Pak. J. Bot., 44(5): 1551-1555, 2012.

EFFECT OF IRRIGATION AND NITROGEN LEVEL ON YIELD, YIELD COMPONENTS AND SOME MORPHOLOGICAL TRAITS OF SUNFLOWER

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Abstract

To study the effect of water deficit and N fertilizer on some morphological traits, yield and yield components of sunflower cv. Progress, a study was carried out as a split plot experiment based on a Randomized Complete Block Design with three replications in research field of Islamic Azad University, Birjand Branch, Iran in 2009. In this study, the irrigation was the main plot at three levels including supplying 100, 67 and 33% of plant water requirement (PWR) and N fertilizer was the sub-plot at four levels of 0, 60, 90 and 120 kg N/ha. The results of analysis of variance showed that irrigation significantly affected plant height, stem diameter, head diameter, seed number per head, 1000-seed weight and seed yield, and N significantly affected all morphological traits, yield and yield components, but the interactions between irrigation and N level significantly affected none of the studied traits. The treatment of supplying 100% of PWR produced the highest seed number per head (680.43), 1000-seed weight (46.58 g) and seed yield (3567.67 kg/ha) which was superior over the treatments of supplying 67 and 33% of PWR by 24.1 and 67% in the case of seed number and by 27.2 and 57.8% in the case of 1000-seed weight, respectively. The seed yield under the treatment of supplying 100% of PWR was 2.64 times greater than that under the treatment of supplying 33% of PWR and with the decrease in supplying PWR from 100 to 33%, plant height, stem diameter and head diameter decreased by 32, 21.9 and 30.8%, respectively. In addition, with the increase in N fertilizer level from 0 to 120 kg/ha, plant height, stem diameter, leaf number, head diameter, seed number/head, 1000-seed weight and seed yield significantly increased by 15.6, 14.4, 13.2, 17.1, 24.2, 13 and 49.1%, respectively. In total, on the basis of the results, the treatment of optimum irrigation and application of 120 kg N/ha can be recommended for realizing high productivity in sunflower cultivation under the conditions of the current study.

Introduction

Iran is climatically regarded as an arid and semi-arid region in the world, where the lack of precipitation and its inappropriate distribution, high temperature and extensive evaporation makes the irrigation the main way for meeting plants water demand. Without supplying enough moisture, it is impossible to realize optimum yield and to optimally utilize other inputs like machineries, fertilizers, seeds, pesticides and all production-related farming operations (Rana & Katerji, 2000; Iftikhar *et al.,* 2010; Babar *et al.,* 2011). Hence, studying the effect of irrigation on agriculture is more important in arid regions like most parts of Iran where water is a limiting factor of cultivation area and yield per unit area.

Sharing 2.8% of total world oilseeds (around 107 million ton), sunflower is the fifth most important edible oil producer, following soybean, rape, cotton and peanut (FAS, 2005). Its cultivation is interested in different environments because of its high yield as well as its extensive adaptability and acclimation, high photosynthesis potential and high harvest index (Agele *et al*., 2007).

Goksoy *et al*., (2004) also reported the adverse effect of limited irrigation on plant height of sunflower. David *et al*., (2000) and Noora *et al*., (2009) indicated that N application had significant effect on final height of sesame plants. Abazarian *et al*., (2010) showed that the increase in N level improved N absorption and stem growth so that the highest sunflower stem length and diameter was obtained at N level of 180 kg/ha. Also N application increased LAI in barley (Jan *et al.,* 2011).

In a study on the effect of N fertilizer on sunflower cv. Progress, Mardan & Kazemi (2010) reported that the stem length and diameter significantly increased as N level was increased from 25 to 150 kg/ha. An increase in head diameter with the increase in N fertilizer application has also been reported in study Mahal & Makota (1998).

Various studies have stated the decrease in sunflower grain yield under limited irrigation conditions (Ohashi *et al*., 2009; Poormohammad Kiani *et al*., 2007; Goksoy *et al*., 2004; Erdem *et al*., 2006). Daneshian *et al*., (2009) and Gholinejad *et al*., (2009) demonstrated that sunflower 1000-seed weight and seed yield significantly decreased as affected by water deficit stress. Daneshian *et al*., (2008) suggested that limited irrigation decreased seed number per head through severely decreasing head diameter and dry weight on one hand and it decreased seed yield through significantly decreasing 1000-seed weight on the other hand.

Seed number/head and seed weight are regarded as the main components of sunflower seed yield which are affected by such environmental factors as soil fertility. Abazarian *et al*., (2010) stated that 1000-seed weight increased with the increase in N availability and N transfer to seeds. In a study on the effects of different N levels and plant densities on yield and yield components of sunflower cv. Progress, Mardan & Kazemi (2010) reported that the application of 150 kg N/ha produced the highest seed yield (3948 kg/ha) and the application of 25 kg N/ha produced the lowest one (2826 kg/ha). Due to their importance and multiple functions in plant living processes, water and N are considered as important environmental factors affecting plants cultivation and production. Therefore, the current study was carried out to investigate sunflower yield traits as affected by these two factors in Birjand, east of Iran.

Materials and Methods

The study was carried out in research field of Islamic Azad University, Birjand Branch, Birjand, Iran (Long. 59°13´ E., Lat. 32°52´ N., Alt. 1480 m) during spring of 2009. The soil texture was loam, its PH was 8.05 and its total N content was 0.034%. The study was a split plot experiment based on a Randomized Complete Block Design with three replications. The main plot was irrigation treatment at three levels of supplying 33, 67 and 100% of plant water requirement (PWR) and the sub-plot was N fertilizer at 4 levels of 0, 60, 90 and 120 kg N/ha.

The plots were 6 m long and 2.7 m wide including 6 rows. The basic fertilizer (100 kg potassium sulfate/ha + 150 kg super phosphate triple /ha) was applied before seedbed preparation. The seeds of sunflower cv. Progress were manually planted at the depth of 4 cm on July 9, 2009.

The final thinning of plants was carried out at 4-5-leaf stage with keeping inter-plant spacing of 25 cm on rows on July 20. Afterwards, the plots were irrigated once every 6-8 days according to irrigation treatments. Contour and pressurized irrigation system was used and PWR was determined by FAO method using evaporation for class A evaporation pan and considering 90% efficiency of water distribution over field. Based on this method, to determine PWR, the evapotranspiration of reference plant was calculated by daily data of evaporation from evaporation pan and then, sunflower water demand was determined by applying crop coefficient (K_c) (Helen *et al*., 1998). Half of required N fertilizer (urea source) was applied at the first irrigation after thinning and the remaining was applied with irrigation at mid-August along with the initiation of reproductive stage of plants.

The plants were harvested during September-October 2009 when the stems started to get dried from inside and the back of heads had been browned. To measure morphological traits, 10 plants were randomly harvested from two middle rows and their plant height, stem diameter, leaf number/plant and head diameter were measured. To determine yield, the seeds of the plants in the middle 4 m^2 were collected and winnowed. To determine 1000-seed weight of various treatments, 1000 seeds were randomly selected from seed pool of each plot by seed-counter and weighed. Seed number per head was calculated on the basis of 1000-seed weight, seed yield and harvested head number in each plot, too. The harvest index (HI) was determined by:

$$HI = (\text{grain yield}/\text{biological yield}) \times 100$$

Finally, the data were analyzed by software MSTAT-C for each trait and the means were compared by Duncan Multiple Range Test at 5% level.

Results and Discussion

1. Morphological traits: The results showed that irrigation significantly affected plant height, stem diameter and head diameter but it had no significant effect on leaf number/plant (Table 1). Means comparison showed that the plant height, stem diameter and head diameter were the highest under optimum irrigation and they decreased by 32, 21.9 and 30.8% with the decrease in irrigation amount from 100 to 33% of plant water requirement, respectively (Table 2). It appears that water deficit stress mainly affects leaf size. Lawlor (2002) reported that water deficit stress suppressed the growth of stem and leaf cells and decreased leaf area, but it did not affect leaf number which was in agreement with the results of the current study. The decrease in final plant height and head diameter with the decrease in soil moisture under severe water deficit stress can be related to the disruption of photosynthesis due to water deficit stress and the decrease in production of assimilates to be partitioned among growing parts of the plants and eventually, the inability of plant in realizing its genetic potential in terms of head diameter and height. Baroutzadeh *et al*., (2009) also stated that the decrease in plant height under water deficit stress was due to the high sensitivity of cell division and growth to drought stress since the decrease in water potential of tissues reduced cell turgor pressure so much that it was not enough for their enlargement and it led to the decrease in cell enlargement. These results are in agreement with the findings of some studies on sunflower like Daneshian *et al*., (2008).

Table 1. Variance analysis for effects of irrigation and nitrogen level on morphological traits and yield and yield components of sunflower.

Harvest index	Seed yield	1000 seed weight	Seed number per head	Head diameter	Leaf number per plant	Stem diameter	Plant height	df	SOV
99.223 ns	409578.133 ns	16.631 ns	18343.325*	0.776 ns	17.503 ns	0.415 ns	156.963ns	2	Replication
97.698ns	14906978.566**	880.604**	223560.965**	39.938*	3.659 ns	22.72**	5515.774**	2	Irrigation (A)
20.463	114797.183	16.5	734.537	2.273	2.959	0.821	59.062	4	Error a
29.752*	1544594.675**	54.866*	22528.174**	4.85**	25.144**	3.759**	401.55**	3	Nitrogen (B)
4.34 ns	205460.817 ns	12.789 ns	2893.017 ns	0.528 ns	2.042 ns	0.456 ns	12.263 ns	6	A × B
6.901	92119.671	19.692	1977.494	0.254	1.906	0.175	11.777	18	Error b
8.41	12.69	11.81	8.15	5.04	4.68	3.86	3.21	-	CV (%)

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 and yield and yield components of sunflower.

Harvest Index (%)	Seed yield (kg/ha)	1000 seed weight (gr)	Seed number per head	Head diameter (cm)	Leaf number per plant	Stem diameter (mm)	Plant height (cm)	Irrigation (% supply plant water requirement)
28.00b	1350.80c	29.52c	407.49c	8.16c	29.55c	9.65c	88.8c	33
33.37a	2257.07b	36.63b	548.21b	10.27b	29.98b	10.35b	101.5b	67
32.36ab	3567.67a	46.58a	680.43a	11.79a	28.88a	12.35a	130.6a	100

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

Our result are in agreement with Goksoy *et al*., (2004), Cox & Julliff (1988) and Mozzafari *et al*., (1996) who also reported the decrease in sunflower head diameter under water deficit and limited irrigation stress.

Since stem diameter is a trait with a direct relation with growth status and assimilate transfer to head, thus it affects seed yield and seed acquires much of its required nutrients from storages of stem and head under drought stress, then stem and head diameter decreases.

Analysis of variance showed that the change in applied N level significantly affected studied morphological traits at 1% level, but the interaction between irrigation and N did not significantly affect them (Table 1). Means comparison at different N levels showed the positive effect of the increase in N level on morphological traits, so that with the increase in N level from 0 to 120 kg N/ha, plant height, stem diameter, leaf number per plant and head diameter increased by 15.6, 14.4, 13.2 and 17.1%, respectively (Table 2).

Probably, leaf insufficiency or early leaf shedding due to N deficiency which decreases plant photosynthesis potential, can be the main causes of the decrease in vegetative growth under low N levels. In other words, the decrease in leaf area index and duration and as a result, the decrease in photosynthesis potential can be regarded as the reasons for the significant decrease in morphological traits under N deficiency. Also, other reports regarding sunflower show that plant vegetative growth increases with increasing N fertilizer level (Mardan & Kazemi, 2010; Abazarian *et al*., 2010).

It is reported that head diameter was more affected by environmental factors than by genetic factors and was severely affected by N level, so that higher N levels increased head diameter. Other studies such as Gholinejad *et al*., (2009) and Mahal & Makota (1998) reported an increase in head diameter with the increase in N fertilizer level, too.

2. Seed yield and yield components: The results of analysis of variance indicated that irrigation and N levels significantly affected sunflower seed number per head, 1000-seed weight and seed yield at 1% level, but the interaction between irrigation and N level did not significantly affect any traits and harvest index was only affected by N level (Table 1).

According to the results of means comparison, the highest seed number per head (680.43) was obtained under the treatment of supplying 100% of PWR which was significantly greater than that under moderate and severe stress treatments by 24.1 and 67%, respectively (Table 2). Since potential flower number is the factor changing seed number per head which is determined particularly by leaf expansion during vegetative growth period (Shakoori, 2004), water deficit stress during growing period decreases plant photosynthesis source and enzymatic activity by the decrease in leaf area and its shedding (Roshdi *et al*., 2006) and then, it decreases head size and flower number per head.

Seed number per head increased by 7.1, 10.9 and 24.2% with the increase in fertilizer level from 0 to 60, 90 and 120 kg N/ha. The treatment of no-fertilizer application had the lowest seed production potential per head (493.27 seeds per head) (Table 3). It appears that higher N levels increased diameter size mainly through increasing plant photosynthesis potential and providing assimilates due to the increase in leaf area index and duration by which it allowed the formation of more seeds per head. Different studies reported that N fertilizer significantly increased seed number per head (Fathi *et al*., 1997; Mishra *et al*., 1995).

Table 3. Effect of nitrogen level on morphological traits and yield and yield components of sunflower

Harvest Index (%)	Seed yield (kg/ha)	1000 seed weight (gr)	Seed number per head	Head diameter (cm)	Leaf number per plant	Stem diameter (mm)	Plant height (cm)	Nitrogen (kg N/ha)
29.59b	1961.16c	36.03c	493.27c	9.30b	27.80c	10.19c	100.1c	0
30.58b	2197.60bc	35.22c	528.46bc	9.63b	28.42bc	10.50c	104bc	60
30.99b	2484.80b	38.35b	547.30b	10.47a	30.19b	11.02b	108.1b	90
33.82a	2923.82a	40.70a	612.49a	10.89a	31.46a	11.66a	115.1a	120

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

According to the results, water deficit stress decreased 1000-seed weight, so that the treatment of supplying 100% of PWR produced the highest 1000-seed weight (46.58 g) which was higher than that under moderate and severe stress by 21.4 and 36.6%, respectively (Table 2). This is in agreement with the results of Rafie *et al*., (2005) and Noorka *et al.,* (2011). The decrease in 1000-seed weight under water deficit stress was probably because of the decrease in water and minerals uptake by plant and the decrease in assimilate building and transfer to seeds and half-filling of seeds.

The increase in N fertilizer application had positive effect on the increase in seed weight, so that the application of 120 kg N/ha produced the highest 1000-seed weight (40.70 g) which was 13% higher than thosewith no-fertilizer application (Table 3). Seemingly, with the increase in N application, plant photosynthesizing area and assimilate production and distribution among sources increased and therefore 1000-seed weight increased. Mardan and Kazemi (2010) reported similar results for sunflower.

Means comparison showed that the treatment of supplying 100% of PWR (optimum irrigation) produced the highest seed yield (3567.67 kg/ha) which was 2.64 times as great as that under severe water deficit stress (Table 2). The decrease in sunflower seed yield under drought stress is in agreement with the results of Haji Hassani *et al*., (2008), Goksoy *et al*., (2004), Chimenti & Halll (2002) and Erdem *et al*., (2006). It can be said that seed yield decreased under limited irrigation conditions because of the decrease in plant growing period, seed filling, head diameter, seed number per head and 1000-seed weight and the increase in unfilled head percentage. Overall, it can be concluded that probably the stomatal closure and as a result, the decrease in CO_2 inflow to the plant along with the decrease in leaf area and duration were the main reasons for the decrease in photosynthesis under water deficit conditions and the decrease in seed yield and yield components.

The increase in N application from 0 to 60, 90 and 120 kg/ha increased seed yield by 12.1, 26.7 and 49.1%, respectively. The lowest seed yield (1961.16 kg/ha) was associated with no-fertilizer application (Table 3). It can be said that the increase in N level paved the way for the increase in head diameter, 1000-seed weight and seed number/diameter by increasing plant assimilate-making capacity (increasing leaf area and duration).

In the current study, irrigation and the interactions between irrigation and N did not significantly affect seed harvest index, but N fertilizer significantly affected it at 5% level (Table 1). Nonetheless, means comparison showed that the treatment of supplying 67% of PWR with seed harvest index of 33.37% was significantly superior over the treatment of supplying 33% of PWR with seed harvest index of 28% (Table 2). The results of the study are in agreement with the findings of Cox & Julliff (1988) who reported that dry matter decreased with the decrease in applied water, but the loss of seed yield due to the water deficiency was greater than the decrease in biological yield.

Means comparison showed that the treatment of applying 120 kg N/ha produced the highest seed harvest index (33.82%) which was superior over other N levels (Table 3). Also, Aboomardani *et al*., (2010) reported that harvest index increased from 20.62 to 22.80% with the increase in N application from 0 to 80 kg/ha.

Conclusion

In total, the results of the current study indicated that nitrogen and water deficiency significantly decreased sunflower economical yield by decreasing seed number per head and 1000-seed weight and the treatment of optimum irrigation and application of 120 kg N/ha can be recommended for realizing high productivity in sunflower cultivation under the conditions of the current study.

References

Abazarian, R., K. Khosroyar, D. Sarvari, P. Arvin and M. Barzgar. 2010. Effect of different N levels on morphological traits, yield and yield components of sunflower (cv. Masters). Proceedings of 3rd International Conference on Oilseeds and Edible Seeds, Tehran, Iran, Dec. 22-23.

Aboomardani, Y., A. Faraghi, M. Asadi, A. Atrakchali and R. Mhafi. 2010. Study of different nitrogen and plant density levels on yield and harvest index of canola. Proceedings of 3rd International Conference on Oilseeds and Edible Seeds, Tehran, Iran, Dec. 22-23.

Agele, S.O., I.O. Maraiyesa and I.A. Adeniji. 2007. Effects of variety seed set efficiency in late season sunflower (*Helianthus annus* L.) in a humid zone of Nigeria. *Academic journals*, 2: 80-88.

Anonymous. 2005. Oilseeds: world market and trades. Current World Production, Market and trade reports. http://www.fas.usda.gov.

Babar, L.K., T. Iftikhar, H. N. Khan and M. A. Hameed. 2011. Agronomic trials on sugarcane crop under Faisalabad conditions, Pakistan. 43(2): 929-935. *Pakistan Journal of Botany*.

Baroutzadeh, M., A. Ayeneband and M. Alavifazel. 2009. The study water deficit stress and plant density levels on yield and morphological traits of maize. Proceedings of 1rd National Conference of water crisis in agriculture. Islamic Azad University, Sharerey Branch, Iran.

Chimenti, C.A. and J. Hall. 2002. Osmotic adjustment and yield maintenance under drought in sunflower. *Field Crops Research*, 75: 235-246.

Cox, E. and G.D. Julliff. 1988. Growth and yield of sunflower and soybean under soil deficits. *Agron. J*., 78: 226-230.

Daneshian, J., H. Hadi and P. Jonoubi. 2009. Study of quantitative and quality characteristics of soybean genotypes in deficit irrigation condition. *Iranian Journal of Crop Science*, 11(4): 393-409.

Daneshian, J., H. Jabbari, A. Moghadam Khamseh, A. Lotfifar, G. Akbari, M. Panahi and P. Joonoobi. 2008. Evaluation of responses of sunflower hybrids to different irrigation levels. *Journal of Modern Agronomical Technology, Special Issue on Soil and Water Sciences*, 2(1): 21-29.

David, B., L. Lambert. B. Mccarty and W.C. Bridges. 2000. Mowing and nitrogen influence green kyllinga (*Kyllinga brevifolia*) infestation in tifway Bermudagrass (*Cynodon dactylon, C. transvaalensis*) turf. *Weed Technology*, 14: 471-475.

Erdem, T., Y. Erdem, A.H. Orta and H. Okursoy. 2006. Use of a crop water stress index for scheduling the irrigation of sunflower (*Helianthus annuus* L.). *Turk. J.* Agric. *For*., 30: 11-20.

Fathi, G., G.K. Mc. Donald and R.C.M. Lance. 1997. Effects of post-anthesis water stress on the yield and grain protein concentration of barley grown at two levels of nitrogen *Aust. J. Agri. Res.,* 48: 67-80.

Gholinejad, A., A. Ainehband, A. Hassanzadeh, A. Barnoosi and H. Rezaei. 2009. Study of effect of drought stress at different N levels and planting densitie son yield, grain yield components and harvest index of sunflower in Urumiah, *Iran. J. Plant Prod. Res.*, 16(3): 1-27.

Goksoy, A.T., A.O. Demir, Z.M. Turan and N. Dagustu. 2004. Responses of sunflower to full and limited irrigation at different growth stages. *Filed Crops Res*., 87: 167-178.

Hajihassani Asl, N., M. Roshdi, M. Ghafari, A. Alizadeh and A. Moradiaghdam. 2008. Effects of drought stress and thinning on growth indices of oil sunflower. *Journal of Research on Agronomical Sciences*, 1(1): 34-41.

Hllen, R. G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop evapotranspiration – guidelines for computing crop water requirements . *FAO Irrigation and Drainage*, No 56. pp: 125-132.

Iftikhar,T., L. K. Babar, S. Zahoor, N. G. Khan. 2010. "Best Irrigation Management Practices In Cotton" *Pakistan Journal of Botany*. 42(5): 3023-3028.

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.

Lawlor, D.M. 2002. Limitation to photosynthesis in water-stressed leaves: stomata vs. metabolism and the role of ATP. *Ann. Bot.*, 89: 871-885.

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.

Rafi'e, F., A. Kashani, R. Mameghani and A. Golchin. 2005. Effect of irrigation stages and N application on yield and some morphological traits of sunflower, hybrid Golshid. *Iranian Journal of Agriculture Sciences*, 7(1): 44-54.

Rana, G. and N. Katerji. 2000. Measurement and estimation of actual evapotranspiration in the field under meditrranean climate: a review. *European J. of Agron*., 13: 125-153.

Roshdi, M., S. Rezadoost and J. Khalilimahaleh. 2006. Study of effects of planting density and thinning at development stages on yield and yield components of sunflower. Proceedings of 9th Iranian Conference on Agronomy and Planting Breeding, Tehran University, p. 95.

Shakoori, A. 2004. Study of effects of different soil-preparing systems and foliar spray of zinc and magnesium on qualitative and quantitative yield of sunflower. M.Sc. Thesis on Agronomy, Department of Agriculture, University of Uromiah, Iran.

Mardan, R. and S. Kazemi. 2010. Effect of different N levels and planting densities on yield and yield components of sunflower cv. Progress. Proceedings of 3rd International Conference on Oilseeds and Edible Seeds, Tehran, Dec. 22-23.

Mahal, S. S. and H. S. Makota. 1998. Performance of spring sunflower (*Helianthus annuus* L.) under different levels of soil moisture regime and nitrogen. *Environmental Ecology*, 16(3): 599-692.

Mishra, A., P. Dash and R. K. Paikaray. 1995. Yield and nutrient uptake by winter sunflower (*Helianthus annuus*) as influenced by nitrogen and phosphorus. *Ind. J. Agron*., 40: 137-138.

Mozafari, K., A. Arshi and H. Zeinali Khaneghah. 1996. Effect of drought stress on some morpho-physiological traits and grain yield components of sunflower. *Journal of Seeds and Seedlings*, 12(3): 24-33.

Noora, M., A.A. Shahnaz and S. Paigham. 2009. Nitrogen levels and its time of application influence leaf area, height and biomass maize planted at low and high density. *Pak. J. Bot*., 41(2): 761-768.

Ohashi, Y., N. Nakayama, H. Saneoka, P.K. Mohapatra and K. Fujita. 2009. Differences in the responses of stem diameter and pod thickness to drought stress during the grain filling stage in soybean plants. *Acta. Physiol. Plant*, 31(2): 271-277.

Poormohammad Kiani, S., P. Grieu., P. Hewezi., L. Gentzbittel and A. Sarrafi. 2007. Genetic variability for physiological traits under drought conditions and differential expression of water stress-associated genes in sunflower (*Helianthus annuus* L.). *Theor Appl. Genet*., 114: 193-207.

(Received for publication 29 September 2011)