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Full Length Research Paper

Outcomes of irrigation regimes and nitrogen fertilizer on seed yield of calendula (*Calendula officinalis* L.)

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This research was conducted in experimental field of Islamic Azad University of Takestan branch in Iran during 2006. The experimental unit was designed by achieved treatment in factorial on the basis of completely randomized block design with four replicates. The nitrogen was applied to the main plots at the rate of non-application, 30, 60 and 90 kg N ha^{-1} and the irrigation after 40, 80 and 120 mm water evaporation from evaporation pan assigned factorially to the subplots. The results showed that irrigation had a significant effect on seed yield, thousand seed weight, head diameter and number of seeds per head (P 0.01) such that maximum head diameter (25.67 mm), number of seeds per head (31 seed/head), thousand seed weight (15.18 g) and seed yield (3044 kg ha^{-1}) were achieved under irrigation after 40 mm evaporation. Nitrogen had a significant effect on all plant characteristics (P 0.01) and highest thousand seed weight (12.66 g), seed yield (1998 kg ha^{-1}), head diameter (23.96 mm) and number of seeds per head (29.25 seed/head) achieved after application of 90 kg N ha^{-1}. The results of this experiment showed that nitrogen increased the seed yield and delay of irrigation reduced seed yield of calendula significantly.

Key words: Nitrogen, irrigation, seed yield, head diameter, calendula.

INTRODUCTION

Drought resistance refers to a plant's ability to grow and reproduce satisfactorily under drought conditions, and drought acclimation refers to a plant's ability to slowly modify its structure and function so that it can better tolerate drought (Turner, 1986). Drought stress is one of the most important environmental stresses affecting agricultural productivity around the world and may result in considerable yield reductions (Boyer, 1982; Ludlow and Muchow, 1990). Apart from the effect of drying soil, it affects transport of nutrients to plant roots. The morphological and physiological mechanisms involved in cellular and whole plant responses to water stress are of considerable interest and are frequently examined (Hsiao, 1973; Levitt, 1980; Blum, 1988; Neumann, 1995).

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The effect of water deficit stress on seed yield has been studied in excised leaves of palmarosa (*Cymbopogon martinii* var. *motia*) and citronella java (*Cymbopogon winterianus*) and seed yield reduced under water deficit stress (Fatima et al., 2006). An experiment was carried out to study the effect of drought stress on morphological characteristics of balm. The results of this experiment showed that these Aliabadi et al. (2009) reports that although yield characteristics shows reduction under drought stress but it increases essential oil percentage increase under this condition in balm. Also, Khalid (2006) evaluated the influence of water deficit stress on seed yield of *Ocimum basilicum* L. (sweet basil) and *Ocimum americanum* L. (American basil). Both showed increased essential oil percentage and the main constituents of essential oil under water deficit stress. Seventy five percent field water capacities resulted in the highest yield of herb and essential oil for both species. Also, water deficit stress had significant effect on flowering shoot yield,

Table 1. Results of soil analyses.

Soil texture	Sand (%)	Silt (%)	Clay (%)	K (mg ka^{-1})	P (mg ka^{-1})	N (mg ka^{-1})	Na (Ds m^{-1})	EC (1: 2.5)	pH	Depth of sampling (cm)
Sa	49	30	21	147.2	6.2	34.7	0.04	0.19	8.1	0-15
Sa.c.L	56	25	19	124.3	3.7	28.2	0.03	0.16	7.9	15-30

essential oil yield and essential oil percentage of coriander and highest all plant characteristics were achieved under without stress condition, but highest oil percentage was achieved under water deficit stress condition (Aliabadi et al., 2008). Taheri Asghari et al. (2008) found that non-drought stress treatment significantly increased seed yield of chicory plants. Nitrogen is the major nutrient that influences plants yield and protein concentration. When the amount of available soil N limits yield potential, additions of N fertilizers can substantially increase plants yield (Olson and Swallow, 1984; Grant et al., 1985). Abbaszadeh et al. (2006) indicated that N fertilizer had significant effect on seed yield of balm. Their results showed that highest seed yield was achieved under application of 100 kg N ha^{-1} and highest oil yield was achieved under application of 50 kg N ha^{-1}. Also, Sharifi and Abbaszadeh (2003) investigated the effect of N fertilizer on seed yield and composition of fennel and N application increased seed yield significantly. Therefore, the objective of this study was to evaluate the effects of nitrogen fertilizer and irrigation regimes on seed yield of calendula (*Calendula officinalis* L.).

MATERIALS AND METHODS

This study was conducted on experimental field of Islamic Azad University of Takestan branch, Iran (36° 04' N, 49° 42' W; 1265 m above sea level) from 20 May to 20 September 2006, with sandy soil (Table 1), relative humidity (55 to 65), mean annual temperature (15 to 20) and rainfall in the study area is distributed with an annual mean of 250 mm. The experimental unit was designed by achieved treatment in factorial on the basis of completely randomized block design with four replicates. The nitrogen was applied to the main plots at the rate of non-application, 30, 60 and 90 kg N ha^{-1} and the irrigation after 40, 80 and 120 mm water evaporation from evaporation pan assigned factorially to the subplots. For this approach experimental field was prepared in the dimension of 15 m^2 per plot (5 m × 3 m), totally 48 plots and calendula (*C. officinalis* L.) was used in this experiment. Initially, plant nutrient need of phosphorus and potassium were added by applying 100 kg ha^{-1} ammonium phosphate, 200 kg ha^{-1} K_2O and nitrogen (urea) treatments at planting time respectively. To determine seed yield, head diameter, thousand seed weight and number of seeds per head, 10 plants were selected randomly from each plot at maturity. The data were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) computer software at P < 0.05 (SAS institute Cary, USA 1988).

RESULTS

Final results of plants characters showed that irrigation had significant effect on seed yield, head diameter, thousand seed weight and number of seeds per head (P 0.01) and highest all plant characteristics were achieved under irrigation after 40 mm evaporation (Tables 2 and 3). Those findings were in agreement with the observations of Aliabadi et al. (2008), Fatima et al. (2006) and Aliabadi et al. (2009). In addition, nitrogen had a significant effect on seed yield, head diameter, thousand seed weight and number of seeds per head (P 0.01) and highest thousand seed weight (12.66 g), seed yield (1998 kg ha^{-1}), head diameter (23.96 mm) and number of seeds per head (29.25 seed/head) were achieved under application of 90 kg N ha^{-1}. Therefore, our findings indicated a significant improvement in morphological characteristics of plant under application of nitrogen (Tables 2 and 3). Those results were similar with the findings of Abbaszadeh et al. (2006), Alizadeh et al. (2006) and Sharifi and Abbaszadeh (2003). Data of the interactive effect between application of nitrogen and irrigation has been demonstrated in Table 4. Significant difference between plants treated with application of nitrogen under irrigation after 40 mm evaporation was highlighted as compared to non-application of nitrogen under irrigation after 80 and 120 mm evaporation. Interaction had significant effect only on head diameter (P 0.01) and seed yield, thousand seed weight and number of seeds per head were not significantly affected by the interaction (Table 2). Also, highest seed yield (3332 kg ha^{-1}), head diameter (28.3 mm), thousand seed weight (16.27 g) and number of seeds per head (33.75 seed /head) were achieved under application of 90 kg N ha^{-1} and irrigation after 40 mm evaporation (Table 4). Our results of treatments interaction were similar to the results of Eghball and Maranville (1993), O'Neill et al. (2004) and Diaz et al. (2005).

Table 2. Analysis of variance.

Sources of Variation	df	Mean Squares			
		Seed yield	Thousand seed Weight	Number of seeds per head	Head diameter
Replication	3	48266.33	11.103	12.389	9.845
Irrigation	2	17998632.75 **	186.444 **	193 **	83.871 **
Error a	6	12261.11	10.337	4.22	6.435
N fertilizer	3	155808.13 **	8.02 **	51.5 **	7.71 **
Irrigation × N fertilizer	6	24528.17	0.495	10.5	5.312 **
Error b	27	13877.88	1.044	6.07	1.47
CV (%)		6.4	8.58	9.13	5.23

* and ** : Significant at 5 and 1% levels respectively.

Table 3. Means comparison of main treatments.

Treatments		Seed yield ($kg\ ha^{-1}$)	Thousandseed weight (g)	Number of seeds per head (seed/head)	Headdiameter (mm)
Irrigation regimes	40 mm evaporation	3044 a	15.18 a	31 a	25.66 a
	80 mm evaporation	1437 b	12.16 b	25.25 b	22.66 b
	120 mm evaporation	1042 c	8.37 c	24.75 b	21.17 b
	Non-application	1734 c	11.22 b	24.25 c	22.13 b
N fertilizer	30 kg N ha^{-1}	1789 c	11.17 b	24.5 ab	22.98 ab
	60 kg N ha^{-1}	1842 b	12.56 a	24 b	23.6 a
	90 kg N ha^{-1}	1998 a	12.66 a	29.25 a	23.95 a

Means within the same column and factors, followed by the same letter are not significantly difference ($P < 0.05$).

Table 4. Means comparison of Interaction.

Survey instance qualification		Seed yield ($kg\ ha^{-1}$)	Thousand seed Weight (g)	Number of seeds per head (seed/head)	Head diameter (mm)
40 mm evaporation	Non-application	2901 b	14.7 bc	27 bcd	24.15 bc
	30 kg N ha^{-1}	2965 b	13.92 cd	33.75 a	24.99 b
	60 kg N ha^{-1}	2980 b	15.8 ab	29.75 b	25.24 b
	90 kg N ha^{-1}	3332 a	16.27 a	33.5 a	28.3 a
80 mm evaporation	Non-application	1337 d	11.27 f	22.5 e	21.69 de
	30 kg N ha^{-1}	1395 cd	11.6 ef	25.5 cde	23.13 cd
	60 kg N ha^{-1}	1459 cd	12.85 de	26.25 bcde	23.05 cd
	90 kg N ha^{-1}	1556 c	12 de	26.75 bcd	22.79 cd
Irrigation after 120 mm evaporation	Non-application	937 e	7.69 g	23.25 de	20.56 f
	30 kg N ha^{-1}	1008 e	7.99 g	23.26 de	20.82 ef
	60 kg N ha^{-1}	1087 e	8.99 g	25 cde	22.54 cde
	90 kg N ha^{-1}	1108 e	8.8 g	27.5 bc	20.87 ef

Means within the same column and factors, followed by the same letter are not significantly difference ($P < 0.05$).

DISCUSSION

As it was shown in our results, water deficit stress had a negative effect on most of the emphasized growth compounds. In contrary, reducing water supply in soil achieved a situation for plant to pursue root growth through soil depth. This shows that in order to resist water deficit stress, the plant employed different strategies throughout individual survival struggle by water deficit stress conditions. In terms of reduction in evaporation; plants showed an extreme reduction in leaf length and width (reduction in evaporation area) . Although significant reduction in plant height and lateral stem number might be due to decreasing of the evaporation area of leaves and it eventually caused low dry matter at the end of growth period under water deficit stress conditions. Those might be correspond to the fact that under water deficit stress stomata become blocked or half-blocked and this leads to a decrease in absorbing CO_2 and on the other hand, the plants consume a lot of energy to absorb water, which cause a reduction in producing photosynthetic matters. Our observation indicated with rising increase of water deficit stress, its biological yield and grain yield decreased with rising of drying in soil. Further reducing of shoot dry weight might be due to the reduction of photosynthesis area in leaf, drop in producing chlorophyll, the rise of the energy consumed by the plant in order to take in water and to increase the density of the protoplasm and to change respiratory paths and activation of the path of phosphate pentose, or the reduction of the root development, etc. Also, the results showed that applications of N fertilizer increased seed yield of calendula, because nitrogen, which is a primary constituent of proteins, is extremely susceptible to loss when considering that average recovery rates fall in the range of 20 to 50% for dry matter production systems in plants. Nitrogenous fertilizers generally cause deficiency of potassium, increased carbohydrate storage and reduced proteins, alteration in amino acid balance and consequently change in the quality of proteins and are a main element in chlorophyll production (Cooper, 1974). Toxic concentrations of nitrogen fertilizers cause characteristic symptoms of nitrite or nitrate toxicity in plants, particularly in the leaves. Although pre plant fertilizer applications decrease the potential for nutrient deficiencies in early stages of growth, presence of residual soil NO_3N (plant-available mineral N from the previous season) may pose a risk to the environment. The soil water is salty by inordinate N application which increases its potential (Alizadeh et al., 2006) . Finally, the plant use high energy to absorb salt water that causes dry matter reduction.

Conclusion

The results showed that N fertilizer under irrigation after 40 mm evaporation increased seed yield of calendula. Our finding may give applicable advice to farmers and medicinal and aromatic plants researches for management and proper use of nitrogenous fertilizers in arid and semi-arid areas.

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