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Effect of sweet pepper cultivation on the content of phytotoxic phenolic compounds in substrates

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Abstract

The aim of the conducted study was to determine to what extent the cultivation of sweet pepper lowers the phytotoxicity of a substrate. The examined material was a highly phytotoxic substrate due to repeated cucumber growing on it. This substrate was a mixture of pine and beech bark, low peat and sawdust. Five sweet pepper cultivars: Amador, Bell Boy, Culinar, Poznańska Słodka and WSE 2/82 were planted. During vegetation of the sweet pepper phytotoxicity and phenolics levels were determined in the substrate. It was found that cultivation of sweet pepper had a significant effect on lowering phytotoxicity and phenolics content in the substrate. Among the five tested cultivars, the highest detoxicating ability was exhibited by Amador, Culinar and WSE 2/82 while the Poznańska Słodka did not show such abilities.

INTRODUCTION

Decreasing profitability of vegetable production under glass leads not only to a search for new, cheaper components of horticultural substrates but also for ways of making their repeated use possible. Pudelski (1976) worked on this problem and observed that prolonged usage of the same substrates in cucumber growing causes a decrease in their productivity. Later it was found that the main cause of this phenomenon are phytotoxic phenolic compounds accumulating in the substrates (Pudelski et al., 1982; Politycka et al., 1984).

Microbiological investigations revealed that fungal microflora is responsible for producing these substances (Kaczmarek et al., 1984, 1988). It was also found that pepper introduced as an aftercrop following cucumber effectively lowered substrate toxicity (Pudelski and Wójcik-Wojtkowiak, 1984).

The aim of the following research was to check whether there are any intercultivar differences in the detoxicating effects of pepper on the substrates.

MATERIAL AND METHODS

A mixture of two greenhouse substrates A and B in a 1:1 ratio was investigated. The substrate composition was: (by volume) substrate A – low peat (50%), pine bark (25%), sawdust (25%); substrate B – 15-year-old beech bark compost. During 1982-85 these substrates were used in spring-summer growing of cucumber and in autumn growing of tomato (1982-83) or tomato and sweet pepper (1984-85). In the last year of utilization, 25% sawdust and 20% pinebark (by volume) were added to substrates A and B, respectively, to improve their physical properties.

A vegetative experiment with sweet pepper was carried out on a mixture of these substrates. Prior to the actual experiment shortened a (4 week) culture of cucumber Skierniewicki cv. was introduced to raise the substrate phytotoxicity. Immediately after removal of this crop five sweet pepper cultivars: Amador, Bell Boy, Culinar, Poznańska Słodka and WSE 2/82 were planted. The substrate without plants was the control. The experiment was set in random complete blocks. The sweet pepper was grown under glass in polyethylene containers containing 10 dm^3 of the substrate. The moisture content was kept at 80% of field water capacity. The plants were grown without cutting. The leaves were removed systematically to the level from which the fruits were collected.

The phytotoxicity and level of phenolic compounds were determined in the substrate throughout the carry of the experiment.

The inhibition of cucumber root growth in a biological test (Pudelski et al., 1982) was taken as the criterion for phytotoxicity. Extracts for the biotest and for determination of phenolic compounds in the substrate were prepared by shaking 200 g of the substrate with 400 cm^3 of distilled water for 2 h.

Determination of phenolic compounds: the water extracts were extracted three times with equal volumes of ethyl ether. Combined ether fractions were evaporated to dryness and the remains were dissolved in 80% ethanol. The content of phenolic compounds was determined colorimetrically according to the Swain and Hillis (1959) method using chlorogenic acid as the standard.

The substrates were sampled five times: 1 – at the beginning of vegetation of sweet pepper (2 June); 2 – full blooming (25 June); 3 – at the beginning of fruit formation (1 July); 4 – at the peak of fruit production (29 July) and 5 – at crop picking (1 October 1986).

RESULTS

Highly significant changes in phytotoxicity and in the level of phenolic compounds took place during the growth of sweet pepper both in the substrate carrying the crop and in the one without it.

The dynamics of phytotoxicity changes in the substrate is given in Figure 1.

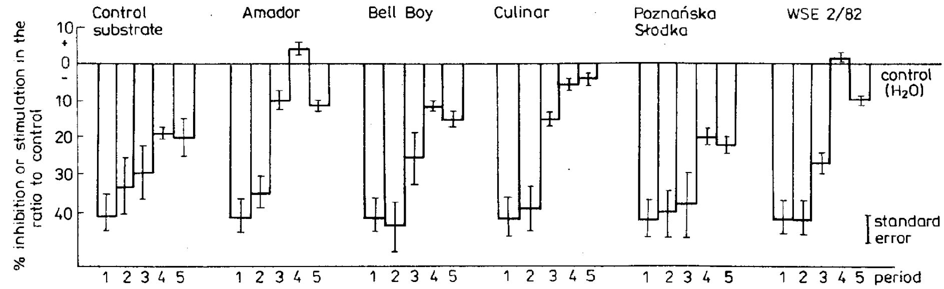

Fig. 1. Dynamics of changes in substrate phytotoxicity. Periods: 1 – beginning of sweet pepper vegetation (2 June); 2 – full blooming (25 June); 3 – beginning of fruit formation (1 July); 4 – peak of fruit production (29 July); 5 – crop removal (1 October)

The substrate had the highest toxicity level at the beginning of sweet pepper growth (41% inhibition). A considerable drop occurred between blooming and start of fruit formation (periods 2 and 3), and was even greater when the plants reached peak fruit formation (period 4). At this stage the substrates under cultivars Amador and WSE 2/82 were toxicity-free and in the case of Culinar and Bell Boy, it fell to 5 and 12%, respectively.

Poznańska Słodka did not show any detoxicating effect, since the toxicity of the substrate under it remained similar to that of the control and amounted to about 20%. After harvesting of the fruits (period 5) an increase in toxicity was noted for most of the substrates.

The effects brought about by growing sweet pepper are presented in Table 1. They are expressed in the form of differences between toxicity of the control

Table 1

The effect of growing five sweet pepper cultivars on lowering substrate phytotoxicity. (Difference between toxicity of the substrate without plants and the substrate under sweet pepper – in per cent of inhibition determined in a biotest)

Period	Cultivar				
	Amador	Bell Boy	Culinar	Poznańska Słodka	WSE 2/82
Blooming	–	–	–	–	–
Beginning of fruit formation	19.55	3.72	14.86	–	2.97
Peak of fruit formation	23.50	7.50	13.42	0.11	20.52
Removal of crop	8.49	4.13	15.55	2.35	9.47
Mean	17.18	5.12	14.61	1.23	10.99

substrate and of the substrates carrying sweet pepper. It is clear that there are distinct differences among these cultivars in respect to the moment the detoxicating effect occurs. In the case of the Amador and Culinar cultivars it already appeared at the initial period of fruit formation, whereas with WSE 2/82 and Bell Boy, its rise occurred only at the time of peak fruit production. The effective lowering of substrate toxicity by each cultivar ranged from 17 to 1%. These differences were highly significant. From the point of view of their effectiveness, the varieties can be ordered in the following decreasing sequence: Amador>Culinar>WSE 2/82>Bell Boy>Poznańska Słodka.

The changes taking place in the phytotoxicity level are reflected in the changes in the content of phenolic compounds (Fig. 2). During the vegetative

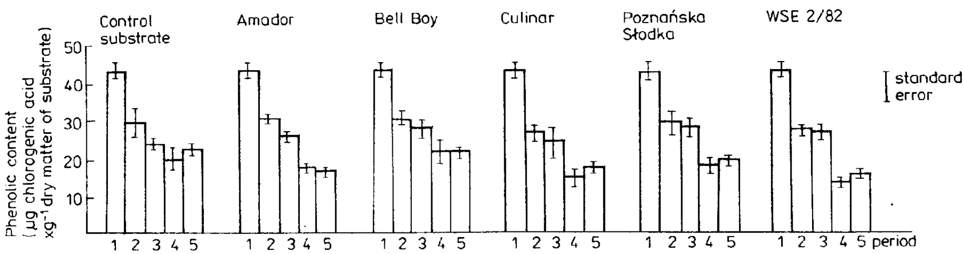

Fig. 2. Changes in the content of phenolic compounds in the substrate. Periods 1-5 as in Figure 1

period the amount of phenols fell both in the pepper-carrying substrates and in the control. Their quantity in all the substrates was the lowest when the sweet pepper was at the peak of fruit production and when the phytotoxicity level of the substrates was also the lowest (period 4). The drop in their amount as compared to the initial content was, at that time, 63% on average. Following the termination of the sweet pepper crop, a tendency towards to a rise in the phenol level appeared in the majority of the substrates.

DISCUSSION

The results of our previous research into the possibility of repeated utilization of substrates for vegetables cultivation under glass proved that introduction of sweet pepper after cucumber led to a significant fall in the substrate phytotoxicity (Pudelski, 1983; Pudelski and Wójcik-Wojtkowiak, 1984). It is also known that the phytotoxicity in soils or substrates disappears with time (Shindo and Kuwatsuka, 1975; Borys et al., 1976; Wójcik-Wojtkowiak, 1980). Our results confirm this literature data since they prove the disappearance of substrate toxicity during the vegetative season (Fig. 1). This was due both to the changes taking place in the substrate itself and the influence of sweet pepper growing. However, the latter effect was stronger. This was seen most clearly in the case of Amador and WSE 2/82 cultivars which, at the peak of fruit production, brought about complete detoxication of the substrates while the fall in toxicity in the control at the same time was only 50% of its initial value.

The gradual decrease in the substrate phytotoxicity was accompanied by the fall in their phenolic compounds content (Fig. 2). This finding supports our earlier statements about phenolic compounds being responsible for the phytotoxicity of the examined substrates (Politycka and Wójcik-Wojtkowiak, 1984).

It is generally known that simple phenolic compounds which are toxic for plants do not occur in high concentrations in their free form in actively metabolizing tissues but are bound as esters or glucosides. Synthesis of these compounds can be carried using both the phenols normally appearing in tissues or on those taken from the external environment (Towers, 1964). Glass and Bohm (1971) proved that glucosilation processes of phenols take place in roots from where the resulting glucosides are moved, by active transport, to above-ground plant parts.

The initial results suggest that the detoxication of the substrate takes place through glucosilation involving the phenols occurring in the substrate causing its toxicity.

After removal of the sweet pepper crop, phytotoxicity returned to the substrates carrying Amador and WSE 2/82 and, in the case of Bell Boy, it increased. These findings may be accounted for by the changes occurring in the sweet pepper root environment. According to Sauerbeck et al. (1975), microbiological degradation of the root system starts at early stages of development reaching its peak at harvest time. Thus it can be supposed that in the substrates, two opposing processes occurred concomitantly: detoxication of phenolic compounds by means of their uptake by sweet pepper and their simultaneous release from decaying root systems. The relation between these processes changes throughout the vegetative season. In its final phase the uptake of phenols by sweet pepper ceased and the process of root degradation intensified.

Among the examined sweet pepper cultivars only Poznańska Słodka did not show the detoxicating effect. This may result from the fact that this is a field cultivar which grows poorly in greenhouse conditions, and, in comparison with other cultivars, showed a very poor growth rate.

To conclusion, it can be stated that sweet pepper, grown on substrates of high phytotoxicity caused by the presence of phenolic compounds, brought about substrate detoxication. Among the examined cultivars this effect was the strongest in Amador and Culinar while it was absent in Poznańska Słodka.

Research aimed at explaining the mechanism of the sweet pepper detoxicating ability is in progress.

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Wpływ uprawy papryki na zawartość fitotoksycznych związków fenolowych w podłożach

Streszczenie

Celem podjętych badań było wyjaśnienie, w jakim stopniu uprawa papryki wpływa na obniżenie fitotoksyczności podłoży.

Obiektem badań było podłoże o wysokim stopniu fitotoksyczności spowodowanej wielokrotną uprawą ogórka. Podłoże stanowiła mieszanina kory sosnowej, kompostu z kory bukowej, torfu

niskiego i trocin, uprawiano na nim 5 odmian papryki: Amador, Bell Boy, Culinar, Poznańska Słodka i WSE 2/82.

Podczas wegetacji papryki w podłożu oznaczono poziom fitotoksyczności oraz zawartość związków fenolowych. Stwierdzono, że uprawa papryki wywarła istotny wpływ na obniżenie fitotoksyczności oraz zawartość związków fenolowych w podłożu.

Spośród pięciu testowanych odmian największą zdolność do detoksykacji podłoża wykazały odmiany Amador, Culinar i WSE 2/82, natomiast odmiana Poznańska Słodka nie przejawiła tych właściwości.