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The Effect of Nitrogen Rate and Plant Density on Morphological Traits and Essential Oil Yield of Coriander

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Abstract

In order to study the effect of nitrogen rate and plant density on morphological traits and essential oil and fruit yield of coriander, a split-plot experiment was carried out in research field of Islamic Azad University, Birjand Branch, Birjand, Iran in 2010 based on a randomized complete block design with three replications. The main plots were nitrogen rates at four levels (0, 40, 80 and 120 kg N/ha) and the sub-plots were plant densities at three levels (30, 40 and 50 plants/m^2). The results showed that nitrogen rate had significant effect on fruit yield, essential oil percent and yield traits and interaction between nitrogen rate and plant density only affected fruit yield but change in plant density significantly affected all traits except essential oil percent. Means comparison 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. Also, essential oil percent increased from 0.153 to 0.33% and essential oil yield was greater 2.68 times. Moreover, means comparison showed that the increase in plant density from 30 to 50 plants/m^2, increased plant height, first fruit distance from ground, fruit and essential oil yield by 14.3, 27.6, 31.3 and 36.8%, respectively while stem diameter and branch number per main stem were decreased by 22.2 and 13.9%, respectively. Given the results of the study, the treatment of 80 kg N/ha application with the density of 50 plants/m^2 recommended for the cultivation of coriander in Birjand, Iran.

Keywords: Coriander, Nitrogen rate, Plant density, Morphological traits, Essential oil, Fruit yield.

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is widely distributed and mainly cultivated for the seeds. The seeds contain an essential oil (up to 1%) and the monoterpenoid, linalool, is the main component. The seeds are mainly responsible for the medical use of coriander and have been used as a drug for indigestion, against worms, rheumatism and pain in the joints (Wangensteen *et al.*, 2004) and have been recommended for dyspeptic complaints, loss of appetite, convulsion, insomnia and anxiety (Emamghoreishi *et al.,* 2005).

The applied nitrogen rate and plant density are two important parameters influencing the yield of medicinal plants. Das *et al.* (1991) studied the effect of nitrogen fertilization on coriander and concluded that increased plant height and branch number per main stem with 40 kg N/ha application. Rahimi *et al*. (2009) stated that nitrogen application had significant and positive effect on plant height and branch number per main stem. Also, in another study Oliver *et al*. (2003) found that the highest of plant height observed in 80 kg N/ha application treatment which was 17.4% greater as compared with no nitrogen application treatment. In studies of some researchers reported that with increasing of nitrogen application increased essential oil percent of coriander (Gulen, 1995; Yalcintas, 1995; Bhati, 1988).

Akbarinia *et al.* (2006) in study the effect of nitrogen rates and plant densities on fruit yield, essential oil percent and yield of coriander fruits concluded that the highest fruit yield was obtained by using 60 kg N/ha while the highest essential oil percent and yield were obtained with 90 kg N/ha application. Moreover, they stated that fruit and essential oil yield were higher in 30 plants/m^2 density, while essential oil percent was higher in 30 and 40 plants/m^2 densities. Nevertheless, Ghobadi and Ghobadi (2010) and Dierchesen (1996) reported the highest fruit yield of coriander at density 50 plants/m^2.

Masood *et al.* (2004) in an experiment on fennel showed that with increasing of plant density, plant height increased. According to the results of study of Amarjit *et al.* (1992) on dill, plant density no had significant effect on essential oil percent, but increase in density significantly increased essential oil yield. Also, in study on the impact densities of 20, 25, 40 and 50 plant/m^2 on chamomile, Rahmati *et al*. (2009) found that the increase in density had positive and significant effect on essential oil yield.

Given the importance of determining desirable nitrogen rate and plant density for the cultivation of a newly-introduced plant in a region, the current study was carried out in order to investigate the effects of different levels of nitrogen rate and plant density on coriander in Birjand, Iran.

MATERIALS AND METHODS

The study was carried out in research field of Islamic Azad University of Birjand, Iran (Long. 59°13´ E., Lat. 32°52´ N., Alt. 1400 m) in 2010. The average long-time minimum and maximum temperature is 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 sandy-clay loam, its acidity, total N content and EC were 8.4, 0.031% and 5.86 ms/cm, respectively at the depth of 0-30 cm. The field had been left fallow in the previous year.

The study was a split-plot experiment based on a randomized complete block design with three replications. The main plots were nitrogen rates at four levels (0, 40, 80 and 120 kg N/ha) and the sub-plots were plant densities at three levels (30, 40 and 50 plants/m^2). Each sub-plot was 2.4 m×6 m with 6 rows. The spacing was 1 m between sub-plots and 2 m between main plots and replications.

According to the results of soil test, 100 kg/ha potassium sulfate (42% potassium) and 100 kg/ha triple super phosphates (46% phosphorus) was applied to the soil before final disking. Having disinfected by fungicide carboxin thiram (2:1000), the seeds were dry-sown at the depth of 2-3 cm.

Given the local climatic conditions, the plots were irrigated once every 7-10 days and the weeds were removed 3 times during growth period. The plants were thinned at 4-5 leaf stage and the desired densities were adjusted by changing the spacing between plants intra rows.

In order to measure morphological traits including plant height, stem diameter, first fruit distance from ground and branch number per main stem, 10 plants were randomly selected from the middle of each plot and these traits were measured. In order to calculate the fruit yield, an area of 2 m^2 was harvested from the middle of each plot. Also, 100 g winnowed fruit was selected from each plot to determine their essential oil percentage by clevenger extractor using steam distillation method. Then, it was multiplied by seed yield to have essential oil yield.

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

RESULTS AND DISCUSSION

Morphological Traits

The results showed that nitrogen rate and interaction between nitrogen rate and plant density had no significant effect on plant height, stem diameter, first fruit distance from ground and branch number per main stem but change in plant density significantly affected these traits at 1% level (Table 1). Nevertheless, means comparison showed that as N fertilization rate was increased from 0 to 80 kg N ha^{-1}, plant height was increased by 19.9% (Table 2).

As shown in Table 3, the increase in plant density had a positive effect on plant height and first fruit distance from ground, so that with increasing plant density from 30 to 50 plants/m^2, these traits were increased by 14.3 and 27.6%, respectively while stem diameter and branch number per main stem were decreased by 22.2 and 13.9%, respectively.

It appears that the increase in plant height following the increase in plant density was brought about by the increase in the inter-plant competition over light and the disruption of the balance of growth regulators. In other words, the decrease in light penetration into middle and lower layers of canopy decreases auxin decomposition and thus, plant height increases and under these conditions, plant height increases if other environmental parameters such as moisture and soil fertility, do not limit the growth of plants (Imam and Ranjbar, 2000). Also, Ghobadi and Ghobadi (2010) and Kumar *et al.* (2007) on coriander, Rassam *et al*. (2007) on anise, Boromand-Rezazadeh *et al*. (2005) on ajowan and Mir *et al*. (2011) on roselle reported the increase in plant height with the increase in plant density which is agreement with results of the current study. They stated that the increase in internode length was the main reason for the increase in plant height. Nonetheless, Rezvani Moghaddam *et al*. (2005) stated that increase in plant density had no significant effect on sesame plant height.

Greater distance of first fruit and/or fruit-bearing branch from ground at higher densities can be related to the increase in leaf area index and the decrease in light penetration into lower layers of canopy and the necessity of intercepting direct radiation for the activation of reproductive buds as well as the increase in internode spacing due to the competition of plants over light. Also, Mohammadi Nikpoor and Keshavarzi (1995) reported that as safflower plant density was increased, plant height as well as the distance of the first flowering branch and fruit from ground significantly increased.

The decrease in branch number per main stem at higher densities can be related to fiercer inter-plant competition and lower space for each plant to develop its canopy. Also, Khorshidi *et al.* (2009) in fennel and Rezvani Moghaddam *et al*. (2005) in sesame reported the significant decrease in branch number with the increase in plant density

Clearly, adjacent plants more fiercely compete over water, nutrients and other resources at higher densities and thus, lower share of all resources available to plants is allocated to the production of dry matter which is partly allocated to the diagonal growth of stem. Moosavi (2011) in fennel and Mir *et al.* (2011) in roselle reported that the increase in plant density significantly decreased stem diameter which is in agreement with our results.

Fruit Yield

As the results showed, nitrogen rate, plant density and their interaction significantly affected fruit yield at 1% level (Table 1). The highest fruit yield (615.16 kg/ha) was obtained at 80 kg N/ha application treatment which was 74.1, 39.2 and 29.6% greater than that at the treatments of 0, 40 and 120 kg N/ha application, respectively (Table 2).

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 and fruit yield of coriander under low N levels. On the other hand, increase in fruit yield as a result of increasing applied N rate up to 80 kg N/ha was because of formation of strong sinks (more fruits per plant) and source activity (higher LAI and longer leaf area duration). Generally in this study, increase in the yield of fruit can be attributed to the better growth of plants and subsequently the better canopy development which led ultimately to the better use of solar irradiance and higher photosynthesis. This result is according with reports of Hans Raj and Takral (2008), Khan et al. (1999), Munir (2005) and Mehfoz and Sharaf-Eldin (2006) in fennel. It is seems that in application of 120 kg N/ha treatment, increasing of shedding and respiration and then reduction of net photosynthesis, significantly declined fruit yield.

Also, means comparison indicated that fruit yield significantly increased by 12.4 and 31.4% as population was increased from 30 to 40 and 50 plants/m^2, respectively (Table 3). More fruit yield at higher densities was probably due to the quick formation of canopy, the increase in leaf area index and better utilization of solar radiation and other resources. The studies of Bahreininejad *et al*. (2006) and Koocheki *et al*. (2006) on (*Foeniculum vulgare* Mill.), Shareh (1999) and Rassam *et al*. (2007) on *Pimpinella anisum*, Rezaei Nejad (2011) on *Cuminum cyminum* L., Ebdali Mashadi and Fahti (2003) on *Silybum marianum* and Tabatabayi *et al.* (2010) on *Trachyspermum copticum* L. showed the increase in seed yield with the increase in plant density, too.

The highest fruit yield (708.13 kg/ha) was obtained at 80 kg N/ha application with the density of 50 plants/m^2 treatment and the lowest one (282.1 kg/ha) was obtained at no nitrogen application with the density of 30 plants/m^2 treatment (Fig. 1).

Essential Oil Percentage

As the results showed, applied nitrogen rate significantly affected essential oil percentage at 1% level but plant density and their interaction had no effect on this trait (Table 1). Also, Amarjit *et al.* (1992) in dill and Darzi *et al*. (2002) in fennel showed that the increase in plant density had no significant effect on essential oil percentage of which confirms the results of the current study. However, Hajseyyedhadi *et al.* (2002) reported the increase in essential oil percentage of chamomile at lower densities.

The results indicated that increase in applied N rate had a positive and significant effect on this trait and the highest essential oil percentage (0.33%) was obtained at 120 kg N/ha application treatment (Table 2) which is in agreement with the results of studies Gulen (1995), Yalcintas (1995) and Bhati (1988) on coriander and Rahmati *et al.* (2009) on chamomile.

N application keeps plant in younger physiological growth stage and cause increasing of essential oil percentage. Also, plant nutrition indirectly affect on essential oil production, so that increase it with nitrogen and phosphorus application (Franz, 1983).

Essential Oil Yield

Applied N rate and plant density change significantly affected, but their interaction no had effect on this trait (Table 1). Means comparison revealed that the increase of N fertilization rate from 0 to 80 kg N/ha had a positive and significant effect on essential oil yield and increased it 2.68 times, but there was not any significant difference between 80 and 120 kg N/ha application treatments (Table 2).

Given results can be said that increase of essential oil yield in 80 and 120 kg N/ha application treatments were due to increasing of fruit yield and essential oil percentage, respectively. These results are in agreement with the results of Akbarinia *et al*. (2006) and Yalcintas (1995) on coriander.

The results indicated that as the density was increased from 30 to 50 plants/m^2, essential oil yield increased by 37.4% (Fig. 3) because of the increase in fruit yield and essential oil percentage at higher densities. Some reports on chamomile showed the increase in essential oil yield at higher plant densities (Hajseyyedhadi *et al.*, 2002; Rahmati *et al.*, 2009). Also, the study of Amarjit *et al*. (1992) on *Anethum graveolens* and Pirzad *et al*. (2007) on *Matricaria chamomilla* L. showed that the increase in plant density increased essential oil yield which confirm the results of the current study.

CONCLUSION

In total given the results of the study, the treatment of 80 kg N/ha application with the density of 50 plants/m^2 because optimum leaf area production and better growth of plants and subsequently the better canopy development which led ultimately to the better use of solar irradiance and higher photosynthesis and finally highest fruit and essential oil yield recommended for the cultivation of coriander in Birjand, Iran.

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Tables

Table 1. Mean square for traits of coriander as affected by different levels of nitrogen and plant density.

SOV	df	Plant height	Stem diameter	first fruit distance from ground	branch number per main stem	Fruit yield	Essential oil percent	Essential oil yield
Replication	2	76.286 ^{ns}	0.03 ^{ns}	1.423 ^{ns}	1.231 ^{ns}	22920.107 ^{ns}	0.003 ^{ns}	0.124 ^{ns}
Nitrogen rate (N)	3	75.443 ^{ns}	1.259 ^{ns}	0.713 ^{ns}	2.929 ^{ns}	106483.242**	0.048**	1.824**
Error a	6	20.675	0.664	0.449	3.235	6401.436	0.001	0.49
Plant density (D)	2	80.567**	1.614**	2.843**	3.534**	50804.854**	0.003 ^{ns}	0.389*
N× D	6	2.254 ^{ns}	0.047 ^{ns}	0.078 ^{ns}	0.394 ^{ns}	5243.698**	0.003 ^{ns}	0.1 ^{ns}
Error b	16	2.25	0.124	0.172	0.204	1240.178	0.002	0.73

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

Table 2. Means comparison for traits of coriander as affected by different rates of nitrogen.

Nitrogen rate (kg N/ha)	Plant height (cm)	Stem diameter (mm)	first fruit distance from ground (cm)	branch number per main stem	Fruit yield (kg/ha)	Essential oil percent
0	34.7 b	2.41 a	3.78 a	7 a	353.3 c	0.153 c
40	38.6 ab	3.07 a	3.86 a	7.6 a	442.1 bc	0.226 b
80	41.6 a	3.22 a	3.82 a	8.1 a	615.2 a	0.243 b
120	37.1 ab	4.38 a	3.16 a	6.9 a	474.7 b	0.33 a

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

Table 3. Means comparison for traits of coriander as affected by different levels of plant density.

Density (plant/m^2)	Plant height (cm)	Stem diameter (mm)	first fruit distance from ground (cm)	branch number per main stem	Fruit yield (kg/ha)	Essential oil percent
30	35.6 c	3.33 a	3.51 c	7.9 a	411.7 c	0.226 a
40	37.7 b	2.96 b	3.89 b	7.5 b	462.4 b	0.234 a
50	40.7 a	2.59 c	4.48 a	6.8 c	540.4 a	0.254 a

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

Figures

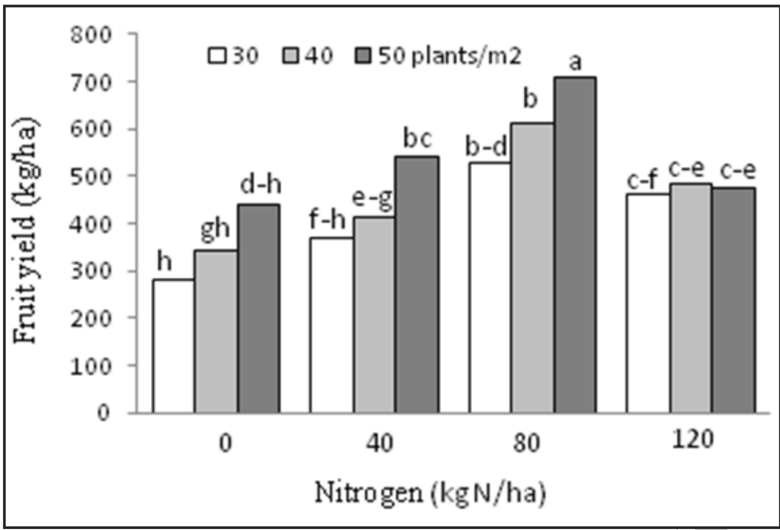

Fig. 1. Nitrogen fertilizer and plant density interaction on fruit yield of coriander.

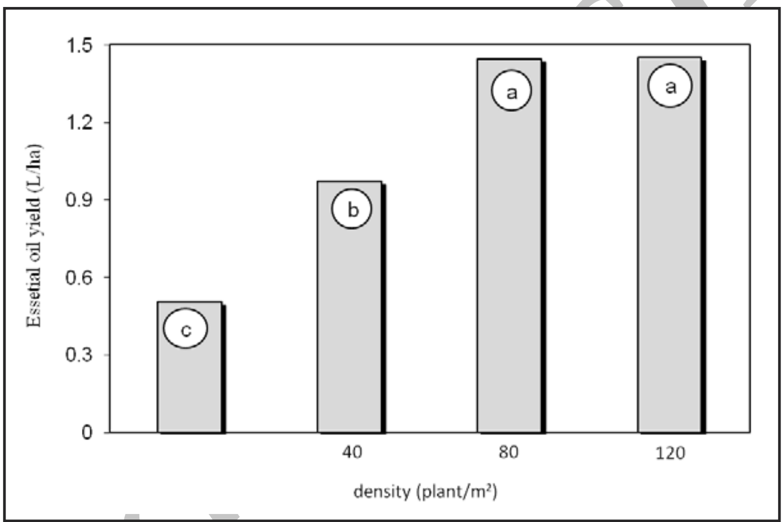

Fig. 2. Effect of p nitrogen fertilizer on essential oil yield of coriander.

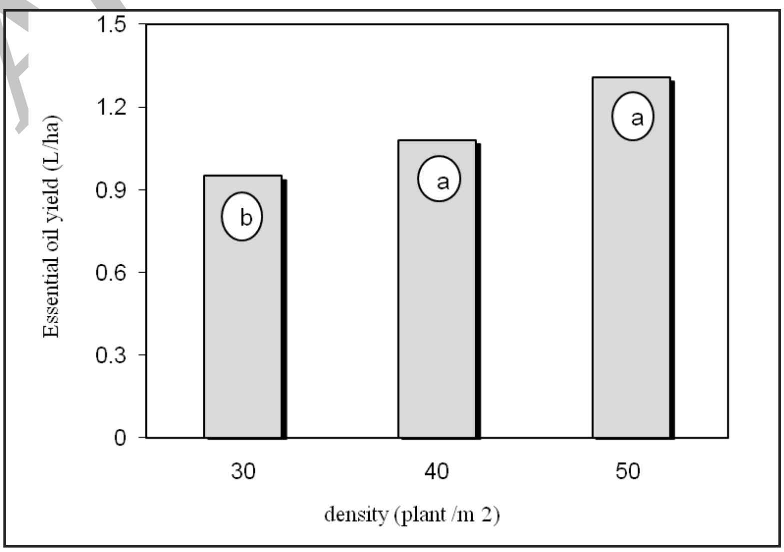

Fig. 2. Effect of plant density on essential oil yield of coriander.