

# Evaluation of Drought Stress on Irrigation Efficiency, Yield and Yield Components in New Maize Hybrids

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**Abstract** – Maize is one of the most important cereals which its global production is severely affected by drought in many parts of the world. In order to study the effect of drought stress on yield and yield components and irrigation efficiency, an experiment was carried out on 14 maize hybrids in a randomized complete block design with three replications at Seed and Plant Improvement Institute in Karaj, Iran in 2009-2010. The main plots included three irrigation levels; normal irrigation, mild stress and severe stress (irrigation after 70, 100 and 130 mm cumulative evaporation from Class A pan evaporation respectively) and subplots included 14 maize hybrids. Two years analysis showed that effect of year and its interactions with irrigation regimes, were significant ( $P \leq 0.01$ ) on most of the traits. Using the results of current experiments, hybrid K74/2-2-1-2-1-1-1×K3545/6 had more tolerance to drought stress condition.

**Keywords** – Drought Stress, Hybrid, Dry Forage Yield, Maize.

## I. INTRODUCTION

Drought is the main cause of great losses in growth, production of crops and total yield in plants. Some areas are more exposed to drought condition. More than 26% of cultivable parts of earth exposed to drought stress [6]. Regarding that Iran is an arid and semi-arid area with average rain fall of 250 mm (about one third of average rain fall in the world) in which falling is not arranged, drought stress is one of the most important limitation which affect crop plants in most of the growth stages [7], [29], [23]. Generally, among different non-biological stresses, drought is the main and most prevalent limitation for growth of crops in arid and semi-arid areas [31]. Corn silage is becoming more important in dairy rations. It is valued because of its high yield, ability to make excellent silage, and it can be harvested in a single operation without significant leaf loss. Increased use of no-till practices has reduced the soil erosion potential associated with growing forage corn. Corn stover (aboveground vegetation less ears) after grain harvest is also an important feed resource for beef cattle and sheep either as grazed forage or for feed after being conserved by baling [15]. Digestibility of leaves is higher than stems and increasing in leaves to stems rate results in higher digestibility in forage [12] indicated that drought stress caused severe reduction in evaporation, respiration and finally seed yield, in corn. [25] stated that drought stress before flowering, during flowering and after flowering stages reduced corn yield by 25, 50 and 21%. [26] reported that low irrigation in initial stage of vegetative growth decreased leaf area indices, plant height, growth

speed and dry matter in corn slowly, but they are decreased severely in reproductive stage by low irrigation. [20] stated that the ratio of grain to stover is the most effective energy factor in corn silage. [30] studied effect of drought stress on growth and development of corn. They reported that drought stress has limited growth and development of female inflorescence in corn. Also, reduction of cob length and diameter, and also dry and fresh weight of cob duo to water limitation is reported. [3] indicated that low water stress in different stages of corn growth reduced the yield in different amounts. Therefore reduction of yield not only depends on stress severity, but also depends on the plant growth stage. This study was conducted to evaluate effect of drought stress on some morphological and physiological traits in 14 new forage corn (*Zea mays* L.) hybrids

## II. MATERIALS AND METHODS

This experiment was conducted in Seed and Plant Improvement Institute Karaj, Iran in 2009-2010. The Research Station located in 50°, 55' eastern latitude and 35°, 47' northern longitude with 1254 height above mean sea level (AMSL). The soil texture of the location was loam-clay with pH= 7.5 and the Electrical Capacity (EC) = 0.7 dsm<sup>-1</sup>. The statistical design was laid out as a split-plot in randomized complete block with three replications. Three irrigation levels as main factor including; Normal irrigation (S1), mild stress (S2) and severe stress (S3) as irrigation after 70, 100 and 130 mm evaporation from Class A evaporation pan respectively. And 14 late maturity forage corn hybrids (Table 1) were considered as sub plots.

Table 1: List of the new maize hybrids were used in this experiment

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×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×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

Each plot included 3 lines each 7 meter long. Distance between planting rows and seeds in the rows was 75 and 17.5 cm respectively (75000 plant/ha). In order to prevent irrigation confliction, two rows at the beginning and the end of each main plot were not cultivated and were considered as marginal rows. Using fertilizer was based on the soil test. 400 kg/ha urea was applied; one half before cultivation and the other half at 6-7 leaf stage. Irrigation time was determined using daily evaporation rate of standard class A evaporation pan. To determine the volume of water per irrigation, a sample of each plot from depth of root development was prepared before irrigation. The samples were kept in oven 80°C for 24 hours. The weight of soil moisture content was calculated and the volume of water per irrigation was calculated 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,  $\rho_b$  is soil bulk density,  $\theta_{F.C}$  is the moisture level at field capacity,  $\theta_m$  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. SAS software version 9.1 was used for statistical analysis and Duncan multiple range tests at 5% statistical probability level was used for means comparison.

### III. RESULTS AND DISCUSSIONS

#### *Stem Dry Weight*

Effect of year on stem dry weight was significant ( $P < 0.05$ ) (Table 2). Stem dry weight in the first year, was lower than the second year (Table 3). Analysis of variance showed that the effect of different irrigation regimes was not significant for stem dry weight which could be attributed to significant difference between irrigation regimes and year. Plant growth reduction caused by drought stress leads to vegetative weight reduction [35] Stem dry weight increment by drought stress has also been reported by [36], [37] There was no significant difference among hybrids. Nevertheless they were different from 443.08 (hybrid 3) to 622.31 g/m<sup>2</sup> and (hybrid 8). Interaction between year and hybrid was significant ( $P < 0.05$ ) but the other Interaction effects were not significant (Table 5).

#### *Leaf Dry Weight*

Effect of year on leaf dry weight was significant ( $P < 0.01$ ) (Table 2). Dry weight of leaf was lower in the first year (Table 3). Different irrigation regimes had no significant effect on leaf dry weight. It could be due to significance of year  $\times$  irrigation regimes. Means of irrigation regimes indicated that following increase of drought stress, leaf dry weight was decreased, although this difference was not significant in this study (Table 4). The results of 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 [10], [13], [42] stated that drought stress causes premature of leaves, reducing the number of leaves, leaf area and grain weight and thus reduce the yield. [35] showed that water shortage during the grain filling stage reduced leaf dry weight which lead to reduction of plant growth and vegetative dry weight. Despite of no significant difference among hybrids, they varied by 282.79-317.63 g/m<sup>2</sup> (hybrid 12 and hybrid 4, respectively) (Table 5).

#### *Ear Dry Weight*

Ear dry weight was not affected by year, whereas it affected by different irrigation regimes significantly ( $P < 0.05$ ) (Table 4), so that increasing in stress caused decreasing in ear dry weight (Table 4). Similar result was also reported by [30] They also stated that in normal conditions enhanced photosynthesis will increase after receiving enough water and transfer of stem storage materials during rapid grain filling will prevent seed sterility. But in drought stress conditions due to reduction of water and mineral uptake producing of photosynthetic materials, transferring and grain assimilation will decrease and leads to a shorter grain filling period. Interaction effect of year  $\times$  hybrid was significant at 1% of probability level, However the highest ear dry weight was achieved from hybrid 8 and the lowest was observed in hybrids 5 and 10 (Table 5).

#### *Leaf to Stem Ratio (Dry)*

Leaves digestibility are higher than stems and by increasing of leaf to stem ratio, forage quality generally increase [12] In this research the ratio was not affected by year and irrigation regimes (Table 3). Different hybrids didn't show significant difference for ratio of leaf to stem, but it was affected by year  $\times$  hybrid significantly ( $P < 0.01$ ). Therefore the hybrids had different leaf to stem ratio in first and second year of experiment.

#### *Leaf Area Index (LAI)*

Leaf area index was not affected by year (Table 3), while it affected by year  $\times$  irrigation regimes. Means comparison of irrigation regimes indicated decreasing in leaf area index, although this reduction was not statistically significant (Table 4). Interaction of year  $\times$  hybrid was significant ( $P < 0.01$ ). No significance difference observed for hybrids could be explained by significant different among year  $\times$  hybrid. Since mean comparison of hybrids showed that the hybrids 4 and 5 had the highest leaf area index, while the hybrid 11 had the lowest (Table 5). Other researchers, such as [24], [33], [26] also reported significant reduction in LAI during drought stress [34] also reported no difference for 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.

#### *Leaf Number*

Analysis of variance showed that number of leaves was affected by year (Table 2). The most number of leaves was in the first year (Table 3). Effect of year  $\times$  hybrid was significant ( $P < 0.01$ ), while effect of irrigation regimes

and year  $\times$  irrigation regimes were not significant (Table 4) In the early growth stages of corn, leaves are produced in more desirable conditions but in environmental stress conditions early formed leaves will die [18].

#### Dry Forage Yield

Evaluation of dry forage showed significant difference between years ( $P < 0.01$ ). Means comparison of the years showed that dry forage yield was lower in the first year (Table 3). Interactin effect of irrigation regimes  $\times$  year was significant and statistically caused non-significant difference for dry forage yield in the irrigation regimes. This difference could be due to low ability of hybrids in uptake, transport and food construction during water shortages that led to reduce dry matter accumulation. Dry weight loss and reduce of photosynthetic materials due to water limitation have also been reported by other researchers such as [17], [25] There were no significant difference among hybrids, but the highest amount of dry forage yield was in hybrid 8 and the lowest was in hybrids 3, 5, 10 and 11.

#### Irrigation Efficiency

In this experiment, water consumption for forage yield in irrigation after 70, 100 and 130 mm evaporation from evaporation pan was 9872.67, 8598.94 and 8264.81 m<sup>3</sup>.ha<sup>-1</sup> respectively (Table 6). Difference of irrigation efficiency in the evaluated irrigation regimes can be explained also by comparison between yield and water usage. Forage yield in mild stress condition was 46385 kg/ha which in comparison with control (53519 kg/ha) reduced by 13.33%. While water consumption in mild stress (8598.94 m<sup>3</sup>/ha) reduced by 12.9% in comparison with control

(9872.67 m<sup>3</sup>/ha) (Table 6). Forage yield in severe stress condition was 41280 kg/ha which reduced by 22.87 % compared to control treatment (53519 kg/ha). Water consumption in severe stress condition was 8264.81 m<sup>3</sup>/ha and it was reduced by 16.29 % in comparison with control (9872.67 m<sup>3</sup>/ha). Therefore, increase in drought stress followed by decrease in irrigation efficiency for forage yield.

## IV. CONCLUSION

There was significant difference between normal irrigation and stress conditions, and also among the hybrids for most of the traits. Forage dry yield affected by different irrigation regimes. Among the all dry forage yield components, cob dry weight affected by water limitation. Severe drought stress condition reduced most of the traits such as cob and stem dry weight and forage dry matter while it increased ratio of dry leaf to stem ratio significantly. Regarding the amount of fresh and dry forage yield in the hybrids in normal and stress conditions, hybrid 8 was better than the others due to its higher yield. Finally, drought stress decreased dry forage yield due to lack of sufficient water and its unfavorable effect on photosynthesis absorption and reducing growth because of reducing the number of fertile reproductive organs. Whereas this decreases could be considered regarding water usage in mild stress (reducing 13.33% of yield by 12.9% reducing water usage) but severe stress is not explained economically (reducing 23% yield by 16% reducing water usage).

Table 2: Analysis of variance of some morphological traits for 14 new maize hybrids under 3 irrigation regimes

S.O.V	DF	Dry forage yield	Leaf number	Leaf area index	Ear dry weight	Leaf dry weight	Stem dry weight	Leaf to stem ratio (dry)
Year	1	1125207366 **	131.96**	3.15	795025.1	809241.7**	1873673.6 *	37.7
Replication $\times$ Year	4	70942076	1.66	0.45	108515.4	9545.6	242592.8	958.5
Irrigation regimes	2	696963375	3.73	2.04	*2723811.1	45788.9	605529.9	2996.7
Irrigation regimes $\times$ Year	2	149526348*	1.91	0.74*	209232.4	30767.1**	374115.5**	1446.4
E <sub>a</sub>	8	23156608	0.58	0.12	162809.8	2845.3	49905.1	497.4
Hybrid	13	15341251	1.97	0.79	78228.02	2209.1	47723.3	371.6
Hybrid $\times$ Year	13	11912526	2.07 **	0.54**	67280.4**	1820.5	54987.4 *	620.9**
Hybrid $\times$ Irrigation regimes	26	5885637	0.38	0.07	25947.6	1413.9	27720.2	216.6
Hybrid $\times$ Irrigation regimes $\times$ Year	26	12458350	0.26	0.12	31656.1	836.2	31038.1	154.8
E <sub>b</sub>	156	7437874	0.561	0.125	21926.4	1413.7	27839.4	150.8
CV	-	16.5	5.7	9.38	20.7	12.5	30.6	20

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

Table 3: Means comparisons of the years for the evaluated traits

Year	Dry forage yield (kg.ha <sup>-1</sup> )	Leaf number	Leaf area index	Ear dry weight (gr)	Leaf dry weight (gr)	stem dry weight (gr)	Leaf to stem ratio (dry)
2009	14372 b	13.87 a	3.67 a	657.97a	243.68 b	459.1b	60.95 a
2010	18598 a	12.42b	3.89 a	770.3 a	357.02 a	631.6 a	61.73 a

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

**Table 4: Means Comparison of different irrigation regimes for the evaluated traits**

Irrigation treatments	Dry forage yield (kg.ha <sup>-1</sup> )	Leaf number	Leaf area index	Ear dry weight (gr)	Leaf dry weight (gr)	Stem dry weight (gr)	Leaf to stem ratio (dry)
Irrigation after 70 mm of evaporation	19266 a	13.38 a	3.95 a	906.7 a	320.88 a	595.95 a	56.86 a
Irrigation after 100 mm of evaporation	16674 a	13.07 a	3.75 a	685.8 ab	305.23 a	592.71 a	59.12 a
Irrigation after 130 mm of evaporation	13515 a	12.97 a	3.64 a	549.9 b	274.95 a	447.3 a	68.11 a

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

**Table 5: Means Comparison of 14 new maize hybrids for the evaluated traits**

Hybrid	Dry forage yield (kg.ha <sup>-1</sup> )	Leaf number	Leaf area index	Ear dry weight (gr)	Leaf dry weight (gr)	Stem dry weight (gr)	Leaf to stem ratio (dry)
1	16171 ab	13.3 a	3.82 ab	720.23 ab	293.19 a	516.52 a	62.05 a
2	16178 ab	12.56 a	3.62 ab	709.69 ab	307.96 a	486.31 a	70.68 a
3	15785 ab	12.99 a	3.75 ab	747.9 ab	299.46 a	443.08 a	70.51 a
4	17459 ab	13.46 a	4.21 a	720.98 ab	317.63 a	614.67 a	60.38 a
5	15726 ab	12.96 a	4.12 a	606.73 b	305.28 a	570.1 a	59.44 a
6	16682 ab	13.04 a	4.04 ab	670.27 ab	316.77 a	579.88 a	59.08 a
7	17019 ab	13.61 a	3.78 ab	777.31 ab	302.08 a	542.99 a	59.87 a
8	18618 ab	13.28 a	3.67 ab	839.17 a	312.15 a	622.31 a	57.18 a
9	15825 ab	13.49 a	3.61 ab	680.29 ab	301.54 a	515.5 a	65.31 a
10	15542 ab	13.64 a	3.62 ab	601.4 b	291.35 a	574.77 a	58.17 a
11	15398 ab	12.86 a	3.46 b	667.06 ab	283.77 a	513.21 a	59.23 a
12	16493 ab	13.06 a	3.77 ab	745.42 ab	282.79 a	542 a	59.18 a
13	17677 ab	13.08 a	3.64 ab	784.52 ab	291.13 a	601.88 a	55.69 a
14	16218 ab	12.7 a	3.79 ab	727.02 ab	299.83 a	511.33 a	62.05 a

**Table 6: Average rate of water use and yield reduction in different irrigation regimes**

	Irrigation after 70 mm evaporation	Irrigation after 100 mm evaporation	Irrigation after 130 mm evaporation
Water consumption (m <sup>3</sup> .ha <sup>-1</sup> )	9872.6	8598.94	8264.81
Forage yield (kg.ha <sup>-1</sup> )	53519	46385	41280
Saving water consumption (Percent)	1	12.9	16.29
Yield reduction	1	13.33	22.87

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