# Effect of Nitrogen Rate on Mucilage Content, Yield and Yield Components of Borage (*Borago officinalis*)

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**Abstract**

Borage (*Borago officinalis* L. Boraginaceae) has been widely recognized as a medicinal plant with high nutritive value and for γ linolenic acid (GLA), extracted from the oil seed. Information on cultural practices for borage production is limited and evaluation of environmental factors affecting vegetative and seed yield would be required. In this study, the effect of 5 nitrogen levels including 0, 50, 100, 150 and 200 kg ha$^{-1}$ on mucilage content, yield and yield components of borage was studied in a randomized complete block design with three replications. Nitrogen treatments had significant effect on the number of inflorescence per plant, the number of floret per plant, plant dry matter, flower and stem mucilage while plant height and leaf mucilage percentage were not affected by nitrogen treatment. The highest number of floret per plant as flower yield and mucilage of flower were found in 100 kg ha$^{-1}$ nitrogen level. Using appropriate amount of nitrogen fertilizer is suggested to obtain higher mucilage for medicinal proposes in borage crop.

## 1. Introduction

Medicinal plants are the source of secondary metabolites useful for traditional remedies of physical and mental disorders. Production of these useful metabolites could be environmentally affected by different stresses (such as drought and salinity) and nutrient factors (such as nitrogen rate) (Singh et al., 2003). Borage, (*Borago officinalis*) as a medicinal plant is native to Europe, Asia and North Africa. It has been used as a culinary herb of purposed medical value. Leaves of borage are used like spinach, in pickles and salads, in iced drinks and the flowers are used as an edible decoration for salads. In many Mediterranean countries, the edible part of the plant is the basal leaf petiole, which has a high nutritive value (Medrano et al., 1992). Borage has invaluable potential market for the γ linolenic acid (GLA) extraction, an unusual fatty acid extracted from the seed and this may be led to increasing agricultural interest. The oil content of the seed is 30–40% by weight, of which 20–30% is GLA that commonly used as nutritional and pharmaceutical prescription to control heart disease, diabetes, arthritis, multiple sclerosis and cyclical mastalgia (Horrobin, 1990; Horrobi, 1997; Barre, 2001).

There is little information on the effect of environmental factors such as seeding date and nitrogen fertilization on borage flower and mucilage yields. Slinkard and Kulow (1996) suggested the first week of June as seeding date of borage in the Dark Brown soil zone of Saskatchewan, Canada to maximize GLA content in the seed. Suchorska and Osinka (1997) observed that early seeding had significantly higher seed yield than late planting and El Hafid et al. (2002b), reported that delay in planting reduced total dry matter of borage. Berti et al. (2002), also showed that seed yield and harvest index were both decreased due to seeding postpone. An interaction was found between borage yield and the medicinal compounds that could be due to planting date and nitrogen fertilization (Berti et al., 2002). Nitrogen has a significant impact on growth parameters and essential oil of medicinal plants (Emongor and Chweya, 1992; Johnson and Franz, 2002). Ramash et al. (1989) and Omidbaigi and Mohebby (2002) have reported the higher values of mucilage content with application of nitrogen fertilizer in isabgol, (*Plantago ovata)*. There was also significant effect of nitrogen application on saffron flower production (Unal and Cavusoglu, 2005). Medicinally important vegetative growth of *Asparagus racemosus* has been also increased using nitrogen utilization (Hossain et al., 2006).

In borage, Deibert et al.,(2001) using nitrogen rates of 67 and 134 kg ha$^{-1}$ concluded that increasing nitrogen rate in the soil and plant tissues induced vegetative growth and flower yield, while harvest index was not affected (Johnson et al.,2001). The highest seed yield in borage was reported to be obtained using 20 to 40 kg ha$^{-1}$ nitrogen (El Hafid et al., 2002a). The range of 8.2 to 11.1% was also reported for gum and mucilage percentage. It seems that climate condition may have affected the results of different studies. Therefore the suitable planting date and appropriate nitrogen rate should be optimized in each condition. This information is not accessible in some cold climate conditions. The objective of this study was to evaluate the effect of five nitrogen rates on borage flower and essential matter (gum and mucilage yield). 2-to find the appropriate nitrogen level to maximize borage medicinal yield in cold climate of Hamadan, Iran.

## 2. Material and methods

Field studies were conducted in 2003-2004 at the Agriculture Research Center of Hamadan, Iran (53°25′ N, 113°33′ W) on a sandy clay soil. Annual precipitation is 320 mm and minimum and maximum average temperature is -7.5 and 13.5 ˚C, respectively. Based on lab analysis, soil electric conductivity (EC) was 0.7 m℧ (millimhos) cm$^{-1}$, and soil pH was 8.5. The nitrogen content of a composite soil sample determined prior to planting to a depth of 60 cm was also 50 kg N ha$^{-1}$. Plots for five nitrogen fertility rates as treatment including 0, 50, 100, 150 and 200 kg ha$^{-1}$ N, were established, and treatments were arranged in a randomized complete block design with four replications. Individual plots consisted of six rows, 6 m-long with a row spacing of approximately 30 cm. Borage crop was seeded at 17 kg ha$^{-1}$, and phosphate was applied with the seed at 150 kg P ha$^{-1}$. Plots were hand-weeded as needed.

Borage crop has indeterminate growth habit; therefore, plots were manually harvested during growing season from early to the end of flowering. Total above-ground dry weight biomass (DTW) was assessed by manually harvesting of the area of approximately 1 m$^2$ within each plot. Gum and mucilage content were determined using a mixture of 5 g powder in 50 ml distilled water. Samples were placed for 24 h in room temperature and then 50 ml extra water was added. After shaking, 10 ml of mixture was transferred to an erlenmyer and 30 ml ethanol 70% was mixed. Gum and mucilage content was sedimented, then filtered, was dried 15 min. in 105$^0$C and then was measured.

Data were analyzed using the PROC ANOVA procedure of SAS (SAS Inst., 1988) and means were compared, using Fisher's protected LSD (0.05).

## 3. Results and Discussion

There were significant differences among different nitrogen levels for vegetative and reproductive growth except of height, and percent of leaf mucilage (Table 1). There was clear response of borage plant dry weight (Table 2), number of branches and inflorescence plant$^{-1}$, number of floret inflorescence$^{-1}$, number of florets plant$^{-1}$ and percent mucilage of flower and stem (Table 2).

Plant height and percentage of leaf mucilage were significantly increased by increasing nitrogen rats from 0 to 100 kg, but they

Table 1: Analysis of variance summary of nitrogen treatments on studied traits

| Source of variation | Df | Height | No. of branch plant$^{-1}$ | Plant dry weight | No. of inflorescence plant$^{-1}$ | No. of floret inflorescence$^{-1}$ | No. of floret plant$^{-1}$ | Mucilage of flower | Mucilage of leaf | Mucilage of stem |
|---|---|---|---|---|---|---|---|---|---|---|
| Rep | 2 | 124.65 | 16.69$^*$ | 0.057 | 0.03 | 3.20 | 175.63 | 0.11 | 2.99 | 0.32 |
| Nitrogen | 4 | 50.74 | 14.17$^{**}$ | 0.66$^{**}$ | 9.75$^*$ | 353.87$^{**}$ | 26033.90$^{**}$ | 55.31$^{**}$ | 1.2 | 9.08$^{**}$ |
| Error | 16 | 53.57 | 3.72 | 0.074 | 0.22 | 1.57 | 216.48 | 0.70 | 3.68 | 0.62 |

Note: $^*$ and $^{**}$ Significant mean square at probability levels of 0.05 and 0.01, respectively

Table 2: Mean comparisons of different nitrogen rates for studied traits

| Nitrogen rates (kg ha$^{-1}$) | Height (cm) | No. of branch plant$^{-1}$ | Plant dry weight (g) | No. of inflorescence plant$^{-1}$ | No. of floret inflorescence$^{-1}$ | No. of floret plant$^{-1}$ | Mucilage of flower (%) | Mucilage of leaf (%) | Mucilage of stem (%) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 90.85$^a$ | 7.35$^d$ | 1.26$^c$ | 10.45$^d$ | 17.09$^d$ | 178.59$^e$ | 7.09$^c$ | 7.00$^a$ | 9.23$^a$ |
| 50 | 93.80$^a$ | 9.31c | 1.38$^{bc}$ | 11.94$^b$ | 30.51$^c$ | 364.28$^d$ | 11.95$^b$ | 7.47$^a$ | 7.48$^b$ |
| 100 | 92.30$^a$ | 10.87$^{bc}$ | 1.63$^b$ | 13.87$^a$ | 34.78$^b$ | 482.39$^a$ | 13.42$^a$ | 7.84$^a$ | 7.87$^b$ |
| 150 | 98.46$^a$ | 11.58$^b$ | 1.66$^b$ | 11.81$^{bc}$ | 36.50$^a$ | 431.06$^b$ | 11.54$^b$ | 7.03$^a$ | 6.17$^c$ |
| 200 | 95.03$^a$ | 14.66$^a$ | 2.12$^a$ | 11.26$^c$ | 35.64$^{ab}$ | 401.30$^c$ | 6.81$^c$ | 7.38$^a$ | 6.42$^c$ |

Note: In each column, means with the same letter are not significantly different, $p$<0.05.

decreased to some extent in higher nitrogen levels. The number of branch plant$^{-1}$ and plant dry weight were continuously increased from 7.35 to 14.66 and 1.26g to 2.12g respectively, as nitrogen application was increased from 0 to 200 kg ha$^{-1}$ (Table 2). In contrast, the number of inflorescence plant$^{-1}$, the number of floret plant$^{-1}$ and percentage of flower mucilage were increased from 10.45 to 13.87, from 178.6 to 482.4 and from 7.09 to 13.42% by 100 kg ha$^{-1}$ nitrogen rate, respectively, and then they were decreased (Table 2). The number of florets inflorescence$^{-1}$ was maximum after 150 kg ha$^{-1}$ nitrogen treatment (Table 2). The increase in plant height in response to application of N fertilizers is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates and thereby resulted in more mucilage content and dry matter accumulation (Chaturvedi , 2005) Results are supported by Abreu et al., (2002) findings on Insulina plants, *Cissus sicyoides*, who showed that the higher biomass gain and mucilage production occurred using higher nitrogen dose in soil culture.

The results showed that increasing nitrogen rates, increased the vegetative growth including height, number of branch and plant dry weight, but reproductive growth including the number of florets and inflorescences and mucilage content were reduced with higher rates of nitrogen application. Ramash et al. (1989) and Omidbaigi and Mohebby (2002) working on the effect of nitrogen fertilizer on seed yield and mucilage content of Isabgol, *Plantago ovata*, also reported that the best level of nitrogen application was to use 100 kg ha$^{-1}$ nitrogen and increasing the nitrogen rate reduced the values of traits. In contrast to other traits, percent of stem mucilage was significantly reduced from 9.23 to 6.42 as nitrogen rate was increased from 0 to 200 kg ha$^{-1}$. It seems that stem reserves including mucilage may be consumed with induced growth of branches and florets due to nitrogen application. In fact, an adequate supply of nitrogen is associated with high photosynthetic activity and vigorous vegetative growth, however nitrogen supply could influence the utilization of carbohydrates (Hakoomat et al., 2005) in the stem and therefore the negative effect of higher nitrogen rates on stem mucilage content may be observed.

Studies by Johnson et al. (2001) and El Hafid et al. (2002a) showed that high nitrogen rates promote vegetative growth and reduce reproductive growth, but results on the effect of nitrogen application on borage seed yield and dry weight was not conclusive. There are also some reports on adverse effect of increasing nitrogen rate on other oilseed species (Wander and Bouwmeester, 1998; Nelson et al., 1999). Therefore higher nitrogen rates (200 kg N ha$^{-1}$ and beyond) should not be recommended since promoted vegetative growth are obtained in expense of reduced gum and mucilage content, lower flower yield and possibly seed oil and GLA content. Furthermore higher nitrogen rates may be precluded considering production cost and ground water contamination.

## 4. Conclusion

Application of Nitrogen fertilizer upto 100kg ha$^{-1}$ promoted significantly flower yield and mucilage of flower in borage. Therefore, the optimum dose of applied nitrogen fertilizer may have a marked effect on some of the components and medicinal uses of *Borago Officinalis*.

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