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THE EFFECT OF WATER DEFICIT STRESS AND NITROGEN FERTILIZER LEVELS ON MORPHOLOGY TRAITS, YIELD AND LEAF AREA INDEX IN MAIZE

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Abstract

In order to study the effect of water deficit stress at different growth stages and N fertilizer levels on morphological traits, yield and yield components of maize cv. Single Cross 704, an experiment was conducted as a split-plot based on a Randomized Complete Block Design with three replications. The main plot included irrigation at four levels (irrigation stop at 10-leaf, tasselling and grain-filling stages and optimum irrigation) and the sub-plot was N fertilizer at three levels (75, 150 and 225 kg N/ha). The results of analysis of variance showed that water-deficit stress and N fertilizer level significantly affected leaf area index at silking stage, ear length, grain number per ear, 1000-grain weight and grain yield. Stem diameter, ear diameter and harvest index were only affected by irrigation treatments and the interaction between irrigation and N level did not significantly affect the studied traits. Means comparison indicated that ear diameter under optimum irrigation was higher than that under the treatments of irrigation stop at 8-leaf, tasselling and grain-filling stages by 29.9, 19.1 and 33.5%, respectively; and ear length was higher than them by 38.1, 28.9 and 25.2%, respectively. Moreover, the highest grain number per ear, 1000-grain weight and grain yield were obtained under optimum irrigation treatment, and irrigation stop at 10-leaf, tasselling and grain-filling stages decreased grain yield by 52.8, 66.4 and 44.9%, respectively; and it decreased grain number/ear by 45.9, 59.3 and 30.1%, respectively. In addition, optimum irrigation treatment with mean 1000-grain weight of 289.2 g was significantly superior over other irrigation stop treatments by 27.6-42.8% and produced the highest leaf area index at silking stage (4.1). Means comparison of traits at different N levels indicated that N level of 225 kg/ha produced the highest ear length (17.82 cm), grain number per ear (401.9), 1000-grain weight (258.8 g), leaf area index at silking stage (4.05) and grain yield (768.5 g/m^2) which were significantly higher than them under N level of 75 kg/ha. According to the results, the treatment of optimum irrigation with minimum N level of 150 kg/ha is recommended for realizing high maize yield in Gonabad, Iran.

Introduction

Water deficiency is one of the most limiting factors of crop production like maize throughout the world. Owing to its climatic diversity, Iran is one of the most prone regions for maize production, whereas two-third of its fields are located in semi-arid regions with frequent drought stresses (Sakinejad, 2003). Severe stress leads to the retardation of tassel emergence until the end of pollination which may be brought about by available water deficiency for the growth of silk cells (Moghadam & Hadizadeh, 2000).

The effect of drought on crop production like maize and its economical losses, particularly during flowering and grain-setting stage has been reported (Abdelmula & Ebrahim-sabile, 2007; Setter *et al*., 2001). Andrade *et al*., (2002) stated that the final grain number of maize had a high correlation with the amount of pre-flowering stored assimilates. Jones & Setter (2000) reported that drought stress changed the synthesis rate of the hormones involved in bearing the grains which in turn, weakened the relationship between assimilate and grain which resulted in ovule sterilization. In a study on the effect of drought stress at different growth stages of maize, Abdelmula & Ebrahim-sabile (2007) found that drought stress at reproductive stage had the most decreasing effect on yield so that the grain yield was 4310 kg/ha under optimum irrigation while it was 3060 kg/ha under drought stress at reproductive stage.

In addition to drought stress, the changes in soil stored N can also affect plant growth and development, too. Lack *et al*., (2008) reported that the decrease in applied N from 220 to 140 kg/ha decreased dry matter yield on average by 235.81 g/m^2. Uhart & Andrade (1995) reported that grain yield and grain number per ear significantly decreased under N deficiency treatments. They suggested grains loss, seed sterilization, the increase in abortion and their undergrowth as the likely reasons for it. Hokmalipour *et al*., (2010) stated increasing of nitrogen levels led to significantly increase in number of seed per ear, 1000-seeds weight and seed yield. Hammad et al., (2011) concluded that maximum plant growth, number of seed per ear and grain yield were recorded in 250 kg N/ha application treatment. Haghighi *et al*., (2010) recorded 5.1 LAI with the application of 300 kg N ha-1. Khaliq et al., (2009) and Cheema *et al.,* (2010) stated that nitrogen application had positive effect on yield in maize and canola, respectively.

Considering the importance of water and N fertilizer in crop production, the current study was carried out in order to study the effect of different N levels and irrigation stop at vegetative and reproductive stages on yield and agronomical traits of maize in Gonabad, Iran.

Materials and Methods

The study was carried out in research field of Islamic Azad University, Gonabad Branch, Gonabad, Iran in 2008. After soil selection, it was prepared and leveled in March-April 2008. Then, the field was furrowed by tractor and furrower with inter-row spacing of 70cm. The soil texture was loam-sandy with pH of 7.7 and total N content of 0.02%. Given the results of soil analysis, the field was fertilized with 110 kg triple super phosphate/ha and 120 kg potassium sulfate/ha. All phosphorus and potasium fertilizer were applied at field surface with planting and then, they were mixed with soil. However, N fertilizer was applied at two phases (8-leaf and tasselling stages) with irrigation water in closed furrows. The seeds were planted in May-June 2008 at the depth of 5 cm with the spacing of 20 cm on each row so that the density of 71400 plants/ha was obtained.

The study was a split plot based on a Randomized Complete Block Design with three replications. The factors included irrigation as main plot at four levels of irrigation stop at 10-leaf, tasseling and grain-filling stages and optimum irrigation (no-stress irrigation) and N fertilizer as the sub-plot at three levels of the application of 75, 150 and 225 kg N/ha. It should be noted that in irrigation-stop treatments, it was stopped for 15 days and then, it was re-started with delay. Afterwards, the irrigation was carried out in constant intervals. Each plot was composed of 6 planting rows and 6 meters long.

For measurement of leaf area index in taselling stage, four plants were randomly selected from the central rows in each plot and using leaf area meter (CI-202), then leaf area index (LAI) was calculated by following formula:

$$LAI = \text{Leaf area} / \text{Ground area}$$

Ten plants were randomly selected from two middle rows and their stem and ear diameter and ear length were measured. The final harvest was conducted at physiological maturity simultaneous with black layer stage in October 7. At final harvest, 3 m^2 of the middle of each plot was selected and then, 1000-grain weight, grain number per ear, grain yield and harvest index were determined. To determine 1000-grain weight, two 1000-grain samples were randomly selected from each plot and were weighed by a digital scale (0.01-gram precision). The grain yield was calculated on the basis of 14% moisture.

At the end, the data were analysis by software MSTAT-C and the means were compared by Multiple Range Duncan Test at 5% probability level.

Results and Discussion

Morphological traits: The irrigation significantly affected morphological traits include stem diameter and length and diameter of ear (Table 1). Means comparison showed that stem diameter under no-stress irrigation treatment (2.24 cm) was significantly higher than those under the other irrigation treatments, but its variation was not significant among water deficiency treatments (Table 2). It appears that water-deficit stress decelerated yield growth rate and therefore, the decrease in assimilate during growth season led to the decrease in dry matter accumulation in stem intercalary meristem and consequently, the decrease in stem diameter. In addition, since the stress at final growth stages may decrease assimilate build-up, the plant resorted to the remobilization of stem storages for filling the grains which led to the decrease in stem diameter. Abdelmula & Ebrahim-sabile (2007) also reported that maize stem diameter decreased under drought stress.

Table 1. Mean square analysis for effects of irrigation and nitrogen levels on morphological traits, leaf area index, yield and yield components of maize.

SOV	df	Ear length	Ear diameter	Stem diameter	Leaf area index	Seed number per ear	1000 seed weight	Seed yield	Harvest index
Replication	2	6.481^{ns}	0.17^{ns}	0.063*	0.047^{ns}	1529.8^{ns}	3.59^{ns}	31551.45^{ns}	2.08^{ns}
Irrigation (A)	3	102.55**	5.721**	0.061*	0.81*	181748.9**	144.4*	945875.5**	823.86**
Error a	6	4.382	0.034	0.009	1.061	2109.03	19.995	13277.7	66.83
Nitrogen (B)	2	30.404**	0.577^{ns}	0.043^{ns}	1.05**	24998.8**	35.97**	135903.25**	11.75^{ns}
A × B	6	1.882^{ns}	0.047^{ns}	0.006^{ns}	0.079^{ns}	659.1^{ns}	4.12^{ns}	3955.88^{ns}	36.26
Error b	16	3.598	0.389	0.18	0.103	1051.14	3.57	100085.58	24.09
CV (%)	-	11.76	17.45	6.25	8.63	9.8	7.87	15.1	12.62

ns Non Significant at 0.05 probability level and ***, **** Significant at 0.05 and 0.01 probability levels, respectively

Table 2. Effect of irrigation on morphological traits, leaf area index, yield and yield components of maize.

Stage of irrigation stop	Ear length (cm)	Ear diameter (cm)	Stem diameter (cm)	Leaf area index	Seed number per ear	1000 seed weight (g)	Seed yield (g/m^2)	Harvest index (%)
optimum irrigation	20.89a	4.75a	2.24a	4.1a	538.9a	298.2a	1128a	48.9a
at 10-leaf	12.99c	3.32b	2.09b	3.3b	291.6c	233.7b	532.5b	37.3b
tasselling	14.91c	3.84c	2.19b	3.6ab	219.2d	219.8b	379.4c	26.4c
grain -filling	15.71b	3.17bc	2.06b	3.7ab	376.6b	208.8b	621.2b	42.9ab

Means followed by the same letters in each column-according to Duncan's multiple range test are not significantly (p<0.05)

The means comparison showed that ear diameter under optimum irrigation conditions was 29.9, 19.1 and 33.5% higher than that under the treatments of irrigation stop at 8-leaf, tasselling and grain-filling stages, respectively, and ear length under optimum irrigation conditions was 38.1, 28.9 and 25.2% higher than that under those treatments, respectively (Table 2). The decrease in ear diameter under water deficit stress was probably because the assimilate produced by photosynthesis was lower under drought stress and this lower amount of assimilate was consumed and/or stored in sources (i.e. leaves); hence, the growth of cobs as the main influencing factor of final ear diameter, which should develop at this stage, was not realized under drought stress. The results showed that the water deficit stress treatments led to the decrease in ear length which was in agreement with Ghadiri & Majidian (2003).

The results of analysis of variance indicated that the change in applied N level significantly affected ear length at 1% level, but it had no significant effect on ear and stem diameter (Table 1). Ghasemi Pirbalooti (2002) did not report significant differences in stem diameter with increased application of N level.

Means comparison showed that ear length was higher under N level of 225 kg/ha than N levels of 150 and 75 kg/ha by 12.1 and 21.6%, respectively (Table 3). The results are in agreement with Ghadiri & Majidian (2003)'s study. It appears that ear length decreased under N deficiency conditions due to the decrease in leaf area and therefore, in assimilates production.

Table 3. Effect of nitrogen levels on morphological traits, leaf area index, yield and yield components of maize.

Nitrogen (kg N/ha)	Ear length (cm)	Ear diameter (cm)	Stem diameter (cm)	Leaf area index	Seed number per ear	1000 seed weight (g)	Seed yield (g/m^2)	Harvest index (%)
75	14.66c	3.38a	2.06b	3.5b	313.7c	224.4b	555.9b	37.7a
150	15.89b	3.53a	2.14ab	3.7b	354.1b	237.7b	671.4a	39.6a
225	17.82a	3.81a	2.18a	4.1a	401.8a	258.8a	768.5a	39.3a

Means followed by the same letters in each column-according to Duncan's multiple range test are not significantly ($p<0.05$)

Leaf area index (LAI): The change in irrigation water quantity and N level significantly affected LAI at silking stage (Table 1). The mean LAIs under the treatments of no-stress irrigation and irrigation stop at 8-leaf, tasselling and grain-filling stages were 4.11, 3.3, 3.6 and 3.7, respectively (Table 2). The increase or decrease in LAI directly affects plant growth rate. These indexes are the main tool for enhancing photosynthesis capacity and assimilate production. Lizaso *et al*., (2003) also stated that the average absorbed photosynthetic active radiation (PAR) by leaf area at silking stage was the determining factor of maize grain number and the decrease in grain yield had a high correlation with the decrease in maize leaf area.

Means comparison of LAI indicated that the application of 225 kg N/ha had higher LAI than the application of 75kg N/ha by 16.3% (Table 3). It seems that N deficiency decreased the LAI due to decreased leaf area expansion and leaf area duration. Also, Hammad *et al.,* (2011) concluded that the highest LAI obtained with the application of 250 kg N/ha, while Oscar & Tollenaar (2006) on maize and Jan *et al.,* (2011) on barley stated that LAI of increased with the application of higher rate of N. Leaf expansion was improved in plants by giving optimum nitrogen fertilizer and leaf area expansion was illustrated in terms of leaf length and numbers of leaves.

Grain yield components: Given that the maize cultivar 704 is single-ear, its grain yield is dependent on grain number per ear and grain weight and the factors influencing these 2 components changes its grain yield. The results of analysis of variance showed that grain number/ear and 1000-grain weight were significantly affected by irrigation and N level, while the interaction did not significantly affect them (Table 1).

Grain number per ear: Means comparison showed that the treatment of no-stress (optimum) irrigation had the highest grain number per ear (538.9) which was higher than that under the treatments of irrigation stop at 8-leaf, tasselling and grain-filling stages by 45.9, 59.3 and 30.1%, respectively (Table 2).

It seems that the direct effect of drought stress on grain number was because of the decrease in ovary water potential. On the other hand, the final grain number in maize is highly dependent on pre-flowering stored assimilate and the increase in assimilate level is directly related to the crop growth rate. Therefore, irrigation stop at every growth stage adversely affected grain number/ear. It is likely that the significant decrease in grain number under the treatment of irrigation stop at tasselling stage was due the unsimultaneous emergence of male and female organs and the period of time from flowering of tassels to silking was extended. Furthermore, the severe decrease in this trait under irrigation stop conditions can be associated with the disruption in the transfer of flowing and stored assimilates to ears. These results are in agreement with the results of Lack *et al*., (2008) on maize. Ghadiri & Majidian (2003) suggested that drought stress during vegetative phase decreased grain number/ear and the stress during flowering had more moderate effect on grain number and so did the stress during grain-filling stage on grain number, and its strongest effect was on grain weight.

The increase in N application level had a significant positive effect on main grain number/ear, so that its grain production potential was increased by 28.1% as N application level increased from 75 to 225 kg N/ha (Table 3).

Higher N application level increased LAI and assimilate availability to ears by photosynthesis persistence and hence, grain number per ear increased because of the lower inter-grain competition over nutrients. Ghasemi Pirbalooti (2002) similarly reported that nutrient availability particularly N at critical stage of grain formation, i.e. from 1-2 weeks before silk formation to 3 weeks after that, affected grain number by accelerating plants growth.

Girardin *et al*., (1978) also stated that N deficiency from germination stage to the stage of the development of sixth and seventh leaves led to the decrease in grain number/ear. They also noted that the stored carbohydrates and N during flowering phase was the determining factor of grain-setting level of ears and N deficiency affected grain number through decreasing assimilates. The correlation coefficient of seed per ear with seed yield was highly significant (R^2= 0.971, Table 4). These results agree with those of Hammad *et al.,* (2011) and Melchiori & Caviglia (2008) in this regard.

Table 4. Correlation coefficient between traits of maize

Trait	Seed yield	Number of seed per ear	1000 seed weight	Harvest index	Leaf area index	Stem diameter	Ear length	Ear diameter
Seed yield	1							
Number of seed per ear	0.971**	1						
1000 seed weight	0.752**	0.825**	1					
Harvest index	0.823**	0.723**	0.397*	1				
Leaf area index	0.519**	0.5**	0.44**	0.232ns	1			
Stem diameter	0.436**	0.447**	0.419**	0.193ns	0.432**	1		
Ear Length	0.768**	0.667**	0.641**	0.463**	0.635**	0.399*	1	
Ear diameter	0.8**	0.819**	0.715**	0.579**	0.474**	0.546**	0.654**	1

ns Non Significant at 0.05 probability level and *, ** Significant at 0.05 and 0.01 probability levels, respectively

1000-grain weight: The results of the current study showed that although the treatment of irrigation stop at vegetative and reproductive stages showed no significant differences, the treatment of optimum irrigation (with mean 1000-grain weight of 289.2 g) significantly had higher 1000-grain weight than the treatments of irrigation stop by 27.6 up to 42.8% (Table 2). The decrease in 1000-grain weight under irrigation stop treatments could be related to the lower level of carbohydrates stored in vegetative organs before pollination and to the decrease in leaf area duration which resulted in shortened grain-filling period. The results of current study confirm the results of the earlier studies in which it has been suggested that drought stress decreased the source potential and available assimilates level and hence, decreases grain weight (Borra's *et al*., 2003).

With increased of N application from 75 to 225 kg/ha, 1000-grain weight also significantly increased by 15.3% (Table 3). Hokmalipour *et al*., (2010) also on maize and Noorka *et al.*, (2011) on sesame reported that that N deficiency decreased 1000-grain weight. It seems that the increase in applied N level up to 225 kg/ha increased 1000-grain weight by increasing leaf area index and duration, extending gain-filling period and producing more assimilates.

Grain Yield: The results of analysis of variance showed that drought stress and N fertilizer had significant effect on grain yield at 1% level, but their interactions were in significant (Table 1). Means comparison indicated that grain yield was considerably higher under optimum irrigation treatment (1128 g/m^2) than under irrigation stop treatments (Table 2).

The final yield of maize depends on successful development of flowers, their full fertility, embryo development and starch and protein accumulation in grains and each of them needs continuous supply of assimilates (Tollenaar & Daynard, 1978). However, moisture stress decreases assimilate supply by decreasing leaf area and duration and disrupting nutrient intake and transfer and hence, it decreases grain yield components and yield. Grant *et al*., (1989) stated that water deficit severely decreased yield through abnormal development of embryo sac and grain sterility and finally, it decreased fertile grain number.

Means comparison of grain yield at different N levels showed that as N level was increased from 75 to 225 kg N/ha, grain yield increased accordingly by 38.2% (Table 3). The increase in grain yield due to the increase in applied N level was due to the formation of strong sources – i.e. more grains – and source activity – i.e. higher LAI and longer leaf duration. Girardin *et al*., (1978) and Hammad *et al.*, (2011) also stated that N deficiency decreased grain yield by decreasing seed number per ear and seed weight.

In the current study, it was found that N availability under water deficit conditions caused that the part of the decrease in yield which was due to the delayed development under drought stress was compensated. There is significant positive correlation between seed yield with its components, LAI and morphological traits (Table 4). Otegui & Andrade (2000) reported positive relationship of grain yield with these traits. Difference in the yield components, LAI and morphological traits lead to significant change grain yield.

Harvest index (HI): The results of analysis of variance indicated that irrigation treatment had significant effect on HI, but applied N level and the interaction between irrigation and N were insignificant (Table 1). The comparison of means showed that the highest HI (48.94%) was obtained under optimum irrigation treatment (Table 2). The decrease in HI under water deficit stress showed the fact that both grain yield and total dry matter decreased under drought stress, but grain yield decreased more that decreased HI. In the current study, total dry matter was 2306.6, 1420.3, 1414.4 and 1468.4 g/m^2 under the treatments of no-stress and stress at 8-leaf, tasselling and grain-filling stages which showed that the decreased dry matter production on one hand and decreased grain yield on the other hand that led to the decrease in HI. Lack *et al*., (2008) also reported that maize HI decreased under drought stress. Perhaps, in addition to decreasing produced dry matter, water deficit disrupts the partitioning of carbohydrates to grains and hence, decreases HI. Lack *et al*., (2008) suggested that N application did not change assimilate partitioning and increased grain yield and dry matter similarly. The results of Ghadiri & Majidian (2003) also confirmed the results of this study.

Conclusion

It is concluded that water-deficit stress at different growth stages can considerably decrease yield and yield components of maize. However, growth and yield loss of maize was greater when drought stress occurred at tasselling stage than when it occurred at vegetative growth and grain-filling stages. In addition, the increase in N application could partly compensate the yield loss due to the low irrigation.

References

Abdelmula, A.A. and S.A. Ibrahim Sabie1. 2007. *Genotypic and differential responses of growth and yield of some maize (Zea mays L.) genotypes to drought stress*. University of Kassel-Witzenhausen and University of Gottingen.

Andrade, F.H., L. Echarte, R. Rizzalli, A. Della Maggiora and M. Casanovas. 2002. Kernel number prediction in maize under nitrogen or water stress. *Crop Science*, 42: 123-132.

Borra's, L., M.E. Westgate and M.E. Otegui. 2003. Control of kernel weight and kernel water relation by post-flowering source-sink ratio in maize. *Annals of Botany,* 91: 857-867.

Cheema, M.A., M.F. Saleem, N. Muhammad, M.A. Wahid and B.H. Baber. 2010. Impact of rate and timing of nitrogen application on yield and quality of canola (*Brassica napus* L.). *Pak. J. Bot.,* 42(3): 1723-1731.

Ghadiri, H. and M. Majidian. 2003. Effect of different nitrogen fertilizer levels and moisture stress during milky and dough stages on grain yield, yield components and water use efficiency of corn (*Zea mays* L.). *J. Sci. & Technol. Agri. Nat. Res.,* 7(2): 103-112.

Ghasemi Pirbalooti, A. 2002. *Study of effect of different N levels on dry matter partitioning pattern in corn cv. 704 in Varamin, Iran*. M.Sc. Thesis on Agriculture, University of Tehran, Tehran, Iran.

Girardin, P., M. Tollenaar, A. Deltour and J. Muldoon. 1987. Temporary N starvation in maize (*Zea mays* L.) effects on development, dry matter accumulation and grain yield. *Aronornie (Paris)*, 22: 289-296.

Grant, R.F., B.C. Jackson, J.R. Kiniry and G.F. Arkin. 1989. Water deficit timing effects on yield components in maize. *Agron. J.,* 81: 61-65.

Haghighi, B.J., Z. Yarmahmodi and O. Alizadeh. 2010. Evaluation the effects of biological fertilizer on physiological characteristic and yield and its components of corn (*Zea mays* L.) under drought stress. *Ameri J. Agri & Bio Sci.,* 5(2): 189-193.

Hammad, H.M., A.A. Ahmad, A. Wajid and J. Akhter. 2011. Maize response to time and rate of nitrogen application. *Pak. J. Bot.,* 43(4): 1935-1942.

Hokmalipour, S., M. Shirie-Janagard, M. Hamele Darbandi, F. Peyghamie-Ashenaee, M. Hasanzadeh, M. Naser Seiedi and R. Shabani. 2010. Comparison of agronomical nitrogen use efficiency in three cultivars of corn as affected by nitrogen fertilizer levels. *World Applied Sciences Journal,* 8(10): 1168-1174.

Jan, A., I. Daur, Z. Muhammad and I.A. Khan. 2011. Effect of mungbean and nitrogen levels on barley. *Pak. J. Bot.,* 43(4): 1905-1908.

Jones, R. and T. Setter. 2000. Hormonal regulation of early kernel development. In: *Physiology and modeling kernel set in maize*. (Eds.): M. Westgate and K. Boote. CSSA Spec. Publ. 29. CSSA, Madison, WI. pp. 2542.

Khaliq, T.A. Ahmad, A. Hussain and M.A. Ali. 2009. Maize hybrids response to nitrogen rates at multiple locations in semiarid environment. *Pak. J. Bot.,* 41(1): 207-224.

Lack, S., A. Naderi, S.A. Siadat, A. Ayenehband, G.H. Nourmohammadi and S.H. Moosavi. 2008. The effects of different levels of irrigation, nitrogen and plant population on yield, yield components and dry matter remobilization of corn at climatical conditions of Khuzestan. *J. Sci. & Technol. Agri. Nat. Res*., 11(42): 1-14.

Lizaso, J.I., W.D. Batchelor. M.F. Westgate, and L. Echarte. 2003. Enhancing the abil Iity of CERES-Maize to compute light capture. *Agric. Syst.,* 76: 293-311.

Melchiori, R.J.M. and O.P. Caviglia. 2008. Maize kernel growth and kernel water relations as affected by nitrogen supply. *Field Crops Res.,* 108: 198-205.

Moghadam, A. and M.H. Hadizadeh. 2000. Study in density stress in selection of drought tolerant varieties in corn. *Iranian journal of Crop Sci.,* 2(3): 25-38.

Noorka, I.R., S.I. Hafiz and M.A.S. El-Bramawy. 2011. Response of sesame to population densities and nitrogen fertilization on newly reclaimed sandy soils. *Pak. J. Bot.,* 43(4): 1953-1958.

Oscar, R.V. and M. Tollennar. 2006. Effect of genotype, nitrogen, plant density and row spacing on the area-per-leaf profile in maize. *Agron J.,* 98: 94-99.

Otegui, M.E., and F.H. Andrade. 2000. New relationships between light interception, ear growth and kernel set in maize. In: *Physiology and modeling kernel set in maize*. (Eds.): M.E. Westgate and K. Boote. CSSA Spec. Publ. 29. CSSA. pp. 89-102.

Sakinejad, T. 2003. *Study of effect of water deficit on the trend of uptake of N, P, K and Na at different growth stages considering the morphological and physiological traits of maize in Ahvaz climate*. Ph.D. Thesis on Crop Physiology, Science and Research Branch, Ahvaz, Iran, Pp. 288.

Setter, T.L., B.A. Flannigan and J. Melkonian. 2001. Loss of kernel set due to water deficit and shade in maize: carbohydrate supplies, abscisic acid, and cytokinins. *Crop Sci*., 41: 1530-1540.

Tollenaar, M. and T.B. Daynard. 1978. Effect of defoliation on kernel development in maize. *Can. J. Plant Sci.,* 58: 207-212.

Uhart, S.A. and F.H. Andrade. 1995. Nitrogen deficiency in maize: II. Carbon-nitrogen interaction effects on kernel number and grain yield. *Crop Sci.,* 35: 1384 -1389.

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