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EFFECT OF FOLIAR FERTILIZERS ON PHYSIOLOGICAL CHARACTERISTICS OF POTATO

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ABSTRACT

Limited information is available on physiological response of potato (*Solanum tuberosum* L.) to the application of foliar fertilizers. Therefore, the aim of this study was to determine the effect of three commercial foliar fertilizers (EPSO Microtop, Megagreen and Drin) compared with control (without foliar fertilizer) on the intensity of photosynthesis, concentration of photosynthetic pigments in potato leaves and tuber dry matter yield at various intervals after planting. Greenhouse experiment was conducted during two growing seasons (2006 and 2007), which were characterized by higher than optimum temperatures. Foliar fertilizers were applied five times during vegetation in ten-day intervals starting at tuber initiation phase. Control plants achieved higher intensity of photosynthesis at tuber initiation phase (50 and 55 days after planting) in comparison to all foliar treatments. In all other days after planting, control and foliar treatments had similar intensity of photosynthesis. Application of foliar fertilizers did not increase the concentration of chlorophyll *a* and chlorophyll *b* in potato leaves and the aboveground dry matter yield. The highest tuber dry matter yield under conditions of higher than optimum temperature was obtained with the foliar fertilizer Megagreen, which contains calcium.

Key words: foliar fertilization, intensity of photosynthesis, photosynthetic pigments concentrations, tuber dry matter yield.

INTRODUCTION

Fertilization is an important factor in potato (*Solanum tuberosum* L.) production technology to achieve optimum yield and quality of tubers. The potato is a plant with high nutrient demands because of forming abundant vegetative mass and a high quantity of tubers at the unit area. It is a great consumer of nitrogen, phosphorus, potassium, magnesium and calcium, as well as micro elements (Fit and Hangan, 2010). High potato yields can only be obtained through the application of optimal nutrient doses in balanced proportions (Poljak et al., 2007). In potato production in Croatia, soil mineral fertilization is based on three macronutrients (nitrogen, phosphorus and potassium). However, soil mineral reserves and soil fertilization are not always sufficient to satisfy the needs of crops. Disorders in potato nutrition occur in acidic and alkaline soils. In acid soils, there is a lack of calcium, magnesium and phosphorus for growing crop, and in alkaline there is lack of boron, manganese and zinc (Marschner, 1995). The alternative approach is the application of these nutrients to plant leaves and stems through foliar fertilization. Foliar fertilization is a supplemental nutrition with macro and micro nutrients. Foliar nutrition is ideally designed to provide many elements in conditions that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (Hiller, 1995). On the market there are different foliar fertilizers, which are often mixtures of micronutrients and secondary nutrients. Their application is recommended to increase the yield and quality of crops. Observed effects include an increase

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in crop yield and quality of potato crop (Jablonski, 2003; Mousavi et al., 2007). However, some studies could not confirm the positive results of foliar fertilization in potato (Allison et al., 2001). There is considerable lack of scientific results based on effectiveness of foliar fertilizers on the plant metabolism. In a preliminary study, Horvat et al. (2006) did not find any positive effect of foliar fertilizer Megagreen (44.1% CaO) on chlorophyll content in potato leaf. Chapagain and Wiesman (2004) determined a significant increase of chlorophyll content in tomato (*Lycopersicon esculentum* Mill) leaves after foliar application of Nutri-Vant-PeaK (95% monocalcium-phosphate).

Physiological response of potato to the application of foliar fertilizers is not sufficiently known. The aim of this study was to determine the effect of three commercial foliar fertilizers on the intensity of photosynthesis, concentration of photosynthetic pigments and tuber dry matter yield.

MATERIAL AND METHODS

Greenhouse experiment

The experiment was conducted in the greenhouse of the Faculty of Agriculture, University of Zagreb during two growing seasons (2006 and 2007). Sprouted potato tubers (28-35 mm) of medium-late variety "*Courage*" were planted in 25 L pots on May 1st 2006 and March 19th 2007. The pots were filled with a mixture of soil and perlite at a ratio of 3:1. Soil properties were: pH 5.04; 1.30% humus; 8.90 mg K_2O 100 g^{-1} and 16.50 mg P_2O_5 100 g^{-1} dry soil. The basic fertilization, calculated per pot, was carried out with 700 kg ha^{-1} N–P–K fertilizer (7:20:30) combined with 250 kg ha^{-1} of calcium ammonium nitrate fertilizer (27% N).

Treatments. The experiment with three commercial foliar fertilizers (EPSO Microtop, Drin, Megagreen) and control treatment (without foliar fertilizer) was arranged in a randomized complete block design with three replications. Each fertilizer treatment included five plants in five pots. The tested commercial foliar fertilizers were:

- EPSO Microtop (K+S KALI GmbH, Germany) is magnesium sulphate fertilizer (15% MgO, 12% S) with 0.9% B and 1% Mn.
- Drin (Green Has Italia, Italy) is physiological biostimulator containing L-alpha amino acid 39% (alanine, arginine, aspargin acid, cysteine, glutamic acid, glycine, hidroxy proline, histidine, isoleucine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tirosin, valine);
- Megagreen (Velebit Inf. International d.o.o., Croatia) is a natural fertilizer obtained by nanotechnology activation of calcite and contains 44.1% CaO, 9.1% SiO_2, 2.2% MgO, 1.2% Fe_2O_3, 0.1% SO_4 and micro elements in trace amounts.

Foliar fertilization was carried out five times during vegetation (50, 60, 70, 80 and 90 days after planting-DAP) in the period from the start of tuber formation to the stage of full tuberization with rates recommended by manufacturers. EPSO Microtop was applied at 25 kg ha^{-1}, Drin at 0.5 L ha^{-1} and Megagreen at 2 kg ha^{-1} with the water amount of 300 L ha^{-1}, calculated per pot. Plants were irrigated by drip system.

Measurements of photosynthesis intensity. From the beginning of tuber formation (50 DAP) to the stage of full tuberization (90 DAP), measurements of intensity of photosynthesis by LCpro apparatus (ADC, Bio Scientific Ltd. Great Britain) were conducted at five day intervals. The measurements were made on the youngest, fully developed leaf on three plants per treatment. Three measurements were carried out for each plant. The measurements of the photosynthesis intensity were carried out under constant light conditions (PAR 1000 µmol $m^{-2}s^{-1}$) and CO_2 concentration of 370±10 µmol mol^{-1}.

Sampling of plant material and photosynthetic pigments extraction. Sampling of plant material (leaf tissue) for determination of photosynthetic pigments was carried out twice during the growing season, at 70 and 80 DAP (after the second and third foliar application).

Samples were taken from the youngest but fully developed leaves from three plants per treatment. Leaf material was cut in pieces to get a representative sample (0.1 g). Pigments extraction was made in 80% acetone and concentrations of chlorophyll *a*, chlorophyll *b* and total carotenoids were calculated using molar absorption coefficients by Lichtenthaler and Wellburn (1983). To assess the effectiveness of foliar application on tuber dry matter yield, during the growing season samples were taken from one plant per treatment 70 and 80 DAP (after the second and third foliar application). Final harvest was performed at 100 DAP. To determine the tuber dry matter yield three plants were taken per treatment.

Control of temperature and humidity. Measurements of temperature and relative humidity (Table 1) were conducted daily during the growing seasons by using THG312 electronic thermo-hygrometer (Oregon Scientific, USA).

Table 1. Average minimum and maximum temperature and relative humidity in the greenhouse during the growing seasons 2006 and 2007

Month	2006				2007			
	Air temperature (ºC)		Relative humidity (%)		Air temperature (ºC)		Relative humidity (%)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
March	-	-	-	-	3.5	28.7	25.5	95.9
April	-	-	-	-	5.5	35.1	21.5	93.3
May	10.1	28.6	23.5	92.8	11.1	36.3	25.1	94.9
June	14.6	31.1	26.2	93.2	16.7	39.9	24.3	95.7
July	16.8	34.9	22.5	90.3	-	-	-	-
August	14.5	32.8	27.7	95.2	-	-	-	-
Average	14.0	31.8	25.0	93.0	9.2	35.0	24.1	95.0

Statistical analysis

Data were analyzed using mixed model procedures (SAS Institute, 1997) and subjected to the combined analysis of variance. For comparing average values, LSD test was used when F test was significant at the level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Foliar treatments were significantly different in the intensity of photosynthesis at various DAP, as shown by the significance of the interaction between days after planting and treatments (Table 2).

Control achieved significantly higher intensity of photosynthesis at 50 DAP compared to Drin and EPSO Microtop (Table 3). The difference in the intensity of photosynthesis between treatment Megagreen and control was not significant at 50 DAP. At 55 DAP the control achieved significantly higher rates of intensity of photosynthesis compared to all other treatments.

Table 2. Combined analysis of variance for intensity of photosynthesis in potato leaves

Source of variation	df	Intensity of photosynthesis
Growing season (GS)	1	**
Days after planting (DAP)	8	**
GS × DAP	8	**
Treatment (T)	3	*
GS × T	3	NS
DAP ×T	24	*
GS × DAP × T	24	NS

NS Not significant; * Significant at $P \leq 0.05$;
** Significant at $P \leq 0.01$.

At all other DAP, differences in the intensity of photosynthesis between treatments and control were not significant. In our experiment relatively low intensity of photosynthesis was achieved and a positive effect of foliar treatments was not observed. This could have been caused by high temperatures in the greenhouse during the study. The average maximum temperature during the growing season 2006 was 31.8ºC and in the 2007 was 35.0ºC. Timlin et al. (2006) stated that the optimum temperature for potato leaf photosynthesis is about 24ºC. Prange et al. (1990) suggested that temperature above 24ºC cause reduction of efficiency of photosystem II, more than the increase in the rate of respiration or decrease of leaf surface. High temperature in a greenhouse probably resulted in accelerated senescence, loss of chlorophyll, reduced stomatal conductance, and damage of photosystem II and inhibition of Calvin cycle.

Table 3. Average intensity of photosynthesis of foliar treatments compared to control in different days after planting

Day after planting (DAP)	Intensity of photosynthesis (μmol CO_2 $m^{-2}s^{-1}$)			
	Treatment			
	Drin	EPSO Microtop	Megagreen	Control
50	7.02	8.92	9.97	11.24
55	9.01	9.07	8.88	10.78
60	7.67	7.20	7.93	8.01
65	6.36	5.53	6.27	5.47
70	7.40	6.93	6.86	7.80
75	6.81	7.00	6.62	7.01
80	5.45	4.84	5.17	5.76
85	4.84	4.99	4.66	4.56
90	3.88	3.61	4.19	3.44
LSD (0.05) †	1.75			
LSD (0.05) ‡	1.53			

† LSD values for comparing means across various days after planting;
‡ LSD values for comparing means within the same days after planting.

Effect of foliar fertilizers on the concentration of chlorophyll *a*, chlorophyll *b* and concentration of total carotenoids in potato leaves was not significant (Table 4). In contrast, some studies have confirmed a significant effect of foliar fertilizers on the concentration of photosynthetic pigments in potato leaves. For example, Eleiwa et al. (2012) stated that foliar application of Folifertile (22% N; 21% P_2O_5; 17% K_2O with microelements) significantly increased concentration of chlorophyll *a*, chlorophyll *b* and carotenoids in potato leaves compared to control treatment. Dkhil et al. (2011) determined a significant increase of chlorophyll *a* concentration by 15.8% in response to the 1 g KNO_3 L^{-1} foliar treatment at 95 DAP compared to control.

The analysis of variance (Table 4) showed that the vegetation season significantly affected both aboveground and tuber dry matter yield. In the vegetation season of 2006 significantly higher aboveground and tuber dry matter yield was achieved compared to vegetation season 2007 (data not shown). A significant impact of DAP on aboveground dry matter yield was determined (Table 4). Significantly higher aboveground dry matter yield was achieved 80 DAP and amounted 14.74 g per plant compared to 70 DAP (13.13 g per plant). No significant difference of tuber dry matter yield was determined under the influence of DAP. Barghi et al. (2012) stated that from the beginning of growth period to its end, tuber dry weight per plant increased significantly and its highest value was acquired in 118 DAP.

This proportional assimilate allocation was not found in our research most likely due to high temperatures in the greenhouse. Jenkins and Mahmood (2003) found that temperature above 23ºC favours allocation of dry matter to the foliage at the cost of tuber growth. At high temperatures, the shoot becomes an important sink for photosynthates (Basu and Minhas, 1991). This suggests that heat stress has larger effect on translocation of sugars to tubers than on the production of sugars from photosynthesis (Timlin et al., 2006).

Table 4. Combined analysis of variance for photosynthetic pigments concentration in potato leaf, aboveground and tuber dry matter yield

Source of variation	df	Chlorophyll *a*	Chlorophyll *b*	Total carotenoids	Aboveground dry matter yield	Tuber dry matter yield
Growing season (GS)	1	NS	**	NS	*	*
Days after planting (DAP)	1	**	**	**	*	NS
GS×DAP	1	**	**	**	NS	NS
Treatment (T)	3	NS	NS	NS	NS	*
GS×T	3	NS	NS	NS	NS	NS
DAP×T	3	NS	NS	NS	NS	NS
GS×DAP×T	3	NS	NS	NS	NS	NS

NS Not significant; * Significant at P≤0.05; ** Significant at P≤0.01.

Tuber dry matter yield significantly differed under the influence of treatments applied in the research (Table 4).

The highest tuber dry matter yield achieved in control and Megagreen which is based on calcium (Figure 1).

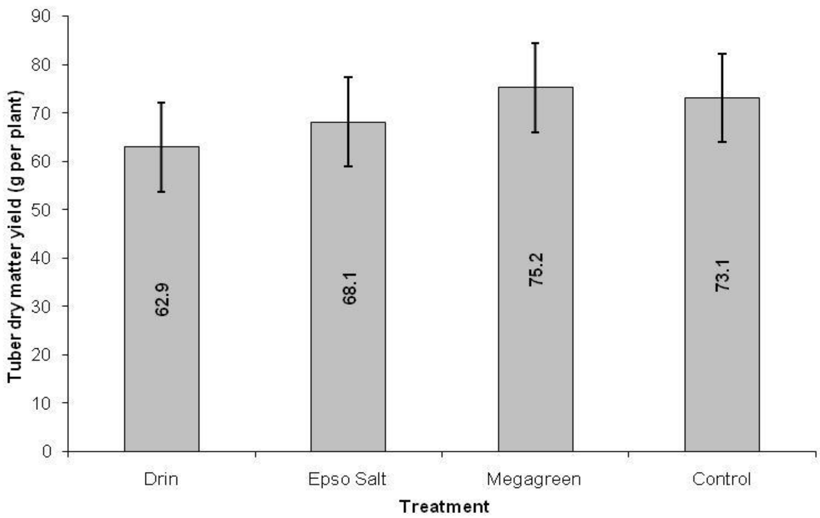

Figure 1. Average tuber dry matter yield following application of foliar ferilizers, compared to control. LSD 0.05 = 9.2 g per plant

Wada et al. (1996) in their research on the impact of foliar application of calcium on tomato fruit yield determined increase of yield and quality of fruit. The relatively low intensity of photosynthesis observed in this study was accompanied by lower yields. Barghi et al. (2012) in their investigation quoted tuber dry matter yields of 120 g per plant at 80 DAP. Wheeler (2006) stated that temperature of 22ºC is required to achieve optimal tuber yield, but higher temperatures existed during our research. Calcium which is the part of the foliar treatment Megagreen probably alleviated the negative effect of high temperature on the intensity of photosynthesis and tuber dry matter yield of potato. This is in agreement with Palta (1996), who stated that the application of calcium fertilizer during the potato bulking under high temperature led to an increase in tuber yield by 20-30% compared to the control.

Under high temperature, by the application of calcium the potato plants achieved significantly greater mass of aboveground parts, higher concentration of calcium in the leaf as well as higher stomatal conductance. It is not yet known how calcium reduces the impact of high temperatures on potatoes. This author noted that the application of calcium increased stomatal conductance, thus transpiration process increased and mitigated the effect of high temperatures. Also one of the factors that affect the stomatal opening is H+-ATP-ase in the plasma membrane, and its activity is regulated by protein kinase, which is stimulated by calcium. In this way calcium can regulate stomatal opening mechanism, regulating the activity of H+-ATP-ase in the cells. In our research, the treatment with Drin containing nitrogen (as amino acids) produced significantly lower tuber dry matter yield compared to control.

However, many studies pointed the positive effect of foliar application of nitrogen in obtaining higher yields. Danilchenko et al. (2005) suggested that foliar fertilization with liquid complex fertilizer Aggrene (2% N; 0.44% P; 0.83% K) increased tuber dry matter yield in *Voke* variety by 24% compared to control (without foliar fertilizer). Boliglowa (2003) reported an increase of tuber yield with foliar application of 6% solution of urea.

There was no significant difference in tuber dry matter yield between treatment EPSO Microtop and control, suggesting that the micronutrients contained by this foliar fertilizer (Mg, S, B and Mn) did not influence the yield in the conditions of our experiment.

CONCLUSIONS

Application of foliar fertilizers did not increase the intensity of photosynthesis compared to the control. In tuber initiation phase (50 and 55 DAP) control plants achieved higher intensity of photosynthesis compared to foliar treatments. However, in all the other days after planting no significant differences in the intensity of photosynthesis existed between treatments and control. Effect of foliar fertilizers on the concentration of chlorophyll pigments and concentration of total carotenoids in potato leaves was not significant. However, the highest tuber dry matter yield under conditions of higher than optimum temperature was obtained with the foliar fertilizer Megagreen, which contains calcium.

REFERENCES

Allison, M.F., Fowler, J.H., Allen, E.J., 2001. *Effects of soil-and foliar-applied phosphorus fertilizers on the potato (Solanum tuberosum) crop*. Journal of Agricultural Science, 137: 379-395.

Barghi, A., Tobeh, A., Hassanzadeh, N., 2012. *Effect of nitrogen fertilizer levels on tuber filling rate and protein assimilation in early and late maturing potato*. Annals of Biological Research, 3 (9): 4264-4275.

Basu, P.S., Minhas, J.S., 1991. *Heat tolerance and assimilate transport in different potato genotypes*. Journal of Experimental Botany, 42: 861-866.

Boliglowa, E., 2003. *Effect of foliar fertilizers on potato yield, its structure, wholesomeness and storage life of tubers.* Acta Agrophysica, 85: 99-106.

Chapagain, B.P., Wiesman, Z., 2004. *Effect of Nutri-vant_PeaK foliar spray on plant development, yield and fruit quality in greenhouse tomatoes*. Scientia Horticulturae, 102 (2):177-188.

Danilchenko, V., Dris, R., Niskanen, R., 2005. *Influence of organic and mineral fertilization on yield, composition and processing quality of potatoes*. Journal of Food, Agriculture & Environment, 3 (1): 143-144.

Dkhil, B.B., Denden, M., Aboud, S., 2011. *Foliar potassium fertilization and its effect on growth, yield and quality of potato grown under loam-sandy soil and semi-arid conditions*. International Journal of Agricultural Research, 6 (7): 593-600.

Eleiwa, M.E., Ibrahim, S.A., Mohamed, M.F., 2012. *Combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (Solanum tuberosum L.)*. African Journal of Microbiology Research, 6 (24): 5100-5109.

Fit, E-M., Hangan, M-C., 2010. *The effect of differential fertilization upon Desirée and Ostara potatos production on districambosol soil*. Research Journal of Agricultural Science, 42 (3): 137-142.

Hiller, K.L., 1995. *Foliar fertilization bumps potato yields in northwest. Rate and timing of application, plus host of other considerations, are critical in applying foliars to potatoes*. Fluid Journal, 3 (3): 29-30.

Horvat, T., Poljak, M., Majić, A., Gunjača J., 2006. *Response of potato to foliar fertilization*. In: Jovanovac, S., Kovačević, V. (eds), Proceedings of the 41st Croatian and 1st International Symposium on Agriculture. Faculty of Agriculture, University of J. J. Strossmayer, Osijek: 385-386.

Jablonski, K., 2003. *Efficiency of foliar and „to soil” fertilization of potatoes the urea-ammonium-nitrate solution (UAN 32)*. Acta Agrophysica, 85: 125-135.

Jenkins, P.D. Mahmood, S., 2003. *Dry matter production and partitioning in potato plants subjected to combined deficiencies of nitrogen, phosphorus and potassium*. Ingentaconnect, 143 (2): 105-112.

Lichtenthaler, H.K., Wellburn, A.R., 1983. *Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents*. Biochemical Society Transactions, 11: 591-592.

Marschner, H., 1995. *Mineral nutrition of higher plants*. Second edition. Academic Press, London

Mousavi, S.R., Galavi, M., Ahmadvand, G., 2007. *Effect of zinc and manganese foliar application on yield, quality and enrichment on potato (Solanum tuberosum L.)*. Asian Journal of Plant Sciences, 6: 1256-1260.

Palta, J.P., 1996. *Role of calcium in plant responses to stresses: Linking basic Research to the solution of practical problems*. Hort. Science, 31(1): 51-57.

Poljak, M., Herak-Ćustić, M., Horvat, T., Čoga, L., Majić, A., 2007. *Effects of nitrogen nutrition on potato tuber composition and yield*. Cereal Research Communications, 35: 937-940.

Prange, R.K., McRae, K.B., Midmore, D.J., Deng, R., 1990. *Reduction in potato growth at high temperature: Role of photosynthesis and dark respiration*. American Potato Journal, 67: 357-369.

SAS Institute., 1997. *SAS/STAT software: Changes and enhancements through release 6.12*. SAS Inst., Cary, NC.

Timlin, D., Lutfor Rahman, S.M., Baker, J., Reddy, V.R., Fleisher, D., Quebedeaux, B., 2006. *Whole plant photosynthesis, development and carbon partitioning in potato as a function of temperature*. Agronomy Journal, 98: 1195-1203.

Wada, T., Ikeda, H., Ikeda, M., Furukawa, H., 1996. *Effects of foliar application of calcium solutions on the incidence of blossom-end rot of tomato fruit*. Journal of the Japanese Society for Horticultural Science, 65 (3): 553-558.

Wheeler, R.M., 2006. *Potatoes for human exploration of space: Observations from NASA-sponsored controlled environment studies*. Potato Research, 49: 67-90.