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IMPACT OF FOLIAR FERTILISATION OF PLANT ON THE CONTENT OF MACROELEMENTS IN POTATO

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ABSTRACT

The 1990-1992 research investigated the impact of foliar fertilisation on the chemical composition of potato leaves, stems, stolons and tubers over flowering. It was observed that neither foliar fertilisation with a 6% of aqueous solution of carbamide and a multi-component fertiliser (Agrosol - K) nor solid fertilisation caused significant differences in the contents of N, P, K, Ca, Mg in respective potato plant parts. During the flowering period the most equivalent K : (Ca + Mg) ratios were found in stem.

Key words: potato, foliar fertilisation, content of microelements

INTRODUCTION

In the time of greatest demand for nutrients (flowering phase), tubers become the main place of the accumulation of assimilates and minerals [1,3,7,9,10,12]. The plant supplies of the major components over that time have a major impact on the quality and quantity of the yield [1,2,5,6].

Soil fertilisation does not always meet plant nutritive requirements. Over the vegetation period the potato, producing starch, shows high demand for magnesium, manganese and boron, to mention just a few [11]. It appears that the needs are met with a multi-component foliar fertilisation. In Poland typical multi-component foliar fertilisers used for potato are Agrosol-K, liquid fertilisers type Wuxal, Ekolist, Plonis-3 and others. The

chemical composition of Agrosol-K includes nitrogen and magnesium as well as zinc, iron, boron, copper, manganese, molybdenum at the doses proportional to the requirements of the plant. Plant foliar fertilisation is considered to be one of the forms of top dressing with the fertiliser being employed in the form of aqueous solution which remains a considerable supplement of the basic root-applied fertilisation [4,5,10,13]. Additionally, fertilising with nitrogen or multi-component fertilisers has a double effect on the plants; it stimulates them to absorb other nutrients as well as it supplies nitrogen throughout the period of their greatest demand for it [5,8]. According to Czuba [4], foliar fertilisation with nitrogen increases its utilisation (by 40-80%), as compared with the nitrogen applied in a solid form, additionally it makes chemical and biological retrogradation of the other elements applied impossible, decreases fertiliser consumption, increases potato resistance to diseases as well as enhances tuber quality [1,4,5,11]. Foliar fertilisation with multi-component fertilisers remains a simple treatment which is the fastest and most effective in compensating elements shortages in the plant. Additionally foliar application at low doses of fertilisers eases the pollution of soil and ground waters. The literature reports on the impact of mineral fertilisation on the content of macroelements in different potato parts during flowering, yet there is still little coverage on foliar fertilisation.

The aim of the present research was to define the impact of foliar fertilisation with a 6% aqueous solution of carbamide and Agrosol-K on the changes in the content of macroelements in over- and under-the-ground potato parts during flowering.

MATERIALS AND METHODS

The 1990-1992 split-plot field experiment was carried at the Agricultural Experiment Station at Zawady, near the town of Siedlce, on soil of 16 %-silt-and-clay-and-1.63 % -humus topsoil, of a very good rye soil suitability complex. The research investigated the content of macroelements in over- and under-the-ground potato parts in two potato cultivars with different vegetation periods (‘Darga’ – mid-early and ‘Marta’- mid-late) as exposed to foliar fertilisation with carbamide and Agrosol - K:

K_1 - 1 · 33.2 kg N·ha^{-1} top-dressing in a solid form,
K_2 - 4 · 8.3 kg N·ha^{-1} in the form of a 6% aqueous solution,
K_3 - 4 · 1.5 l·ha^{-1} Agrosol - K in water,
K_4 - 2 · 8.3 kg N·ha^{-1} in the form of a 6% aqueous solution + 1.5 l·ha^{-1} Agrosol - K,
K_5 - 3 · 8.3 kg N·ha^{-1} in the form of a 6% aqueous solution,
K_6 - 3 · 8.3 kg N·ha^{-1} in the form of a 6% aqueous solution + 1.5 l·ha^{-1} Agrosol - K.

The foliar fertilisation included a 6% aqueous solution of carbamide and Agrosol-K (multi-component solution). The treatments coincided with the time of the production of lateral branches since the beginning of April.

Potatoes were cultivated after cereals. In autumn manure was applied at 25 t·ha^{-1} as well as phosphorus fertilisers (60 kg P_2O_5·ha^{-1}) and potassium fertilisers (90 kg K_2O·ha^{-1}). Soil tillage and plant nurturing was typical for potato. The main fertilisation at 30 kg N·ha^{-1} took place in spring prior to tuber planting.

Throughout flowering, the dry matter of leaves, stems, stolons and tubers were investigated to define total nitrogen with the Kjeldahl method, phosphorus with the vanadium-and-molybdenum method, potassium and calcium with the flame photometry as well as magnesium with the atomic spectrophotometric absorption (ASA).

The results obtained (mean for cultivars) were variance-analysed with the Tukey test to compare the differences at 0.05, being the level of significance. Additionally there was defined a relationship between the chemical composition of different over-the-ground potato parts with linear correlation coefficients.

RESULTS

During flowering the over-the-ground potato parts (leaves and stems) contained more macroelements than the stolons and tubers (Table 1). The leaves, as compared with the tubers being set, showed higher contents of nitrogen and magnesium. In stems there was observed an especially high potassium content (9.22% of d. m.). The contents of phosphorus and calcium in respective plant parts, except for tubers, remained similar.

Table 1. Content of macroelements in over- and under- the-ground parts of potato plant during flowering (1990-1992)

Plant parts	N	P	K	Ca	Mg
	% in d.m.				
Leaves	4.867	0.494	4.900	1.555	0.349
Stems	2.752	0.458	9.222	1.518	0.203
Stolons	2.015	0.549	3.824	1.060	0.106
Tubers	1.822	0.345	2.745	0.143	0.093

The linear correlation showed no significant relationship between the content of nitrogen in leaves and all the macroelements in the plant parts analysed (Table 2). The contents of phosphorus, potassium and magnesium in leaves were significantly positively correlated with phosphorus and negatively with magnesium in stems. Additionally phosphorus and potassium in leaves showed a negative correlation with nitrogen. In stolons and tubers there was noted a positive correlation between the contents of P, K, Ca, Mg and the contents of phosphorus and potassium in leaves. Magnesium in leaves showed a significant correlation with all the other elements in stolons and in tubers, except nitrogen, while the content of calcium in leaves was negatively correlated with phosphorus in stems and stolons, calcium and magnesium in stolons and with all the other elements in the tubers being set, except for nitrogen.

Table 2. Linear correlation coefficients between macroelements in the plant parts of potato during flowering (1990-1992)

Plant parts	Macroelements	Macroelements in leaves, % in d.m.				
		N	P	K	Ca	Mg
Stems	N	0.056	-0.566**	-0.610**	0.393	-0.404
	P	0.361	0.920**	0.688**	-0.790**	0.504*
	K	-0.143	0.240	0.390	0.108	0.388
	Ca	-0.384	-0.533**	-0.242	0.647**	-0.126
	Mg	-0.169	-0.771**	-0.751**	0.464*	-0.607**
Stolons	N	0.118	0.533**	0.521*	-0.262	0.530**
	P	0.319	0.929**	0.773**	-0.696**	0.584**
	K	0.131	0.779**	0.817**	-0.415	0.699**
	Ca	0.211	0.775**	0.720**	-0.474*	0.657**
	Mg	0.202	0.843**	0.777**	-0.521**	0.691**
Tubers	N	0.009	0.239	0.422*	0.027	0.330
	P	0.116	0.819**	0.761**	-0.478*	0.652**
	K	0.069	0.627**	0.595**	-0.378	0.561**
	Ca	0.261	0.698**	0.576**	-0.476*	0.422*
	Mg	0.189	0.680**	0.590**	-0.478*	0.570**

* Significant at $\alpha < 0.05$
** Highly significant at $\alpha < 0.01$

Foliar fertilisation during vegetation showed the most favourable equivalent K : (Ca + Mg) ratios in stem. The highest ratios of potassium to sum of calcium and magnesium were noticed for tubers, while the lowest for leaves (Table 3). Out of the objects compared, only a four-time-applied Agrosol-K helped to maintain the optimal equivalent K : (Ca + Mg) ratio in stems and tubers. In the other objects exposed to foliar fertilisation with a 6% aqueous solution of carbamide or as combined with Agrosol-K there noted no differences in the equivalent ratios of potassium to sum of calcium and magnesium, as compared with the solid fertilisation.

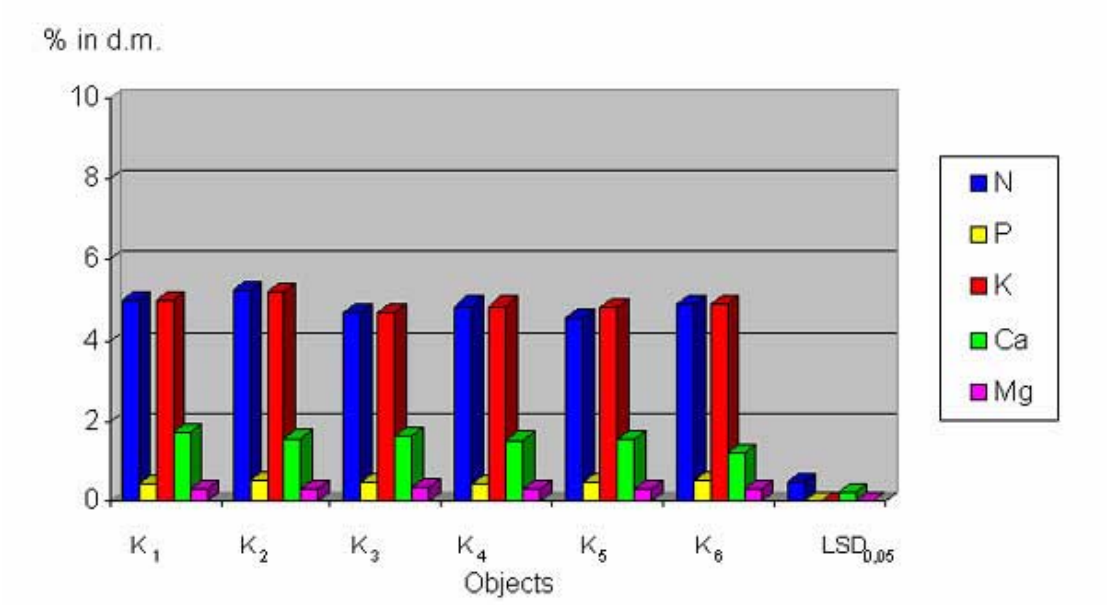
Table 3. Equivalent K : (Ca +Mg) ratio in over- and under- the-ground parts of potato plant during flowering (1990-1992)

Objects	Leaves	Stems	Stolons	Tubers
K_1- top dressing - solid form	1.11	2.57	1.71	5.14
K_2 - 6% solution	1.24	2.80	1.56	4.25
K_3 - in water	1.06	2.38	1.53	4.50
K_4 - 6% solution	1.18	2.44	1.39	5.00
K_5 - 6% solution	1.17	2.53	1.62	5.46
K_6 - 6% solution	1.40	2.57	1.47	5.67

K_1 - K_6: see, Material and Methods

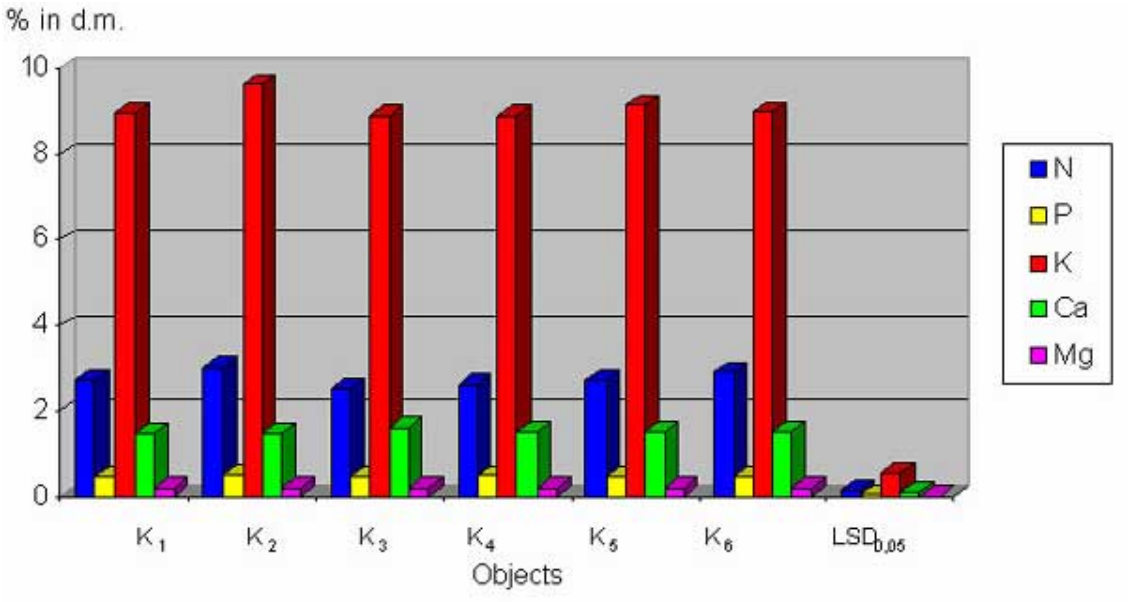
A thorough chemical analysis of plants during flowering showed significant differences in the contents of macroelements due to foliar fertilisation with a 6% aqueous solution of carbamide and the multi-component fertiliser (Agrosol-K). The four-time foliar fertilisation with a 6% aqueous solution of carbamide increased the content of N in leaves as compared with the four-time application of Agrosol-K as well as with three-time foliar application of a 6% aqueous solution of carbamide (Fig. 1). Fertilisation with a solid carbamide gave a significant increase in the content of the element only as compared with a three-time plant spraying with a 6% aqueous solution of carbamide. At that time a four-time plant spraying with a 6% aqueous solution of carbamide or three-time spraying as combined with Agrosol-K, gave a significant increase in the content of phosphorus in leaves, except for a four-time application of Agrosol-K, exclusively. Both the content of potassium and the content of magnesium did not depend on potato foliar fertilisation, while a significantly higher content of calcium in leaves was observed due to the solid carbamide fertilisation only when compared with a three-time spraying with a 6% aqueous solution of carbamide as combined with Agrosol-K.

Figure 1. Content of macroelements in leaves during potato plant flowering (1990-1992)



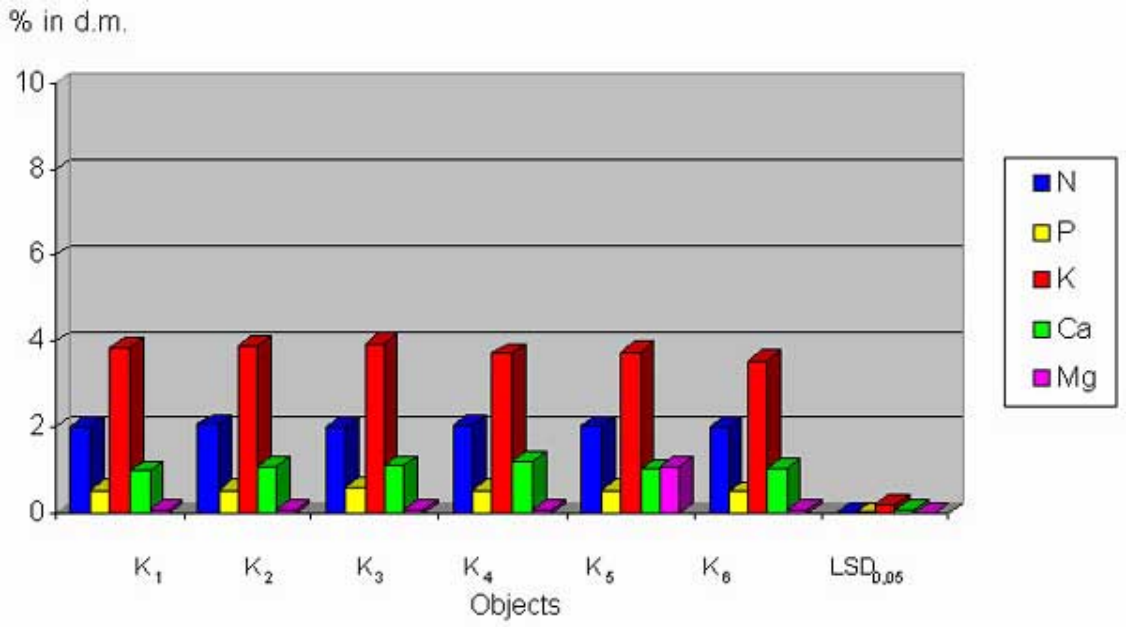
In stems the highest contents of N, P and K were noted for a four-time application of a 6% aqueous solution of carbamide (Fig. 2). The nitrogen content was significantly higher as compared with all the objects of foliar fertilisation, except for three-time foliar application of a 6% aqueous solution of carbamide with Agrosol-K, while the content of phosphorus here was significantly higher, as compared with the three-time potato foliar fertilisation with a 6% aqueous solution of carbamide. The lowest content of phosphorus was observed for solid carbamide fertilisation. A four-time fertilisation with a 6 % aqueous solution of carbamide helped a significant increase in the potassium content, while with Agrosol-K, only - an increase in the content of calcium, while the content of magnesium did not depend on foliar fertilisation.

Figure 2. Content of macroelements in stems during potato plant flowering (1990-1992)



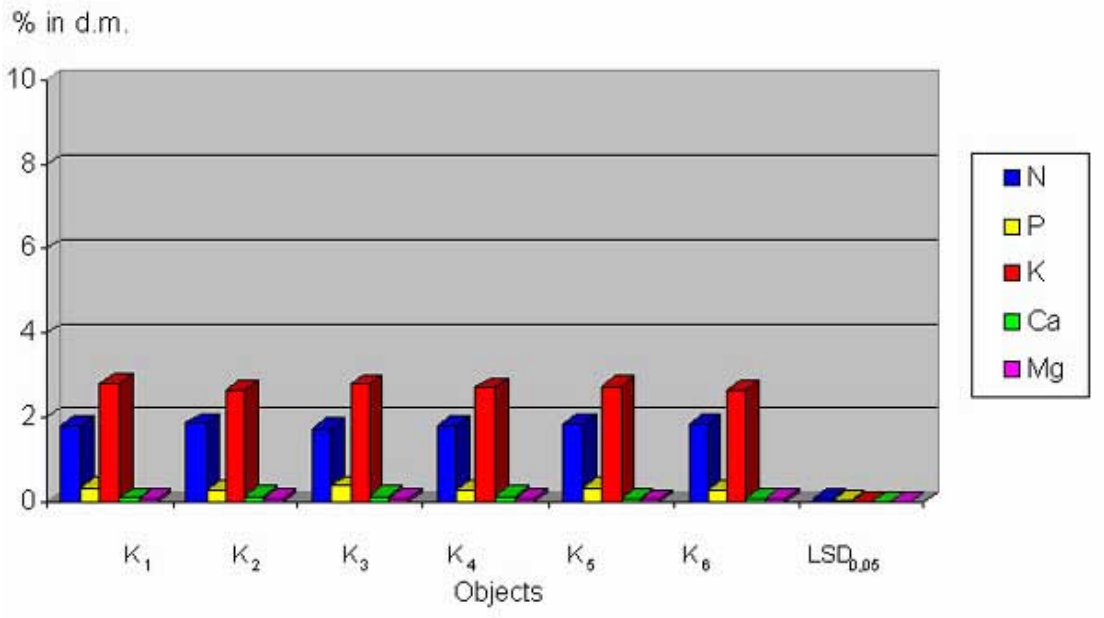
Foliar fertilisation did not influence the contents of nitrogen and magnesium in stolons (Fig. 3). The highest contents of P, K and Ca in that plant part were observed due to a four-time application of Agrosol-K exclusively. The content of phosphorus was significantly higher due to a four-time potato fertilisation with Agrosol-K, except for a two-time foliar fertilisation with a 6% aqueous solution of carbamide as combined with Agrosol-K. The content of potassium increased significantly only for a two- and three-time plant fertilisation with a 6% aqueous solution of carbamide as combined with Agrosol-K.

Figure 3. Content of macroelements in stolons during potato plant flowering (1990-1992)



At the time of tuber setting, foliar fertilisation influenced the tuber contents of N and P only (Fig. 4). A four-time application of a 6% aqueous solution of carbamide enhanced a significant increase in the content of nitrogen only as compared with a four-time application of Agrosol-K only. The content of phosphorus increased significantly due to a four-time application of Agrosol-K as compared with a 6% aqueous solution of carbamide applied four times and twice or three times as combined with Agrosol-K.

Figure 4. Content of macroelements in tubers during potato plant flowering (1990-1992)



DISCUSSION

During its intensified bio-activity, potato plants showed a high demand for nutrients. It was observed in the present research that during flowering potato leaves contained three times as much nitrogen and calcium and magnesium as the other plant parts did. Similar observations are reported by Kapoor and Li [9] as well as Boliglowa [1]. Yet no correlation was noted between those elements in leaves and macroelements in stems, stolons and tubers. The results obtained confirm the findings of Sattelmacher and Marschener [12].

Potato can consume infinite potassium quantities. During flowering the macroelements-oriented investigation showed high potassium content in all the plant parts, especially in stems. However the contents of N, P, K, Ca, Mg at that time of potato growth and development point to no greater differences in chemical composition in respective plant parts, as compared with the literature reports on solid fertilisation [2,6,7]. Potato foliar fertilisation with a 6% aqueous solution of carbamide and with a multi-component fertiliser (Agrosol-K) did not cause significant differences in the chemical composition of respective plant parts, as compared with solid fertilisation. Similar observations are reported by Czuba [4,5] and Warcholowa [13]. It is important to emphasise that nitrogen and magnesium are the only macroelements present in Agrosol-K. The contents of phosphorus, potassium and calcium defined showed that foliar fertilisation with Agrosol-K as well as with carbamide mobilised these elements and started their intake from soil with the root system.

Moreover a significant correlation was found between the contents of P and K as well as Mg in leaves and the contents of N, P, K, Ca, Mg in stolons and tubers. However there is no thorough coverage on the correlation between macroelements during potato plant flowering.

The contents of respective elements during flowering were, as follows: in leaves - N > K > Ca > P > Mg; in stems - K > N> Ca > P > Mg; in stolons - K > N> Ca > P > Mg; in tubers - K > N> P > Ca > Mg.

Foliar fertilisation with a 6% aqueous solution of carbamide and with Agrosol-K did not cause major differences in the equivalent ratios of potassium to sum of calcium and magnesium, as compared with solid fertilisation. Similar reports are available from Brogowski et al. [3]. Yet most equivalent K : (Ca + Mg) ratios during potato plant flowering were observed in stems.

CONCLUSIONS

1. During flowering there were noted higher contents of macroelements in leaves and stems than in stolons and tubers.
2. Foliar fertilisation with a 6% aqueous solution of carbamide and with Agrosol-K caused significant differences neither in the content of macroelements nor in the equivalent K : (Ca + Mg) ratios, as compared with solid fertilisation.

3. During potato plant flowering, the most equivalent K : (Ca + Mg) ratios were observed in stems.
4. A significant positive correlation was observed between the contents of P, K, Mg in leaves and the contents of all the macroelements in stolons and tubers.
5. The content of magnesium was observed to be of high stability and depended neither on the form nor on the dose of nitrogen.

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