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The Effect of Forecrop on the Emergencies and Healthiness of Soybean

Wpływ przedplonu na wschody i zdrowotność soi

Abstract. The choice of an adequate plant as forecrop or aftercrop can have a significant influence on healthiness and yielding of the main plant. In the presented studies soybean of Polan cv. was the main plant cultivated in the soil with spring wheat, winter wheat and potato as forecrop whereas monoculture of soybean was a control. The influence of particular plants cultivated before soybean was varying. The best emergencies with the best healthiness were noticed in the combination of soybean cultivation with winter wheat as forecrop. In the control combination only 40% of the sown seeds grew into seedlings and they were all characterized by large, visible necrotic spots on the roots and stem base. As a result of laboratory microbiological analysis it was found out that 1 g of dry weight of soil taken from the soil cultivated with winter wheat as a forecrop contained the greatest number of bacteria colonies and the smallest one of fungi colonies. The smallest number of bacteria colonies and the greatest one of fungi colonies were obtained from 1 g of dry weight of soil of soybean cultivated in monoculture.

INTRODUCTION

Field plants have a big influence on the physico-chemical properties and the biological activity of the soil. Particular plant species differ in their chemical composition and physiology. Hence, plants through their root exudates and the substances formed as a result of the decay of their aftercrop residue have a varying effect on soil microorganisms. Root exudates may contain carbohydrates, aminoacids, organic acids, enzymes, ions of elements and other compounds (Rovira, 1969; Funck-Jensen and Hockenhull, 1984). These substances can stimulate or inhibit the growth of both pathogenic and saprophytic microorganisms (Baker and Cook, 1974; Funck-Jensen and Hockenhull, 1984; Parke, 1990; Rovira, 1965; Schoruvitz and Zeigler, 1989; Schroth and Hildebrand, 1964; Schroth and Weinhold, 1986). Like the substances exudated by the roots in the period of vegetation, the aftercrop residue constitutes the subsoil for the growth of soil microorganisms. The chemical composition of root exudates and the organic substance modify the numerosity of the population of pathogenic and saprophytic fungi. The choice of a proper plant cultivated as a forecrop or aftercrop can have a big effect on the healthiness and yielding of the main plant (Gawrońska et al., 1984; Kurowski et al., 1994). The information presented in the paper justifies the studies signalled in the title. The main purpose of the studies was to find out the effect of different plants cultivated as a forecrop on soybean and to determine their influence on the biological activity of the soil.

MATERIAL AND METHODS

The studies concerned soybean of Polan cv. growing in pots after four cultivations, namely winter wheat (Kobra cv.), spring wheat (Sigma cv.), potato (Bronka cv.) and in a combination with repeated cultivation of soybean as control. The studies were conducted in a growth chamber in controlled conditions of temperature, humidity and lighting. The experimental design and the conditions created for the germination of soybean seeds and for the plants' growth are presented in detail in an earlier paper (Pięta et al., 1999).

150 soybean seeds were sown into each pot regardless of the species of the plant which was the forecrop. Eight weeks after the experiment was set, the number of the grown seedlings and their healthiness were determined. The degree of infection for the plants with disease symptoms was found out according to the accepted 5-degree scale earlier used for bean (Pięta, 1992).

Next, the studies determined the number of plants of a given degree of infection for all combinations and repetitions, after which the disease index was found out according to Mc

Kinney's model (Łacicowa, 1969). Ten plants with necrotic symptoms on their roots and stem base were taken from each combination with the aim of carrying out a laboratory mycological analysis according to the method described by Pięta (1988). Besides, soil samples were taken from particular pots for microbiological analysis. The manner of doing this and performing the analysis was according to the method described by Martyniuk et al. (1991). Also, a chemical analysis of the soil was conducted after the cultivation of winter wheat, spring wheat, potato and soybean, and of the soil after the soybean cultivation with those plants as forecrop. The analysis was performed at the Chemical-Agricultural Station in Lublin.

RESULTS

Eight weeks after the soybean seeds were sown, different numbers of plants were observed in particular combinations. The greatest number of soybean seeds (90%) grew in the pots where winter wheat had been cultivated earlier, while the lowest number was observed in the control, i. e. in the cultivation of soybean in monoculture (Tab. 1). Good emergencies were found out in the case of soybean cultivation after spring wheat. Much worse numbers of plants (59%) were characteristic of soybean cultivation after potato. Plants with necrotic spots on the roots and the stem base appeared in all the pots regardless of the species of the forecrop. The proportion of plants with disease symptoms ranged from 8 to 100%. On the other hand, in the control combination, all the plants were infected, and the disease symptoms were the biggest, since the disease index was more than 80 (Tab. 1).

In the case of soybean cultivated after spring wheat, the studies found out more infected plants and with more conspicuous symptoms of necrosis than in soybean cultivated after winter wheat. The proportion of infected plants and the disease index of soybean cultivated after potato were greater than of soybean cultivated after the grain crops. The mycological analysis of the infected seedlings from particular experimental combinations found out

Tab. 1. Number, healthiness and disease index of soybean seedlings

Experimental combination	Number of grown plants (affected)	Disease index
Soybean after winter wheat cultivation	135 (11)	19.0
Soybean after spring wheat cultivation	110 (29)	27.5
Soybean after potato cultivation	89 (33)	32.48
Soybean after soybean cultivation	60 (60)	80.91

different species composition of fungi (Tab. 2). Only the species of *Fusarium oxysporum* was often isolated from the infected tissues of soybean taken from all the experimental combinations, while the fungus of *Fusarium avenaceum* was isolated from the studied plant material of soybean cultivated both after winter wheat and spring wheat (Tab. 2). The species of *Fusarium solani* was particularly often isolated from the plants of soybean cultivated after potato. Besides, the species of *Rhizoctonia solani* was also frequently isolated from those plants (Tab. 2).

Results of the microbiological analysis of the soil after soybean cultivation with winter wheat, spring wheat, potato forecrop and in monoculture pointed at considerable differentiation in the numbers of both bacteria and fungi. The greatest numerosity of bacteria colonies (240×10^6) and the lowest of fungi colonies (309.4×10^3) was observed in 1 g of dry mass of the soil after soybean cultivation with winter wheat forecrop (Tab. 3). A little fewer bacteria colonies (166.82×10^6) were found in the soil taken after soybean cultivation with spring wheat forecrop. In the case of soil after soybean cultivation with potato forecrop, the studies found out a further decrease in the numbers of bacteria colonies with considerable increase of the number of

Tab. 2. Fungi isolated from soybean seedlings

Fungus species	Number of isolates							
	Soybean after spring wheat		Soybean after winter wheat		Soybean after potato		Soybean after soybean	
	r	sb	r	sb	r	sb	r	sb
Aspergillus flavus Link	2	2					13	18
Chrysosporium pannorum (Link) Hughes			1					
Fusarium avenaceum (Corda ex Fr.) Sacc.	3	20	4	20				
Fusarium equiseti (Corda) Sacc.	3							
Fusarium oxysporum Schl.	4	29	9	24	12	69	45	75
Fusarium solani (Mart.) Sacc.			2		2	28		4
Penicillium spinulosum Thom							5	
Phoma exigua Desm.						3		
Rhizoctonia solani Kühn					3	20		
Total	12	51	16	44	17	120	63	97

r — root
sb — stem base

Tab. 3. Number of bacteria and fungi in soil after soybean cultivation with various forecrop

Type of soil	Total number of bacteria (mln per 1 g of d.m. soil)	Number of bacteria *Bacillus* genus (mln per 1 g of d.m. soil)	Number of bacteria *Pseudomonas* genus (mln per 1 g of d.m. soil)	Total number of fungi (thous. per 1 g of d.m. soil)
Soil after soybean cultivation with winter wheat forecrop	240.0	1.13	18.64	309.4
Soil after soybean cultivation with spring wheat forecrop	166.82	0.49	9.05	382.66
Soil after soybean cultivation with potato forecrop	136.36	2.16	5.21	597.73
Soil after soybean cultivation in monoculture	128.47	0.86	3.03	695.14

fungi colonies. The lowest number of bacteria (128.47×10^6) and the greatest number of fungi colonies (695.14×10^3) were observed in 1 g of dry mass of the soil after soybean cultivation in monoculture, that is in control (Tab. 3).

In the group of bacteria, the number of colonies from the genera of *Bacillus* and *Pseudomonas* in 1 g of dry mass of the soil from particular experimental combinations was differentiated and it ranged from 0.49×10^6 to 2.16×10^6 and from 3.03×10^6 to 18.64×10^6, respectively. The greatest numbers of colonies of *Bacillus* spp. were obtained from the soil after soybean cultivation with potato forecrop and it was 2.10×10^6, and with winter wheat forecrop, which was 1.13×10^6. Definitely the most colonies of *Pseudomonas* spp. were isolated from the soil after soybean cultivation with winter wheat forecrop (Tab. 2). The lowest number of *Bacillus* spp. colonies was found in the soil after soybean cultivation with spring wheat forecrop, and the lowest number of *Pseudomonas* spp. colonies was observed after soybean cultivation in monoculture (Tab. 3).

The chemical analysis of the soil showed that the cultivation of soybean after grain crops (winter wheat, spring wheat) and potato had an effect on the increase of the available forms of $P_2 0_5$, $K_2 0$. Soybean cultivation especially increased the quantity of $N\text{-}NO_3$, while having no effect on the change of soil reaction and the level of the available form of Mg or the elements of Fe^{+3} (Tab. 4).

Tab. 4. Chemical analysis of soil

Soil sample	pH in 1 n KCl	Content of available forms in mg/100 g of soil			$N\text{-}NO_3$ in mg/l	Fe^{+3} in mg/kg of soil
		P_2O_5	K_2O	Mg		
		Before soybean sowing				
Soil after spring wheat cultivation	5.0	37.7	48.3	11.5	132	1140
Soil after winter wheat cultivation	5.3	38.2	43.8	14.4	110	1180
Soil after potato cultivation	5.4	34.5	43.7	11.1	117	1285
Soil after soybean cultivation	5.7	55.0	75.8	14.8	318	1195
		After soybean cultivation				
Soil after soybean cultivation with winter wheat forecrop	5.2	55.2	77.0	14.0	379	1190
Soil after soybean cultivation with spring wheat forecrop	5.2	48.0	75.1	14.5	362	1115
Soil after soybean cultivation with potato forecrop	5.3	44.2	72.6	14.9	355	1095
Soil after soybean cultivation in monoculture	5.8	54.6	75.7	14.7	381	1185

DISCUSSION

It was found out on the basis of the studies that winter wheat as a forecrop of soybean had a positive effect on the number of seedlings and their health state. In the case of soybean cultivation after spring wheat, the number of seedlings decreased by 15%, and the number of diseased plants was nearly three times greater as compared to the case when winter wheat was the forecrop. Opinions on the value of spring wheat as a forecrop are differentiated: some researchers define it as positive (Niewiadomski, 1980; Zawiślak et al., 1982), others as negative (Hruszka and Niewiadomski, 1984; Hruszka and Kurowski, 1995; Kurowski et al., 1992).

Potato did not turn out to be a positive plant as a forecrop for soybean, since the emergencies and healthiness of soybean seedlings were unsatisfactory.

The positive effect of cereals on the growth and development of soybean confirmed earlier studies about the cultivation of this plant in crop rotation with cereals (Szyrmer, 1983; Wilcox, 1987; Varvel and Peterson, 1992). Advantages of soybean production in rotation with cereals are seen

in the fact that favourable conditions are created in the soil for the growth of saprophytic fungi by root exudates and aftercrop residue (Funck-Jensen and Hockenhull, 1984; Bujak and Targoński, 1988, 1990; Keel, 1992).

Results of the microbiological analysis showed that particular plant species have various effects on the growth of fungi and bacteria, including *Bacillus* spp. and *Pseudomonas* spp. Favourable conditions for the growth of bacteria are created by cereals, particularly by winter wheat. This is shown in especially high numbers of *Pseudomonas* bacteria in the soil after cereals were cultivated. According to Keel (1992), Lynch and Ebben (1986), and Weller (1988), those bacteria are capable of active colonization of plant roots, owing to which they can effectively compete with pathogens for the nutritional elements available in the root exudates, thus becoming a biological factor in plant protection. A small proportion of *Pseudomonas* spp. in the soil after soybean cultivation with potato forecrop and in monoculture decreases the protective effect of those bacteria, which was confirmed by poor emergencies and a big number of infected plants. The total number of fungi in the soil affected the plants' healthiness. With a repeated cultivation of soybean the studies found out twice as many fungi as in the soil after soybean cultivation with winter wheat forecrop. It should be supposed that in the soil of soybean monoculture a big content of $N\text{-}NO_3$ caused an increase of the number of fungi colonies. Besides, this nitrogen form increases the susceptibility of plants to infection by phytopathogens (Engelhard, 1989). The fact that the content of nitrate nitrogen decreased three times after the cultivation of winter wheat, spring wheat and potato pointed at limitation of the development of fungi, which had a positive effect on the healthiness of soybean. Winter wheat cultivation contributed to active resistance of the soil to pathogenic fungi through numerous appearance of saprophytic microorganisms with antagonistic effect.

CONCLUSIONS

1. The greatest and the best healthiness of soybean was noticed in the combination with winter wheat as a forecrop.

2. Winter wheat stimulated particularly the development of saprophytic organisms in the soil.

3. Emergencies and healthiness of soybean cultivated after spring wheat were worse than the ones with winter wheat as a forecrop.

4. Potato appeared not to be a profitable forecrop of soybean because of poor emergencies and the great number of diseased plants.

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STRESZCZENIE

Dobór właściwej rośliny uprawianej jako przedplon lub poplon może mieć duży wpływ na zdrowotność i plonowanie rośliny głównej. W prezentowanych badaniach rośliną tą była soja odm. 'Polan' wzrastająca w glebie po uprawie pszenicy ozimej, pszenicy jarej, ziemniaka, a kontrolę stanowiła monokultura soi. Wpływ poszczególnych roślin poprzedzających uprawę soi był różny. Najlepszymi wschodami z najlepszą zdrowotnością roślin wyróżniała się kombinacja uprawy soi po pszenicy ozimej. W kombinacji kontrolnej siewki wyrosły tylko z 40% wysianych nasion i wszystkie rośliny wyróżniały się rozległymi, wyraźnymi plamami nekrotycznymi na korzeniach i podstawie łodygi.

W wyniku laboratoryjnej analizy mikrobiologicznej stwierdzono, że w 1 g s.m. gleby spod uprawy soi uprawianej po pszenicy ozimej było najwięcej kolonii bakterii, a najmniej kolonii grzybów. Najmniejszą liczbę bakterii i największą liczbę kolonii grzybów uzyskano z 1 g s.m. gleby spod soi uprawianej w monokulturze.