

Effect of Nitrogen on the Yield and Nitrate Content of Early Potato Grown under Greenhouse Conditions

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Abstract: A major reason for early potato production under greenhouse conditions is the fact that this type of potato ensures early marketable yields, high prices and cost-effectiveness of production. Fertilization is an essential cultural operation in early potato production and therefore it should be given serious attention, as excessive fertilization during a short growing period can cause high nitrate accumulation in early potato tubers. An experiment involving five potato cultivars (Liseta, Adora, Cleopatra, Amorosa and Kondor) and four nitrogen rates (0, 60, 120 and 180 kgN/ha) was conducted to identify the most suitable nitrogen rate that would facilitate high yields and simultaneous optimal nitrate accumulation in potato tubers. The average potato yields produced showed that mineral nutrition had a significant effect on yield, which ranged from 13.2 t/ha (cv. Kondor) to 18.2 t/ha (cv. Cleopatra). Nitrogen fertilization rates of up to 120 kg/ha did not pose a risk of increased nitrate accumulation in potato tubers, whereas the 180 kgN/ha rate resulted in higher-than-average nitrate levels in potato tubers.

Key words: early potato, cultivar, nitrates, yield, greenhouse

Introduction

Potatoes are vegetable/field crops widely distributed and largely used in the human diet in different consumable and processed forms. Particular importance is given to producing early potato under greenhouse conditions for earliest marketable yields as well as under open field conditions using agrotexiles to cover the crop (Đurovka *et al.* 2006). Greenhouse production of early potato has been practiced in Serbia for the last several years and the reasons for its initiation include early marketable yield and good integration into the greenhouse vegetable production

structure. Another advantage of greenhouse early potato production is its cost-effectiveness in that it ensures early marketable yield and, hence, very high prices. Cultivars designed for this type of production include early-maturing, red- and blue-skinned cultivars characterized by rapid tuber setting and intensive tuber filling.

Fertilization is one of the most vital cultural operations in early potato production under greenhouse conditions, due to the fact that sufficient amounts of available nutrients should be provided for the undisturbed growth and development of young plants during a short growing period. Particular attention should be given to the selection of fertilizer types and rates, as excessive fertilization, primarily with nitrogen, can have a negative effect on the uptake and accumulation of harmful nitrates in early potato tubers (Stevanović *et al.* 2004). Apart from the effect of fertilization, increased nitrate accumulation in the plant can be also induced by light intensity, the fact being of significance in greenhouse cultivation (Kastori 1995, Bosković-Rakočević *et al.* 2008).

Given the economic importance and nutritional value of early potato and its high proportion in the human diet, this paper focused on examining the effect of different nitrogen rates and cultivars on the yield and nitrate accumulation in edible parts of this crop.

Material and Methods

A study on the effect of different nitrogen fertilization rates on the yield and nitrate accumulation in certain potato cultivars was conducted on alluvial soil, at a production/experimental field in Trbušani, Čačak. The trial was performed in semi-high greenhouses without additional heating, including the following treatments: control ($\emptyset$), 60, 120 and 180 kgN/ha. Nitrogen was added through CAN (calcium ammonium nitrate) during the top dressing stage. The study involved potato cultivars Liseta, Adora, Cleopatra, Amorosa and Kondor.

Amorosa is an early-maturing, red-skinned and light yellow-fleshed cultivar used fresh.

Cleopatra is the earliest-maturing red cultivar, having oval-shaped tubers, red skin and light yellow flesh; high-yielding.

Adora is the earliest maturing cultivar, having fine oval to round/oval shaped tubers, light yellow skin and flesh, particularly designed for early potato markets.

Liseta is a very tasty, medium-maturing cultivar, having elongated to oval shaped tubers and light yellow skin and flesh; high-yielding.

Kondor is medium-maturing red potato cultivar; very large elongated to oval shaped tubers; light yellow-fleshed; producing high and stable yields under all climates.

Lettuce was used as a preceding crop. Following its harvest, the soil was sampled for basic agrochemical analysis. Planting of Original seed potato for all cultivars was performed at a spacing of 70 x 25 cm during a spring growing cycle. Standard greenhouse early potato cultivation measures were employed during the growing season.

Early potato tubers were harvested at the harvest maturity stage, following which yield and yield components were evaluated and early potato tubers sampled for nitrate content. Standard chemical methods were used to perform agrochemical analyses of the soil and determine the nitrate content of potato tubers.

The results obtained in this study were subjected to a statistical two-factor analysis of variance. The statistical significance of differences was analyzed by the LSD test.

Results and Discussion

Potatoes can be cultivated in any type of soil, producing, however, highest yields on structural and fertile soils providing sufficient amounts of available nutrients. This study was conducted on alluvial soil (Table 1), which was a neutral soil well supplied with all biogenic nutrients, the fact being the first precondition for producing high-yielding and high-quality early potato.

Tab.1. Basic soil agrochemical characteristics

Location	pH		Total N (%)	NH ₄ -N mg/kg	NO ₃ -N mg/kg	P ₂ O ₅ mg/100 g soil	K ₂ O mg/100 g soil
	H ₂ O	KCl					
Trbušani	7.23	6.71	0.27	8.4	157.8	82.77	130.0

Tuber number per plant is an important and stable cultivar-specific trait directly affecting yield, its effect being higher than that of tuber weight (Ćota and Španović 2000). The results given in Table 2 show that the applied nitrogen rates did not induce an increase in tuber number per plant in all cultivars, which was as expected, tuber number being a genetically determined trait. The average number of tubers across cultivars ranged from 5.4 in cv. Kondor to 8.2 in cv. Liseta. Significant differences in tuber number were found only between cvs. Kondor and Adora as compared to cv. Liseta. Similar results in tuber number in early potato per plant and the absence of the effect of different fertilization rates on this trait in early potato production were also obtained by Marković *et al.* (1992).

Tab. 2. Tuber number per plant

Cultivar	N fertilization (kg/ha)				
	Control	60	120	180	Average
Liseta	7.2	8.0	9.1	8.5	8.2
Cleopatra	6.9	7.4	7.1	7.8	7.3
Kondor	4.9	5.5	5.2	5.8	5.4
Amorosa	7.1	6.8	7.7	6.8	7.1
Adora	4.2	4.8	6.8	6.1	5.5
Average	6.1	6.5	7.2	7.0	6.7

		A	B	AB
LSD	0.05	1.1439	1.0246	2.2894
	0.01	1.5288	1.3694	3.0597

The results given in Table 3 show differences in individual tuber weight between the cultivars and treatments used in this study. The increasing nitrogen application rates induced an increase in tuber weight in all early potato cultivars,

giving an average individual tuber weight of 61.5 g in the control and 86.3 g under the highest nitrogen rate applied, which was a statistically significant difference. The highest increase in tuber weight under the rate of 180 kgN/ha, as compared to the control, was obtained in cv. Cleopatra, being 30.5 g, which was statistically very significant, whereas the smallest but equally statistically significant difference was found in cv. Adora (an 18.7 g increase as compared to the control). Deviations in individual tuber weight between the cultivars studied were not statistically significant, average tuber weight ranging from 63.7 g in cv. Amorosa under all nitrogen application rates to 81.2 g in cv. Kondor, which conformed to the results of Bročić *et al.* (2000).

Tab. 3. Individual tuber weight (g)

Cultivar	N fertilization (kg/ha)				Average
	Control	60	120	180	
Liseta	57.8	63.6	66.8	82.7	67.7
Cleopatra	64.8	69.5	72.8	95.3	75.6
Kondor	70.2	75.0	84.2	95.4	81.2
Amorosa	52.2	57.0	68.9	76.7	63.7
Adora	62.5	68.8	77.5	81.2	72.5
Average	61.5	66.8	74.0	86.3	72.1

		A	B	AB
LSD	0.05	10.4849	9.3774	20.9687
	0.01	14.0128	12.5326	28.0240

In terms of profitability, high yields of early potato should be produced in minimum time, therefore the selection of adequate cultivars to this end is one of major preconditions for this production. Important parameters for obtaining high yields include, apart from the selection of cultivars, adequate mineral nutrition, which should be adapted to soil fertility conditions. Since the soil in this study had a good nutrient supply and the factors evaluated included different potato cultivars and nitrogen rates, the different yields produced were due to the interactive effects of these two factors (Table 4).

The highest yield of early potato was produced by cv. Cleopatra (18.2 t/ha), which was as expected, Cleopatra being the earliest maturing cultivar and most commonly produced under both greenhouse and open field conditions. The lowest average yield was obtained by cv. Kondor (13.2 t/ha), suggesting that tuber filling and high yields occur later in the growing period in this late-maturing and less commonly grown early potato cultivar. The average potato yields produced in this study, as dependent on the nitrogen application rate, indicated that yield was substantially affected by mineral nutrition. The nitrogen application rates of up to 120 kg/ha revealed statistically significant differences in yields as compared to the lower rates and had an economic effect. Further increases in fertilization rates to 180 kg/ha did not induce significant yield increases and were not economically justifiable. Therefore, the rate of 120 kgN/ha should be recommended as an optimal rate to be used in fertilizing early potato, as also reported previously by Marković *et al.* (1992) and Quasem (1978).

Tab. 4. Potato yield (t/ha)

Cultivar	N fertilization (kg/ha)				Average
	Control	60	120	180	
Liseta	12.8	15.5	19.2	19.7	16.8
Cleopatra	13.4	16.3	20.5	22.6	18.2
Kondor	10.2	12.4	14.1	16.1	13.2
Amorosa	9.9	13.3	16.4	17.2	14.2
Adora	10.1	14.0	17.4	18.5	15.0
Average	11.3	14.3	17.5	18.8	15.5
LSD	0.05	A	B	AB	
	0.01	2.3080	2.0655	4.6162	
		3.0845	2.7604	6.1694	

Among the external factors affecting nitrogen accumulation in plants, nitrogen content of soil is the most important. As the soil in this study had a high nitrate content, nitrate concentration in potato tubers, particularly under the highest nitrogen rate, was above the average for this crop, being below 200 mg/kg (Corré and Breimer 1979). The obtained results given in Tab. 5 show that the increasing nitrogen rates applied in this study led to an increase in nitrate content of potato tubers, as well as that nitrogen rates of up to 120 kg/ha did not pose a risk of increased nitrate accumulation in edible parts of potatoes, which conformed with the findings of Đurovka *et al.* (1992).

Tab. 5. Nitrate content of potato tubers (mg/kg)

Cultivar	N fertilization (kg/ha)				Average
	Control	60	120	180	
Liseta	115	202	388	559	316
Cleopatra	52	78	104	218	113
Kondor	83	132	216	337	192
Amorosa	78	101	129	256	141
Adora	105	198	282	435	255
Average	92.6	142.2	219.8	359.0	203.4
LSD	0.05	A	B	AB	
	0.01	18.9064	16.9097	37.8113	
		25.2678	22.5993	50.5335	

The analysis of the early potato cultivars in this study suggested an uneven nitrate uptake, being lowest in cv. Cleopatra (113 mg/kg) and highest in cv. Liseta (316 mg/kg) and showing statistically highly significant differences between all cultivars. The above results indicated that the highest genetic tolerance of nitrate accumulation was found in cv. Cleopatra, the earliest-maturing red early potato cultivar, as well as that nitrogen rates should not exceed 120 kg/ha in cv. Adora which gave a high average nitrate content (255 mg/kg).

Conclusion

The study on different early potato cultivars fertilized at different nitrogen rates under greenhouse conditions suggested the following:

- Tuber number per plant, as an important cultivar-specific and yield-affecting trait, ranged from 5.4 (cv. Kondor) to 8.2 (cv. Liseta).
- Individual tuber weight in all early potato cultivars was directly dependent on increasing nitrogen rates, the lowest and highest being produced by cv. Amorosa (63.7 g) and cv. Kondor (81.2 g), respectively.
- The average potato yields showed that mineral nutrition had a significant effect on yield, which ranged from 13.2 t/ha (cv. Kondor) to 18.2 t/ha (cv. Cleopatra).
- Nitrogen fertilization rates of up to 120 kg/ha did not pose a risk of increased nitrate accumulation in potato tubers, whereas the rate of 180 kgN/ha resulted in the nitrate content of potato tubers being above the average for this crop.
- The rate of 120 kgN/ha was the most optimal nitrogen rate in fertilizing early potato, whereas further increases in nitrogen fertilization rates were not economically justifiable. The highest yields and lowest nitrate accumulation were obtained in cv. Cleopatra, which is therefore recommended for cultivation in terms of safe vegetable production.

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UTICAJ AZOTA NA PRINOS I SADRŽAJ NITRATA KOD MLADOG KROMPIRA U PLASTENIČKOJ PROIZVODNJI

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Rezime

Proizvodnja mladog krompira u zaštićenim prostorima je počela da se primenjuje najviše iz razloga ranog pristizanja na tržište, kada se postižu visoke cene i ostvaruje visoka ekonomičnost proizvodnje. U toj proizvodnji jedna od najvažnijih tehnoloških operacija je đubrenje, čemu se mora pokloniti velika pažnja, jer prekomerno đubrenje u kratkom vegetacionom periodu može izazvati veliku akumulaciju nitrata u krtolama mladog krompira. U cilju iznalaženja najpovoljnije doze azota koji će omogućiti postizanje visokih prinosa, uz istovremeno optimalno nakupljanje nitrata u krtolama krompira, postavljen je ogled sa pet sorti krompira (Lizeta, Adora, Kleopatra, Lizeta i Kondor) i četiri doze azota (Ø, 60, 120 i 180 kgN/ha). Postignuti prosečni prinosi krompira pokazuju da je mineralna ishrana imala značajnog uticaja na prinos, koji se kretao u intervalu od 13.2 t/ha (sorta Kondor) do 18.2 t/ha (sorta Kleopatra). Đubrenje azotom do 120 kg/ha ne predstavlja rizik za nakupljanje većih sadržaja nitrata u krtolama krompira, dok je primenom 180 kgN/ha sadržaj nitrata u krtolama krompira bio iznad prosečnih vrednosti za ovu kulturu.