ВЛИЯНИЕ НА МИНЕРАЛНОТО ТОРЕНЕ ВЪРХУ СЪДЪРЖАНИЕТО НА ПЛАСТИДНИ ПИГМЕНТИ В ЛИСТАТА И КАЧЕСТВОТО НА КЛУБЕНИТЕ ПРИ КАРТОФИ
INFLUENCE OF MINERAL FERTILIZATION ON THE LEAF PLASTID PIGMENT CONTENT AND TUBER QUALITY OF POTATOES

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Abstract

The influence of separate and combined fertilization with nitrogen, phosphorus and potassium, as well as the addition of magnesium to the triple fertilizing combination on the leaf plastid pigments and tuber quality of potatoes under field experimental conditions was studied. The trail was conducted during the vegetation periods of 2013 and 2014. The experiment included the following variants: control (without fertilization), N, P, K, NP, NK, PK, NPK and NPK+Mg. The highest chlorophyll A+B content average for the period of investigation was found in the leaves of variant NP (2,30 mg/g). The fertilization did not influence the carotenoids content in the leaves, which was about 0.70 mg/g in all variants. The highest dry matter content of 23.10% and 22.58% was observed in the tubers of the control variant and variant NPK respectively. In the variant fertilized with nitrogen only (N) the dry matter content was very low – 17.51 %. The fertilization with NPK+Mg had a positive influence on the starch content of the tubers. The content for that variant was 15.42% averagely for the period. The starch content in the tubers of the other variant was lower and varied between 13.01% and 14.90%. The content of reducing sugars did not depend on the fertilization and was about 0.30% in all variants. The quantity of vitamin C was increased in all fertilized variants compared with the control. The highest content of vitamin C was found after the fertilization with NPK+Mg for both years – 11.25 mg/100 g. A positive influence of the separate N fertilization on the content of crude protein in the tubers was observed averagely for the studied period.

Key words: potatoes, fertilization, plastid pigments, quality parameters.

INTRODUCTION

Potatoes require high quantities of nutrients in the soil. For their development and obtaining high yields they need nitrogen, phosphorus, potassium, calcium, magnesium and various micronutrients (Bogatsevska et al., 2008). Nitrogen is very dynamic nutrient and its uncontrolled usage can lead to more expensive production, as well as pollution of the environment. Nitrogen fertilization rates should be consistent with the requirements of the grown varieties and with the production direction of potatoes. The highest yield of 30 t ha^{-1}at rate 150 kg Nha^{-1} was obtained (Srek et al., 2010; Ruza et al., 2013). Potato tubers which have low nitrogen content more often have low dry matter content, as well as higher rates of reducing sugars. Reducing sugars are critical precursors for acrylamide formation during frying which is considered carcinogenic and neurotoxic for humans (Zorb et al*.,* 2014). On the other hand the high nitrogen content in soil delays tuberization and decreases dry matter content in tubers (Iritani and Weller, 1980; Sowokinos and Preston, 1988; Dean and Thornton, 1992). Nitrogen fertilization increased chlorophyll content in leaves, but with the aging of plants the plastid pigments content decreased (Poljak et al., 2008; Neshev et al., 2014). Klein et al. (2015) evaluate the influence of phosphorus fertilization on vitamin C, lipids, total nitrogen and protein content in potato tubers. In the trail mono ammonium phosphate at rates of 0, 56, 112 and 168 кg/ha^{-1} was applied. A significant increase of vitamin C, total nitrogen and protein content with the increasing of the phosphorus fertilization rates was observed (Singh and Rai, 2011). Phosphorus fertilization Increased dry matter content in the tubers of potatoes grown in glasshouse conditions (Maiera et al., 2007). Potassium not only influences the yields but also affects the quality parameters of potato tubers. Field experiments for estimation the form of potassium fertilizers and increased potassium fertilizer rates on yield and quality of potatoes was performed. The studied rates were 0, 150 and 225 kg Kha^{-1}, repeated tree times.

The form of used potassium fertilizers were sulphate and chloride. Significant increase of the yields at rate 150 kg Kha^{-1}compared to the control and for both potassium forms was recorded. The sulphate form of fertilizer improved tuber quality parameters like dry matter, starch and vitamin C content (Imas and Bansal, 2002; Khan et al., 2012). Potatoes are fertilized mainly with potassium sulphate as chloride decreases quality of tubers (Herlihy and Carroll, 1969; Manolov et al., 2015). Potassium fertilization did not considerably influence the total chlorophyll content, but combined with nitrogen the plastid pigments content was considerably increased (Abu-Zinada, 2009).

The aim of the study was to determine the influence of mineral fertilization on the leaf plastid pigments content and some quality parameters of potato tubers.

MATERIALS AND METHODS

The field trail was conducted on shallow brown forest soil (Cambisols–coarse) at one of the main potato growing regions in Bulgaria - Smolian region. The trail was performed by the randomized block design in 4 replications. The size of the harvesting plot was 15 m^2. The nitrogen was applied as NH_4NO_3, phosphorus like triple superphosphate, and potassium as K_2SO_4. In the experiment a variant with magnesium fertilization supplied as patentkali combined with the triple NPK combination was investigated. The fertilizers were applied before planting of potatoes. Potato planting distance was 25x70 cm.The same fertilizer rates for the concrete element at all variants were used (N – 14 kg/da, P_2O_5 – 8 kg/da, K_2O – 10 kg/da, MgO – 3,3 kg/da). The studied variants were: control (not fertilized), N, P, K, NP, NK, PK, NPK, NPKMg. Before the beginning of the experiment in 2013 the soil contained 32,35 mg N min/kg soil, 44 mg P_2O_5 and 21,6 mg K_2O/100 g. The $pH_{(H2O)}$ of the soil was 5,39. The soil from experimental plot in 2014 contained 26,04 mg N min/kg soil, 21 mg $P_2O_5$and 50 mg K_2O/100 g before beginning of the experiemnt. Soil $pH_{(H2O)}$was 4,85.

Plant material: mid-early to mid-late potato variety “Picasso”.

Physiological analysis: Quantitative content of plastid pigments (chlorophyll A+B and carotenoids) inleaves (Berova i dr., 2007). Biochemical analysis of some tuber quality parameters: dry matter, starch, vitamin C, reducing sugars and crude protein content. Dry matter (%) was determined by oven drying at 70°C for 24 h. The amount of starch was determined by using a polarimetric method as described by Liutskanov i dr. (1994). Vitamin C was evaluated by dichlorophenolindophenol titration method (Ivanov i Popov, 1994). The method of Hagedorn and Jensen with some modifications was followed to establish the content of reducing sugars (Ivanov i Popov, 1994). Crude protein was determined by Kjeldal’s method (Tomov i dr., 2009).

Statistical analysis of collected data was performed by using Duncan’s multiple range test (1955) bySPSS program. Statistical differences were considered significant at $p < 0,05$.

RESULTS AND DISCUSSION

Plastid pigments are the most important components of photosynthetic apparatus. They are divided into three groups: chlorophylls, carotenoids and phycobilins. Phycobilins occur in blue-green and red algae (Kerin, 2002). That is why in the current study only the pigments from the first two groups were analyzed. Chlorophyll biosynthesisis influenced by factors like day length, temperature, water, soil aeration, availability of nutrients and genetic factors (Kerin, 2002). Vascular plants content two types of chlorophyll - ‚A’ (with blue-green color) and, B’ (with yellow-green color) (Kolev i dr., 1993).

Table 1. Chlorophyll A+B content in leaves (mg/g)
Таблица 1. Съдържание на хлорофил А+Б в листата (mg/g)

Year/variant	2013	2014	Average for the period
Control	2,31	1,36	1,83
N	2,07	1,74	1,90
P	2,68	1,24	1,96
K	2,19	1,42	1,80
NP	2,33	2,28	2,30
NK	2,26	1,97	2,11
PK	2,31	1,88	2,09
NPK	2,47	1,86	2,16
NPKMg	2,28	2,13	2,20

The highest chlorophyll A+B content average for the period of investigationwas observed for variant NP - 2,30 mg/g plastid pigments (Table1). Bayrami et al. (2012) registered increase of chlorophyll A+B content in leaves after fertilization with triple superphosphate. That was in accordance with the results from 2013 only when 2,68 mg/g chlorophyll A+B at the variant with separate phosphorus fertilization was observed. The next year (2014) the results were absolutely opposite and the amount of chlorophyll at variant with P was the lowest among all variants - 1,24 mg/g. Probably the high content in leaves in 2013 was due to the dry weather conditions during the vegetation. Bojović and Marković (2007) established that phosphorus fertilization helps for chlorophyll preservation in leaves of wheat at unfavorable environment conditions. Magnesium represents 2,7% from the chlorophyll molecule (Stanchev i dr., 1989). Combined NPK+Mg fertilization led to increasing of those pigments in leaves, as the chlorophyll A+B content at variant NPKMg was 2,20 mg/g average for the trail conditions. This content was approximately 24% higher than the chlorophyll A+B content in the control's leaves.

Carotenoids are plastid pigments implementing two main purposes – absorbing light with its quality of supplementary pigments and protect chlorophyll from irreversible photooxidation (Kimenov, 2000). The ratio chlorophylls : carotenoids in leaves is 2 (3) : 1 (Kerin, 2002). In our study the carotenoids content in potato leaves was not influenced by fertilization and the content of carotenoids were very closeat all variants (Table 2). According to Stefanelli et al. (2010) the usage of nitrogen fertilizers increased the carotenoids content. The highest carotenoids content was observed at variant NP - 0,73 mg/g, average for the period.

Westermann et al. (1994) concluded that the fertilization with nitrogen and potassium fertilizers provide significant influence on dry matter and starch content in tubers. The highest dry matter content average for the period was found in tubers fromthe control and variant NPK - 23,10 and 22,58%, respectively (Table 3). At the variant fertilized with nitrogen only (N), the quantity of dry matter in tubers in 2014 was the lowest (17,51%). Average for the period dry mater content for this variant was approximately 25%lower than that of the control variant and 15% lower from that of variant NPKMg.

Table 2. Carotenoids content in leaves (mg/g)
Таблица 2. Съдържание на каротиноиди в листата (mg/g)

Year/Variant	2013	2014	Average for the period
Control	0,73	0,60	0,67
N	0,72	0,66	0,69
P	0,87	0,54	0,70
K	0,71	0,61	0,66
NP	0,72	0,74	0,73
NK	0,67	0,73	0,70
PK	0,75	0,70	0,72
NPK	0,79	0,63	0,71
NPKMg	0,67	0,66	0,67

Table 3. Dry matter content in tubers (%)
Таблица 3. Съдържание на сухо вещество в клубените (%)

Year/Variant	2013	2014	Average for the period
Control	25,53 a	20,67 a	23,10
N	20,61 e	14,45 f	17,51
P	20,13 e	17,49 d	18,81
K	22,23 d	20,50 a	21,36
NP	25,35 a	16,63 e	20,29
NK	24,06 b	18,36 c	21,21
PK	23,33 c	20,57 a	21,95
NPK	25,59 a	19,57 b	22,58
NPKMg	23,37 c	17,79 d	20,58

Figures with different letters are with proved difference according to Duncan's multiple range test ($p < 0,05$).
Цифрите с различни букви са с доказана разлика според теста на Дънкан ($p < 0,05$).

Starch content in tubers is influenced by the fertilization with organic and mineral fertilizers, as well as the meteorological conditions (Baniuniene and Zekaite, 2008). In this study the combined NPK+Mg fertilization had a positive influence on starch content in tubers. The highest content of starch 15,42%, average for both experimental years was observed at variant NPKMg (Table 4). Negative influence of fertilization with N, NKand PKon starch content was found. Average for the period, the starch content in tubers for these variants was the lowest. The content of starch of13,54 %at variantNwere approximately 12% lower than those of variant NPKMg and 7% lower from the control variant.

Reducing sugars (glucose and fructose) were not influenced by the fertilization. Their content in potato tubers from all variants was about 0,30% for both years that is why the results were not shown. The differences between variants were not proved accordingto Duncan's multiple range test ($p < 0,05$).The obtained data were in accordance with the results from the trails of Järvan and Edesi (2009) who did not reportsignificant differences in this quality parameter after applied fertilization.

The most important vitamin in potato tubers is vitamin C. Its content in tubers varies between10 to 20 mg/100 g. Optimal phosphorus and potassium fertilization increase its quantity (Mashev i dr., 1999).The results from our experiment showed positive influence of fertilization on ascorbic acid (vitamin C) content in potato tubers. The vitamin C content was higher at all fertilized variants compared to the unfertilized control. The highest content was achieved after the combined NPK+Mg fertilization in both studied years (Table 5). Average for this period the content of 11,25 mg/100 g at variant NPKMg was approximately 44% higher than those of the control.

Table 4. Starch content in tubers (%)
Таблица 4. Съдържание на скорбяла в клубените (%)

Year/Variant	2013	2014	Average for the period
Control	17,92 a	11,76 b	14,48
N	17,14 b	9,94 f	13,54
P	18,23 a	10,60 e	14,41
K	16,37 c	11,83 b	14,10
NP	16,99 b	10,86 d	13,94
NK	15,40 d	10,74 de	13,07
PK	14,74 d	11,29 c	13,01
NPK	18,35 a	11,45 c	14,90
NPKMg	18,77 a	12,06 a	15,42

Figures with different letters are with proved difference according to Duncan's multiple range test ($p < 0,05$).
Цифрите с различни букви са с доказана разлика според теста на Дънкан ($p < 0,05$).

Table 5. Vitamin C content in tubers (mg/100 g)
Таблица 5. Съдържание на витамин С в клубените (mg/100 g)

Year/Variant	2013	2014	Average for the period
Control	6,15 f	6,01 f	6,08
N	9,70 d	9,15bc	9,42
P	9,70 d	9,11bc	9,40
K	10,55 b	9,90 b	10,22
NP	7,90 e	7,25 e	7,57
NK	9,20 de	8,50 d	8,85
PK	10,15 c	9,78 b	9,96
NPK	10,15 c	9,93 b	10,04
NPKMg	11,85 a	10,65 a	11,25

Figures with different letters are with proved difference according to Duncan's multiple range test ($p < 0,05$).
Цифрите с различни букви са с доказана разлика според теста на Дънкан ($p < 0,05$).

Table 6. Crude protein content in tubers (%)
Таблица 6. Съдържание на суров протеин в клубените

Year/Variant	2013	2014	Average for the period
Control	13,63 e	18,44 e	16,03
N	17,63 b	28,06 a	22,84
P	12,31 f	21,44 d	16,87
K	13,75 d	20,50 d	17,12
NP	16,72 c	26,94 b	21,83
NK	16,41 c	23,94 c	20,17
PK	14,31d	18,63 e	16,47
NPK	18,66 a	26,31 b	22,48
NPKMg	18,59 a	25,06 b	21,82

Figures with different letters are with proved difference according to Duncan's multiple range test (p < 0,05). Цифрите с различни букви са с доказана разлика според теста на Дънкан (p < 0,05).

Potato protein has higher biological quality than those of grains because of its richness in indispensable aminoacids (Eggum, 1969). Our results showed positive influence of fertilization with nitrogen only on crude protein content in tubers at variant N for both years of the study (Table 6). The lowest content of crude protein was found at the control and variants P and PK. In 2014, which was characterized with heavy rainfalls in the area of the experiment, the crude protein content at all variants that were fertilized with nitrogen was above 23%. The highest results were found for variant N - 28,06%.

CONCLUSIONS

1. The combined NP fertilization contributes to the highest chlorophyll A+B content in leaves at variant NP – 2,30 mg/g plastid pigments. Carotenoids content was not influenced by the fertilization. The highest dry matter content average for the period was observed at the control and variant NPK – 23,10 and 22,58% respectively. At the variant with alone nitrogen fertilization the quantity of dry matter in tubers was the lowest (17,51%).

2. Application of triple fertilizer combination plus magnesium (NPKMg) ensure the highest content of starch in potatoes (15,42%). Negative influence of fertilization with nitrogen at variant N, as well as for the fertilizing combinations NK and PKon starch content was found. Average for the period, the content of starch in tubers for these variants was the lowest. Reducing sugars were not influenced by the fertilization and their content in potato tubers was about 0,30% for all variants.

3. The highest vitamin C content was achieved after the combined NPK + Mg fertilization for both studied years. The content of vitamin C at variant NPKMg (11,25 mg/100 g) was approximately 44% higher than that of not fertilized control. Alone fertilization with nitrogen had positive influence on crude protein content in tubers.

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