAI between normal irrigation and drought condition were observed at the end of growing season which plants under stress condition lost leaf area earlier. Hybrids LAI mean comparison showed that hybrid number 4 had the highest rate of LAI (4.069) and hybrid number 11 had the lowest LAI (3.176) (Table 4).

Leaf Chlorophyll: Effect of different irrigation treatments and various hybrids on leaf chlorophyll showed a significant difference (P<0.01) but the interaction between irrigation and hybrids were not significant (Table 2). Mean comparison of different irrigation treatments showed that from irrigation after 70 to 100 mm of evaporation significantly decreased leaf chlorophyll, while although irrigation after 100 mm to 130 mm evaporation also reduced leaf chlorophyll but was not significant (Table 3). Water deficiency causes pigment and plastid damage. Drought stress decrease chlorophyll and carotenoids [23]. Mean comparison of hybrids (Table 4) showed that the highest and lowest leaf chlorophyll levels were obtained in hybrids 2 (38.612) and 4 (28.885) respectively.

Ear Dry Weight: According to Table 2, a significant difference (P<0.01) was observed among different irrigation treatments and various hybrids for ear dry weight but the interaction between the two factors was not significant. Mean comparison of different irrigation treatments significantly decreased ear dry weight by the increment of intervals between irrigation (Table 3). Song and Dai [6] also reported similar result. They also stated that in normal conditions and after receiving enough water, enhanced photosynthesis increase and also the transfer of shoot storage materials during rapid grain filling will prevent seed sterility. But in drought conditions due to water and solute uptake reduction by plants, consequently reduction of photosynthetic materials synthesis and transfer and grain assimilates occur which leads to a shorter period for seeds to be filled and completed. According to Table 4, hybrids number 8 and 4 had the highest dry weight per ear (769.58 and 771.54 g respectively) and hybrid number 10 had the lowest (435.29 g).

Leaf Dry Weight: Effect of different irrigation treatments showed a significant difference (P<0.01) on leaf dry weight while various hybrids and the interaction between different irrigation treatments and hybrids were not significantly different (Table 2). Mean comparison of various irrigation treatments showed that between irrigation after 70 mm evaporation and irrigation after 130 mm evaporation there was a significant difference due to leaf area reduction caused by the applied stress condition (Table 3). The results of conducted soil water and moisture deficiency experiments leading to leaf area reduction due to photosynthesis confusion and chloroplast reduction, consequently resulting in rapid leaf necrosis, implies that leaves is considered to play an important role as a mechanism for adaptation to drought [24, 25]. Yegappan *et al*. [26] stated that drought stress causes leaves premature aging, reducing the number of leaves, leaf area, seed weight and thus reduce the yield. Shrestha *et al*. [27] showed that water shortage during the grain filling stage reduced leaf dry weight which was due to reduction of plant growth and the vegetative dry weight. The mean comparison of hybrids (Table 4) showed that hybrid No. 6 had the highest (268.13 g) and hybrid No. 11 had the lowest (220.04 g) leaf dry weight.

Shoot Dry Weight: Effect of different irrigation treatments on dry shoot weight was significant (P<0.01) while hybrids and interaction between different irrigation treatments and hybrids were not significant (Table 2). Mean comparison of different irrigation treatments showed that irrigation after 70 and 100 mm evaporation was significantly different than irrigation after 130 mm evaporation. This was because of the reduction in shoot dry weight in plants treated with irrigation after 130 mm evaporation. This could be explained as in this treatment (130 mm evaporation) stored materials were transferred from shoot to seeds in order to prevent seed sterility (Table 3). Plant growth reduction caused by moisture stress leads to vegetative weight reduction [27]. Shoot dry weight increment by drought stress has also been reported by Schussler and Westgate [28] and Sinclair *et al*. [29]. Mean comparison of hybrids (Table 4) showed that hybrid No. 6 had the highest (588.08 g) and hybrid No. 10 had the lowest (354.54 g) shoot dry weight. Hybrid No. 6 in terms of total dry weight per plant also had the highest rate of dry matter, states the important role of shoot photosynthesis in the production and accumulation of photosynthetic materials in these hybrids.

Leaf to Stem Ratio (Dry): The effect of different irrigation treatments and various hybrids on leaf to stem ratio (dry) showed a significant difference (P<0.01 and P<0.05, respectively) but the interaction between the two factors was not significant (Table 2). Mean comparison of different irrigation treatments showed that after 70 and 100 mm evaporation there was no significant differences, while irrigation after 130 mm of evaporation was significantly different. Due to higher decrement of dry stem weight (46%) in comparison to leaf dry weight (28%) in the treatment of irrigation after 130 mm evaporation, leaf to stem ratio (dry) increased under stress conditions (Table 3). Leaves digestibility are higher than stems and by the increment of leaf to stem ratio, forage quality generally increase [3]. According to Table 4 mean comparison of hybrids showed that hybrid No.4 had the highest leaf to stem ratio (62.961%) as it was a late hybrid and hybrid No.6 had the lowest leaf to stem ratio (50.962%).

Plant Height: Effect of different irrigation treatments and various hybrids on plant height showed significant difference (P<0.01 and P<0.05 respectively) but the interaction of different irrigation treatments and hybrids did not show any significant difference (Table 2).

Mean comparison of different irrigation treatments demonstrated that normal irrigation conditions (after 70 mm evaporation) plants height was at the highest level (178.54 cm) and under drought stress condition (irrigation after 130 mm evaporation) plants height was at the lowest level with a mean height of 121.56 cm (Table 3). Sarvar and Ali [30] studied the effect of water stress on two maize genotypes (wild and mutant genotypes) and reported plant height reduction in both genotypes. El Neomani *et al*. [31] also reported that at the beginning of rapid growth stress dramatically decrease maize height although dry matter production depends on levels of photo-assimilate products. This ultimately reduces the amount of photo-assimilate during grain filling in the ear. Hogenboom *et al*. [32] also mentioned the effect of dehydration on plant height by reduction of photosynthesis and consequently reduction of internodes length. Our results are consistent to those reported by Pandey *et al*. [9], Traore *et al* [33], Yazar *et al*. [34], Denmead and Show [35] and Gavloski *et al* [36]. Comparing the hybrids for plant height (Table 4) showed that the highest height was produced by hybrid No.4

Table 5: Traits correlation coefficients

	Leaves to stem ratio (dry)	Leaves number	Leaf area index	Leaves chlorophyll	Shoot dry weight	Ear dry weight	Leaves dry weight	Plant height	Fresh foliage yield
Leaves number	-0.01^{ns}								
Leaf area index	-0.30**	0.34**							
Leaves chlorophyll	-0.13^{ns}	-0.02^{ns}	0.06 ^{ns}						
Shoot dry weight	-0.85**	0.09^{ns}	0.48**	0.01^{ns}					
Ear dry weight	-0.36**	0.28**	0.41**	0.44**	0.48**				
Leaves dry weight	-0.61**	0.16^{ns}	0.56**	0.11^{ns}	0.87**	0.64**			
Plant height	-0.51**	0.31**	0.46**	0.38**	0.54**	0.79**	0.64**		
Fresh foliage yield	-0.46**	0.22*	0.44**	0.69**	0.49**	0.69**	0.66**	0.78**	
Dry foliage yield	-0.65**	0.22*	0.52**	0.89**	0.82**	0.89**	0.88**	0.79**	0.73**

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

(161.71 cm) and hybrid No.10 had the lowest height (142.86 cm). Bert *et al*. [37] believed that genotype with long growth period are taller than the other genotypes because plants elongation continues until flowering time but the genetic potential of hybrids is also an effective factor.

Traits Correlations: According to traits correlations (Table 5) dry and fresh forage yields are significantly correlated with all other traits. Leaf to stem ratio (dry) had a significant negative correlation with LAI, ear dry weight, leaf dry weight, shoot dry weight, plant height and fresh and dry forage yield and a significant negative correlation exists. Number of leaves showed a positive significant correlation with LAI, ear dry weight, plant height and fresh and dry forage yield. LAI had a significant correlation with ear dry weight, leaf dry weight, shoot dry weight, plant height, dry forage yield and fresh forage yield. Leaf chlorophyll also showed highly significant positive correlation with all traits except leaf and shoot dry weight. Ear dry weight and plant height both showed a highly significant positive correlation with all other traits. Fresh and dry forage yield had a significant positive correlation with each other. According to traits correlation table (Table 5) it can be concluded that leaf to stem ratio (dry), leaf number, LAI, leaf chlorophyll, shoot dry weight, ear dry weight, leaf dry weight and plant height can impact fresh and dry forage yield under deficient soil moisture conditions. Therefore by breeding hybrids for these traits, crop performance reduction can be largely avoided under drought condition.

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