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THE EFFECT OF UREA AND UREA WITH UREASE INHIBITOR ON THE CONTENT OF MACRONUTRIENTS IN TUBERS AND TOPS OF POTATOES (*SOLANUM TUBEROSUM* L.)

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Abstract

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In two-year small-plot field experiments in Žabčice u Brna we explored the effect of nitrogen fertilisation with urea and urea with urease inhibitor (Urea + UI) on the content of macronutrients (N, P, K, Ca, Mg) in tubers and tops of potatoes of the variety Karin. The experiment involved 7 treatments. Nitrogen rates in treatments 1–7 were the following: 1) 90 kg N/ha – Urea; 2) 72 kg N/ha – Urea; 3) 54 kg N/ha – Urea; 4) 90 kg N/ha – Urea + UI; 5) 72 kg N/ha – Urea + UI; 6) 54 kg N/ha – Urea + UI; 7) unfertilised control. Each treatment was repeated 4 times.

Both fertilisers (Urea, Urea + UI) were reflected irregularly in the contents of N, P, K, Ca, Mg in the potato biomass and were based on the weather of the year, rate of fertiliser and analysed plant organ (tuber, top). In both years the contents of N, K, Ca and Mg were higher in the tops. The P content was balanced both in the tops and tubers. Some changes in the chemical composition were observed particularly in the case of nitrogen. In 2010 the nitrogen content was higher in tubers (1.44–1.65% N) after the application of both of the higher rates of urea + UI than after the application of urea alone (1.30–1.34% N). In 2011 the N content in tops decreased to 2.97–3.26% N when the highest rate of N was applied in both fertilisers, as against the other treatments (3.60–4.09% N). The contents of the other elements (P, K, Ca, Mg) were not significantly affected by the kind fertiliser and way of fertilising or the differences among treatments were minimal. In general we can conclude that after the application of both types of fertilisers the contents of the observed elements did not change fundamentally in the tops or tubers.

potatoes, urea, urease inhibitor, macronutrients, tuber, tops

Potato (*Solanum tuberosum* L.), a staple food in many countries (McLaughlin *et al.*, 1994) is an important crop all over the world. One of the basic conditions for intensive potato production is to supply the soil with nutrients from mineral fertilisers in order to achieve balanced rates of nutrients and at the same time to maintain soil fertility. Of the main mineral nutrients nitrogen is seen to have the greatest effect on physiological manifestations of potatoes (Vokál *et al.*, 2004). The form of most of the soil nitrogen is organic. Organic nitrogen is very important in plant nutrition and soil fertility (Kelley and Stevenson, 1995). The plant may take up nitrogen in the form of NH_4^+, NO_3^- or as a whole urea molecule. Urea decomposes in the soil under the effect of the enzyme urease to $(NH_4)_2CO_3$ and then to NH_4^+, CO_2 and H_2O. Ammonium (NH_4^+) may absorb in the soil to a sorption complex, succumb to nitrification or be taken up by the plant (Richter and Hlušek, 1994; Mengel and Kirkby, 2001).

Urea (46% N) is the most widespread nitrogen fertiliser in the world. This fertiliser frequently poses problems in terms of its application (Schlegel, 1991). Surface application of urea causes ammonia emissione. Warm weather, some soil properties (soil type, content and composition of organic matter, biological activity, high pH) and windy weather increase nitrogen losses to as much as 47% (Watson, 2005; Dawar *et al*., 2011; Wang *et al*., 1991). The losses of NH_3 may have an economic and environmental impact (Sanz-Cobena *et al*., 2011; Malhi *et al*., 2001). That is why urease inhibitors are used because they slow down the transformation of urea to NH_4^+, leaving more time for the surface applied urea to penetrate deeper down into the soil after rainfall. In this way the concentrations of NH_4^+ on the on the soil surface or subsurface layer are not very high. At the same time the negative affect of urea hydrolysis, the accumulation of NO_2^- in the process of nitrification, is reduced as this could be detrimental to seed germination and to young plants (Gasser, 1964; Watson, 2005), and it rapidly changes the osmotic pressure in the soil solution (Banerjee *et al*., 1999). Urease is produced by plant and animal cells; their amount in the soil is based particularly on the amount of microorganisms. One property is that for a certain period of time after the microorganisms die off and the contents of their cells are released into the soil environment, urease remains to be active (Mráz, 2007). One of the most effective and most frequently used inhibitors is NBPT (N-(n-butyl) thiophosphoric triamide) which is suitable to reduce the degree of urea hydrolysis and losses by volatilisation of ammonia in various soils. Among the preparations with urease inhibitor Agrotain which contains 20% of NBPT is the most widespread in the world (Růžek and Pišanová, 2007).

MATERIALS AND METHODS

The small-plot experiment was established at the School Farm in Žabčice (ca 30 km south of Brno) in 2010 and 2011 on medium heavy fluvisol in a maize growing area. Tab. I gives agrochemical characteristics of the soil. For the experiment we used the early potato variety Karin which was planted on 8 April 2010 and 7 April 2011, spacing 750 × 250 mm. Prior to planting both mineral fertilisers (urea and urea with urease inhibitor NBPT – UREA stabil) were applied to the soil surface. During planting these fertilisers were incorporated into the soil. The N rates of the 7 treatments of the experiment are as follows: 1) 90 kg N/ha – Urea; 2) 72 kg N/ha – Urea; 3) 54 kg N/ha – Urea; 4) 90 kg N/ha – Urea + UI; 5) 72 kg N/ha – Urea + UI; 6) 54 kg N/ha – Urea + UI; 7) unfertilised control. Tab. II gives the pattern of the experiment. Each treatment was repeated 4 times. During vegetation standard weed, disease and pest control was carried out using chemical preparations. On 12 July 2010 and 2011, i.e. 90–100 days after planting, the plants were harvested and samples were taken for analyses of the macronutrients (N, P, K, Ca, Mg) in tubers and tops (leaves and stems). The plant samples were dried, homogenised and mineralised. After wet mineralisation (H_2SO_4 + H_2O_2 for determination of N and P, and HNO_3 + H_2O_2 for determination of K, Ca, Mg) the individual elements were determined as follows: N according to Kjeldahl; P using colorimetry; K, Ca, Mg using the AAS method.

The results were processed statistically using variance analysis and then tested according to Scheffe ($p < 0.05$).

RESULTS AND DISCUSSION

Mineral fertilisers are a factor boosting higher yields and quality of production (Coraspe-Leon *et al*., 2009; Toledo and Burlingame, 2006). The elements (nutrients) are important in plant metabolism when no single element can fully substitute the function of another element (Barker and Pilbeam, 2007). The chemical composition of the biomass reflects the uptake of nutrients from the soil. On uptake the nutrients in the soil, both exchangeable bound to the sorption complex and those in the soil solution, interact in a positive (synergism) and negative (antagonism) manner (Mengel and Kirkby, 2001; Marschner, 2002). The contents of macronutrients in tubers and tops (Tabs. III–VI) varied according to the concrete treatment and year. In both years the contents of N, K, Ca and Mg were higher in the tops. The P content was balanced both in tubers and tops.

II: *Pattern of experiment*

Treat. No.	Pattern	N rate in fertilisers (kg/ha)
1	Urea	90
2	Urea	72
3	Urea	54
4	Urea + UI	90
5	Urea + UI	72
6	Urea + UI	54
7	unfertilized control	-

UI – urease inhibitor; Urea + UI = UREA stabil fertiliser

I: *Agrochemical characteristics of the soil before establishment of experiment (Mehlich III)*

$pH/CaCl_2$	mg/kg			
	P	K	Ca	Mg
5.9	79	197	3,133	346
weak acid	suitable	good	good	very high

III: *Nutrients content in tubers – 2010*

Treat. No.	N	P	K	Ca	Mg
			%		
1	1.34 b	0.24 a	2.12 a	1.52 a	0.09 a
2	1.30 ab	0.24 a	2.16 a	1.58 a	0.09 a
3	1.24 a	0.26 a	2.30 b	1.54 a	0.10 a
4	1.65 d	0.26 a	2.17 a	1.58 a	0.10 a
5	1.44 c	0.25 a	2.11 a	1.65 a	0.10 a
6	1.22 a	0.25 a	2.13 a	1.62 a	0.10 a
7	1.01 e	0.23 a	1.87 c	1.66 a	0.08 a

Different letters (a, b, c) indicate significant differences among treatments

IV: *Nutrients content in tubers – 2011*

Treat. No.	N	P	K	Ca	Mg
			%		
1	1.45 a	0.25 a	2.15 ab	1.63 a	0.09 ab
2	1.52 a	0.26 a	2.18 ab	1.67 a	0.09 ab
3	1.47 a	0.25 a	2.16 ab	1.62 a	0.10 ab
4	1.56 a	0.27 a	2.14 a	1.66 a	0.08 a
5	1.53 a	0.26 a	2.19 ab	1.74 a	0.10 ab
6	1.45 a	0.25 a	2.21 ab	1.73 a	0.10 ab
7	1.43 a	0.25 a	2.23 b	1.73 a	0.12 b

Different letters (a, b, c) indicate significant differences among treatments

V: *Nutrients content in tops – 2010*

Treat. No.	N	P	K	Ca	Mg
			%		
1	2.90 b	0.20 a	4.54 a	2.55 a	0.46 a
2	3.00 b	0.19 a	4.86 a	2.72 a	0.51 a
3	3.19 c	0.21 a	4.22 a	2.72 a	0.57 b
4	2.98 b	0.20 a	4.35 a	2.51 a	0.50 a
5	2.66 a	0.17 a	4.56 a	2.98 b	0.52 ab
6	2.93 b	0.20 a	4.62 a	3.02 b	0.54 ab
7	2.41 d	0.18 a	4.23 a	2.77 a	0.55 ab

Different letters (a, b, c) indicate significant differences among treatments

VI: *Nutrients content in tops – 2011*

Treat. No.	N	P	K	Ca	Mg
			%		
1	3.26 a	0.23 a	4.33 a	2.41 a	0.53 b
2	4.09 c	0.25 a	4.22 a	2.31 a	0.56 b
3	3.77 b	0.23 a	4.55 a	2.35 a	0.53 b
4	2.97 a	0.21 a	4.34 a	2.23 a	0.55 b
5	3.60 b	0.23 a	4.35 a	2.46 a	0.49 a
6	3.64 b	0.24 a	4.29 a	2.86 b	0.53 b
7	4.08 c	0.26 a	4.36 a	2.55 a	0.53 b

Different letters (a, b, c) indicate significant differences among treatments

a) nitrogen content in potato tubers and tops

Nitrogen is one of the most important macronutrients (Tong *et al.*, 2011). It is the basic component of amino acids and has an immediate effect on the quality of production and on yields (Ju and Christie, 2011).

In tubers the N content increased significantly with the N rate only in 2010 (Tab. III), while in 2011 there were no differences among the treatments (Tab. IV). Leszczyński and Lisińska (1988) reached similar conclusions; they analysed tubers of 14 potato varieties after graded nitrogen fertilisation. The N content in tubers was the lowest in the unfertilised controls only in the first year of the experiment. After application of both of the highest rates of urea + UI (treatments 4–5) in 2010 the N content in tubers was higher than when only urea was applied (treatments 1–2). In 2010 the content of nitrogen in both tubers and tops was lower than in 2011 and may be connected with heavier rainfall and with the risk of leaching.

The N content in tops (Tabs. V, VI) was higher than in tubers. In 2010 the N content in tops showed irregular fluctuation (Tab. V). In 2011 the N content in tops and tubers was the reverse. The highest N rate applied in both fertilisers (treatments 1 and 4) resulted in a lower N content in tops as against the other treatments. Yassen *et al.* (2011) arrived at the same conclusions; they discovered that the N content in potato tops decreased from 3.01% to 2.84% N and was connected with increasing N rate from 200 to 250 kg N/ha.

b) phosphorus content in potato tubers and tops

Phosphorus is an important macronutrient necessary for plant growth and development (Qin *et al.*, 2011).

In the two years there were no significant differences among the treatments in phosphorus contents in the tubers and tops (Tabs. III–VI). A higher content of NH_4^+ in the soil stimulates phosphorus uptake which was not proved in our experiments (Richter and Hlušek, 1994). Yassen *et al.* (2011) also discovered that the P content increased in potato tubers (0.19–0.24–0.28% P) and tops (0.25–0.33–0.38% P) after increasing rates of nitrogen nutrition (0–150–250 kg N/ha). By contrast Ukom *et al.* (2009) found that in most cases the P content in tubers decreased with increasing rates of N (0–40–80–120 kg N/ha as urea).

c) potassium content in potato tubers and tops

Together with nitrogen and phosphorus potassium is an indispensable (biogenic) element (Wang *et al.*, 2011).

In the two years no significant differences in potassium contents (Tabs. III–IV) were detected between the N rates of both fertilisers. In 2010 the K content was the lowest in the unfertilised control (treatment 7) and is in accordance with the findings of Mengel and Kirkby (2001) that synergic nitrate nitrogen influences potassium uptake. In the two years no significant differences among the treatments were detected in potassium contents in the tops (Tabs. V, VI); the highest level of potassium was found in the tops (above 4% K in dry matter). Yassen *et al.* (2011) discovered that the K content increased both in potato tubers (2.07–2.18–2.41% K) and tops (2.87–3.10–3.42% K) with increasing rates of N (0–150–250 kg N/ha).

d) calcium content in potato tubers and tops

Calcium is very important in plant metabolism; it is the key element in cell structures (Barker and Pilbeam, 2007).

In the two years the calcium content in the potato tubers did not significantly to differ among the treatments (1.52–1.66% in 2010 and 1.62–1.74% in 2011). The Ca content in the tops (Tabs. V, VI) increased with decreasing rates of urea + UI (treatments 5–6) as against the highest rate of urea + UI (treatment 4). This is consistent with the findings of Laughlin (1971) that the content of Ca and Mg in the tops drops with an increasing rate of N-fertiliser applied in rows, while the trend is the opposite when the fertiliser was mixed with the soil.

e) magnesium content in potato tubers and tops

Magnesium is involved in a number of metabolic processes in the plant. Very important is its function in chlorophyll (Marschner, 2002).

The Mg content in tubers (Tabs. III–IV) was very low and varied within a narrow range of 0.08–0.12% Mg with no significant differences among the treatments.

The content of magnesium in tops (Tabs. V–VI) was on average 5 times higher than in tubers. In both years there were only minor differences in Mg contents among the treatments. Ukom *et al.* (2009) described the ambiguous reaction of varieties (in terms of the Mg content in tubers) to graded rates of N (0–40–80–120 kg N/ha as urea).

SUMMARY

Based on results we can conclude that both fertilisers (Urea, Urea + UI) were reflected in the N, P, K, Ca, Mg contents in the biomass of potatoes irregularly in dependence on the year, rate of fertiliser and analysed plant organ (tubers, tops). In both years the contents of N, K, Ca and Mg were higher in the tops. The P content was balanced both in the tops and tubers. Some changes in the chemical composition were found with nitrogen. In 2010 after the application of higher rates of urea + UI the nitrogen content in tubers was higher than after the application of urea by itself. In 2011 the N content in tops decreased when the highest rate of N was applied in both fertilisers as against the remaining treatments. The contents of the other nutrients (P, K, Ca, Mg) were either not significantly

affected by the two fertilisers or the differences were minimal. In general we can conclude that after the application of both types of fertilisers the contents of the nutrients in potato tops and tubers did not fundamentally change.

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