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FOLIAR NUTRITION OF POPPY PLANTS (*PAPAVER SOMNIFERUM* L.) WITH SELENIUM AND THE EFFECT ON ITS CONTENT IN SEEDS*

Petr Škarpa, Rostislav Richter

Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition
Mendel University in Brno

Abstract

Selenium is a trace element which in small amounts is necessary for human and animal nutrition. In a living organism, it helps a number of antioxidant enzymes to function normally. In many parts of the world, including the Central European region, its content in agricultural products is very low. Attempts are therefore made to increase its content and cover human requirements with biologically valuable products by incorporating selenium into the system of plant nutrition. In a vegetation trial established in 2008 and 2009, we explored the effect of foliar applications of Se(IV) on yields and on its content in seeds and the uptake of selenium by a poppy (*Papaver somniferum* L.) stand. Selenium was applied at a rate of 300 g ha^{-1} during the stage of the end of elongation growth and after the fall of blossoms. Poppy yields were significantly influenced by the weather in the experimental years. In the dry year of 2009, poppy production was 40.6% lower than in 2008. Selenium application at the end of elongation growth reduced poppy seed yields by an average of 11.5%. Late supplementary nutrition at the stage after blossom fall also reduced yields (by 11.8%). Owing to the effect of extra-root Se nutrition, the content of selenium in poppy seeds increased highly significantly from 139 μg kg^{-1} to 757 μg kg^{-1} of seeds. Also the uptake of selenium by the poppy stand was significant and after foliar application it increased 4.8 times.

Key words: selenium, poppy, foliar application, yield of seeds, quality of seeds.

Ing. Petr Škarpa, Ph.D., Prof. Ing. Rostislav Richter, DrCs., Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: petr.skarpa@mendelu.cz

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NAWOŻENIE DOLISTNE MAKU (*PAPAVER SOMNIFERUM* L.) SELENEM I WPŁYW NA ZAWARTOŚĆ SELENU W ZIARNIE MAKU

Abstrakt

Selen to pierwiastek śladowy, który w niewielkich ilościach jest niezbędny w żywieniu ludzi i zwierząt. W żywym organizmie selen wspomaga prawidłowe działanie wielu enzymów antyoksydacyjnych. W wielu rejonach świata, łącznie z obszarem Europy Środkowej, zawartość selenu w produktach rolnych jest niewielka. W związku z tym podejmowane są starania, by zwiększyć jego zawartość przez wprowadzenie selenu do systemu nawożenia roślin uprawnych, by pokryć zapotrzebowanie na ten pierwiastek w diecie dzięki biologicznie wartościowym produktom.

W doświadczeniu wegetacyjnym przeprowadzonym w latach 2008 i 2009 badano wpływ dolistnego nawożenia Se(IV) na plonowanie maku (*Papaver somniferum* L.) oraz na zawartość selenu w ziarnie maku i pobór tego pierwiastka przez rośliny. Selen zastosowano w dawce 300 g ha^{-1} pod koniec fazy wzrostu łodygi oraz w czasie przekwitania. Plony maku były silnie uzależnione od warunków pogodowych w czasie doświadczenia. W suchym 2009 r. plon maku był o 40,6% niższy niż w 2008 r. Zastosowanie selenu pod koniec fazy wzrostu łodygi ograniczyło plon maku o średnio 11,5%. Późniejsze zastosowanie nawożenia selenem, w fazie przekwitania, także zmniejszyło plony (o 11,8%). Dzięki dodatkowemu dożywieniu korzeni selenem zawartość Se w ziarnie maku wzrosła istotnie ze 139 μg kg^{-1} do 757 μg kg^{-1}. Pobór selenu przez łan maku także był istotny, i wzrósł 4,8-krotnie po nawożeniu dolistnym tym pierwiastkiem.

Słowa kluczowe: selen, mak, nawożenie dolistne, plon ziarna, jakość ziarna.

INTRODUCTION

Selenium is classified into a group of micronutrients which appear in plants in the form of a number of allotropic variants, like sulphur (TERRY 2000). In human and animal organisms, it ensures a number of metabolic functions. Its deficiency damages the enzyme systems which protect cells from oxidation stress and in humans it strengthens the defence system of the organism (COMBS, GRAY 1998, BROOME 2002, ARTHUR 2003).

Plant products lack Se, particularly in the Central European region. Therefore, efforts are made to increase its content and to cover human demands with biologically valuable products by incorporating selenium into the system of plant nutrition (SMRKOLJ, STIBILJ 2004, GERM et al. 2007, O•BOLT et al. 2008). The recommended daily rate of selenium ranges around 40 μg in women and 50 μg in men (ALEXANDER 2005) or – according to the National Health and Medical Research Council – from 50 to 200 μg per individual/day (PFANNHAUSER 1994). It is administered in the form of inorganic compounds and is more difficult to utilise than biologically bound selenium in plants.

Although there are many reference sources dealing with foliar applications of Se to various plant species, such as potatoes (POGGI et al. 2000, CUDERMAN et al. 2008), rice (FANG et al 2008, LIU and GU 2009), soybean (YANG et al. 2002, MARTINEZ et al. 2009), leguminous plants and grasses (HU et al.

2009, Hambuckers et al. 2008), or various vegetable species (Smrkolj et al. 2005, Slejkovec, Goessler 2005, Kapolna et al. 2009, Rios et al. 2010), relatively little is known about the effect of selenium application on the growth and development of poppy grown as foodstuff.

MATERIAL AND METHODS

In 2008 and 2009, in small-plot field experiments, we monitored the effect of foliar applications of Se(IV) on yields and quality of poppy seeds. In 2008, an experiment was conducted in Morkovice (49˚14»48.53"N, 17˚12»19.61"E), and in 2009 it was set up in Žabčice (49˚0»42.32"N, 16˚36»9.98"E). The experiment was established according to the design given in Table 1. The basic data about the agrochemical soil composition are given in Table 2.

Table 1

Design of the experiment

Variant no.	Treatments of fertilization	Dose of Se (g ha^{-1})	Source of Se (IV)	Time of application
1	control	0	-	-
2	Se1	300	Na_2SeO_3	end of elongation growth
3	Se2*	300	Na_2SeO_3	after flowering

*only in 2009

Table 2

Agrochemical characteristics of the soil

Year	$pH/CaCl_2$	Content of nutrients in mg kg^{-1} DM soil (Mehlich 3)					
		$N_{min.}$	P	K	Ca	Mg	$S_{water\text{-}sol.}$
2008	6.2	15.0	91	254	2672	244	29.0
2009	6.2	5.0	66	179	4477	313	10.6

An Accord seeding machine was used for sowing spring poppy, variety Major, on 15 February 2008 and 24 March 2009. The seeding rate in both years was 1.5 kg ha^{-1}, inter-row spacing 0.2 m. The size of the experimental plot was 15 m^2 (2008) and 10 m^2 (2009) and each treatment was repeated 4 times. Nitrogen was applied in both years at a rate of 60 kg ha^{-1}. Pests and fungi were controlled according to their occurrence in the respective years of the experiment. Poppy was harvested in the stage of full maturity on 5 August 2008 and 10 August 2009. Table 3 shows the average monthly temperatures and sums of precipitation in the experimental years.

The content of selenium was determined in the seeds after wet mineralisation using an atomic absorption spectrophotometer (AAS).

The results were assessed using the programme Statistica 7.1 CZ by applying variance analysis (ANOVA) followed by Fisher's test at a 95% and 99% level of significance ($P<0.05$, $P<0.01$).

RESULTS AND DISCUSSION

Tables 4 and 5 show that poppy seed yields in the experimental years were significantly ($P<0.01$) affected by the weather. While the average yield in 2008 reached 1.781 t of poppy seeds per ha, in 2009 the yield was 40.6% lower (1.059 t ha^{-1}). The cause was dry and warmer than average April and the first half of May in 2009 (Table 3), which inhibited growth of the aerial plant mass and resulted in reduced seed production.

Table 3

Course of weather conditions in 2008 (Morkovice) and in 2009 (Žabčice)

Month	Sum of precipitation (mm)				Temperature (°C)			
	Morkovice		Žabčice		Morkovice		Žabčice	
	2008	LTA	2009	LTA	2008	LTA	2009	LTA
January	11.3	27.0	20	24.8	2.42	-2.2	-3.3	-2.0
February	3.1	25.0	57.6	24.9	3.52	-0.7	0.4	0.2
March	48.4	31.0	78.1	23.9	4.23	3.7	5.0	4.3
April	39.4	42.0	3.6	33.2	9.33	8.7	14.5	9.6
May	68.0	65.0	42.4	62.8	14.37	14.2	15.6	14.6
June	77.9	74.0	114.7	68.6	19.00	16.9	17.3	17.7
July	58.4	78.0	74.0	57.1	19.26	18.8	20.7	19.3
August	44.3	78.0	29.6	54.3	19.74	17.8	21.1	18.6

LTA – long term average

The application of Se in the individual years of the experiment at a rate of 300 g per ha significantly ($P<0.05$) reduced the yields of poppy seed. Table 4 shows the production of poppy seeds in 2008 reduced by 7.1% compared to the control. In 2009, the production of poppy seeds showed a similar trend; the application of selenium during the stage of the end of elongation growth reduced seed yields by 18.3% (Table 5). In literature, the information about the effect of Se on growth and production of oil plants is contradictory. In their experiment, BANUELOS et al. (1997) discovered that yields of rape were lower due to a high supply of Se in the soil (40 mg kg^{-1}

Table 4

Effect of Se application on the poppy yield in 2008

Variant of fertilization	Yield (t ha^{-1}) ± SE	Rel. (%)	*P*<0.05
Control	1.770 ± 0.029	100.0	*a*
Se1	1.645 ± 0.022	92.9	*b*

P<0.05 – statistical significance at a 95% level of significance.
Variants with identical letters express statistically non-significant differences.

Table 5

Effect of Se application on the poppy yield in 2009

Variant of fertilization	Yield (t ha^{-1}) ± SE	Rel. (%)	*P*<0.05
Control	1.165 ± 0.015	100.0	*a*
Se1	0.952 ± 0.049	81.7	*b*
Se2	1.028 ± 0.075	88.2	*ab*

P<0.05 – statistical significance at a 95% level of significance.
Variants with identical letters express statistically non-significant differences.

of soil). Likewise Ruiz et al. (2007) reported inhibited growth of sunflowers after the application of selenium, which appeared as reduced yield of ach enes. In contrast, Torshin et al. (1994) and Dadnia et al. (2008) reported that soil and foliar applications of selenium had a positive effect on seed and achene yields in oil plants. In our experiment, late supplementary fertilisation with selenium during the stage after the fall of blossoms (var. Se2) also reduced yields (by 11.8%). However, the reduction in poppy production was not significant (*P*<0.05).

Based on average yields in the experimental years (Table 6), it was evident that poppy seed yield was reduced by 11.5% due to the application of 300 g Se per ha during the end stage of elongation growth as compared to the treatment where selenium had not been applied, but the reduction was not statistically significant (*P*<0.05).

Table 6

Average effect of Se application on the poppy yield

Variant of fertilization	Yield (t ha^{-1}) ± SE	Rel. (%)	*P*<0.05
Control	1.468 ± 0.115	100.0	*a*
Se1	1.299 ± 0.133	88.5	*a*

P<0.05 – statistical significance at a 95% level of significance.
Variants with identical letters express statistically non-significant differences.

Due to Se application to plants at the end of elongation growth, the content of selenium in poppy seeds increased statistically highly significantly (P<0.01) – Figure 1, i.e. from 139 μg kg^{-1} to 757 μg kg^{-1} of seeds, which means a nearly 5.5-fold growth compared to the treatment not fertilised with selenium. Many references report (Gupta, MacLeod 1999, Grant et al. 2007, Dadnia et al. 2008, Lyons et al. 2009, Dadnia et al. 2009) a multiple growth in the selenium content in seeds of various plants as a result of its soil or foliar application. In our experiment, the uptake of selenium per unit of area increased almost five times due to supplementary fertilisation (Table 7).

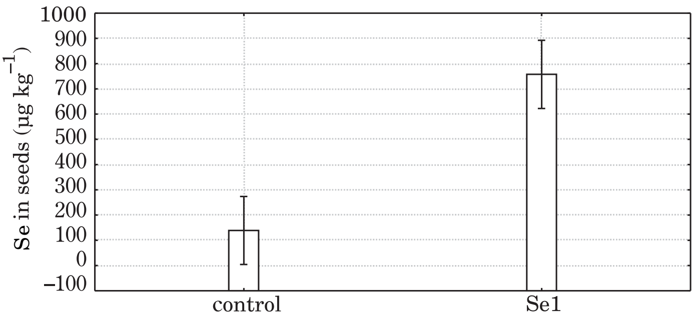

Fig. 1. Average content of Se in poppy seeds (μg kg^{-1}). Error bars present Fisher P<0.05

Table 7

Selenium uptake by poppy seeds (mg ha^{-1})

Variant of fertilization	Se uptake (mg ha^{-1})	Rel. (%)	P<0.05
Control	204.1	100.0	*a*
Se1	983.3	481.9	*b*

P<0.05 – statistical significance at a 95% level of significance.
Variants with identical letters express statistically non-significant differences.

CONCLUSIONS

In respect of the experimental years, the reduction of poppy seed production was more marked in 2009, when the poppy plants were stressed by the dry and warm weather at the beginning of vegetation. Foliar application of Se at the end of elongation growth at a rate of 300 g ha^{-1} reduced poppy seed yields by 11.5% as an average of the experimental years. The reduction in seed yields (by 11.8%) after the application of selenium in the period after the fall of blossoms was not statistically significant. The amount of selenium in seeds and its uptake in poppy yields owing to foliar application increased 5.4 and 4.8 times, respectively.

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