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Release of Phenolic Compounds from Apple Residues Decomposing in Soil and the Influence of Temperature on Their Degradation

B. Politycka*, D. Adamska

Department of Plant Physiology, Agricultural University of August Cieszkowski
Wołyńska 35, 60-637 Poznań, Poland

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Abstract

Investigations have been performed on phenolic compounds and allelochemical effect in soil from an apple orchard enriched with 1% apple leaves or roots and stored for 3 months at different temperatures (-5°C, +5°C and 20°C). As a result of the addition of apple residues to the soil its phenolic content increased 4-fold in the case of leaves and 7-fold in the case of roots. Temperature played a key role in the changes of phenolic compounds occurring in the soil. Their level did not decline at all for 3 months at -5°C, whereas at +5°C it decreased by 20% in the soil with the addition of leaves and by 40% in the soil with the addition of roots. A temperature of +20°C had a stronger influence: after 3 months the level of phenolics decreased to that observed in the control and in the soil with the addition of leaves and in this one with roots. The allelochemical effect of the soil with apple residues had mainly a stimulating activity, but it also showed its highly significant negative correlation with the content of phenolic compounds. This suggests that apple residues as a source of phenolics, when occurring locally at high concentrations, may also have an inhibitory effect. A negative allelochemical effect can be maintained by low temperature in winter, which is not conducive to phenolic degradation.

Keywords: apple residues, *Malus domestica* Borb., decomposition, temperature, phenolic compounds.

Introduction

It is a well-known fact in orchard practice that after removal of an old orchard and replanting the same species trees in its place, it often comes to the occurrence of a replant disease. The disease manifests itself in the delayed start of vegetation and poor growth of replanted trees as well as in a delayed bearing [1, 2].

The reasons of replant disease may be various; however, the main ones are reported to be an excess development of pests, especially parasitic nematodes and pathogenic fungi, bacteria and actinomycetes in soil, as well as accumulation of phytotoxic substances [3, 4, 5, 6]. But if participation of nematodes and pathogens as causative agents of replant disease has been well documented in the literature, there are little data concerning phytotoxic substances.

Phenolic compounds constitute one of the most important groups of phytotoxic substances which are responsible for soil sickness as a result of long-term cultivation of the same plant species on the same site [7]. Their source is decomposing plant residues. In our previous work [8]

*Corresponding author, e-mail: barpolit@jay.au.poznan.pl

we found that soil from a young apple orchard with replant disease contained phenolic compounds at a high level. For that reason it was of interest to find out whether phenolic compounds may release from apple leaves and roots and, if so, whether their accumulation in soil may be one of the reasons of replant disease.

The goal of this work was to trace changes of phenolic compounds released from apple leaves and roots at the initial stage of their decomposition in soil under diverse thermal conditions and to evaluate their allelochemical effect.

Material and Methods

An object of these studies was soil (light clay sand) from the experimental orchard, which belongs to the Agricultural University of Poznań. The soil was taken immediately after removal of a 20-year-old apple orchard. Air-dried and crumbled apple residues of the cv. "Cortland" were introduced into the soil (at 70% field water capacity) in the following way: 1) 1% of leaves were added to the soil taken from the arable (0-20 cm) layer, and 2) 1% of roots were added to the soil taken from the pits formed after tree uprooting (30-60 cm). The soil without the addition of apple residues constituted control combinations. The soil samples were stored for 3 months at -5°C, +5°C and +20°C. In that period, the content of phenolic compounds in the soil was determined and the soil allelochemical effects were evaluated in a biological test, the criterion of which was the radical growth of cucumber. Extraction of phenolic compounds was carried out using the method of Biehn et al. [9] modified by Politycka and Wójcik-Wojtkowiak [10]. The content of phenolic compounds was determined colorimetrically according to the Swain and Hillis method [11] with the use of p-coumaric acid as a standard. The methods of bioassay are described in the paper of Pudelski et al. [12]. The inhibition of radical root growth of cucumber was accepted as the criterion of soil phytotoxicity. The bioassay was carried out in 5 replications and determination of phenolic content was performed in 3 replications. The obtained results were subjected to analysis of variance and to regression analysis.

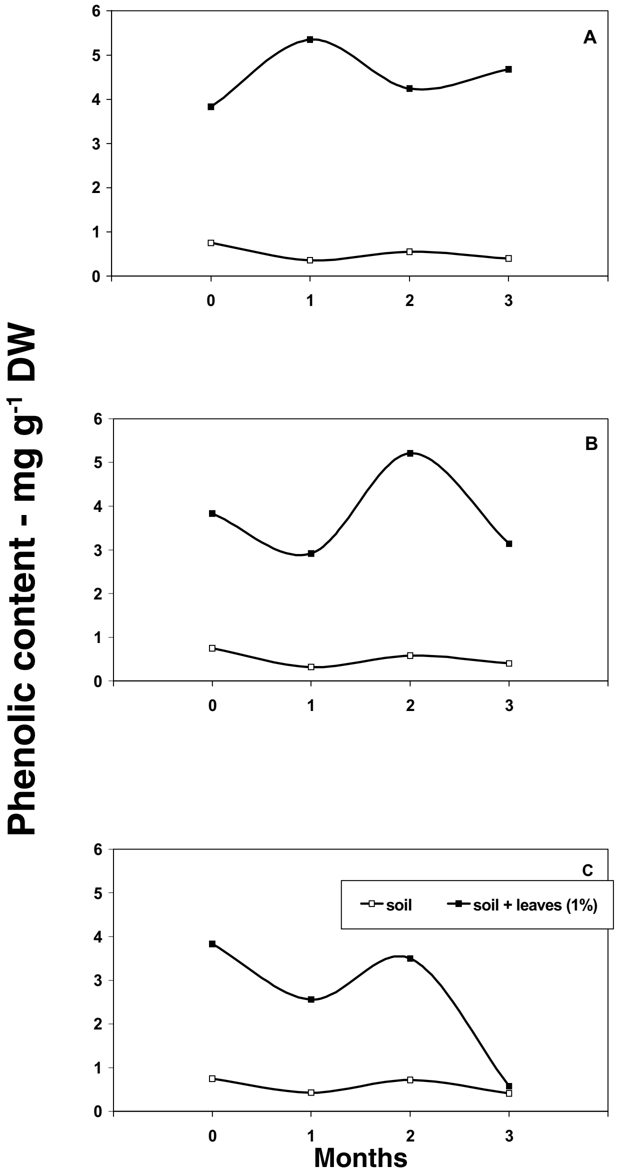

Fig. 1. Changes phenolic contents during decomposition of apple leaves in soil at different temperatures: -5°C (A), 5°C (B) and 20°C (C). Values differ at P≤0.01.

Results and Discussion

In the present studies, the possibility of phenolic compound release from decomposing leaves and roots into the soil was also considered. The soil without apple leaf (Fig.1) and root (Fig. 2) residues had a low content of phenolic compounds, which did not significantly change throughout the entire period of the experiment. The introduction of apple leaves and roots into the soil caused a 4- and 7-fold increase in the phenol level, respectively.

Studies of Fulcher et al. [13] have proved that in plants of the genus *Malus* there occur comparatively large amounts of phenolic compounds, among which primarily phloridzin besides phloretin, naringein, chlorogenic acid and catechin were identified. The content of phloridzin in the apple leaves may reach even 6.75% of their dry mass [14]. This compound and its degradation products after release into the soil show their toxicity to young apple seedlings [15].

A large influence on the rapidity of changes in the content of phenol compounds in the soil was exerted by temperature, at which soil samples with apple residues were stored. At -5°C (Fig. 1A and Fig. 2A), no decrease in the content of phenol compounds was observed for 3 months, but periodically their content increased as compared to that at the initial term in the soil with the addition of both leaves and roots. After 3 months, at +5°C the content of phenolic compounds decreased by 20% in the soil with the addition of leaves (Fig. 1B) and to over 40% (Fig. 2B) in the soil with the addition of roots in comparison to the initial value. A significantly higher fall of phenolic content occurred at

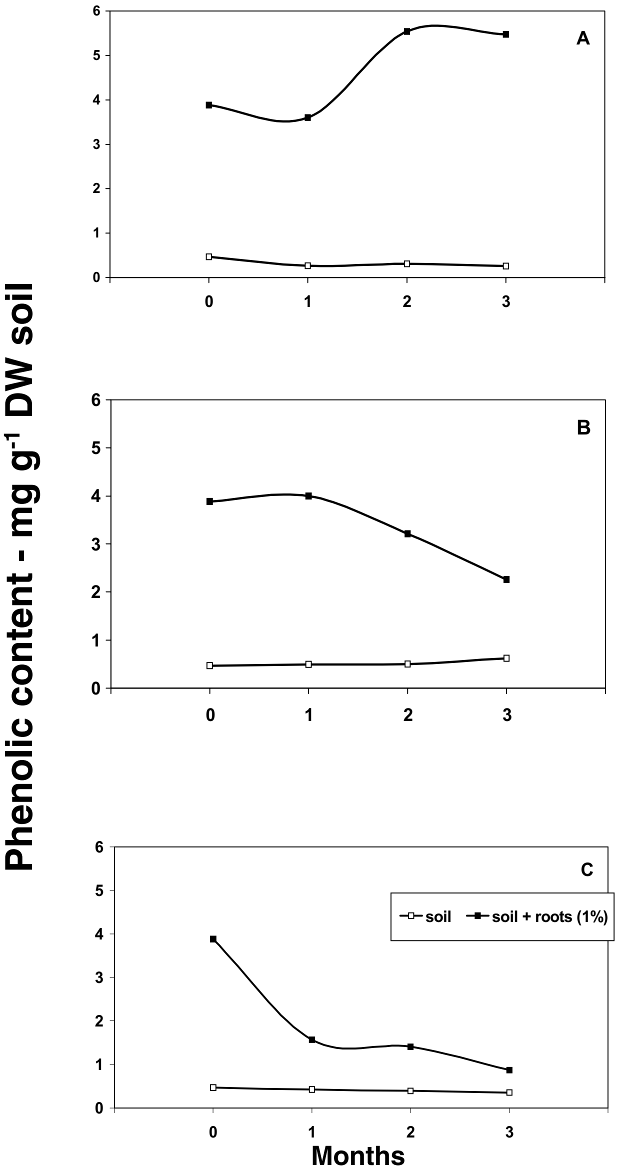

Fig. 2. Changes phenolic contents during decomposition of apple roots in soil at different temperatures: -5°C (A), 5°C (B) and 20°C (C). Values differ at P≤0.01.

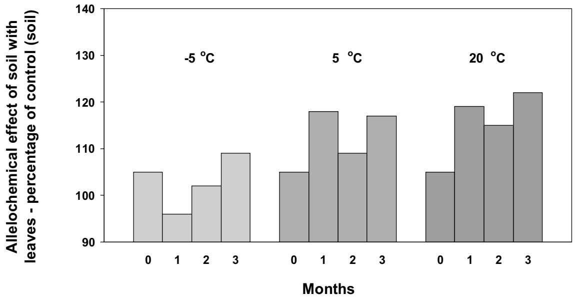

Fig. 3. Allelochemical effects apple leaves during their decomposition in soil. Values differ at P≤0.01.

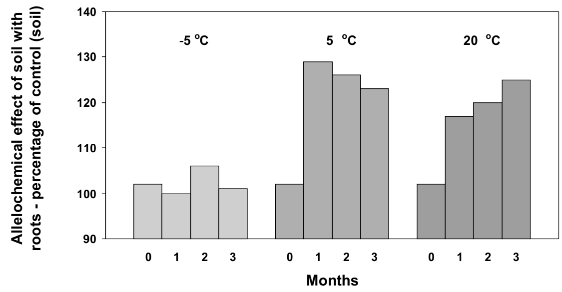

Fig. 4. Allelochemical effects apple roots during their decomposition in soil. Values differ at P≤0.01.

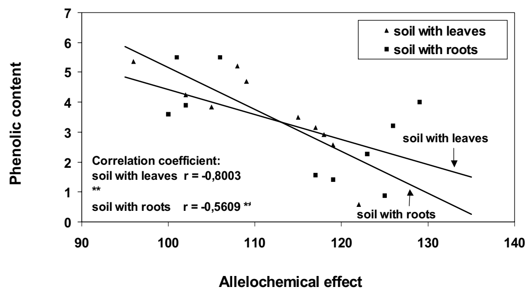

Fig. 5. Correlations between phenolic contents and allelochemical effect of soil with the decomposing apple residues.
**means significant differences at P≤0.01.

20°C, when their level dropped to that of the control after 3 months in the soil with the addition of both leaves (Fig. 1C) and roots (Fig. 2C).

It is commonly observed that the level of phenolics released into the soil from decomposing plant residues decreases after a certain time. Reduction in the content of phenolics is caused by their oxidation, sorbtion by soil minerals and metabolizing by microflora [16, 17].

The allelochemical effect of soil with the addition of leaves (Fig. 3) or roots (Fig. 4), which was evaluated in a bioassay, generally showed a stimulating activity, whereas sporadically it displayed a slight inhibiting one. A characteristic dependence between the effect exerted by allelochemical compounds and their concentration is stimulation of plant growth at their low concentrations and inhibition at high concentrations [18]. The performed regression analysis showed a highly significant negative correlation between the root growth of a tested plant and the content of phenolic compounds in soil (Fig. 5). Therefore, the result of regression analysis suggests that phenolic compounds from apple leaves and roots may cause growth inhibition, if they occur at higher concentrations.

In summary, it should be inferred that phenolic compounds from decomposing apple leaves and roots may occur at higher concentrations, when the accumulation of these residues in soil is larger, and then they can display an inhibitory effect in relation to young apple trees and, therefore, may become a causative agent of replant disease. Under climatic conditions with negative temperatures not conducive to degradation of phenolic compounds in soil in the winter period, the unfavourable allelochemical effect may last for a longer period of time.

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