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THE EFFECT OF FATIGUED SOIL ON THE GROWTH OF STRAWBERRY PLANTS IN RHIZOBOXES

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A B S T R A C T

The objective of the experiments was to evaluate the effect of fatigued soils on the growth of strawberry plants. The experiments were carried out during the growing seasons of 2005 and 2006. Strawberry plants of the cultivar 'Senga Sengana' were planted in 2 spring cycles (April 15 – July 15), and 2 summer cycles (July 16 – October 15). The soil for the plants was taken from 5 localities, which represented experimental combinations: 1 – soil from virgin land (on which only agricultural crop plants had been grown before); 2 – soil taken from an old sour-cherry orchard; 3 – soil from herbicide fallow strips in an old apple orchard; 4 – soil from grass strips in an old apple orchard; 5 – soil from an apple orchard after 3 replantations. The following measurements were carried out: leaf surface area, diameter and weight of crowns, and length and weight of root.

The vegetative growth of the strawberry plants grown in rhizoboxes significantly depended on the origin of the soil used. Cultivation of apple-trees for many years in the same locality significantly worsened strawberry plant growth, expressed by decrease of leaf area, crown weight and diameter and root weight. The nutrients content in the vegetative parts of the strawberry plants analysed depended on the time of cultivation and the soil origin. The level of nutrients was significantly higher in the summer-cultivated plants than in those cultivated in the spring, and in those soils in which the growth of the strawberry plants was stronger. The strawberry plants were found to respond strongly to soil fatigue and thus appear to be a good plant species for testing orchards for soil fatigue.

Key words: strawberry, rhizoboxes, growth, soil, replantation disease

INTRODUCTION

Successful growing of orchard plants cultivated for many years in the same place depends to a high degree on the locality. Important are not only the type of the soil and the level of ground waters but also the types of crops grown previously. This is particularly important in the case of the recently introduced shortened production periods for fruit trees and berry shrubs, which frequently lead to frequent replantations. Replantation (growing the same species in the same place in succession) and the associated soil fatigue create problems for producers everywhere in the world (Hoestra, 1994; Aldea, 1998).

In spite of many experiments being done and continually improved research techniques, the causes of soil fatigue have not been determined conclusively. However, the consequences of it are very well known: poor plant growth, decreased yielding, reduction of leaf area, and sometimes dying of the whole plants (Constante et al., 1991; Sobiczewski, 2000).

Replant disease affects many fruit plants species. Peach, apple, sour cherry, strawberry and red raspberry are regarded as the most sensitive (Rebandel, 1987). The disease can be caused by biotic and abiotic factors (Utkhede and Smith, 1994; Szczygieł, 1997; Sobiczewski, 2000; Pacholak, 2003). The occurrence of one or more contributing factors in the plantation without crop rotation may lead to soil deterioration, primarily its physico-chemical properties. Therefore, the time when soil fatigue occurs depends on the intensity and interaction of various factors responsible for this phenomenon.

The objective of the experiments carried out in the years 2005-2006 was to evaluate the effect of soils from different locations on the growth of strawberry plants cultivated in rhizoboxes as test plants for quick detection of soil fatigue.

MATERIAL AND METHODS

The experiments were carried out at the Department of Pomiculture, the University of Life Sciences in Poznań during 2005-2006, in four cultivation cycles: 2 spring cycles (April 15 – July 15), and 2 summer cycles (July 16 – October 15). The plant material were 'Senga Sengana' strawberry plants grown in rhizoboxes measuring 37 x 18 x 7 cm and filled in with 5.7 kg of soil.

The soil was taken from 5 different locations, which represented the experimental combinations:

1 – soil from a virgin land (on which only agricultural crop plants had been grown previously),
2 – soil taken from the old sour-cherry orchard,
3 – soil from a herbicide fallow strip in a tree row of the old apple orchard,
4 – soil from grassed strips in the interrows of the old apple orchard,
5 – soil from the apple orchard after 3 replantations.

The soils were put into rhizoboxes and four strawberry plants were planted in four replications for each

Table 1. Chemical composition of the soil samples from different localities

Soil origin	pH in KCL	Mineral nutrients content [mg 100 g^{-1}]			K/Mg ratio
		P	K	Mg	
1. Virgin soil	6.8 b*	8.9 e	15.6 b	16.9 b	0.9
2. Soil from old sour-cherry orchard	5.8 a	5.4 d	11.4 b	10.9 b	1.0
3. Soil from herbicide fallow strips in old apple orchard	5.3 a	3.6 b	13.4 b	3.6 a	3.8
4. Soil from grass strips of old apple orchard	5.7 a	2.7 a	15.8 b	4.0 a	3.9
5. Soil from apple orchard after 3 replantations	5.8 a	4.2 c	5.8 a	10.5 b	0.6

*Mean values marked with the same letters do not differ significantly at the probability level of p = 0.05

soil. The plants were grown for a period of three months, with loosening the soil and watering when necessary.

In order to permit the roots to grow in the direction of the transparent wall of the rhizobox, the rhizoboxes with plants were positioned in such a way that the transparent wall was tilted at an angle of 50-60° relative to the ground. The boxes were covered with thick black foil to block the light.

Prior to planting, the P, K and Mg contents and pH in the soils investigated was analysed (Tab. 1). The highest pH (6.7) had the virgin soil, while the lowest pH value was recorded for the soil originating from herbicide fallow in tree rows of the old apple orchard. The levels of a mineral nutrients were compared with the threshold values for soils with 1.43% humus content and 23% silt and clay fractions. The phosphorus content ranged from medium values in the soil from herbicide fallow and from the grass strips to high values in the remaining combinations. A low potassium content was found in the soil taken from the orchard after 3 replantations, a medium level was in the soil from an old sour cherry orchard, and high K values in the remaining combinations. Also the magnesium content ranged from low values in the soil from the herbicide fallow in the old apple orchard to high values for the remaining locations. The K/Mg ratio was high in the soils from herbicide fallow and grass strips of the old apple orchard, while in the remaining localities this ratio was at the recommended level.

At the end of the experiment the following measurements were carried out on each plant: total leaf area (all the leaves from each plant), diameter and weight of the crown and root length and weight.

After the measurements, all vegetative parts of the strawberry plants were dried and ground and the content of macro elements (N, P, K, Mg and Ca) was determined, separately for each cultivation cycle, according to the procedure given by Ostrowska et al. (1991). The obtainned results were statistically elaborated significance of differences between means was evaluated with Duncan's t test at p = 0.05.

RESULTS AND DISCUSSION

Changes in the dimensions, primarily in height, but also in volume and weight, are regarded as important indices of plant growth (Listowski, 1970).

The experiments, carried out in the years 2005-2006 during four strawberry cultivation cycles, were intended to determine the influence of soil locality on the growth of strawberry plants in rhizoboxes. The results have shown that the origin of the soil, and particularly the method of preceding soil utilization, had a significant effect on plant growth measured by the total leaf area (Tab. 2). Regardless of the cultivation cycle, on the average, the smallest total leaf area was found in strawberry plants grown in the soil from the apple orchard after 3 replantations. Among the remaining combinations, no statistically significant differences were found. However, one could notice some tendencies towards an increase in the total leaf surface area in the case of strawberry plants grown in the soil originating from the grassed inter-rows of the old apple orchard. This confirms the hypothesis that the soil fatigue is caused by cultivating apple trees for many years in monoculture (Szczygieł, 1991; Hoestra, 1994; Pacholak, 1997; Pacholak and Zydlik, 2006; Zydlik and Pacholak, 2007).

The experiments showed also a significant difference in total leaf area between the cultivation cycles. A considerably greater leaf area had strawberry plants grown in the spring cycles as compared to the summer cycles.

The results obtained in our experiments show that strawberry plants grown in the soil from a 30-years-old apple orchard were characterized by the poorest growth and development among all the combinations used. Studies have indicated that strawberry is a plant species that responds well to environmental conditions.

The functioning of the root system, which supplies the plant with water and mineral components, depends on the soil. The experiments presented have confirmed the significant effect of the soil origin on the growth of the root system expressed by its weight which, like the total leaf area, varied considerably. A greater root weight was found in the strawberry plants grown in the spring cycle. Analyzing the effect of soil origin one must state that strawberry plants grown in the soil originating from grass strips of an

Table 2. Effect of the soil origin on the growth of the vegetative parts of the strawberry plant (means values for two seasons)

Cultivation Cycle	Soil origin	Total leaf area [cm^2]	Crown diameter [mm]	Crown weight [g]	Root length [cm]	Root weight [g]
Spring	1. Virgin soil	736.9 b	15.7 a	6.9 c	44.1 b*	23.0 b
	2. Soil from old sour-cherry orchard	891.6 b	16.3 a	7.7 c	42.4 b	27.6 bc
	3. Soil from herbicide fallow strips in old apple orchard	854.1 b	16.7 a	7.1 c	35.7 a	22.5 b
	4. Soil from grass strips in old apple orchard	917.8 b	15.4 a	5.8 b	34.5 a	25.1 bc
	5. Soil from apple orchard after 3 replantations	516.3 a	16.0 a	4.3 a	34.9 a	13.0 a
Mean		783.3 b	16.02 b	6.36 b	38.32 a	22.24 b
Summer	1. Virgin soil	415.5 b	13.7 b	4.9 a	44.7 a	5.0 a
	2. Soil from old sour-cherry orchard	341.1 a	10.8 a	5.0 a	37.6 a	6.4 a
	3. Soil from herbicide fallow strips in old apple orchard	333.2 a	14.4 b	6.2 b	43.0 b	7.5 a
	4. Soil from grass strips in old apple orchard	475.0 b	12.1 b	6.2 b	58.7 b	14.5 b
	5. Soil from apple orchard after 3 replantations	342.8 a	14.2 b	6.1 b	48.8 b	7.9 a
Mean		381.5 a	13.04 a	5.68 a	46.56 b	8.26 a

*Explanations, see Table 1

Table 3. Effect of soil origin on the mineral component content in the above-ground parts of strawberry plant

Combination		Mineral component content [% D.W.]				
		N	P	K	Mg	Ca
Leaves	1. Virgin soil	1.62 b*	0.29 c	1.91 b	0.34 c	1.50 c
	2. Soil from old sour cherry orchard	1.55 a	0.23 a	1.88 b	0.36 d	1.51 c
	3. Soil from herbicide fallow strips in old apple orchard	1.78 c	0.25 b	2.10 d	0.29 a	1.16 a
	4. Soil from grass strips of old apple orchard	1.80 c	0.26 b	2.05 c	0.32 b	1.37 b
	5. Soil from apple orchard after 3 replantations	1.89 d	0.23 a	1.50 a	0.48 e	1.35 b
Mean		1.73	0.25	1.89	0.36	1.38
Leaf stalks	1. Virgin soil	0.60 b	0.22 d	2.56 d	0.36 b	1.63 c
	2. Soil from old sour cherry orchard	0.46 a	0.16 b	2.43 b	0.33 a	1.38 a
	3. Soil from herbicide fallow strips in old apple orchard	0.67 c	0.16 b	2.64 e	0.33 a	1.52 b
	4. Soil from grass strips of old apple orchard	0.68 c	0.18 c	2.47 c	0.35 b	1.67 d
	5. Soil from apple orchard after 3 replantations	0.69 c	0.15 a	1.92 a	0.48 c	1.37 a
Mean		0.62	0.17	2.04	0.37	1.51

*Explanations, see Table 1

old apple orchard had the highest root weight (19.8 g), while the smallest root weight had the plants planted in the soil collected from an apple orchard after 3 replantations, where the mean root weight was 10.5 g. In the rema-ining soils, no statistically significant differences were found (Tab. 2).

The occurrence of soil fatigue, as well as its type and intensity, can be determined before replantation with the help of biological tests (Szczygieł, 1991). The use of the strawberry plant as a test plant has proven to be the best solution because it responds perfectly to the degree of soil fatigue by the intensity of its growth and development. The root is a plant organ which develops first, but at the same time, it is also the first organ which becomes affected by the replantation disease (Rebandel et al., 1997). A smaller increase in root weight was obvious in plants grown in the soil affected by soil fatigue. By far the best growth and development of strawberry plants was observed by us in the soil which had not been utilized for orchard before.

Determination of nutrients level in strawberry plants was carried out separately for each organ, i.e. the leaf blades, leaf petioles, crowns and roots. It was found that the levels of macro-elements (N, P, K, Mg and Ca) depended on the time of cultivation (Tab. 3), the location from which the soil had been taken for cultivation, and on the vegetative part which was analysed (Tab. 3-5). With a few exceptions, the levels of all the minerals analysed in all the plant organs were significantly higher for the summer cultivation cycle than for the spring cycle (Tab. 3-5). As revealed by the statistical analysis, the effect of the soil origin was significant, but it depended on the analysed element (Tab. 3-5). The greatest amounts of nitrogen and phosphorus were contained in leaf blades, while leaf petioles contained the greatest amounts of potassium, magnesium and calcium. The chemical analyses of strawberry plant parts also showed differences in the levels of various mineral components when one compare the spring and the summer cultivation cycles. The obtained results confirm the results of studies by Pacholak (1997) that the concentration of a particular mineral component in the leaves depends on weather conditions. This was demonstrated by the higher levels of mineral components in the plants planted in the summer.

CONCLUSIONS

1. The vegetative growth of strawberry plants grown in rhizoboxes significantly depends on soil origin. Cultivation of apple trees for many years in the same locality significantly decreases the growth of strawberry plants in the soil from that locality, as expressed by the total leaf area, crown diameter and weight as well as root weight.
2. The time of cultivation exerted a significant effect on the growth of strawberry plants. The effect was stronger in the spring season than in the summer season, but the responsiveness to the soil origin was preserved.
3. The levels of nutrients in the analysed vegetative parts depended on the time of cultivation and the soil origin. In the summer cultivation, with a poorer plant growth, the nutrient content was significantly higher than in the spring cultivation, and in the soil in which the growth of strawberry plants was stronger.
4. The strawberry plants respond strongly to soil fatigue and can be used for testing soil fatigue in fruit orchards.

Table 4. Effect of soil origin on the level of mineral components in the underground parts of strawberry plant

Combination		Mineral component content [% D.W.]				
		N	P	K	Mg	Ca
Roots	1. Virgin soil	0.87 b*	0.24 e	1.00 c	0.37 d	0.86 a
	2. Soil from old sour-cherry orchard	0.83.a	0.18 c	0.93 b	0.31 b	0.96 c
	3. Soil from herbicide fallow strips in old apple orchard	1.04 c	0.17 b	1.07 d	0.29 a	0.86 a
	4. Soil from grass strips of old apple orchard	1.19 e	0.19 d	1.14 e	0.30 a	0.91 b
	5. Soil from apple orchard after 3 replantations	1.16 d	0.16 a	0.82 a	0.33 c	0.97 a
Mean		1.02	0.19	0.99	0.32	0.89
Crown	1. Virgin soil	0.92 b	0.19 d	1.00 bc	0.27 b	1.60 d
	2. Soil from old sour-cherry orchard	0.62 a	0.14 a	0.93 ab	0.25 a	1.47 c
	3. Soil from herbicide fallow strips in old apple orchard	0.93 b	0.17 c	1.10 c	0.46 d	1.28 b
	4. Soil from grass strips of old apple orchard	0.95 c	0.17 c	1.05 c	0.28 b	1.62 d
	5. Soil from apple orchard after 3 replantations	1.05 d	0.15 b	0.88 a	0.30 c	1.24 a
Mean		0.89	0.16	0.99	0.31	1.44

*Explanations, see Table 1

Table 5. Effect of the time of cultivation on the level of mineral components in the above-the-ground parts of strawberry plants

Cycle	Mineral component content [% D.W.]																			
	leaf blades					leaf stalks					crown					roots				
	N	P	K	Mg	Ca	N	P	K	Mg	Ca	N	P	K	Mg	Ca	N	P	K	Mg	Ca
Spring 2005	1.3 a*	0.22 a	1.68 a	0.23 a	1.57 d	0.41 a	0.15 b	2.09 a	0.27 a	1.56 b	0.58 a	0.13 b	0.91 b	0.22 a	1.54 b	0.84 a	0.20 c	0.76 a	0.23 a	0.83 b
Summer 2005	1.92 d	0.26 b	1.83 b	0.34 b	1.20 a	0.84 d	0.16 c	2.33 b	0.38 c	1.63 c	1.71 d	0.25 d	1.23 d	0.39 d	1.75 c	1.22 d	0.19 b	1.09 d	0.44 d	0.80 a
Spring 2006	1.80 b	0.21 a	2.03 c	0.39 c	1.49 c	0.55 b	0.13 a	2.41 c	0.34 b	1.31 a	0.78 c	0.12 a	1.11 c	0.28 b	1.75 c	1.04 c	0.15 a	1.04 b	0.29 b	1.01 d
Summer 2006	1.86 c	0.32 c	2.01 c	0.40 d	1.26 b	0.67 c	0.25 d	2.78 d	0.49 d	1.55 b	0.70 b	0.18 c	0.74 a	0.33 c	0.72 a	0.97 b	0.22 d	1.07 c	0.35 c	0.92 c

*Explanations, see Table 1

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WPŁYW STANOWISKA GLEBOWEGO I TERMINU UPRAWY NA WZROST I ZAWARTOŚĆ SKŁADNIKÓW MINERALNYCH TRUSKAWKI UPRAWIANEJ W RIZOBOKSACH

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STRESZCZENIE

Badania przeprowadzono w latach 2005-2006 w Katerze Sadownictwa Uniwersytetu Przyrodniczego w Poznaniu w hali wegetatywnej w czterech cyklach uprawowych: 2 wiosenne (od 15 kwietnia do 15 lipca) oraz 2-letnie (od 16 lipca do 15 października). Materiałem do badań były truskawki odmiany 'Senga Sengana' uprawiane w skrzyniach korzeniowych. Glebę pobierano z pięciu stanowisk, które stanowiły kombinacje: stanowisko 1 – gleba z nowiny (wcześniej uprawiano tylko rośliny rolnicze), stanowisko 2 – gleba pobrana ze starego sadu wiśniowego, stanowisko 3 – gleba pobrana z pasów ugoru herbicydowego starego sadu jabłoniowego, stanowisko 4 – gleba pobrana z pasów murawy starego sadu jabłoniowego, stanowisko 5 – gleba pobrana z sadu jabłoniowego po 3 replantacji. Po likwidacji doświadczenia na każdej roślinie wykonano następujące pomiary: powierzchni blaszek liściowych wyrażonej w cm^2 (wszystkie liście z każdej rośliny), średnicy skróconego pędu (mm), masy skróconego pędu (g), długości korzeni (cm) i masy korzeni (g).

Badania wykazały, że wzrost wegetatywny truskawek uprawianych w skrzyniach korzeniowych był istotnie zależny od stanowiska glebowego. Wieloletnia uprawa jabłoni na tym samym stanowisku istotnie obniżała wzrost truskawek wyrażony sumaryczną powierzchnią liści, średnicą i masą skróconego pędu oraz masą korzeni. Zawartość składników pokarmowych w analizowanych częściach wegetatywnych była zależna od terminu uprawy i stanowiska glebowego, na którym uprawiano truskawki. W uprawie letniej przy słabszym wzroście roślin zawartość składników była istotnie wyższa niż w uprawie wiosennej. Wykazano również, że truskawka silnie reaguje na zmęczenie gleby i może być dobrą rośliną testującą występowania w sadzie tego zjawiska.

Słowa kluczowe: truskawka, rizoboksy, wzrost, replantacja