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Response Morphological Traits and yield of Ajowan (*Carum copticum*) to Water deficit stress and Nitrogen Fertilizer

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ABSTRACT: In order to study the effect of water deficit stress and nitrogen levels on morphological traits and yield of Ajowan, 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 2012. In this research water deficit stress set as main factor (irrigation after 70, 140 and 210 mm cumulative evaporation from pan class A) and nitrogen set as sub factor (0, 75,150 and 225 kg N.ha^{-1}). The results showed that irrigation interval had significant effect on plant height, branch number of main stem, stem diameter, straw yield, seed yield and harvest index. With increasing of irrigation interval from 70 to 210 mm cumulative evaporation, these traits reduced 36.6, 41.4, 33.2, 48.3, 65.1.5 and 23.2%, respectively. Also results showed that as N fertilizer rate was increased from 0 to 75 kg N.ha^{-1}, plant height and seed yield were increased by 12.6 and 17.9%, respectively. Moreover, as N fertilizer rate was increased from 0 to225 kg N.ha^{-1}, straw yield was increased 35.4%, but harvest index was decreased 18.6%. According to the results, the treatment of irrigation after 70 mm evaporation with 75 kg N.ha^{-1} is recommended for realizing high ajowan yield in Birjand, Iran.

Keywords*:* *Carum copticum*, irrigation, nitrogen, yield, morphological traits.

INTRODUCTION

Water is an important environmental factor affecting the growth of the crops particularly in arid and semi-arid regions like Iran; so, its optimum use for the production of the crops is vital (Mirzaei *et al.*, 2005). In addition to available water, N is a key element in the structure of many compounds of cells and plays a crucial role in the growth and yield of plants. 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.

Nowadays, given the side effects of chemical medications and growing tendency to herbal medicine, mass cultivation of various medicinal herbs has been interested. *Carum copticum* is a widely distributed annual herbaceous plant and belong to flowering plants in the family apiaceae which grows in the east of India, Iran and Egypt. The fruits of *C. copticum*, commonly known in Iran as Zenyan, have been used extensively in Iranian folk and traditional medicine to treat several disorders like gastrointestinal, rheumatic and inflammatory disorders. Due to the inclusion of essential oils which contain thymol, para-seaman, alpha-pinene and carvacrol used for its therapeutic effects such as diuretic, anti-vomiting, and carminative effects (Goudarzi *et al*., 2011; Davazdah Emami and Majnoon Hosseini, 2009).

Azhar *et al*. (2011) reported that with the increase in drought stress from 100 to 60% field capacity, plant height and herb dry weight were reduced from 60.33 to 44 cm and 1.25 g to 0.796 g respectively. The study of the effect of irrigation intervals after 40, 80, 120 and 180 mm evaporation from evaporation pan indicated that the effect of irrigation was significant on plant height, number of branches per plant and fruit yield of fennel and the highest these traits was obtained from irrigation treatment at 40mm evaporation (Yari *et al*., 2013).

Moussavi-Nik *et al.* (2011) reported that with increasing irrigation interval from 7 to 21 days, seed yield was decreased. Arbab *et al*. (2008) showed that drought stress had a significant and negative effect on fruit yield of Coriander. Rahmani *et al.* (2008) stated that when the soil water content decreased seed yield of marigold decreased. Also, these researchers reported that highest seed yield was achieved under application of 90 kg N.ha^{-1} in comparison other nitrogen levels (0, 30 and 60 kg N.ha^{-1}). Safikhani (2009) concluded that severe drought stress decreased plant height and shoot yield of *Dracocephalum moldavica.* 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.

The results of the study of Ansarinia (2010) indicated that water deficit stress significantly decreased harvest index of sunflower. Also, Aboomardani *et al.* (2010) on canola and Ansarinia (2010) on sunflower reported that harvest index increased with the increase in rate of N application.

Nath *et al.* (2008) reported that maximum of plant height, branche number per plant, stem diameter and seed yield in ajowan were obtained with application of 60 kg N.ha^{-1}. Bhunia *et al.* (2009) in study various levels of nitrogen (20, 40 and 60 kg ha^{-1}) stated that higher plant height and branch number per plant^{-1} was recorded with higher rate of nitrogen. Consequently, the highest seed and straw yields were recorded at higher rate of nitrogen (60 kg ha^{-1}). However, highest harvest index (25.01%) was recorded at 40 kg N.ha^{-1} as compared to 20 and 60 kg N.ha^{-1}.

The highest seed yield of ajowan was related to consumption of 200 kg N ha^{-1} and there were no significant difference in seed yield between treatments of 50, 100, 150 and 200 kg N.ha^{-1} (Vahidipour *et al.*, 2013).

Hellal *et al. (2011*) indicated that applying N fertilizer increased the growth and yield of dill (*Anethum graveolens* L.) compared to the untreated control, the highest values of vegetative growth and yield were recorded by the treatment of 100 kg N.ha^{-1}. Shokhmgar (2009) showed that N fertilization significantly affected seed yield of fenugreek, so that the highest seed yield was obtained with the application of 150 kg N.ha^{-1}. Ali Khalid (2013) evaluated effect of nitrogen fertilization rates contain 0, 100, 150 and 200 kg ha^{-1} on morphological traits of Anise, coriander and fennel crops under arid region conditions in Egypt and reported that all nitrogen treatments produced significantly higher values than the control (no nitrogen application) and significantly improved plant height, leaf number pre plant, branch number pre plant, herb dry weight and fruit yield.

Given the importance of water and N and their numerous functions in living processes of a plant, they are regarded as some of the most important environmental parameters affecting the cultivation and production of the crops. Therefore, the current study was carried out to study the effect of irrigation and N fertilization levels on yield and yield components of ajowan in Birjand, Iran.

MATERIALS AND METHODS

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 2012.

The soil texture was loam with pH 8.21, organic matter 0.29%, total nitrogen 0.015% and EC 5.33 ms/cm. The average long-time 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.

In this research, water deficit stress set as main factor with three levels (irrigation after 70, 140 and 210 mm cumulative evaporation from pan class A) and nitrogen set as sub factor with four levels (0, 70, 150 and 225 kg N.ha^{-1} from urea source).

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 2 May 2012 at the depth of 2 cm. The seeds had been disinfected by Carbendazim fungicide (2:1000) before sowing.

After the seed maturation, by harvesting one square meter of each plot with considering the margin effect, the seed yield was determined. The morphological characteristics contain plant height, branch number of main stem and stem diameter were determined by averaging over 8 plants from each plot. The harvest index (HI) was determined by:

$$HI = (\text{Grain yield/Biological yield}) \times 100$$

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

A. Morphological traits

The results showed that irrigation significantly affected plant height, stem diameter and branch number of main stem at 1% level. Also, plant height was affected by nitrogen at 1% statistical level but the interaction between irrigation and nitrogen did not significantly effect on these morphological traits (Table 1). According to means comparison, the delay in irrigation from 70 to 140 and 210 mm cumulative evaporation decreased plant height, 14.99 and 36.58 and branch number per main stem, 13.1 and 33.2 and stem diameter 17.8 and 41.4%, respectively (Table 2). The decrease in water availability by plant under stress is caused by the decrease in turgor pressure of the cells, and the resulting decrease in leaf growth and development and the shedding of aged leaves as a response for adaptation to water deficit conditions and survival. Consequently, lower assimilates are built and the elongation of plant and production of branches is decreased. In other word, stomata closure and the sensitivity of cell division and growth under water deficit conditions can be mentioned as some reasons for lower vegetative growth under these conditions. Mohamed and Abdu (2004) reported that decreasing the irrigation times of ajowan from 6 to 3 in climatic conditions of Egypt significantly decreased the plant height and branches number per plant of fennel. Yari *et al.* (2013) stated that the highest plant height and number of main stem (123 cm and 11.58, respectively) of fennel was obtained from irrigation after 40 mm accumulative evaporation which significantly had superior as comprised with treatments irrigation after 80, 120 and 180 mm accumulative evaporation**.**

Table 1. Mean of squares for the effect of irrigation and nitrogen on ajowan traits.

S.O.V	df	Plant height	Stem diameter	Branch number of main stem	Straw yield	Seed yield	Harvest index
Block	2	22.262^{ns}	6.95*	0.111^{ns}	7725.36^{ns}	12790.84^{ns}	2.598^{ns}
Irrigation	2	1227.1**	33.329**	4.962**	3203954.07**	4011373.64**	346.37*
Error a	4	11.246	0.518	0.247	163891.71	37555.109	61.42
Nitrogen	3	67.146**	0.271^{ns}	0.089^{ns}	380006.71**	155950.67**	151.07**
A× B	6	8.157^{ns}	0.26^{ns}	0.046^{ns}	85448.25^{ns}	26354.1^{ns}	13.021^{ns}
Error b	18	3.96	0.262	0.031	37304.78	10638.65	16.801
CV	(%)	4.37	6.97	7.10	11.79	8.65	10.01

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

Table 2: The means comparison of ajowan traits in irrigation levels.

Irrigation (mm cumulative evaporation)	Plant height (cm)	Stem diameter (mm)	Branch number of main stem	Straw yield (kg.ha^{-1})	Seed yield (kg.ha^{-1})	Harvest index (%)
70	54.98a	3.09a	9.96a	2041.31a	1711.96a	46.06a
140	46.74b	2.54a	8.66b	1818.05a	1296.58b	41.73ab
210	34.87c	1.81b	6.65c	1055.84b	569.69c	35.36b

Means followed by the same letters in each column are not significant according to Duncan’s multiple range test (P<0.05)

Table 3: The means comparison of ajowan traits in nitrogen levels.

Nitrogen rate (kg ha^{-1})	Plant height (cm)	Stem diameter (mm)	Branch number of main stem	Straw yield (kg.ha^{-1})	Seed yield (kg.ha^{-1})	Harvest index (%)
0	41.45b	2.55ab	8.59a	1409.75c	1100.48b	42.89a
75	46.69a	2.58a	8.56a	1623.48b	1297.65a	43.05a
150	47.21a	2.42ab	8.26a	1611.01b	1313.66a	43.33a
225	46.78a	2.37b	8.29a	1909.35a	1059.16b	34.90b

Means followed by the same letters in each column are not significant according to Duncan’s multiple range test (P<0.05)

Means comparison of plant height showed that although application of 75, 150 and 225 kg $N.ha^{-1}$ rates had no significant different but it significantly increased (12.6%) as nitrogen rate was increased from 0 to 75 kg $N.ha^{-1}$. Also, stem diameter was decreased by 7.1%, as nitrogen rate was increased from 0 to 225 kg $N.ha^{-1}$ but all nitrogen levels placed in one statistical group in case branch number of main stems (Table 3).

Probably, the increase in N fertilization rate up to 75 kg $N.ha^{-1}$ increased the photosynthesis potential through increasing the number of leaves and leaf area. This therefore allowed the transfer of more assimilates to stem which caused more height. Yari *et al.* (2013) in study effect of urea foliar application and irrigation on morphological characteristics showed that the increase in N application rate increased plant height of fennel which is in agreement with the results of the current study.

B. Straw yield

According to the results of analysis of variance, the change in irrigation interval and nitrogen rate significantly affect traw yield of ajowan at 1% statistical level but the interaction between factors did not significantly affect this trait (Table 1).

The results showed that the highest straw yield (2041.31 $kg.ha^{-1}$) was obtained at the treatment of irrigation after 70 mm accumulative evaporation which it showed a 12.28 and 93.33% increase compared with the treatments of irrigation after 140 and 210 mm accumulative evaporation, respectively (Table 2). In drought stress conditions, due to reduced photosynthetic materials, plant dry weight decreased; plant for drought escape and survival is early to flower, so the maximum amount of dry weight compared to non-stress conditions is obtained. Vahidipour *et al.* (2013) stated that the highest straw weight (837.95 $kg.ha^{-1}$) was obtained from irrigation interval of 7 days, and the lowest it (588.52 $kg.ha^{-1}$) was obtained from irrigation interval of 14 days. In other words, irrigation of 14 days reduced total straw weight of ajowan 29.76%.

The increase in N rate had positive and significant effect on straw yield, so that the comparisons of means indicated that as the N rate was increased from 0 to 225 $kg.ha^{-1}$, straw yield of ajowan increased by 35.44% (Table 3). The positive effects of N fertilization may be due to the important physiological role of N in molecule structure as porphyrin. The porphyrin structure is found in such metabolically important compounds as the chlorophyll pigments and the cytochromes, which are essential in photosynthesis and respiration. Coenzymes are essential to the function of many enzymes. Accordingly, nitrogen plays an important role in synthesis of the plant constituents through the action of different enzymes activities and protein synthesis that reflected in the increase in growth parameters of plants such as anise, coriander and fennel plants. In other word, 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. Vahidipour *et al.* (2013) stated that among different amounts of nitrogen fertilizer, the highest straw weight with averages of 808.23 $kg.ha^{-1}$ was obtained from consumption of 200 kg $N.ha^{-1}$ and the difference between this treatment with the values of 100 and 150 kg $N.ha^{-1}$ was not significant; least amounts of straw yield was related to the control treatment. In this research, application of 200 kg $N.ha^{-1}$ increased straw weight 31.83%, than control treatment or non-consumption of fertilizer.

C. Seed yield

According to the results of analysis of variance, the change in irrigation interval and nitrogen rate significantly affect seed yield of ajowan at 1% statistical level but the interaction between factors did not significantly affect this trait (Table 1).

As means comparison showed, the highest seed yield (1711.96 $kg.ha^{-1}$) was obtained at the treatment of irrigation after 70 mm accumulative evaporation which it showed a 32.04 and 200.5% increase compared with the treatments of irrigation after 140 and 210 mm accumulative evaporation, respectively (Table 2). It seems that final seed yield of ajowan depends on successful development of flowers, their full fertility, embryo development and assimilates accumulation in fruits, but water stress decreases assimilates supply by decreasing leaf area and duration and disrupting nutrient intake and transfer and hence, it decreases seed yield. Also, in a study on the effects of water deficit during flowering and pollination of corn, Grant *et al.* (1989) stated that it severely decreased yield through abnormal development of embryo sac and grain sterility and finally, it decreased fertile grain number. Also, Osman (2009) in fennel, and Esfandeyari *et al.* (2010) in cumin were stated that water deficit stress decreased fruit yield which is agreement current study. In general can be said that drought stress reduces yield of medicinal plants by three main mechanisms:

First, whole canopy absorption of incident photosynthetically active radiation may be reduced, either by drought-induced limitation of leaf area expansion, by temporary leaf wilting or rolling during periods of severe stress, or by early leaf senescence. Second, drought stress decreased the efficiency with which absorbed photosynthetically active radiation is used by the crop to produce new dry matter (the radiation use efficiency). This can be detected as a decrease in the amount of crop dry matter accumulated per unit of photosynthetically active radiation absorbed over a given period of time, or as a reduction in the instantaneous whole-canopy net CO_2 exchange rate per unit absorbed photosynthetically active radiation. Third, drought stress may limit grain yield of medicinal and aromatic plants by reducing the harvest index. This can occur even in the absence of a strong reduction in total medicinal and aromatic plants dry matter accumulation, if a brief period of stress coincides with the critical developmental stage around flowering (Earl and Davis, 2003).

The increase in N rate had positive and significant effect on seed yield, so that the comparison of means indicated that as the N rate was increased from 0 to 75 and 150 kg.ha^{-1}, seed yield of ajowan increased by 17.9 and 19.4%, respectively (Table 3). Probably, leaf area 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. On the other hand, increase in seed yield as a result N application was because of formation of strong sinks (more fruits and source activity) and higher LAI and longer leaf area duration. Also, Girardin *et al.* (1987) stated that N deficiency decreased grain yield by decreasing grain number per ear and grain weight. Means comparison of seed yield at different N rates showed that as N rate increased from 0 to 120 kg N.ha^{-1}, seed yield of fennel increased by 24.3% (Moosavi *et al.*, 2012). Probably in application of 225 kg N.ha^{-1} treatment, increasing of shading and respiration and then reduction of net photosynthesis, declined seed yield.

D. Harvest index

According to the results of analysis of variance, the change in irrigation interval and nitrogen rate did significantly affect harvest index, but the interactions between factors did not significantly affect this trait (Table 1).

The comparisons of means indicated that the highest harvest index (46.06%) was obtained at the treatment of irrigation after 70 mm accumulative evaporation and according to means comparison, the delay in irrigation from 70 to 140 and 210 mm cumulative evaporation decreased harvest index, 41.73 and 35.36%, respectively (Table 2). In other words, water deficit stress disrupted the mobilization of assimilates to reproductive organs. Thus, it decreased potential flower yield more than biological yield. The results of the study of Ansarinia (2010) indicated that water deficit stress significantly decreased harvest index of sunflower. Also, Moosavi *et al.* (2014) showed that water deficit stress negatively affected harvest index of marigold, so that this index in treatments of irrigation after 180 and 60 mm accumulative evaporation was 19.7 and 21.5%, respectively.

The increase in N rate from 0 to 225 kg.ha^{-1} had negative effect on harvest index so that this trait reduced from 42.89 to 34.90% (Table 3). But, Aboomardani *et al.* (2010) on canola and Ansarinia (2010) on sunflower reported that harvest index increased with the increase in rate of N application. Moreover, means comparison showed that the increase in N fertilization rate from 0 to 180 kg N.ha^{-1} increased flower harvest index from 20.12 to 20.92% which is not in agreement with the results of the current study.

CONCLUSION

In total, the results of this study showed that water deficit stress can considerably decrease seed yield of ajowan, but yield loss was greater when irrigation interval increased from 70 to 210 mm cumulative evaporation. Also, it can be recommended to apply only 75 kg N. ha^{-1} because it stimulates vegetative growth and increases leaf area index and duration, photosynthetic potential and finally, economical yield. Finally according to the results, the treatment of irrigation after 70 mm evaporation with 75 kg N ha^{-1} is recommended for realizing high ajowan yield in Birjand, Iran.

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