Effect of selenium foliar application on its content in winter wheat grain

L. Ducsay, O. Ložek

Slovak University of Agriculture in Nitra, Slovak Republic

ABSTRACT

The effect of foliar application of graduated Se rates (0.5, 1.0, 10 and 20 g Se/ha) on the winter wheat grain yield and Se accumulation in grain was investigated in the accurate field fertilization experiment. Selenium fertilization was realized together with the application of liquid fertilizer DAM-390 (30 kg N/ha) in the growth stage of the 6th leaf (Zadoks = 29). Applied treatments of Se fertilization did not influence the yields of grain. These yields fluctuated within the range of from 5.98 to 6.08, 5.65 to 5.71, and 7.78 to 8.04 t/ha of grain in the years 1999, 2000 and 2001, respectively. Highly significant lower grain yields in the year 2000 comparing to the other experimental years were caused by unfavorable weather conditions. Both the rates of 10 and 20 g Se/ha highly significantly increased Se accumulation in grain in all experimental years. The average Se content in grain dry matter was 0.045 mg/kg under unfertilized treatment and with the Se rates of 10 g and 20 g/ha it increased to the value of 0.088 and 0.145 mg/kg, respectively. The total offtake of Se by grain yield increased in the similar way. It results from the experiment that the rate of 10 g Se/ha is sufficient for achieving the required Se content in winter wheat grain.

Keywords: winter wheat; foliar application of Se; grain yield; selenium content in grain

Selenium is considered to be an essential element for humans, animals and some species of microorganisms. Se enters the food chain through the plants which take it up from soil (Rayman 2000). Recently the insufficient input of Se into human organisms has been frequently discussed. Low Se status in human organism may increase the risk of cardiovascular, cancer and other diseases, which are caused by free radicals (Merian 1991, Rayman 2000). One of the effective measures to solve this situation seems to be the supplement of Se into the food chain. Supplementation of Se into the fertilizers (16 mg/kg for fertilizers established for grain production and 6 mg/kg to those for fodder production) started statewide in Finland in 1984 Lahermo et al. (1998).

Because of the subsequent significant increase of Se in food chain, the amount of Se added to all fertilizers has decreased to 6 mg/kg since 1990 (Aro et al. 1995). Foliar application of Se in the form of Na_2SeO_3 under various crops is stated by MacLeod et al. (1998) and Cao et al. (2001). Differences between essential and toxic rates of Se are very narrow (Tan et al. 2002, Fargašová 2004, Fargašová et al. 2006).

Se uptake by Slovak Republic population is low and ranges from 0.027 to 0.043 mg per day. This low uptake is caused by low content of Se in soils and subsequently in plants, cereals, animals and other parts of food chain. Below average content of Se (from 0.2 to 0.33 mg/kg) is characteristic for a majority of Slovak soils. It includes the prevailing part of Podunajská nížina (upper part of Žitný ostrov and hills), the whole Považské podolie, Orava, Kysuce, vulcanic mountains, northern Spiš and southern Slovak basins.

Average Se concentration in cereals in Slovakia amounts 0.024 mg/kg of grain dry matter, ranging from 0.006 to 0.122 mg/kg. For wheat the range fluctuates from 0.008 to 0.122 mg/kg (0.029 mg/kg on the average), for barley from 0.008 to 0.069 (0.023 mg/kg on the average) and for rye from 0.006 to 0.036 (0.015 mg/kg averagely) (Melicherčík and Melicherčíková 1997).

In this contribution the effect of Se foliar application (together with nitrogen) on the winter wheat grain yield, uptake and accumulation of Se by winter wheat grain is evaluated and discussed.

MATERIAL AND METHODS

Small – plot trials were established in the first decade of October in the years 1999, 2000, and 2001,

Table 1. Agrochemical characteristic of soil (to the depth of 0.3 m) before trial establishment

Soil analyses	1998/1999	1999/2000	2000/2001
pH/KCl	7.26	6.73	7.07
N_{an} (mg/kg)	18.1	24.7	15.2
*N_{an} (mg/kg) in depth of 0.0–0.6 m	10.9	11.6	9.8
P Mehlich II (mg/kg)	81.0	94.0	124.0
K Mehlich II (mg/kg)	210.0	224.0	268.0
Se-total content (HF + HNO_3 + HCl) (mg/kg)	0.27	0.25	0.29
Content of C_{ox} Tjurin (%)	1.28	1.56	1.24

*content of N_{an} in soil analyzed in the phase of 6th leaf of winter wheat plants

respectively at Breeding Station of Sládkovičovo-Nový dvor (17°34'40" east longitude and 48°22'20" west latitude) with winter wheat (*Triticum aestivum* L.), variety Blava. The experiments were realized on loamy degraded chernozem. Experimental plots of 10 m^2 in size were arranged in block pattern and four times repeated. The seeding rate represented 4.5 million of germinating grains per hectare with the span of rows amounting to 0.125 m. Field pea was grown as the previous crop. Agrochemical soil characteristics determined before the trial establishment are stated in Table 1. Average year atmospheric temperature represents 10.46°C and annual sum of precipitation amounts 479.2 mm (Kožnarová and Klabzuba 2002). From the viewpoint of temperature the year 1999 was normal (June was very warm), but over normal wet in precipitation, particularly during summer months. As far as the temperature is concerned the year 2000 was over normal (April extremely warm, May and June very warm) and under normal in precipitation (April dry, May and June very dry). As to the temperature, the year 2001 was normal and insufficient in precipitation (dry April and very dry June). More detailed data on weather conditions of experimental stand in investigated years are stated by Ducsay and Ložek (2004). Productive fertilizing of winter wheat with nitrogen jointly (together) with foliar application of graduated rates of Se was realized at the growth stage of the end of tilling (Zadoks DC = 29) (Chang et al. 1974). Liquid fertilizer DAM-390 and solution of sodium selenite (Na_2SeO_3.5 H_2O) were used for fertilizing. Experimental treatments are illustrated in Table 2. Harvest of the crop was performed by small-plot combine machine. Soil and plant analyses were done by common methods. Se content in wheat grain was determined by HG-AAS method using VARIAN SPECTRAA 300A VGA-76 apparatus. The values of grain yields and Se accumulation were evaluated statistically by analysis of variance and differences between the years and treatments by *LSD* test, respectively.

RESULTS AND DISCUSSION

Various weather conditions highly significantly influenced the winter wheat grain yields in the respective experimental years. The highest yield was harvested in experimental year 2000/2001 (average of all treatments was 7.97 t/ha). Growing season 1998/1999 was on the level of 40-years normal in both temperature and precipitation and achieved average grain yield represented 6.02 t/ha. Considerable yield decline happened in experimental year 1999/2000 when average yield of grain was 5.68 t/ha. Hubík (1995) and Ducsay and Ložek (2004) report significant effect of weather conditions on the winter wheat grain yield formation. Three-year average results

Table 2. Treatments of fertilization in trial with winter wheat

Treatments of fertilization	Nitrogen DAM-390* (kg/ha)	Se Na_2SeO_3 (g/ha)
1	30	–
2	30	0.5
3	30	1
4	30	10
5	30	20

*ammonium nitrate and urea

Table 3. Effect of N fertilization and graduated rates of Se on the Se content in winter wheat grain dry matter

Treatments of fertilization	Se content in dry matter of grain (mg/kg)				Relatively (%) 1 = 100
	1999	2000	2001	3-year average	
1	0.050	0.055	0.030	0.045	100.0
2	0.041	0.070	0.027	0.046	102.2
3	0.077	0.059	0.048	0.061	135.6
4	0.095	0.101	0.069	0.088	195.6
5	0.167	0.130	0.137	0.145	322.2
LSD variants 0.05				0.011^{+}	
LSD variants 0.01				0.014^{++}	
Average	0.086	0.083	0.062		
LSD years 0.05		0.008^{+}			
LSD years 0.01		0.011^{++}			

indicate supposed indifferent effect of graduated Se rates on grain yield formation. Average yields of grain fluctuated from 5.98 to 6.08 t/ha in 1999, from 5.65 to 5.71 t/ha in 2000 and from 7.78 to 8.04 t/ha in 2001.

Average content of Se (Table 3) in treatment without its application reached the value of 0.045 mg/kg in dry matter of wheat grain. Mihailovic et al. (1996) state average content of Se in wheat grain in Serbia amounting the value of 0.027 mg/kg. Alfthan et al. (1992) found in some regions of Hungary average content of Se of 0.034 mg/kg in wheat grain dry matter. Applied rate of Se (0.5 g/ha Se) did not cause statistically significant increase of Se content in grain (0.046 mg/kg Se). Foliar application of 1, 10 and 20 g Se/ha significantly increased Se content in wheat grain to 0.061, 0.088 and 0.145 mg/kg, respectively in comparison with treatment without Se. Milovac et al. (1998) found that foliar application of sodium selenite in the rate of 6 and 12 g Se/ha caused arise of Se content in wheat grain on the values ranging from 0.042 to 0.067 mg/kg and from 0.065 to 0.180 mg/kg dry matter, respectively, what is in harmony with our results. In Finland, effect of Se supplement into the fertilizers applied for field crops fertilization increased average Se content in wheat grain dry matter to the value of 0.174 mg/kg. According

Table 4. Selenium offtake by winter wheat grain dry matter

Treatments of fertilization	Selenium offtake (mg/ha)				Relatively (%) 1 = 100
	1999	2000	2001	3-year average	
1	258.94	269.91	207.75	245.53	100.0
2	211.55	342.99	181.30	245.28	99.9
3	397.09	288.34	330.31	338.58	102.5
4	495.52	491.28	474.89	487.23	198.4
5	872.75	633.56	941.36	815.89	332.3
LSD variants 0.05				71.74^{+}	
LSD variants 0.01				95.63^{++}	
Average	447.17	405.22	417.12		
LSD years 0.05		55.57^{+}			
LSD years 0.01		74.08^{++}			

Table 5. Selenium transition from foliarly applied Se rates to winter wheat grain

Treatments of fertilization	Rates of applied Se (g/ha)	Average Se offtake by grain dry matter (mg/ha)	Uptake of Se by grain from total Se rate applied (%)
1	–	245.53	–
2	0.5	245.28	–
3	1	338.58	9.3
4	10	487.23	2.4
5	20	815.89	2.9

to data obtained in Finland, supplementation of fertilizers with Se is a safe and effective means of increasing the Se intake of both animals and humans that is feasible in countries with relatively uniform geochemical conditions (Aro et al. 1995).

The plant availability of soil Se varies according to its oxidation state. For example, the selenate form (Se^{6+}) is to 10 to 20 times more available than the selenite form (Se^{4+}). MacLeod et al. (1998) state that the Se accumulation in barley grain achieved the level of 0.512 and 1.130 mg/kg in the consequence of the foliar application of Se in the rate of 10 to 20 g Se, respectively in the form of sodium selenate.

An increasing rate of foliar Se application evocated arises of its removal by wheat grain from one hectare (Table 4). The highest average removal was found under the application of 20 g Se/ha amounting the value of 815.89 mg Se/ha and representing so the increase by 232.3% in comparison with control treatment without Se application. Effect of increasing rates of applied Se on the transition of Se to the wheat grain can be seen in Table 5. If 1 g of Se/ha was applied, 9.3% of this amount was transited to wheat grain. This transition represented 2.4 and 2.9% of total applied Se when the rates of 10 and 20 g Se/ha, respectively were applied.

REFERENCES

Alfthan G., Bogye G., Aro A., Feher J. (1992): The human selenium status in Hungary. J. Trace Elem. Elect. Health Dis., *6*: 233–238.

Aro A., Alfthan G., Varo P. (1995): Effects of supplementation of fertilizers on human selenium status in Finland. Analyst, *120*: 841–843.

Cao Z.H., Wang X.C., Yao D.H., Zhang X.L., Wong M.H. (2001): Selenium geochemistry of paddy soils in Yangtze River Delta. Environ. Inst., *26*: 335–339.

Chang T.T., Konzak C.F., Zadoks J.C. (1974): A decimal code for growth stages of cereals. Weed Res., *14*: 415–421.

Ducsay L., Ložek O. (2004): Effect of top dressing with nitrogen on the yield and quality of winter wheat grain. Plant Soil Environ., *50*: 309–314.

Fargašová A. (2004): Toxicity comparison of some possible toxic metals (Cd, Cu, Pb, Se, Zn) on young seedlings of *Sinapis alba* L. Plant Soil Environ., *50*: 33–38.

Fargašová A., Pastierová J., Svetková K. (2006): Effect of Se-metal pair combinations (Cd, Zn, Cu, Pb) on photosynthetic pigments production and metal accumulation in *Sinapis alba* L. seedlings. Plant Soil Environ., *52*: 9–16.

Hubík K. (1995): The effect of fertilization and year on the bread wheat quality. Rostl. Výr., *41*: 521–527. (In Czech)

Kožnarová V., Klabzuba J. (2002): Recommendation of World Meteorological Organization to describing meteorological or climatological conditions. Rostl. Výr., *48*: 190–192. (In Czech)

Lahermo P., Alfthan G., Wang D. (1998): Selenium and arsenic in the environment in Finland. J. Environ. Pathol. Toxicol. Oncol., *17*: 205–216.

MacLeod J.A., Gupta U.C., Milburn P., Sanderson J.B. (1998): Selenium concentration in plant material, drainage and surface water as influenced by Se applied to barley foliage in a barley – red clover – potato rotation. Can. J. Soil Sci., *78*: 685–688.

Melicherčík M., Melicherčíková D. (1997): Bioanorganická chémia. 1. ed. Príroda, Bratislava.

Merian E. (1991): Metals and their compounds in the environment. VCH Verlagsgesell., Weinheim.

Mihailovic M., Lindberg P., Jovanovic I. (1996): Selenium content in feedstuff in Serbia (Yugoslavia). Acta Vet. Yugosl., *46*: 343–348.

Milovac M., Djermanovic V., Djujic I. (1998): Effects of cereal supplementation with selenium. J. Environ. Pathol. Toxicol. Oncol., *17*: 312–320.

Rayman M.P. (2000): The importance of selenium to human health. Lancet, *356*: 233–241.

Tan J., Zhu W., Wang W., Li R., Hou S., Wang D., Yang L. (2002): Selenium in soil and endemic diseases in China. Sci. Total Environ., *284*: 227–235.

Received on March 17, 2005

Corresponding author:

Dr. Ing. Ladislav Ducsay, Slovenská poľnohospodárska univerzita, A. Hlinku 2, 949 76 Nitra, Slovenská republika
phone: + 421 376 508 385, fax: + 421 376 508 387, e-mail: ladislav.ducsay@uniag.sk