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Chicory (*Cichorium intybus*) responses to nitrogen and plant density in Birjand, Iran

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Abstract

Chicory is an important medicinal plant and also used as a leaf vegetable for pasture forage. In order to study the effect of nitrogen and pant density on this plant, an experiment was conducted in the 2009-2010 growing season at the Agricultural Training Center of Mohammadieh, Birjand, Iran. A split plot experiment based on a randomized complete block design with three replications was used. Nitrogen rates including of 0, 100 and 200 kg.ha^{-1} N as urea (N_0, N_{100} and N_{200}, respectively) were arranged in main plots and four planting density (25, 16.7, 12.5 and 10 plants.m^{-2}) were employed in the subplots. The results indicated that nitrogen application had not any significant effect on dry root yield, but application of 200 kg.ha^{-1} N compared to control, increased dry leaf and total yields 39.85 and 31.89 percent, respectively. Although nitrogen application significantly decreased NUE but increasing plant density increased it. Increasing plant density enhanced root and leaf dry yield, but declined plant height, axillary root number and root length. Nitrogen application had not any significant effect on axillary root number and root diameter and length. The effect of nitrogen and plant density on root/shoot ratio was not significant. Totally the result showed that chicory's yield respond positively to increasing plant density (25 plant.m^{-2}) and nitrogen rate (200 kg.ha^{-1}) but increasing the yield was not proportionally to nitrogen fertilizer, consequently NUE declined in the highest nitrogen treatment.

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Introduction

Chicory (*Cichorium intybus* L.) belongs to the family Asteraceae used as a culinary herb (Muthuswami and Pappiah, 1980) and as a leaf vegetable for pasture forage (Muthuswami and Pappiah, 1997). Because the vegetative parts in this plant are economically valuable, increasing soil nitrogen content is very important in its cultivation. Patel *et al.* (2000) showed that chicory herbage yield was significantly increased with increase in the rate of nitrogen. Nitrogen is an integral part of chlorophyll. It is constituent of all proteins and promotes vigorous vegetative growth (Ahmed *et al.,* 2003). However, the lavish use of nitrogen raises cost of production.

A challenge in agricultural production system is to develop management techniques that combine and optimize crop production while ensuring environmental quality (Lafolie *et al.,* 1997). Considerable effort has been made to reduce environmental N losses through improved fertilizer N management practices (Zebarth and Rosen, 2007). One approach to reducing environmental loses of N is to increase the efficiency of N utilization by crop (Zebarth *et al.,* 2008). Crop N use efficiency is commonly defined as plant dry matter production per unit of N supply to the crop (Bock, 1984).

Plant density is an important determinant of yield. Optimum planting density is a key to achieve maximum crop production. In low density the plant can not completely use environmental factors such as light, water and soil; however intra-species competition in high density decreases the yield. Yield per unit area tends to increase as plant density increases up to a point and then declines (Akintoye *et al.,* 2009). Zaferbakhsh *et al.* (2011) reported that increased planting density has increased leaf yield of chicory.

Both chicory shoot and root are used for medical purposes. These parts are strongly influenced by planting density. But there is a little information about the appropriate plant density for this plant. On the other hand, additional nitrogen application can lead to environmental contamination resulting from excessive nitrate leaching (Dong *et al.,* 2005). Therefore this study was conducted to evaluate chicory responses to plant population and N fertilizer.

Materials and methods

Study site

This study was conducted in the 2009 growing season at the Agricultural Training Center of Mohammadieh, Birjand, Iran. Climate in this area is semi-dry to dry (annual rainfall is about 165 mm, maximum and minimum means temperature are 27.5 and 4.6 degrees centigrade, respectively). The soil of the field was clay loam with pH 8.1, contains total N 450 ppm with an EC of 3.2 $m.mohs.cm^{-1}$.

Experimental design and treatments

A split plot experiment based on a randomized complete block design with three replications was used. Each experimental plot was 5m long and 2m wide. Planting rows were 40cm apart. Nitrogen rates including of 0, 100 and 200 $kg.ha^{-1}$ N as urea (N_0, N_{100} and N_{200}, respectively) were arranged in main plots and four planting distances including 10, 15, 20 and 25cm were employed in subplots. Such distances provided 25, 16.7, 12.5 and 10 $plants.m^{-2}$.

Cultivation practices

All plots were fertilized uniformly with potassium sulphate (150 $kg.ha^{-1}$) and triple super phosphate (100 $kg.ha^{-1}$) before seed planting. Different levels of N were applied at two stages (50% at planting and 50% two month later). Main plots were surrounded by dikes with a distance of 1.5m between them to prevent the lateral spread of nitrogen. Sowing was done manually, 0.5cm depth on 15 April. Irrigation was employed with an interval of 4 days immediately after planting for uniform emergence until establishment of seedlings and after that continued weekly. Weeds were controlled by hand, when required.

Harvesting was done in 5 November (when the first chlorosis symptoms were emerged on the crownal leaves) manually by pulling the whole plant out of the soil. Final root, leaf and total dry yield were measured from 2m² of each plot. Morphological traits including plant height, axillary root number and root diameter and length were measured in 10 plants of each plot. Nitrogen use efficiency (NUE) was determined through total dry yield/applied N.

Data analyzing

Data were analyzed by one-way ANOVA using the statistical analysis system and MSTATC software. Means were compared by Duncan's multiple range tests at 5% probability level.

Results and discussion

Physiological traits

Nitrogen application had not any significant effect on dry root yield, but application of 200kg.ha^{-1} N compared to control, increased dry leaf and total yields 39.85 and 31.89 percent, respectively (Table 1). The result of Patel *et al.* (2000) also indicated that the herbage yield of chicory was significantly increased with increase in the rate of nitrogen except for 150 and 100 kg N.ha^{-1}, where the increase was not significant. Also Sifola and Barbieri (2006) showed that N fertilization up to 300 kg.ha^{-1} increased yield of above ground and leaf fresh biomass of basil.

Table 1. Effect of nitrogen on some physiological traits of *Cichorium indicum.*

Nitrogen rate (Kg.ha^{-1})	Root dry yield (g.m^{-2})	Leaf dry yield (g.m^{-2})	Total dry yield (g.m^{-2})	NUE (Biomass.N^{-1})	Root/Shoot
0	81.53 a	450.4 b	532.1 b	-	0.192 a
100	76.85 a	412.8 b	489.8 b	48.98 a	0.202 a
200	71.83 a	629.9 a	701.8 a	35.07 b	0.114 a
LSD	35.36	91.63	111.1	10.76	0.1014

Means followed by the same letter within each column are not significantly different according to Duncan multiple test (P=0.05).

Nitrogen is one of the most quantitatively important elements for plant growth and it has great effects on cell growth and metabolism (Chen *et al.,* 2003). Photosynthetic capacity is closely associated with leaf nitrogen, thus nitrogen limitation reduce photosynthesis and plant growth.

Nitrogen application significantly decreased NUE (Table 1). The results of Jiang and Hull (1998) on Kentucky bluegrass cultivars indicated that NUE negatively related to ambient nitrate levels. Regarding to the fact that treatment with high NUE (N100) had not produced the greatest total dry yield (Table 1), it can be said that high productivity does not depend on high NUE.

Table 2. Effect of plant density on some physiological traits of *Cichorium indicum.*

Plant density (Plant.m^{-2})	Root dry yield (g.m^{-2})	Leaf dry yield (g.m^{-2})	Total dry yield (g.m^{-2})	NUE (Biomass.N^{-1})	Root/Shoot
25	111.00 a	689.9 a	800.9 a	42.92 a	0.171 a
16.7	68.31 b	497.5 b	565.8 b	25.28 b	0.153 a
12.5	67.48 b	429.2 bc	497.0 bc	23.06 b	0.169 a
10	60.16 b	374.3 c	434.6 c	20.80 b	0.185 a
LSD	19.0	97.41	104.3	5.198	0.0543

Means followed by the same letter within each column are not significantly different according to Duncan multiple test (P=0.05).

Increasing plant density increased significantly the yields and NUE (Table 2). Zafarbakhsh *et al.* (2011) in chicory and Khazaie *et al.* (2008) in thyme also showed that increased planting density has increased biomass yield. In high density treatments, sunlight, nitrogen and other soil resources could be used more effectively. Actually when seed is not the main harvested part, the plant is less sensitive to high densities, thus in this condition high planting density could be used.

Root to shoot ratio variations under different nitrogen rates and plant density were not significant (Table 2). This means that these parts affected by the treatments equally.

Morphological traits

Nitrogen application increased plant height (Table 5). Nitrogen is an essential mineral element for plant growth. When N is deficient, plant are stunted. El-Desuki *et al.* (2005) also showed that effect of N on radish (*Raphanus sativus*) height was significant and positive.

Table 3. Effect of nitrogen on some morphological traits of *Cichorium indicum*.

Nitrogen rate ($Kg.ha^{-1}$)	Plant height (cm)	Axillary root number	Root diameter (mm)	Root length (cm)
0	50.0 b	6.02 a	15.63 a	18.10 a
100	55.1 b	5.83 a	14.93 a	17.59 a
200	63.7 a	5.78 a	14.99 a	18.23 a
LSD	7.47	2.032	2.761	2.704

Means followed by the same letter within each column are not significantly different according to Duncan multiple test (P=0.05).

Using N fertilizer had not any significant effect on axillary root number and root diameter and length (Table 3), but the result of Ghanti *et al.* (1989) on radish indicated that N fertilizer increased root length and diameter. Plant height and axillary root number significantly declined in high plant densities (Table 4). Plant height can be considered as one of the indices of plant vigor. Aminifard *et al.* (2012) in an experiment on sweet pepper (*Capsicum annum*) showed that plant height decreased as plant density increased. It might be attributed to the possible competition for nutrients and other resources.

Table 4. Effect of plant density on some morphological traits of *Cichorium indicum*.

Plant density ($Plant.m^{-2}$)	Plant height (cm)	Axillary root number	Root diameter (mm)	Root length (cm)
25	45.6 c	4.544 c	14.63 a	17.11 b
16.7	53.9 b	5.411 bc	14.89 a	18.28 ab
12.5	53.8 b	5.800 b	15.12 a	17.76 ab
10	71.9 a	7.756 a	16.09 a	18.74 a
LSD	7.24	1.085	1.728	1.479

Means followed by the same letter within each column are not significantly different according to Duncan multiple test (P=0.05).

On the other hand the growth and development of a root system is highly sensitive to modification by different factors, such as supply of photosynthate from the shoot and distribution of nutrients in the soil (Bloom *et al.,* 2002; Walch-Liu *et al.,* 2006), thus it is expected that some characteristics of root had not been significantly affected by N.

The lack of N significant effect on axillary root number and decreasing this trait in high plant density showing that in addition to N, there is another deficiency in soil nutrients. In general the response of root architecture to low nutrients availability may act to increase the efficiency of nutrient capture (Lopez-Bucio *et al.,* 2003).

In conclusion the result showed that chicory's yield respond positively to increasing plant density (25 plant.m^{-2}) and nitrogen rate (200 kg.ha^{-1}) but increasing the yield was not proportionally to nitrogen fertilizer, consequently NUE declined in the highest nitrogen treatment.

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