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Water use efficiency and morphological traits of marigold as affected by irrigation and nitrogen rates

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Abstract

In order to study the effect of water deficit stress and different nitrogen levels on plant height, flower diameter, flower yield and water use efficiency (WUE) of *Calendula officinalis* L., an experiment was conducted as split plot design based on randomized complete blocks with three replications, at research field of Islamic Azad University of Birjand branch in 2009. In this research water deficit stress set as main factor with three levels (irrigation after 60, 120 and 180 mm cumulative evaporation from pan class A) and nitrogen set as sub factor with four levels (0, 60,120 and 180 kg N. ha^{-1}). The results showed that increasing irrigation interval from 60 to 120 mm cumulative evaporation reduced flower dry weight and plant height 18.2 and 39.4 percent, respectively. Also in comparison with control, irrigation after 120 and 180 mm evaporation reduced flower dry yield 16.2 and 72 percent, respectively. However, the highest WUE was related to irrigation after 120 mm evaporation (0.161 and 0.788 $kg.m^{-3}$ for dry flower and biomass, respectively). Nitrogen utilization significantly increased flower yield, WUE and plant height, but there was not any significant difference between 120 and 180 kg $N.ha^{-1}$ treatments. Interaction of irrigation and nitrogen on all traits was not significant. Totally, the results indicated that treatment of irrigation after 120 mm evaporation with 120 kg $N.ha^{-1}$ application is suitable for marigold cultivation in Birjand.

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Introduction

Iran is considered as an arid and semi-arid region in the world. Therefore, efficient water management and understanding the influential factors such as N fertilization, and identifying drought-tolerant plants are crucially important. The diverse climate with a great temperature difference (over 50°C) of Iran and coastal, mountainous and desert lands (Javadzadeh, 1997) provides favorable conditions for the cultivation of most drought-tolerant medicinal herbs.

Marigold (*Calendula officinalis* L.) is an annual to perennial plant belonging to the family of Asteraceae. It needs high solar radiation during growing period and is able to well tolerate drought. Hence, it can be considered for cultivation in such regions as Southern Khorasan, Iran. Marigold is known as blood purifier, energizer and anti-convulsion. It heals nausea, liver disorders, peptic ulcer disease, skin wounds, burns and blood cholesterol. It acts as skin softener, too. Marigold is used in production of toothpaste, shampoo and infant lotions (Omidbeigi, 2005, Zargari, 1982). The results of some studies show that organic essence of marigold counteracts HIV (Kalvatchev *et al.*, 1997).

In a study on the effect of different manure levels and drought stress on roselle, Raesi *et al.* (2010) stated that the delay in irrigation from 50 to 200 mm accumulative evaporation from evaporation pan significantly decreased sepal yield and the number of fruits per area unit. Arazmjo *et al.* (2009) studied the impact of various drought stress levels on German chamomile and reported 18.1% loss of dry flower yield and 28.9% loss of plant height under irrigation treatment at 50% of field capacity vs. control. Moosavi *et al.* (1998) reported that both high and low irrigation levels decreased water use efficiency (WUE) of soybean compared with moderate irrigation level. Also, in a study on the effect of irrigation levels on WUE for seed and biological yield, Khajoenejad *et al.* (2005) revealed that water deficit stress showed significant superiority over optimum irrigation and that the highest WUE was obtained under moderate water deficit stress. Also, the treatments of irrigation after 50 and 75 mm accumulative evaporation had significantly higher WUE for capitulum of chamomile and seed production as compared with other treatments (Pirzad, 2007).

In a study on the effect of different N fertilization levels on flower yield of marigold, it was reported that the highest dry flower yield (102.86 $g.m^{-2}$) was obtained by the application of 150 kg $N.ha^{-1}$ (Ameri and Nasiriemahalati, 2008). Krol (2011) Stated that nitrogen fertilization had not a significant impact on flower diameter under investigated factor. Further increase in the amount of nitrogen (120 and 160 kg N. ha^{-1}) did not result in growth of yield. Also, Sharifi and Abbaszadeh (2003) investigated the effect of N fertilizer on fruit yield and composition of fennel and N application increased seed yield significantly. Hellal *et al.* (2011) indicated that applying N fertilizer increased the growth and yield of dill (*Anethum graveolens* L.) plant compared to the untreated control. Khalid (2013) in study of response of anise, coriander and fennel plants to the different rates of nitrogen fertilization on morphological traits of some Apiaceae crops under arid region conditions showed that all nitrogen treatments produced significantly higher values than the control and significantly improved plant growth characters such as plant height, leaf number per plant, branch number per plant and fruit yield. Moosavi *et al.* (2013) in study of 0, 40, 80 and 120 kg $N.ha^{-1}$on coriander showed that as N fertilization rate was increased from 0 to 80 kg N ha-1, plant height and fruit yield were increased by 19.8 and 74.1 %, respectively.

The current study was carried out to study the effect of irrigation and N fertilization levels on morphological traits, flower dry yield and water use efficiency of marigold in Birjand, Iran.

Materials and methods

Study side

This experiment was conducted at the Agricultural Research Station of Islamic Azad University, Birjand branch, Iran (latitude: 32° 52'; longitude: 59° 13' and 1400 m above sea level) in 2009. The average longtime minimum and maximum temperature in Birjand are 4.6 and 27.5°C with average annual precipitation of 169 mm and average minimum and maximum relative humidity of 23.5 and 59.6%, respectively. The regional climate is warm and arid. The soil texture was loam with pH 8.21, organic matter 0.29%, total nitrogen 0.015% and EC 4.33 ms/cm.

Experimental design and treatments

In this research, water deficit stress set as main factor with three levels (irrigation after 60, 120 and 180 mm cumulative evaporation from pan class A) and nitrogen set as sub factor with four levels (0, 60, 120 and 180 kg N.ha^{-1} from urea source).

Cultivation

Given the results of soil analysis, the field was fertilized with 150 kg triple super phosphate per ha and 100 kg potassium sulfate per ha. All phosphorus and potash fertilizer were applied at field surface at planting time. However, N fertilizer was applied at two phases (half after thinning and other half before start of flowering) with irrigation water in closed furrows. The seeds were planted in April 20 at the depth of 2-3 cm.

In this research, the studied traits included the number of plant height, flower diameter, flower dry yield and WUE for flower and biomass production. For this purpose given the unsimultaneous ripening of flowers, the ripened flowers were harvested from two middle rows of each experimental plot from an area of 3 m^2 twenty times during growth period. Then, flower yield which was the total flower weight harvested at different stages.

In addition, WUE for flower and biomass production (in terms of kg.m^{-3}) was measured through dividing flower dry yield by the amount of applied water and through dividing biological yield (biomass) by the amount of applied water, respectively. In order to measure plant height, 10 plants were randomly selected from two middle rows of experimental plots and their means were recorded as plant height. The flower diameter was measured out of the diameter of 20 flowers at each flower harvesting step.

Statistical analysis

The data were analyzed by software MSTAT-C and the means were compared by Multiple Range Duncan Test at 5% probability level.

Results and discussion

Plant height and flower diameter

Considering the results of analysis of variance, plant height and flower diameter were significantly affected by irrigation treatment at 1% level, but the effect of N rate was significant only on plant height (Table 1). The non-significant effect of N fertilization on flower diameter has been reported in chamomile, too (Rahmati *et al.*, 2009). As irrigation interval was increased from 60 to 180 mm accumulative evaporation, plant height and flower diameter were significantly decreased by 39.4 and 22.5%, respectively. Means comparison for plant height and flower diameter indicated classification of irrigation levels in distinct groups (Table 2). Some likely causes of plant height and flower diameter loss under water deficit conditions are the decrease in cell vigor and cellular growth and the resulting loss of leaf area, stomatal closure (Safarnejad, 2003) and photosynthesis limitation (Hassani and Omidbeigi, 2002). The loss of plant height with the increase in water deficit stress has been reported in basil (Hassani and Omidbeigi, 2002), chamomile (Arazmjo *et al.*, 2009) and isabgol (Najafi and Rezvanimoghadam, 2002), too.

Means comparison for plant height and flower diameter showed that although different rates of N application had no significant effect on increasing flower diameter, it significantly affected plant height, so that 180 kg N.ha^{-1} application had 6.3, 8.3 and 17.5% higher plant height than N rates of 120, 60 and 0 kg N.ha^{-1}, respectively (Table 3). It is likely that higher N fertilization levels paved the way for longitudinal growth of stem by extending vegetative growth period and supplying the required assimilates. Moreover, it has been reported that N deficiency decreased plant height by inhibiting the formation of parenchyma and sclerenchyma and N application improved plant height by increasing the division of meristem cells and the turgidity of these cells (Mengel, 1988). Also, Najafpoorenavaei (2002) found the application of N fertilizer important in improving the growth of borage. The increasing effect of N fertilization on plant height has been reported in savory (Alizade Sahzabi *et al.*, 2007) and *Tanacetum parathenium* (Hassani Malayer *et al.*, 2004), too. The results of the current study regarding the effect of water and N deficiency on plant height are consistent with the reports of Ram *et al.* (1995) and Mishra and Srivastava (2000) about mint, Mirshekari *et al.* (2007) about chamomile and Hassani and Omidbeigi (2002) about basil.

Table 1. Means of squares for plant height, flower diameter, flower dry yield and water use efficiency for flower and biomass production of marigold as affected by different levels of irrigation and nitrogen.

Sourcesof variation	df	Plant height	Flower diameter	Flowerdry yield	WUE for flower	WUE for biomass
Replication	2	20.514 ^{ns}	7.83 ^{ns}	207474.35^{ns}	0.004 ^{ns}	0.121^{ns}
Irrigation (A)	2	211.286**	163.99**	3353845**	0.016**	0.386**
Error a	4	6.444	1.577	26023.59	0.001	0.021
Nitrogen rate (B)	3	14.911**	0.314^{ns}	173498.09**	0.002**	0.038**
A × B	6	1.359^{ns}	0.09^{ns}	34024.26 ^{ns}	0.0001^{ns}	0.007^{ns}
Error b	18	1.56	0.394	14027.19	0.0001	0.003
CV (%)	-	6.41	2.21	11.99	10.18	10.02

^{ns} Non Significant at 0.05 probability level and *, ** Significant at 0.05 and 0.01 probability levels, respectively.

Flower dry yield

Analysis of variance showed that irrigation and N fertilization significantly affected the flower dry yield at 1% level (Table 1). The treatments of irrigation after 120 and 180 mm accumulative evaporation resulted in 16.2 and 72% loss of flower dry yield compared with the treatment of irrigation after 60 mm accumulative evaporation, respectively (Table 2). It can be said that the loss of current photosynthesis as well as the coincidence of flowering with high temperatures and the increase in embryo abortion under water deficit conditions can lead to the loss of dry yield through reducing the number of flowers per m^2 and single-flower weight. The decrease in flower yield with the increase in water deficit stress has been reported for marigold (Shubhra *et al.*, 2004) and chamomile (Arazmjo *et al.*, 2009), too.

Table 2. Means comparison for plant height, flower diameter, flower dry yield and water use efficiencyfor flower and biomass production of marigold as affected by different levels of irrigation.

Irrigation (mm accumulative evaporation)	Plant height(cm)	Flower diameter(mm)	Flower dry yield (kg.ha-1)	WUE for flower (kg.m-2)	WUE for biomass (kg.m-2)
60	23.80 a	31.26 a	1399.12 a	0.108 b	0.501 b
120	19.21 b	29.74 b	1172.26 b	0.161 a	0.788 a
180	14.42 c	24.23 c	391.34 c	0.090 b	0.459 b

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

The results indicated that with increase in N rate from 0 to 180 kg N.ha^{-1} significantly increased dry yield by 35 (Table 3). Since N application increased leaf area index and green area duration through which it positively influenced photosynthesis, light use efficiency, plant growth period duration, dry matter accumulation in shoots and flower bearing potential per area unit, it expectedly increased flower dry yield, too. Al-Badavi *et al.* (1995) reported the positive impact of various nitrogenous fertilizers on vegetative growth, the concentration of photosynthesizing pigments and the flowering of marigold compared with no-N fertilization treatment which could be the possible reasons for higher flower yield under abundant N levels.

Table 3. Means comparison for plant height, flower diameter, flower dry yield and water use efficiency for flower and biomass production of marigold as affected by different levels of nitrogen.

Nitrogen rate (kg N. ha^{-1})	Plant height(cm)	Flower diameter(mm)	Flower dry yield ($kg.ha^{-1}$)	WUE for flower ($kg.m^{-2}$)	WUE for biomass ($kg.m^{-3}$)
0	17.84 c	28.21 a	850.40 b	0.102 b	0.508 b
60	19.37 b	28.43 a	897.30 b	0.111 b	0.555 b
120	19.72 b	28.34 a	1051.31 a	0.128 a	0.618 a
180	20.97 a	28.66 a	1151.30 a	0.137 a	0.651 a

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

WUE for flower and biomass production

The results of analysis of variance showed that the effect of levels of irrigation and N was significant on WUE for flower and biomass production at 1% level (Table 1). Means comparison indicated that the delay in irrigation until reaching to 120 mm accumulative evaporation significantly increased these traits as compared with two other irrigation levels; that is, at this irrigation treatment (moderate stress) more flower and biomass yield per each m^3 applied water were produced. The highest WUE for flower and biomass production (on average, 0.161 and 0.788 $kg.m^{-3}$, respectively) was obtained at the treatment of irrigation after 120 mm accumulative evaporation which was 78.9 and 71.7% higher than those obtained at the treatment of irrigation after 180 mm accumulative evaporation (Fig.1 and Table 2).

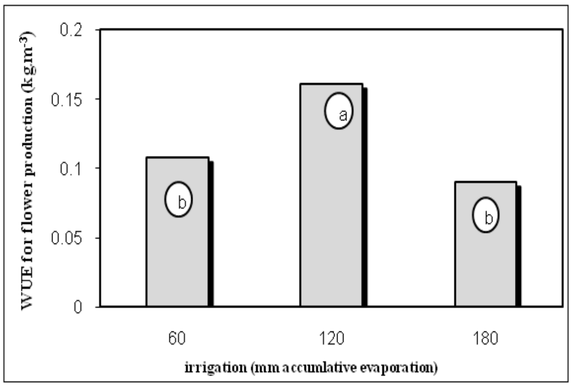

Fig. 1. Effect of irrigation on water use efficiency for dry flower production of marigold.

Higher WUE for flower and biomass production under moderate water deficit stress can be related to greater loss of water by evapotranspiration and deeper penetration at optimum irrigation treatment. On the other hand, the disruption of photosynthesis due to stomatal closure, the loss of leaf area and finally, the loss of biomass and flower yield at severe water deficit stress treatment. Nissanka *et al.* (1997) stated that the loss of WUE at severe moisture stress was caused by greater loss of photosynthesis vs. respiration. They related it to the injuries to leaf mesophyl under moisture stress. In addition, it can be said that increase in mesophyl and stomatal resistance under severe water stress decreased the entrance of CO_2 into plants which in turn, reduced net photosynthesis rate. Therefore, biomass was decreased under water stress. Higher WUE under moderate water deficit stress than under severe or no stress had been reported for chamomile (Pirzad, 2007), soybean (Moosavi *et al.*, 1998) and canola (Vafabaksh *et al.*, 2009), too which is in agreement with the results of the current study.

As N fertilization rate was increased from 0 to 180 kg $N.ha^{-1}$, WUE for flower and dry matter production improved. Means comparison for these traits showed that although N application rate of 180 kg $N.ha^{-1}$ by producing 0.137 kg flower and 0.651 kg biomass per m³ applied water had the highest WUE, the treatments of 120 and 180 kg N.ha⁻¹ were ranked in the same statistical group for these traits (Fig. 3 and Table 3). Given that the same amount of water was used at all fertilization rates, higher WUE for flower and biomass production at higher N rates can be related to the increase in flower and biomass yield. The increase in N application rate enhanced biomass weight by increasing net photosynthesis. Under the conditions of the current study, although higher N rates probably increased transpiration, they finally resulted in higher WUE due to higher flower yield. The increase in WUE with the increase in N fertilization rate has been reported in spinach (Sadegipoor Marvi, 2010), too.

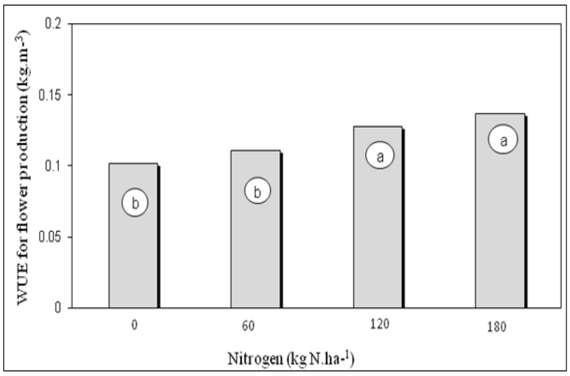

Fig. 2. Effect of nitrogen rate on water use effeciency for dry flower production of marigold.

Totally, the results indicated that treatment of irrigation after 120 mm evaporation with 120 kg N. ha⁻¹ application is suitable for marigold cultivation in Birjand.

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