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Response of leek (*Allium porrum* L.) to different levels of nitrogen dose under agro-climate conditions of Bosnia and Herzegovina

Lutvija KARIĆ[1], Smiljka VUKAŠINOVIĆ[2], Dragan ŽNIDARČIČ[3]

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ABSTRACT

Field experiment was conducted to evaluate growth, yield and quality of leek (*Allium porrum* L.) under different nitrogen levels, on a heavy clay loam soil in the agro-climate of central Bosnia and Herzegovina. Treatments comprised four nitrogen levels (0, 50, 100 and 200 kg ha^{-1}), using local leek variety Karentan. The levels of 100 and 200 kg ha^{-1} were repeated in split applications. Results demonstrated that increasing level of nitrogen to 200 kg ha^{-1} resulted in greater number of leaves per plant (14.4), maximum leaves weight (194.6 g plant^{-1}), higher pseudo-stem diameter (36.3 mm), maximum pseudo-stem weight (146.5 g) and highest total yield (91.98 t ha^{-1}). There was a linear increase in total yield from nitrogen fertilization (r^2 = 0.87). There was also slight evidence that higher nitrogen amount decrease dry matter. Furthermore, increase in nitrogen levels had no appreciable effect on chemical composition (total and reducing sugars, vitamin C) of leek.

Key words: *Allium porrum*, leek, weather conditions, yield, yield components, chemical composition

IZVLEČEK

ODVISNOST PORA (*Allium porrum* L.) OD GNOJENJA Z DUŠIKOM V AGROKLIMATSKIH RAZMERAH OSREDNJE BOSNE IN HERCEGOVINE

V poljskem poskusu na težki ilovnati zemlji v agroklimatskih razmerah osrednje Bosne in Hercegovine smo ugotavljali rast, pridelek in kakovost pora (*Allium porrum* L.), gnojenega z različnimi odmerki dušika. V poskus je bila vključena lokalna sorta Karentan, ki smo jo gnojili s štirimi različnimi količinami dušika (0, 50, 100 in 200 kg ha^{-1}). Gnojenje s 100 in 200 kg ha^{-1} je bilo razdeljeno na več odmerkov. Rezultati so pokazali, da se je z naraščanjem količine dušika pri 200 kg ha^{-1} povečalo število listov na rastlino (14,4), listi so dosegli največjo težo (194,6 g rastlino^{-1}), lažna stebla so dosegla največji premer (36,3 mm) in največjo težo (146,5 g). Pri 200 kg dušika ha^{-1} je bil največji tudi skupni pridelek (91,98 t ha^{-1}), ki je linearno naraščal s količino gnojila (r^2 = 0,87). Opazili smo še rahel trend upadanja suhe snovi z

[1] Assist., M. Sc. Agr., Univ. of Sarajevo, Fac. of Agriculture, Zmaja od Bosne 8, B&H-71000 Sarajevo, Bosnia and Herzegovina,
[2] Prof., Ph. D., ibid,
[3] B. Sc. Agr., Univ. of Ljubljana, Biotechnical Fac., Agronomy Dept. Jamnikarjeva 101, Sl-1111 Ljubljana, Slovenia

naraščajočim gnojenjem. Naraščajoča količina dušika pa ni zaznavno vpliva na kemično sestavo pora (skupni in reducirajoči sladkorji, C-vitamin).

Ključne besede: *Allium porrum*, por, vremenske razmere, pridelek, značilnosti pridelka, kemična sestava

INTRODUCTION

The leek (*Allium porrum* L.) is a herbaceous biennial plant and a member of the *Alliaceae* family. It is closely related to onion. The leaves and long white blanched stem are eaten cooked or can be added to salads (Theunissen and Schelling, 1998). Leek is one of the economically most important field vegetable crops in Europe (Benoit and Ceustermans, 1994). It is especially vulnerable up to harvest to weed interference and nutrient leaching due to its relatively long vegetation period, and its open canopy up to harvest (Müller-Schärer, 1996).

Leek, used for fresh consumption can also be considered a typical vegetable crop in Bosnia and Herzegovina, mostly produced on relatively small family farms. Farmers often find it difficult to develop profitable production and there are still several important questions to be solved including a crop management. Fertilization plays a very important role in crop management. To increase the yield potential of leek, the crop has been reported to respond to good soil fertility and adequate fertilizer (Thorup-Kristensen and Sorensen, 1998).

The major nutrient required by leek for optimum growth is nitrogen (Baker, 1998). Nitrogen is an integral part of chlorophyll. It is a constituent of all proteins and promotes vigorous vegetative growth (Ahmed, 2003). Previous studies have addressed the relationship between different N fertilizers and the growth characters, yield and yield components of leek. However, optimum N amount reported for maximum leek growth by different researches are substantially different. Kristensen et al. (2004) recommended that the application of 50-75 kg N ha^{-1} before sowing ensured germination and plants growth. Baker (1998) mentioned that leeks require about 200-250 kg N ha^{-1}, preferably in three rates – one-third pre-plant incorporated, one-third as a side dressing, and one-third as a top dressing when the leaves are dry. Sorensen (1993) found that the maximum yield for leeks grown for summer and autumn harvest was obtained at total nitrogen supply of 210 and 220 kg N ha^{-1}. According to Savić et al. (2004), the time of nitrogen application influenced growth and nitrogen uptake parameters of leek. They reported that application rate in split doses (125 + 125 kg N) increased vegetative growth. Hochmuth (2000) observed that 120 kg N ha^{-1} produced the highest yield of leek and reduced damage from insects such as thrips. To obtain optimum yield and to utilize applied nitrogen effectively, leeks have to be well supplied with water (Sorensen et al., 1995). However, the response of leek plants to nitrogen will probably vary in different geographical areas, seasons and cultivars, and from different agricultural practices such as planting density, irrigation, fertilization, and other factors.

The study aims to evaluate the effect of N fertilization applied as calcium ammonium nitrate (27% N) on growth and productivity of leek in central Bosnia and Herzegovina, which can help in predicting the optimal N fertilizer requirement and improve the practice of leek production.

MATERIAL AND METHODS

Field studies were established at the Experimental Station Butmir (latitude 43^o 49'N, longitude 18^o 21'E, elevation 505 m) near Sarajevo. Soil classification is according to soil heavy clay content with pH 6.7. Leeks were cultivated in the field after potatoes. The experiment was laid out in randomized complete block design with four replications measuring a net plot size of 2.5 x 1.2 m^2. In autumn 2002, the farmyard manure at the rate of 30 tones per ha^{-1} was applied to improve physical condition and the field was ploughed at a 30 cm depth. Base-fertilization was carried out according to soil analyses with NPK. The amount of 400 kg ha^{-1} of 15N-15P_2O_5-15K_2O was spread on the ground during the spring cultivation.

The bare-root transplants of local variety Karentan with 4.5 mm thick pseudo-stems were produced in nursery beds. On 3 June 2003 leeks were manually transplanted into a plant bed which was cultivated on the previous day, using a rotary cultivator. Prior to transplanting roots and leaves of the transplants were trimmed according to standard practice. Planting depth of transplants was 6 cm. Inter-row spacing was 30 cm, whereas in-row spacing was 15 cm. The plants were watered immediately after transplanting to avoid drought stress.

The total nitrogen supplied ranged from 0 to 200 kg N ha^{-1}. Thus following four different N levels: N_0 - control (residual soil nitrogen only), N_1 (N fertilizer was applied at transplanting at rates of 50 kg N ha^{-1}), N_2 (50 kg N ha^{-1} at transplanting + 50 kg N ha^{-1} 62 days after transplanting) and N_3 (50 kg N ha^{-1} at transplanting + 75 kg N ha^{-1} 62 days after transplanting + 75 kg N ha^{-1} 92 days after transplanting). The nitrogen fertilizer was applied as calcium ammonium nitrate (27% N). The fertilizer was placed by hand in a hand-drawn furrow, about 5 cm on one side of the row and about 5 cm deep, after which the furrow was slightly covered with soil.

All recommended cultural practices such as irrigation, eradication of weeds and plant protection were adopted uniformly according to crop requirements. At the time of maturity, on 3 October, 117 days after transplanting, a sample of twenty random plants from each treatment was undercut by hand. The blade cut was 2 cm beneath the base of the plant. After dividing plants into pseudo-stems and leaves the yield and yield components of leek were determined immediately after harvest. The material from ten plants was dried in a forced ventilated oven at 85 ^{o}C for 24 h to determine dry matter. The fresh material of the remaining ten plants was put in plastic bags and stored in a deep freeze at -30 ^{o}C for later analyses. Vitamin C was determined by the Tilmans method and total sugars and reducing sugars content with the Luff-Schoorol method (Krešić et al., 2004).

A sample of twenty random plants from each plot was taken to obtain number of leaves per plant, leaves weight, pseudo-stem diameter, pseudo-steam height, pseudo-steam weight and to record physicochemical analyses.

The data thus collected were analyzed using analysis of variance techniques and Duncan's multiple rang test at 5% probability levels was applied to test the significance of treatments means.

RESULTS AND DISCUSSION

Climatic conditions

The duration of growth period was 117 days. Climatic data was measured in a meteorological station located in the experimental field, about 200 m distance from the experimental plots. Table 1 presents the course of meteorological conditions during the vegetation of leek. It shows the monthly average air temperature and rainfall from June to September 2003.

The weather conditions during the growth period varied. The 2003 season was relatively hotter than the 50-year average. The temperatures were higher in the beginning of the growing season. Average monthly temperature in the summer period of 1st June to 30th August was above normal. A significant drop in temperature was observed in September, especially in the final third of this month, when the average air temperature was only 14.3 °C. Such temperature distribution limited the growth of leek plants. However, the nutrient accumulation in leek was most essential in September, which was relatively wet and cold. The total precipitation sum during the leek vegetation was insufficient for proper growth and development of plants. The total rainfall received in 2003 was relatively lower than in the 50-year average. Precipitation shortages occurred especially in August (7.2 mm). However, crop growth was not affected by unusual climate events such as exceptional drought because to supplement low rainfall, irrigation was applied several times during the season.

Table 1: Average monthly air temperatures and monthly sums of rainfall in relation to the 50-year average

Month	Air temperature (°C)			Sums of rainfall (mm)		
	2003	50-year average	Differences	2003	50-year average	Differences
June	20.2	16.9	+ 3.3	82.8	91.0	– 8.2
July	20.2	18.9	+1.3	49.8	79.3	– 29.5
August	22.0	18.5	+ 3.5	7.2	70.8	– 63.6
September	14.3	15.1	– 0.8	45.0	70.2	– 25.2
Σ				184.2	311.3	– 127.1

Yields components and yield

Growth was typical of field-grown plants. Results depicted (Table 2) that growth parameters react differently to varying levels of nitrogen. Increasing the rate of nitrogen had a significant effect on the yield components, except on pseudo-stem height.

Further, data revealed that application of N_3 (200 kg N ha^{-1}) resulted in a maximum number of leaves per plant (14.4). No effect was observed on the number of leaves up to N_2. The differences of nitrogen effect on leaves weight became greater. The N_3 and the N_2 treatments were significantly different from the N_1 and the N_0 (control). No significant difference was found between the N_1 and the N_0. However there were significant differences between N_3 and the N_2 treatments. The highest leaves weight of 194.6 g per plant obtained from 200 kg N ha^{-1} applied.

The results indicated that only nitrogen application of 200 kg ha^{-1} affected pseudo-stem diameter. There were significant differences found in the highest level and other levels of treatments. Treatment of N_3 gave the highest pseudo-stem diameter (36.3 mm) and N_0 treatment gave the lowest diameter (32.1 mm). However, no significant differences were found for the effect of nitrogen on diameter among the N_2, N_1 and N_0 treatments.

Pseudo-stem height did not vary according to the nitrogen levels. The response was small and not significant. That means that low and maximum doses of nitrogen have no effect on this yield characteristic. Individual values for pseudo-stem height are very uniform and range from 12.2 to 12.4 cm. The response for nitrogen is different in terms of pseudo-stem weight. Crop has shown direct relation to the increased fertilizer. A similar weight increase was found between the leaves weight and pseudo-stem weight when introducing an increase in nitrogen. Almost identical relation was recognized. The differences established the range from 108.0 g (N_0) to 146.5 g (N_3).

Table 2: Yield components of leek as affected by different levels of nitrogen*

Nitrogen dose (kg ha^{-1})	Leaves plant^{-1} (No.)	Leaves weight (g plant^{-1})	Pseudo-stem diameter (mm)	Pseudo-stem height (cm)	Pseudo-stem weight (g)
N_0	12.6 b	144.5 c	32.1 b	12.2 a	108.0 c
N_1	12.7 b	147.9 c	32.9 b	12.3 a	110.9 c
N_2	12.9 b	171.7 b	33.6 b	12.4 a	131.0 b
N_3	14.4 a	194.6 a	36.3 a	12.4 a	146.5 a
Means	13.5 ab	164.6 b	33.7 b	12.3 a	124.1 b

*Lower case letters indicates significant difference down to the column (level of significance 5%)

Vegetative growth influenced leaves and pseudo-stem growth. It seems that the yield was affected mainly by number of leaves per plant, leaves weight and pseudo-stems weight.

Table 3: Yield, relative yield and dry weight of leek as affected by different levels of nitrogen*

Nitrogen dose (kg ha^{-1})	Dry/fresh weight/plant (%)		Yield (t ha^{-1})	Relative yield (%)
	Leaves	Pseudo-stem		
N_0	11.97 a	16.33 a	65.96 d	100 a
N_1	11.90 a	16.32 a	70.25 c	107 b
N_2	11.76 a	15.91 a	86.83 b	132 c
N_3	11.60 a	15.44 a	91.98 a	139 d
Means	11.81 a	16.00 a	78.75 bc	119 bc

*Lower case letters indicates significant difference down to the column (level of significance 5%)

The dry matter content is the ratio between dry and fresh weight expressed as a percentage. Percentage of dry matter is an important reference parameter, and is somewhat significant as well to a consumer who does not want to buy watery products (Raupp, 2005). In our experiment the applied nitrogen doses did no have significant effect on this parameter. In spite of this fact, there were tendencies for the dry matter content to decrease slightly as the nitrogen level was increased. The portion of dry matter decreased from 11.97% at N_0 to 11.60% N_3. These results are in agreement with those obtained by Sophea at al. (2001) and Sorensen (1999). These researches pointed out that increasing the application rate of nitrogen fertilizer decreased dry matter content in vegetables.

The leek yield (t ha^{-1}) was significantly affected by nitrogen treatment. The differences established the range from 65.96 t ha^{-1} (N_0) to 91.98 t ha^{-1} (N_3). There was a 7% increase in total yield leek for N_1, 32% for N_2 and 39% for N_3 compared to the control treatment. The response of yield to nitrogen level was linear over the range of 0 to 200 kg ha^{-1} ($y = 0.13838x + 66.646$; $r^2 = 0.8798$). This fact implies that there might have been response to even higher levels of application nitrogen.

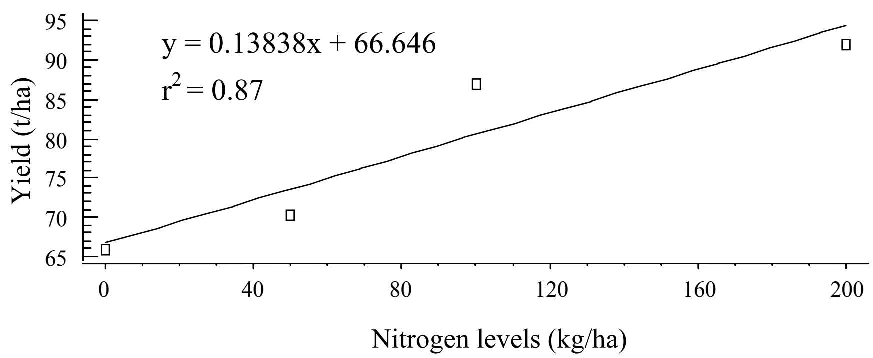

Figure 1: Relationship between nitrogen level and yield of leek

Chemical composition

Mineral fertilization, especially of nitrogen, affects the chemical composition of vegetables. The flavor and palatability of leek plants is a function of relative levels of total sugars (glucose + fructose + saccharose) or reducing sugars (glucose + fructose) and presence of various aromatic constituents. Also C vitamin concentration in plants should not be ignored as an important parameter although quality standards for leek do not include a minimum requirement for it.

The leek analyses showed that the content of vitamin C was not significantly affected by the factor investigated. The highest level of vitamin C (22.24 mg g^{-1}) came from leek leaves in the treatment with the highest amount of nitrogen, declining to value of 16.58 mg g^{-1} for the leek leaves growth in the lowest amount of nitrogen. But these values were not significantly affected. Our results are not conformity with those of Sorensen (1999) and Brunsgard et al. (1997) who mentioned that increasing the rate of nitrogen decreased the concentration of C vitamin. Worthington (2001) claims that increasing the application of nitrogen, increases protein production and reduces carbohydrate production. Because vitamin C is made from carbohydrates, the synthesis of vitamin C is reduced also.

No clear effect of nitrogen level on sugars content has been observed. The share of total sugars was between 2.25% – 4.16% of leaves and 7.10% – 8.99% of pseudo-stem. The total sugars content of the pseudo-stem tended to be higher than in the leaves but there was no relation to the level of nitrogen. On the contrary, the reducing sugars content of leek was higher than in the pseudo-stem but, as in the case of the total sugars content, there was no relationship with the level of nitrogen that was applied. These results are not in correspondence with the findings of Biczak et al. (1998) and Venter (1983) who observed that increasing pre-sowing and top-dressing doses of nitrogen fertilizers cause a decrease of the sugars in vegetables. Where nitrogen levels are limiting, photosynthesis is not fully used in the synthesis of organic nitrogen compounds and sugars are accumulated (Mengel and Kirkbiy, 1978). Our experiment did not confirm this thesis. There were small differences between treatments in total sugars and reducing sugars contents. On the other hand, our results agree with the findings of Brunsgard et al. (1997) who reported that sugars contents were not significantly affected by nitrogen amount.

Table 4: Total and reducing sugars of leek as affected by different levels of nitrogen*

Nitrogen dose (kg ha^{-1})	Total sugars (%)		Reducing sugars (%)		Vitamin C (mg g^{-1})	
	Leaves	Pseudo-stem	Leaves	Pseudo-stem	Leaves	Pseudo-stem
N_0	4.16 a	8.99 a	3.33 a	2.93 a	16.58 a	17.35 a
N_1	2.25 a	7.10 a	1.67 a	1.32 a	16.64 a	17.05 a
N_2	3.17 a	8.64 a	2.73 a	2.36 a	20.31 a	14.07 a
N_3	3.83 a	8.23 a	2.76 a	1.30 a	22.24 a	18.68 a
Means	3.35 a	8.24 a	2.62 a	1.97 a	18.94 a	16.78 a

*Lower case letters indicates significant difference down to the column (level of significance 5%)

CONCLUSIONS

In terms of chemical composition, the results did no find any significant differences in the content of total and reducing sugars and vitamin C of leek under the influence of various levels of nitrogen. It is difficult to determine why there was no chemical composition change in response to nitrogen application in the heavy clay soil experiment with leek crops. There may have been environmental factors that limited growth that were not accounted for in our experiment.

In conclusion, application of 200 kg N ha^{-1} was found to be the best dose of fertilizer and is recommended for the highest yield of leek under the agro-climatic conditions of central Bosnia and Herzegovina.

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