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ORIGINAL ARTICLE

Evaluation of Qualitative and Quantitative Traits of Maize (cv. 604) Under Drought Stress and Plant Density

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In order to study the effects of drought stress and plant density on yield and yields Components of maize (*cv.* 604), an experiment was conducted as a split plot based on randomized complete block design with four replications in Ilam station, Iran during 2007-2008 growing season. The treatment were three levels of irrigation (90, 120 and 150 evaporation (mm) from pan (Class A)) as main plots, four planting densities (90000, 100000, 110000 and 125000 plants ha^{-1}) as sub plot. The results showed that different levels of irrigation on the most of measured traits were significant at 1% probability level. Level of irrigation 90 mm evaporation (mm) from pan had a highest a number grain per row, 1000 kernel weight, grain yield and biologic yield other than traits. Between plating density the most of measured traits were significant. The highest grain yield, row per ear, number grain per row, biologic yield and harvest index obtained in 110000 plants ha^{-1}. Interaction effect of irrigation × plant density was effect on grain yield. The highest grain yield from 90 mm evaporation×110000 plants ha^{-1} and the lowest grain yield from 150 mm evaporation×90000 plants ha^{-1}.

Key words: Drought stress, Planting density, Grain yield, Yield components, Zea mays L.

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Key words: Drought stress, Planting density, Grain yield, Yield components, Zea mays L.

Maize is one of the most important crops which have a great importance in human nutrition, animal rising, poultry feeding, and industry in recent years many efforts have been made to increase the acreage under cultivation in order to reduce the annual imports of corn and many research have been implemented in various fields related to corn (Kafi Ghasemiand Esfahani, 2005). The most important factor limiting crop production in the world is drought stress (Bashandi and Poehlman, 1974). Iran is placed in arid and semi-arid climate and water shortage is one of the basic problems of agriculture in Iran. Therefore, the occurrence of water stress during plant growth is inevitable. The reaction of different crops and different types of the same plant to drought stress is different (Vieira *et al*., 1991). According to the estimates made by Levitt (1980), perhaps only ten percent of the arable lands in the world are categorized as lands free of stress. The drought stress is one of the main stresses which allocate 26 % of the whole stresses to it. Lots of stresses affect plants often directly and indirectly through drought stress. Generally drought affects all aspects of the growth of plants and also most of its physiological aspects (Hung, 2002).

Water shortage influences the opening and closing of stomata due to cell swellings, accordingly the processes of photosynthesis, respiration and transpiration are affected. On the other way, it negatively affects plant growth by effecting enzymatic processes which are directly controlled by water potential (Mansouri-Far *et al*., 2005). Drought stress affects morphological, physiological and biochemical aspects of plant growth through anatomical changes (Emam and Ranjbar, 1999).

Monneveux *et al*. (2006) reported that the main limiting factor in the development and production of maize is seasonal drought. Timl *et al*. (2001) stated that the aggregation process in maize is determined by photosynthesis in maize leaves, the amount of sugars, starch, acid and cytokines. Water shortage and existence of shade in an interval of five days before pollination reduces grain in ending parts of the maize. Water stress during pollination of maize causes a small number of eggs fertilizing, or even it is possible not to fertilize at all, it also can cause abortion, accordingly fewer number of maize grain is produced (Banziger *et al*., 1999; Pervez *et al*., 2004). Water shortage reduces the amount of storage in plants stem through reducing photosynthetic capacity; accordingly grain weight reduces (Campos *et al*., 2004; Echarte *et al*., 2006). Water stress during or before pollination reduces the number of grains, while water stress after pollination reduces grain weight (Banziger *et al*., 2002). The performance of dry matter is the consequence of plant community regarding its use of solar radiation during the growing season. Plant community needs sufficient leaf surface to be distributed evenly covering the earth surface completely. This purpose can be achieved by varying the density of plants and its distribution of plants n ground surface. Shibles *et al*. (1996) reported that in the condition in which the row spacing was 76 cm, the yield performance was 1.5 % more than the condition in which row spaces was 102 cm. They also showed that in the condition in which row spaces was 51 cm, the yield was 3.5 % more. Farnham (2001) reported that with varying the row spaces from 76 cm to 38 cm, the yield performance of maize reduces. Cox and Cherney (2001) stated that the yield performance of dry matter and also the amunt of yield in the primary stages of planting maize is more when the row spacing is 38 cm, compared to the condition in which row spacing was 76 cm. in a two-year study, Banaei *et al*. (2004) showed that there was a significant difference in an agricultural land with this conditions : the single cross being equal to 704, maize being planted in double rows with 20 cm space between them, density of eighty thousand plants per hectare, an average yield of 15.22 tons per hectare, compared to the lands with less or more densities being planted in one row. Ottman and Welch (1989) found that by getting rows wider, the share of radiation absorption became less for the leaves placed in lower part compared to those leaves which are placed in narrow rows. In this experiment, the difference between row spacing of 114 cm and a row spacing of 38 to 76 cm in radiation absorption was clear. When the row spacing was increased to 152 cm, this difference was clearer.

The amount of radiation absorption and the total energy absorbed by the plant is more in lands in which the row spacing is less. Aside from this, the air entry and its exit will improve, the evaporation rate will reduce, and water use efficiency will increase in narrower rows (Fagerria, 1992). Ferreira and Abreu (2001) also stated that by increasing plant density, the yield will increase. Because when the density is lower, the amount of radiation absorption and dry matter production is less. This decline was due to lower leaf surfaces. Amanulla and Ghnlam (1990) stated that by increasing the density of plants to 80 plants per square meter, the number of pods per plant will decrease. Bahrani and Babaei (2007) stated that by increasing plant density, it will be added to yield, but when density is too high, the yield index will decrease.

The reason for this is the increase in shading and competition between shrubs which result in reduction in radiation absorption by plants. Compared to the lands in which the density is lower, less photosynthesis material is allocated to the grain. The purpose of this experiment is to investigate the effect of the interaction between drought and density of plants on the yield and its components.

MATERIALS AND METHODS

In order to study the effects of drought stress and plant density on yield and yields Components of maize (*cv.* 604), an experiment was conducted as a split plot based on a randomized complete block design with four replications in Ilam station, Iran during 2007-2008 growing season. The treatment were three levels of irrigation (90, 120 and 150 evaporation (mm) from pan (Class A)) as main plots, four planting densities (90000, 100000, 110000 and 125000 plants ha^{-1}) as sub plot. The region was placed in 33 degrees latitude, 7 minutes north and 46 degrees longitude, 10 minutes east, the altitude from sea surface was 155. A deep plowing and two perpendicular disks were conducted to prepare a proper condition for planting grains. After spraying and fertilizing operations, another disc was conducted to mix fertilizer and pesticides with soil. Then the leveling operation was conducted. The seeds used in this experiment were Hybrid 604. The rate of precipitation and physical and chemical properties of soil are shown in Table 1&2.

The seeds were disinfected with Vitavax fungicides before planting. When planting, at first 3-5 cm deep furrows were created on each row, to ensure that seeds will grow, 2 seeds were planted in each furrow. After the growing of seeds, the thinning operation of leaves was conducted. In order to supply the fertilizer needed by plants, ammonium phosphate and urea fertilizers were used. 80 kg ha^{-1} of ammonium phosphate were used that all of it was used in the beginning process. 200 kg ha^{-1} of urea was used. Half of the used urea was used in the beginning process and the other half was allocated to the plant in the stage that the stem was growing. After the removal of two adjacent rows and 0.5 m from the beginning and end of each line as a marginal effect, 10 plants were selected randomly from the middle of the row. After harvesting, a note was taken from the number of row grains per ear, number of grains in row, and thousand grain weights. Data analysis was conducted by MSTAT-c software. The means of the traits were compared by Duncan's multiple range tests.

RESULTS AND DISCUSSION

Grain Yield

The results of the analysis of variance of grain yield are presented in Table 3. A significant difference was observed between different levels of irrigation. The most and the least grain yield belongs to the irrigations with 90 mm and 150 mm evaporation respectively (Table 4). We can connect the reduction in grain yield to the effects of water shortage. Water shortage causes accelerating plant aging and reducing the grain filling period. We can also make a connection between the grain reductions, the signals sent from roots to leaves regarding stomata closure and also reduction of photosynthesis (Brevedan and Egli, 2003). The grain yield had a significant difference in various plant densities in the condition in which the water stress had 150 mm evaporation compared to other irrigations with 90 mm and 12o mm evaporations. With increasing water stress, grain yield decreased in all various plant densities. The amount of reduction was less in two levels of irrigation with 90 and 120 evaporation, compared to the third level of irrigation with 150 mm evaporation in which the amount of reduction was so high. These results were consistent with Larson and Clegg (1999) study. Tolk *et al*. (1998) conducted a study about the effect of different soil types and different levels of irrigation on maize, they concluded that a reduction will occur in grain yield when the available water limits in lower levels. Generally all traits showed a negative reaction to water stress and water stress had the highest effect on grain yield. This reduction in grain yield occurs due to a sharp decrease in the number of grains per row, ear length and 1000 grain weight. This is due to water stress in flowering and grain filling stage. Gomes-Sanchez *et al*. (2000), in their studies concluded that water stress in developing stage of the plant can cause reduction in the amount of leaf surface, which may lead to a decrease in grain yield. The analysis of the interactions between the variables show that the highest grain yield belongs to the condition in which irrigation has 90 mm evaporation and plant density is 110000 plants ha^{-1}. And the lowest grain yield belongs to the condition in which irrigation has 150 mm evaporation and the plant density is 90000 plants ha^{-1}.

Number of Row Grains per Ear

The results of the study showed that the difference existing between different levels of irrigation causes a significantly difference in the number of kernel in maize (Table 3). The comparison of means of the number of row grains per ear in different levels of irrigation shows that the maximum and minimum number of row grains per ear was devoted to 90 mm and 150 mm evaporations respectively. The number of row grains per ear did not differ significantly between 120 mm and 150 mm evaporation treatments (Table 4). The overlap between pollen and pollen reception of silk is not possible in the condition of drought stress. So the maize's ovaries will fertilize partially. The fact that the female flowers do not inoculate results in forming irregular rows per ear. These results were consistent with the findings of Andrade *et al*. (2002). The effect of plant density on number of kernel rows per ear was not significant (Table 3). However, the maximum number of kernel rows per ear was observed in 110000 plants ha^{-1} and the minimum number of kernel rows per ear was observed in 90000 plant densities per hectare (Table 4). The analysis of the interaction between these two variables showed that the maximum number of kernel per ear belongs to 60 mm evaporation with 110000 plants ha^{-1}, and the minimum number f grain per ear belongs to the condition with 150 mm evaporation and 90000 plants ha^{-1} (Table 5).

Number of Grains in Row

The results of the analysis of variances related grain number in rows is presented in Table 3. There was a significant difference on the number of grains in row regarding different levels of irrigation (Table 3). As the Table shows, the maximum and minimum number of grains in row belongs to the irrigations with 90 mm and 150 mm evaporations respectively (Table 4). There was a significant difference between different treatments of irrigations with 90 mm and 120 mm evaporation regarding the mentioned variable. Since water stress decreases the transfer of nutrients from leaves and other parts of the plant to seeds, drought stress also leads to soon reaching of seeds. Besides reducing the amount of photosynthesis, this reaction causes a decline in grain yield. The number of grains per row which is a genetic trait of different types of seeds is so sensitive to drought stress. Among the reasons for the occurrence of this difference is that water stress can cause changes in the appearance of tassels. So when tassels appear, the pollination has been done and there is not any live pollen to inoculate female flowers or its amount has declined much. So most of the eggs do not fertilize and therefore they will not form seed and less number of grains per ear will form. Another reason for this is that the fetus of some eggs that have been fertilized will be aborted in this stage due to drought stress or increasing irrigation intervals. So fewer grains will be formed, therefore there will be fewer grain in per row and in the maize. These findings are consistent with Echarte *et al*. (2004) findings. Monneveux *et al*. (2006) stated that the decline in the number of grains per ear has a greater effect on the decrease in the grain yield in comparison with 1000 grain weights effect on grain yield. The effect of different planting arrangements on the number of grains per ear was significant (Table 3). The maximum and minimum number of grains per ear belongs to 110000 and 90000 plant plants ha^{-1}, respectively (Table 4). The analysis of the interactions between irrigation and plant densities showed that the highest number of grain per ear belongs to the situation in which the amount of evaporation is 60 mm and plant density is equal to 110000 plants ha^{-1}, and the lowest number of grains per ear belongs to the situation with 150 mm evaporation and 90000 plants ha^{-1} (Table 5).

1000-Grain Weight

Based on the results, the effect of different irrigation levels on 1000-grain weight were significant at one percent level (Table 3). The maximum and minimum 1000-grain weights, was allocated to 90 mm and 150 mm evaporation respectively, (Table 4). 1000-grain weight depends on photosynthesis materials and remobilization of stored materials. Also the speed of grain filling is a determining factor in 1000-grain weight. The decrease in transfer of supply to seeds can lead to reduction in grain weight. Of course, reduction in the speed of material transfer and reduction in grain filling period can exacerbate the decline. During drought stress at the end of pollination, the effect of lack of moisture is more evident on 1000-grain weight. Campos *et al*. (2004) and Echarte *et al*. (2006) showed that drought stress reduces the amount of material storage by reducing photosynthetic capacity in maize. Finally grain loses weight. Banziger *et al*. (2002) in their experiment stated that grains will wrinkle due to water stress in milky stages, therefore the final weight reduces. It seems that drought stress in this stage causes a reduction in photosynthesis materials. Therefore the leaf surface will reduce and less dry materials will be produced. It leads to grain wrinkling and a loss in grain weight. The finding of this study is consistent with findings of Recap Akir (2004) and Echarte *et al*. (2006). Based on the results, we can say that the effect of different planting arrangements on 1000-grain weight is significant at one percent level of probability (Table 3). The maximum 1000-grain weight belonged to 125000 plants ha^{-1} which was significantly different from other densities (Table 4). The results of the interactions between these two traits show that the highest effect of irrigation and plant density belongs to the situation in which evaporation is equal to 90 mm and plant density is 125000 plants ha^{-1}, and the minimum 1000-grain weight is in the condition with 150 mm evaporation and 90000 plants ha^{-1} (Table 5).

Biological Yield

The effect of different levels of irrigation on biological yield got significant (Table 3). As the Table of the averages of biological yield in three different levels of irrigation shows, the maximum and minimum amount of biological yield belongs respectively to the irrigations with 90 mm and 150 mm evaporations (Table 4). The reduction occurred in biological yield was due to reduction in dry matter accumulation. Since the speed of accumulation of dry materials is still too much in the vegetative phase, reduction in the amount of irrigation will causes a sharp damage to dry materials; eventually biological yields will be affected. If irrigation reduction occurs in the final stages of the development of plant, the amount of damage will be less. Cosculleola and Fact (1992) observed that the increase in the amount of drought stress will cause a high reduction in the amount of the potential water of leaves; therefore dry material yield will reduce. Ourcut and Nilsen (2000) believe that the reduction in dry materials' weight due to drought stress leads to leaf surface reduction which leads to reduction in the amount of light absorption and photosynthesis. Iramki *et al*. (2000) stated that leaves' high temperature due to closure of stomata under drought stress is one of the major causes of reduction in dry matter production in plants. The comparison of biological yield showed that the highest and lowest biological yield belongs to 110000 and 90000 plants ha^{-1} respectively. In lower densities, the amount of radiation absorption is lower, so the coefficient of photosynthetic efficiency is less in lower densities. On the other hand, in higher densities with a higher leaf surface index is, enough solar radiation will be absorbed but photosynthetic efficiency is very low due to mutual shading of leaves. Therefore, the maximum absorption of light in a longer period of vegetation growing season is very important. The analysis of the interaction between different levels of irrigation and plant density shows that the highest biological yield belongs to the situation with irrigation with 90 mm evaporation and 110000 plants ha^{-1}, also the lowest amount of biological yield belongs to 150 mm evaporation and 90000 plants ha^{-1} (Table 5).

Harvest Index

The analysis of variances showed that the effect of different levels of irrigation on harvest index was statistically significant (Table 3). The comparison of the means of harvest index showed that the maximum and minimum amount of harvest belongs to 90 mm and 150 mm evaporations respectively (Table 4). The results show that increasing irrigation intervals leas to a decrease in dry material yield and grain yield, so the harvest index does not differ so much. These findings are consistent with Sinclair *et al*. (1990) investigations. Cox and Julliof (1986) conducted an investigation on soybeans and sunflower in terms of lack of soil moisture, they observed a reduction in dry matter yield and harvest index in both species under drought stress and this reduction was greater in soybean. The results of data analysis showed that the effect of different planting densities were significant at the 1% level (Table 3). The highest harvest index belongs to 110000 plants per hectare and the lowest harvest index belongs to 90000 plants per hectare density (Table 4). The analysis of the interaction between irrigation and plant density shows that the highest harvest index belongs to 90 mm evaporation and 110000 plants ha^{-1}, and the lowest harvest index belongs to 150 mm evaporation and 90000 plants ha^{-1} (Table 5).

Table 1: Monthly mean value of precipitation and relative humidity in Ilam station, Iran in 2007-2008 growing season

Month	Min temp (°C)	Max temp (°C)	Precipitation (mm)	Min. RH (%)	Max. RH (%)
Oct	18.1	36.9	0.4	14	46
Nov.	15.4	27.5	21.0	34	70
Dec.	8.9	19.5	24.6	48	88
Jan.	9.7	20.9	15.7	40	80
Feb.	8.6	20.2	31.7	34	78
Mar.	14.1	26.0	27.2	25	62
Apr.	15.2	29.1	34.0	20	61
May	21.5	35.0	22.7	14	47
Jun.	27.1	44.0	0.0	7	23
Jul.	29.5	45.7	0.0	8	23
Aug.	30.5	46.7	0.0	9	23
Sep.	25.3	42.7	0.0	7	21

Table 2: Physical and chemical properties of soil

Soil texture	EC ($ds.m^{-1}$)	pH	O.C (%)	N (%)	P ($mg.kg^{-1}$)	K($mg.kg^{-1}$)
Sandy loam	0.71	7.3	1.28	1.12	5.4	280

Table 3. Analysis of variance for yield, yield components, harvest index and biological yield

s.o.v	df	Grain yield	number of row grains per ear	number of grains in row	1000-grain yield	Biologic yield	Harvest index
Replication	3	5312.500	0.99	2.1	2.2	14132727.91	0.91
Irrigation	2	41212623.9**	7.1**	312.7**	593.6**	117680692.8**	29.4**
Error	6	5955.9	0.12	0.59	16.3	101056.6	0.8
Plant density	3	823869.6**	0.13 ns	16.5**	591.6**	1164808.4**	21.8**
I×P	6	538164.4**	0.86**	9.3*	581.2**	5916966.1**	70.1**
Error	27	13867.9	0.031	0.4	19.1	159061.3	0.8
c.v (%)		12.6	9.1	7.8	8.2	13.2	7.6

ns: Non-significant *and **: Significant at 5% and 1% probability levels, respectively

Table 4. Mean comparisons of yield, yield components, harvest index and biologic yield

Main effects	Grain yield (kg. ha^{-1})	number of row grains per ear	number of grains in row	1000-grain weight (g)	Biologic yield (kg ha^{-1})	Harvest index (%)
Irrigation (mm)						
90	7650a	15.7a	42.1a	315.1a	16075a	47.5a
120	6415b	14.1b	39.5a	305.6b	14110b	45.4b
150	4431c	13.6b	33.3b	303.3b	9741c	45.4b
Plant density (plants ha^{-1})						
90000	5817c	14.6a	36.3c	312.4a	13070ab	45.17b
100000	6124bc	14.1a	38.9b	310.9b	13100ab	47.75a
110000	6538a	14.7a	41.6a	305.8c	13670a	48.50a
125000	6226b	13.8a	37.8b	304c	1390a	45.75b

Means in each column followed by similar letter(s) are not significantly different using Duncan's Multiple Range Test

Table 5. Mean comparisons of interaction effect for drought stress and plant density on yield, yield components, harvest index and biologic yield

interaction effect		Grain yield (kg ha^{-1})	number of row grains per ear	number of grains in row	1000-grain weight (g)	Biologic yield (kg ha^{-1})	Harvest index (%)
	90000	7530b	15.9b	39.7b	311bc	17430a	43.4fg
90mm	100000	7266c	15.3c	40.3b	366.cd	15520c	45.7de
	110000	7830a	16.2a	42.3a	318.9a	145200e	53.8a
	125000	7081d	15.4c	41.72a	312.5abc	16540b	42.3g
	90000	5819g	14.6ef	37.50c	315.5ab	12760g	45.4de
120mm	100000	6561f	15.1c	38.10b	281.1g	13107fg	50.1b
	110000	7019d	14.3g	47.60a	297.4e	15210d	45.3de
	125000	6772e	14.5fg	39.6b	316.9ab	13380f	50.4b
	90000	4397ij	14.2g	33.2e	289.7f	9308i	46.8cd
150mm	100000	4265j	14.5de	33.5d	303.3de	8880i	47.8c
	110000	4613h	14.4def	32.63de	301.3de	10550h	43.4ef
	125000	4231hi	14.6d	31.5f	312.6abc	10150h	44.3ef

Means in each column followed by similar letter(s) are not significantly different using Duncan's Multiple Range Test

CONCLUSION

The findings of the study showed that drought stress have a significant effect on grain yield, number of grain per ear, number of grain per maize, 1000 grain yield, biological yield and harvest index. The irrigation with 90 mm evaporation allocated the highest amount of yield and yield components to itself and the lowest yield and yield components belong to 150 mm evaporation. Among different plant densities, the density with 110000 plants ha^{-1} has allocated the highest grain yield to itself due to its higher row number and also its higher number of grains in rows.

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