Effect of biodynamic soil additives on uranium uptake by plants

Ewald Schnug
Julius Kühn-Institut

UNIVERSITEIT GENT

Faculty of Bioscience Engineering

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PROCEEDINGS

EFFECT OF BIODYNAMIC SOIL ADDITIVES ON URANIUM UPTAKE BY PLANTS

Susanne Schroetter[1], Maria Thun[2], Ewald Schnug[1]

[1] Institute of Plant Nutrition and Soil Science, FAL Braunschweig-Völkenrode, Bundesallee 50, D 38116 Braunschweig, Germany, susanne.schroetter@fal.de, +049 531 5962112
[2] Experimental Station for Constellation Research in Plant Production, Am Rain 6, D 35216 Biedenkopf-Dexbach, Germany, thun.verlag@t-online.de, +49 6461 6934

Abstract

Uranium (U) is a toxic heavy metal. Recently, new threats for the agricultural soil-plant-system have been reported caused by mineral phosphorus (P) fertilizers originating from rock phosphates, which contain besides the essential nutrient P varying amounts of U. U is accumulated in the A horizons of farmland soils. Soil organic matter, pH value and nutrient supply affected the U content of crops growing on U contaminated soils. Biodynamic soil additives were investigated concerning the diminution of the soil/plant transfer of U. After the application of biodynamic soil additives, a considerable growth-stimulating effect was detected. The dry matter yield of *Lolium perenne* was nearly doubled, the U content of roots and leaves was decreased.

Introduction

The contamination by the toxic heavy metals U may constrict the agricultural use of soils. There are different sources of soil contamination by U and its chemical compounds. The mobility of U is affected by nearly all changes in soil conditions. Besides the level of soil contamination, the rate of U uptake by growing plants depends on the natural soil fertility and the fertilization management. It could be proven that ameliorative P fertilization had the highest decreasing effect on plant availability of U in soil substrates since after the addition of high amounts of P free UO_2^{2+} ions were immediately bond within stable phosphate compounds, and therefore their uptake by plants was prevented (Schroetter et al., 2006). But, the U concentration of commercial P fertilizers ranges between 6 and 149 mg/kg (Schick, 2006). Hence, according to Kratz & Schnug (2006) on average of 10 to 22 g/ha U will be incorporated annually in arable soils by P fertilization. Rogasik et al. (2007) detected increasing U concentrations in the top soil of a long-term field experiment, which after 20 years of annual mineral P fertilization with 36 kg/ha showed an increased U content by 0.7 mg/kg. In this study the effect of biodynamically prepared compost and field spray preparations on the U uptake by roots and shoots of *Lolium perenne* growing in U contaminated soil substrates was investigated. The used preparations consisted of specific minerals or plants treated or fermented with animal organs, water, and/or soil (Steiner, 1974). Raupp (2001) found that after 18 years of differentiated fertilization the use of these

preparations was able to maintain the SOM content and so to enhance the soil fertility. The specific feature of biodynamic preparations runs in their creation. The most important are "Hornmist preparation (500)" and "Hornkiesel preparation (501)". Each will be prepared at it's own ritual and applied in homeopathic doses at specific dates. The cosmic dynamic forces incorporated during the preparation process then benefit the edaphon and the plant development (Thun, 1994).

Material and Methods

Under greenhouse conditions, *Lolium perenne* was cultivated in plastic pots of 380 ml volume. The soil substrate was formerly used in U contamination experiments over 3 years with different plants and was therefore a homogenous and fertile soil mixture. The soil substrate was contaminated at the beginning of the former experiment with the green modification of U_3O_8 (detailed description by Lamas, 2005).

Table 1: Factorial design of the pot experiment 2004, FAL Braunschweig, 4 replications.

Additives and application form (tested in uncontaminated/highly contaminated soil substrate)	
Control	Soil substrate without additives
Fladen A[1)]	Mixture of cowpat compost, guano, basalt sand, stinging-nettle foliage, grinded eggshells, and 36 g/kg liquid "Thun's Fladen preparation"[2)] → thereof 4.4 g/kg were sprayed and than incorporated into the soil substrate before seeding
Fladen B[1)]	Mixture of cowpat compost, guano, basalt sand, stinging-nettle foliage, grinded eggshells, 36 g/kg liquid "Thun's Fladen preparation"[2)], and 80 g/kg liquid "Hornmist (500) preparation"[3)] → thereof 3.6 g/pot were sprayed directly at the soil surface (pre- and post-seeding) → additional, 2 times "Hornkiesel (501) preparation"[3)] was sprayed at the plants: 10 days after germination and between the 2nd and 3rd harvest

1) The original soil substrate was mixed before with 15 vol.-% of matured cowpat compost prepared according to the biodynamic method of Thun (1994).
2) "Thun's Fladen preparation": prepared according to Thun (1994)
3) "Hornmist (500) preparation" and "Hornkiesel (501) preparation" according to Steiner (1974), modified by Thun (1994)

Two soil contamination levels were investigated: uncontaminated, with the natural background U content (about 0.4 mg/kg U), and highly U contaminated (> 700 mg/kg U). Two different biodynamic preparations were tested (Fladen A, Fladen B) and compared with the pure soil substrate without any additives (control) (Table 1). The control pots were fertilized with a commercial liquid fertilizer. The Fladen A and Fladen B treatments were solely fertilized with water extracts of the base material used for preparation of the respective substrate. For the investigation of the plant roots soil samples were taken with a core of 20 cm³ volume after the last cut. Rooting intensity was calculated on the base of the total root length per core volume. The plant material was digested by microwave. The soil samples were digested by Aqua regia for U_t and P_t extraction, and by AAAcEDTA to extract U_{PA} and P_{PA} (according to Lamas et al., 2002). Furthermore, pH value (soil suspension by $CaCl_2$) and organic carbon (C_{org}: by ignition loss determination) were determined. The amounts of U and P containing in the extracts of soil and plant samples were measured by Inductively Coupled Plasma-Quadrupole Mass Spectrometry (ICP-QMS).

Results and Discussion

Both biodynamic preparations stimulated the plant growth (Fig. 1). The grass treated with Fladen A and Fladen B was healthy and showed no growth impairment in spite of stress by the small pot volume, high temperatures during the summer months, and hence extremely variable soil water contents. Independent of the soil U treatment, the grass of the control yielded 4 cuts only, whereas that of Fladen A and Fladen B yielded 5 cuts.

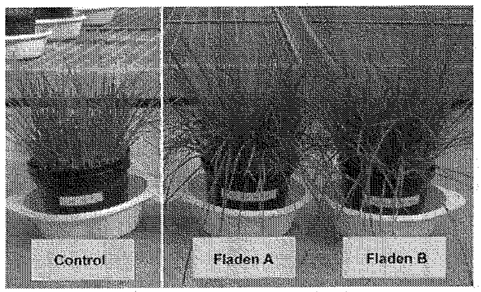

Fig. 1: Influence of biodynamic preparations on the growth of *Lolium perenne* cultivated in highly U contaminated soil substrates (after 134 days, 28 days since the 2nd cut, pot experiment, FAL Braunschweig, 2004).

The total dry matter yield was increased about 70 % (Table 2), attributed to the soil and plant improving effect of the added preparations. "Hornmist (500)" primarily encourages the soil microorganisms, whereby "Hornkiesel (501)" mainly vitalizes the plant (Schlichtmann & Busch, 2000). The visual estimation of the grass roots showed differences in the root morphogenesis. The plants of the contaminated pots developed more fine root hairs, especially at the root tips. The application of biodynamic preparations increased the rooting intensity to a considerable degree. Independently on the U treatment, the root length density of the Fladen A and Fladen B treatment was higher than that of the control (Fig. 2).
In contrast, only the root dry matter yield of the highly U contaminated control was substantially increased. About 30 % more roots were measured (Table 2). High U contents were measured in the grass roots across all treatments in the U contaminated pots.
Comparing the shoots of the conventional fertilized (control) and the biodynamically treated plants of the highly U contaminated soils significantly less U was determined for the grass leaves of the latter. This effect is to be interpreted as a dilution effect, because more biomass was developed due to the better soil conditions of the biodynamically treated pots described in table 3. In model experiments with various crops, Schroetter et al. (2006) found similar effects by sufficient nutrient supply in combination with nearly neutral pH values resulting in higher yields and lower U contents in the aerial plant parts.

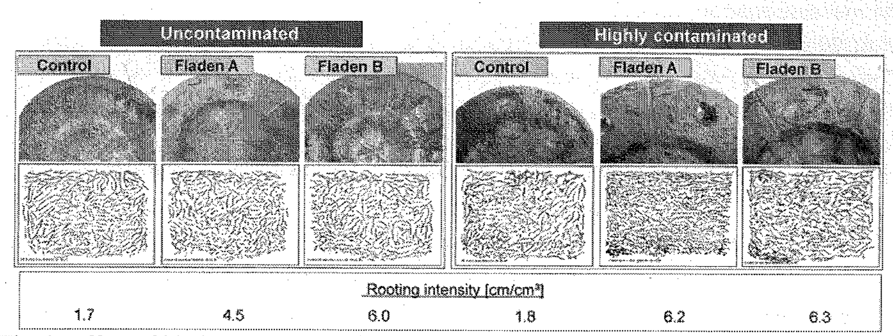

Fig. 2: Effect of biodynamic soil additives on the root formation of *Lolium perenne* growing on uncontaminated and highly U contaminated soil substrates (after 220 days, pot experiment, FAL Braunschweig, 2004).

Table 2: Effect of biodynamic preparations on total dry matter yield of *Lolium perenne*, U content of shoots and roots, and the U uptake by plants (after 220 days, pot experiment, FAL Braunschweig, 2004).

Treatment		Dry matter yield [g] Shoots Per cut	Total	Roots	U content [mg/kg] Shoots	Roots	U uptake [mg/pot] Shoots	Roots	Total
Control	uncontaminated	3.2	12.9	1.3	0.01	7.05	< 0.01	0.01	0.01
	contaminated	3.1	12.3	1.8	1.95	2,136	0.02	3.78	3.80
Fladen A	uncontaminated	4.4	21.8	1.1	0.05	25.37	< 0.01	0.03	0.03
	contaminated	4.5	22.5	1.3	0.49	1,155	0.01	1.53	1.54
Fladen B	uncontaminated	4.2	21.1	1.3	0.02	9.35	< 0.01	0.01	0.01
	contaminated	4.4	21.9	1.2	0.63	1,289	0.01	1.77	1.78

In the present investigation, the calculated total U uptake by the biodynamically treated *Lolium perenne* growing on highly U contaminated substrate was on average 55 % lower compared to that of the grass without preparations (Table 2). The main portion of the absorbed U was determined in the roots; the U uptake by the shoots was marginal. Apparently, an equivalent U transfer into the shoots did not occur. Schick (2006) reported on *Zea mays* growing on U contaminated (by different P fertilizers) sandy substrate and showed that the U content of the roots proportionally raised with increasing U concentration in the substrate, but a correlation between the U load from P fertilization and the detected U content in the maize shoots could not be verified. That confirms that the roots of some plants act as a barrier against toxic and non-essential substances. The adsorbed heavy metal ions remain in the root tissue and are not transported in the aerial plant parts (Schönbuchner, 2002; Duquéne et al., 2006, cited by Schick, 2006).

The soil substrate analysis of the highly contaminated treatments showed that the P content of the control treatment rose over the experimental period because of the periodic mineral P fertilization (Table 3). In the presence of P, the solubility and plant availability of U will be reduced due to the precipitation of slightly soluble uranyl phosphates (Ebbs et al., 1998; Schönbuchner, 2002). This was also confirmed by the results of Schroetter et al. (2006). Furthermore, with increasing P supply U will crystallize out as autunite [$Ca(UO_2)_2PO_4$] in the tips of plant roots or will be located within the cell walls (Cannon, 1957, cited by Schönbuchner, 2002). The translocation of U into other plant organs will also be prevented.

The C_{org} content was increased in the treatments with application of biodynamic preparations: with Fladen A up to 1.2 %, and with Fladen B about 0.8 %, while the C_{org} content of the control was nearly unchanged (Table 3). According to Dushenkov et al. (1997, cited by Schönbuchner, 2002), uranyl ions will bound to carboxyl groups of organic compounds and that way, a lower amount of U will be plant available. Rogasik et al. (2007) compared results of long-term field experiments and confirmed that the U accumulation rates were lower on sandy soils than on soils with higher clay and SOM contents. In this study, the pH values of the contaminated substrates shifted from a neutral to more acid range, whereas the change was more moderate in both of the biodynamically treated substrates (Table 3). In acid soils, the predominant U species is the free, plant available uranyl cation (Ebbs et al., 1998). Hence, the higher U uptake by the grass of the control pots may be due to the changed soil reaction in combination with the lower C_{org} content of this soil substrate (Table 3).

Table 3: Analytical results of the soil substrates of the highly contaminated treatments before and after the pot experiment (FAL Braunschweig, 2004).

Treatment		U_t [mg/kg]	U_{PA}	P_t	P_{PA}	C_{org} [%]	pH
Start of the experiment	Control	734	258	379	74	2.3	5.9
	Fladen A	847	228	460	120	3.2	6.2
	Fladen B	785	219	457	121	3.4	6.2
End of the experiment	Control	740	122	796	223	2.4	4.7
	Fladen A	858	224	430	71	4.4	5.5
	Fladen B	784	202	436	95	4.2	5.7

Regulative effects on the nutrient removal by plants were attributed to biodynamic preparations like "Hornmist" and "Hornkiesel preparations", which can positively affect the metabolism of plants (Matthes et al., 2005; Matthes & Spieß, 2006). In former investigations of Thun (2004, personal communication) on strontium (Sr) contaminated soils, the spraying of "Thun's Fladen preparation" prevented the Sr accumulation in vegetables and cereals. The measurable effect was attributed to an energetically changed, soil improving impact as well

as the enhancement of plant resistance. Summarizing the aforementioned results, the utilization of biodynamic soil additives could contribute to the diminution of the soil/plant transfer of U on contaminated sites.

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SOIL QUALITY UNDER LONG-TERM ORGANIC AND MINERAL FERTILISERS

Simionescu V. [1,2], Bulica I. [1], Cosor F. [1], Tanc M. [1]

[1]Research Station for Irrigated Crops – Valu Traian, 907300, Constanta, Romania, s.violeta@rdslink.ro, [2]„Ovidius" University, Mamaia, 124, 900527, Constanta, Romania, s.violeta@rdslink.ro,

Abstract

The study was done under long-term experiment. The experiment was set-up in the autumn 1970, in randomized design split plots in four replicates on a very uniform area. Among the main treatments are crop rotation, organic fertilizers with cattle manure (control, 20, 40, 60 t ha $^{-1}$, every four years) and mineral fertilizers (annual application of P_0N_0, $P_{50}N_{0-200}$, $P_{100}N_{0-200}$, $P_{150}N_{0-200}$, $P_{200}N_{0-200}$ kg/ha $^{-1}$). Data obtained show that after 30 years of continuous application of organic and mineral fertilizers, significant changes occurred in some chemical and physical soil properties. We found modifications of some agro-chemical parameters of the soil:The pH increases along with the increase of fertilizer dosage, on the varieties fertilized organically, and decreases on the varieties fertilized with mineral fertilizers Soil humus content of increases significantly under organic fertilization and it is altered under the influence of chemical fertilizers with nitrogen and phosphorus. The total nitrogen remains within the normal limits of content for this type of soil regardless of the fertilizer. The mobile phosphorus content increases with the increase of P_2O_5 supply from 12.79 ppm in the unfertilized variety to over 163.60 ppm in the 200 kg P_2O_5 /ha variety. The manure causes an increase of the mobile phosphorus content from 12.79 ppm, as recorded for the unfertilized variety, to 33.73 ppm. The organic nitrogen content rises. The increase of the organic carbon content in the soil by manure application is recognized as an important tool in soil structure forming processes, particularly for soils with native sensitivity to mineralisation. For this type of soil the increase in organic carbon content has a major practical importance especially in the topsoil were the process of organic matter mineralization is accentuated by excessive loosening through tillage applied over the time. Available phosphorus content increases under different doses of manure and mineral fertilizers, in different quantities. Moreover, this nutrient has an important role, stimulating root development with indirect positive consequences on the stability of the soil aggregates. Other chemical measurements show an increasing tendency related to doses applied, all together having a significant importance in improving the soil chemical status.