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STABILIZATION BY SILICON COMPOUNDS OF THE ALLELOPATHIC SOIL REGIME UNDER PERENNIAL FRUIT PLANTATIONS

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To optimize the allelopathic soil regime under perennial fruit plantations of M.M. Gryshko National Botanical Garden of NAS of Ukraine the effect of silicon compounds on phytotoxic and biochemical properties of rhizosphere was examined. The organo-mineral mixture with nanoparticles of the natural siliceous mineral analcite was added (the norm of 500 kg/ha) in dark gray podzolized soil under 30-year-old fruit plantations from orchard areas. Soil samples were taken at a depth of 0–20, 20–40, 40–60 cm. Control for each fruit plant was soil without the silicon compounds. The biochemical state of the soil was evaluated by the redox potential (Eh) values. As a result of the addition of siliceous mixture to the soil its Eh increased in total 1.1–1.4 times, indicating a slowdown in the rate of accumulation of labile organic compounds involved in the phenomena of allelopathic interaction and post-action under the fruit plants. The lowest values of soil Eh were in the most enriched with organic matter upper horizon (0–20 cm) both in control and in the presence of silicon compounds. Phenolic allelochemicals concentration decreased in 1.1–3.1 times compared with the control in the soil with the addition of the mixture. The phenolic compounds content was the highest in the upper horizons and gradually decreased in the direction to the lower, which coincided with the revealed general course of redox processes for the investigated soil profiles. At the siliceous mixture influence, the ammoniac nitrogen amount increased, especially in the soil under the cornel, which may inhibit the synthesis of phenols and prevent phytotoxicity on condition of calcium accumulation. The allelopathic properties of the soil changed due to the improvement its biochemical characteristics by the siliceous mixture action. The growth-stimulatory effect in relation to acceptor plants at 8–55% in comparison with the control was observed. The obtained data showed the efficacy of the silicon compounds use for the reduction of soil sickness in orchards, which is resulted from a decrease in phenolic allelochemicals concentration and phytotoxicity, optimization of redox and nutrient regimes.

Keywords: siliceous mixture; soil sickness; perennial fruit plantations; allelopathic activity; phenolic compounds; redox potential

Introduction

The allelopathic soil regime is formed by the accumulation of plant exometabolites and products their transformation (Матвеев, 1994). It is known that long-term cultivation of single-species fruit plantations can lead to soil sickness. This is especially true for allelopathically active plants that react negatively to their own products of vital functions in rhizosphere soil, in particular for apple, peach and Chinese magnolia vine (Мороз, 1995; Осипова, 2000).

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One of the ways to solve the problem may be the use of silicon compounds, which improve the physical and chemical soil properties, also increase the plants resistance to adverse environmental factors (Guntzer et al., 2012; Заіменко та ін., 2015; Козлов и др., 2015).

The purpose of our work was to study the effect of the siliceous mixture on the phytotoxicity and biochemical processes on the horizons of the soil profile under perennial fruit plantations to optimize the allelopathic regime.

Materials and methodology

The organo-mineral mixture (nanoparticles of the natural siliceous mineral analcite and humus – 1 : 10) was added (the norm of 500 kg/ha) in dark gray podzolized soil under 30-year-old plantations of apple (*Malus domestica* Borkh.), peach (*Prunus persica* (L.) Batsch), cornelian cherry (*Cornus mas* L.) and Chinese magnolia vine (*Schizandra chinensis* (Turcz.) Baill.) from orchard areas of M.M. Gryshko National Botanical Garden of NAS of Ukraine.

During the growing season, the allelopathic and biochemical analysis of the rhizosphere soil was conducted. Soil samples were collected in the following terms: I – for 2 months, II – 5 months after application of the siliceous mixture. Soil samples were taken at a depth of 0–20, 20–40, 40–60 cm. Control for each fruit culture was soil without the silicon compounds.

Allelopathic activity of the soil was studied by direct bioassay method on cress (*Lepidium sativum* L.) root growth (Гродзинский и др., 1990). The redox potential (Eh) and phenolic compounds content in the soil were determined (Гродзинский и др., 1988). Phenols were isolated from soil by ion exchange method (desorption) using ion exchanger KU-2-8 (H^+). The mineral nutrients content was investigated using a modified method (Ринькис и Ноллендорф, 1982).

Experimental data were statistically analyzed using the software package Microsoft Excel.

Results and discussion

The biochemical state of the soil was evaluated by the redox potential (Eh) values. As a result of the addition of siliceous mixture to the soil its Eh increased in total 1.1–1.4 times, indicating a slowdown in the rate of accumulation of labile organic compounds involved in the phenomena of allelopathic interaction and post-action under the fruit plants. The lowest values of soil Eh were in the most enriched with organic matter upper horizon (0–20 cm) both in control and in the presence of silicon compounds. The direction of the redox processes remained unchanged in the soil under *Prunus persica* and *Cornus mas*: moderately and mainly weakly reduced accordingly. Silicon compounds changed the nature of the redox processes under *Schizandra chinensis* and *Malus domestica* from a moderately reduced to weakly reduced. This is more favorable for the course of humification, as well as the nutritional regime, the growth and development of plants (Husson, 2013).

Phenolic compounds determine the degree of humification, but at a certain stage, being in a mobile form, they can act as an allelochemicals and cause soil sickness, replanting problems in orchards (Li et al., 2010; Blum, 2014; Yin et al., 2016). It was found that the concentration of phenolic compounds decreased in 1.1–3.1 times compared with the control in the soil with the addition of the mixture. The same trend was observed when analcite was added to the soil of fruit plants in model experiment conditions (Кудренко та ін., 2011). The phenolic allelochemicals content was the highest in the upper soil horizons and gradually decreased in the direction to the lower, which coincided with the revealed general course of redox processes for the investigated soil profiles.

The anisotropy of the allocation of mineral nutrients in the vertical projection under the fruit cultures was investigated. The calcium concentration under *Cornus mas* was higher at 1.8–3.7 times in the control and in 1.3–5.0 times in the presence of the silicon compounds compared to other plant species. The mixture raised the calcium content under *Schizandra chinensis* in the 2nd term sampling in the horizons 0–20, 20–40 cm. At the siliceous mixture influence, the ammoniac nitrogen amount increased, especially in the soil under the *Cornus mas*, which may inhibit the synthesis of phenolic compounds and prevent phytotoxicity on condition of calcium accumulation.

The allelopathic properties of the soil changed due to the improvement its biochemical characteristics by the siliceous mixture action. The growth-stimulatory effect in relation to acceptor plants at 8–55% in comparison with the control was observed (Figure1).

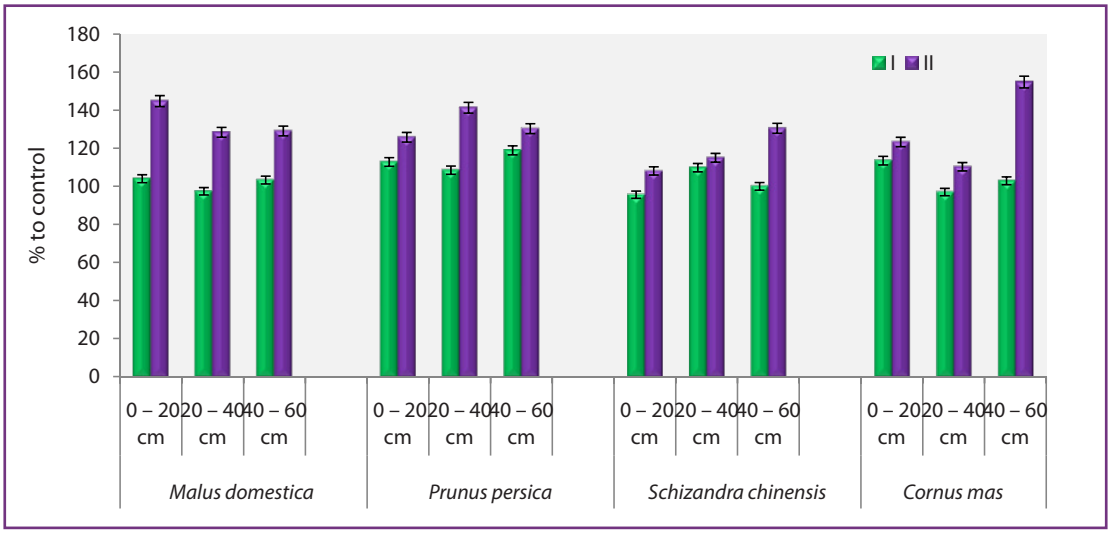

Figure 1 Allelopathic activity on the horizons of the soil profile under perennial fruit plantations, % to control: I – for 2 months; II – 5 months after addition of the siliceous mixture

This was more characteristic for the soil under the *Cornus mas* as an autotolerant culture than for autointolerant *Prunus persica*, *Malus domestica* and *Schizandra chinensis*. Among the last mentioned plant species, the use of the silicon compounds was more effective for optimization the allelopathic soil state under *Malus domestica* and *Prunus persica*.

Conclusions

The obtained data showed the efficacy of the siliceous mixture use for the reduction of soil sickness in orchards, which is resulted from a decrease in the phenolic allelochemicals concentration and phytotoxicity, optimization of redox and nutrient regimes. Further research should be aimed at searching secure, effective compositions based on silicon compounds to improve the allelopathic and biochemical characteristics of depleted soils in monoculture conditions. An alternative ways of improving the allelopathic soil regime in the orchards are multicomponent plantations and implementation schemes of crop rotation in horticulture.

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