

SUSCEPTIBILITY OF STRAWBERRY CULTIVARS TO *Colletotrichum acutatum* J.H. SIMMONDS

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Abstract. The investigations were carried out for three years with 8 strawberry cultivars grown in plastic tunnel. The plants were inoculated with the mixture of *Colletotrichum acutatum* isolates obtained from diseased plants of strawberry. All tested cultivars were susceptible to *C. acutatum* but in the different degree. The results showed that cv. 'Camarosa' was the most susceptible because of the highest disease index and the lowest yield of healthy fruit, while cv. 'Senga Sengana' was the most resistant. The results are important both for the producers and the breeders.

Key words: anthracnose, *Fragaria ananassa*, resistance

INTRODUCTION

Anthracnose of strawberry (*Fragaria ananassa* Duch.) is caused by the fungi of genus *Colletotrichum*: *C. acutatum*, *C. gloeosporioides* and *C. fragariae*. All of them cause similar disease symptoms. In Poland, the most important causal agent of strawberry anthracnose is *C. acutatum*. Recent reports indicate that this species is the most important regarding strawberry anthracnose also in many other countries, such as Spain, Italy, USA, Israel [Freeman et al. 2001, 2002, Curry et al. 2002, Horowitz et al. 2004, Parikka et al. 2006, Meszka and Bielenin 2010]. The pathogen is very dangerous to plants grown both in fruiting fields and in nurseries as it infects all strawberry organs at all development stages. The symptoms occur on leaves, petioles, flowers, fruits, stolons and crowns. Very often the infections are symptomless, what means that the fungus grows latently in plant tissues [Freeman et al. 2001]. The harmfulness of disease is serious when the favorable conditions for the development of fungus occur during the florescence and before and during harvest [Turechek and Heidendrich 2001]. The inves-

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tigations on the susceptibility of strawberry cultivars to fruit and crown rot carried out in the USA showed that the cultivars 'Festival', 'Camarosa' and 'Gaviota' were very susceptible, while 'Earlibrite', 'Sweet Charlie', 'Carmine' and 'Carmino Real' were more resistant. It appeared that the resistance to crown rot caused by *C. acutatum* was not always correlated to the resistance to fruit rot [MacKenzie and Peres 2007].

In Poland this disease is not well-known. The cultivars 'Camarosa', 'Elsanta', 'Albion', 'Aromas' and 'Tudla' are regarded as susceptible to anthracnose. There are no detailed data on which strawberry cultivars are resistant or less susceptible to that disease. The aim of the study was to evaluate the susceptibility of some widely grown in Poland strawberry cultivars to anthracnose caused by *Colletotrichum acutatum*.

MATERIAL AND METHODS

The material for the study contained the stock plants of eight strawberry cultivars: 'Honeoye', 'Camarosa', 'Elsanta', 'Darselect', 'Florence', 'Senga Sengana' and 'Alfa Centauri'. The cultivars were selected on the basis of their popularity among producers. The plants were planted in the plastic tunnel (40 stock plants per inoculation combination and 40 stock plants per the control for each cultivar) in October 2011. In May 2012, 2013 and 2014 the plants were inoculated with the mixture of *C. acutatum* spores (5×10^6 spores/ml) according to the method described by Freeman et al. [2001]. The monoconidial *C. acutatum* cultures used in this study were selected randomly from 400 colonies isolated from strawberry plants in previous years. The isolates were identified according to the procedures described by Sutton [1980].

The evaluation of disease severity was conducted after the appearance of disease symptoms and the presence of acervuli. The mycological analysis of plants was also taken into consideration.

For the evaluation of disease intensity the 5-degree scale was used:

- 0 – no disease symptoms,
- 1 – small necrosis on fruits and petioles,
- 2 – single necrotic spots on leaves, petioles, flowers and fruits,
- 3 – necrotic spots covering half the surface of leaves, flowers, stolons, fruits and the appearance of mycelium and spores,
- 4 – more than 50% of organs covered by necrosis, yellowing, wilting and decaying of plants.

The data were processed by McKinney's formula [Kopacki and Wagner 2004] which gives a percentage index of the disease severity: $DI = (\sum vn) / (NV) \times 100$, where 'v' represents the numeric value of degree, 'n' is the number of the plants assigned to the degree, 'N' is the total number of the plants in the replication and 'V' is the numeric value of the highest degree.

The yield of strawberry was assessed during the first and second decades of June. The ripening fruits were harvested every few days. For every cultivar the healthy, diseased and deformed fruits were weighted separately.

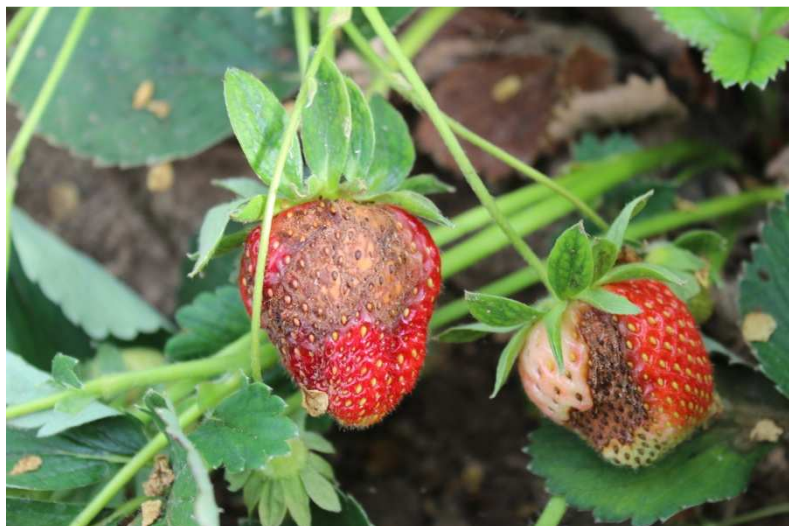
The results were evaluated statistically with the analysis of variance (ANOVA) and the differences between means were estimated by Tukeys test ($p < 0.05$) using Statistica 12.0.

RESULTS

Based on disease index, mycological analysis and obtained yield, the tested cultivars were classified into four groups of susceptibility: relatively resistant, of low susceptibility, moderately susceptible and highly susceptible. As the result of inoculation with the mixture of *C. acutatum* isolates it was stated, that all cultivars were more or less susceptible but in different degree.



Phot. 1. Anthracnose symptoms on flowers and green fruits (photo B. Hetman)



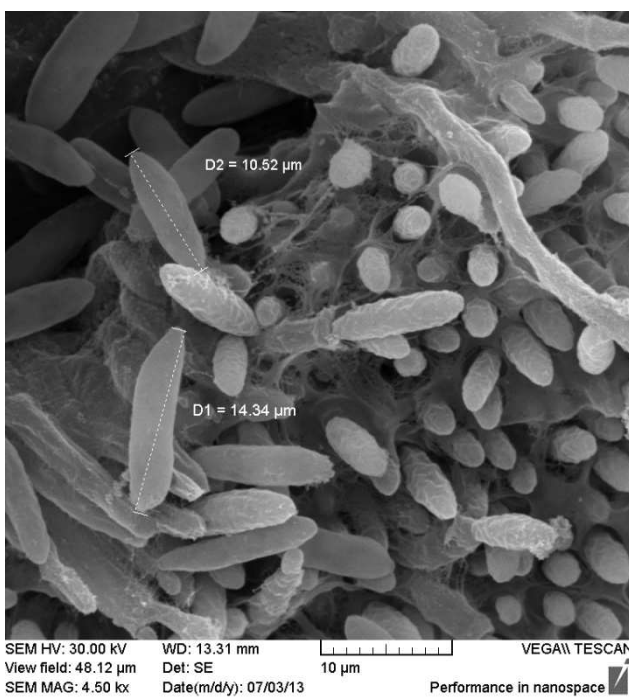
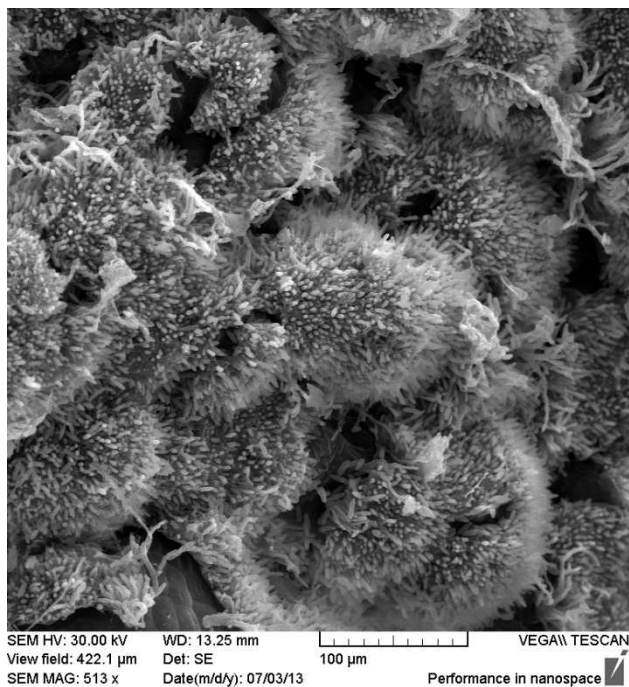
Phot. 2. Anthracnose symptoms on ripe fruits – brown lesions with pink spore masses (photo B. Hetman)

The disease and etiological symptoms (necrosis and pink-coloured spores) were observed on flowers, leaves, stolons, green and ripe fruits of all inoculated with *C. acutatum* cultivars (phot. 1–4). The intensity of disease expressed as disease index ranged from 8.0% to 62.0% during the years of investigations (tab. 1). The lowest values of disease index were noticed in the first year of investigations and they increased gradually in next years. The disease index for cv. 'Senga Sengana' was the lowest and amounted respectively to 8.0, 9.5 and 11.5% during the years of the study. The highest values of disease index were noticed for cv. 'Camarosa' and amounted to 33.0, 45.0 and 62.0% respectively in 2012, 2013 and 2014. The mean values of disease index for cvs. 'Honeoye' and 'Darselect' were lower by a half than that for cv. 'Camarosa' and amounted to 23.16 and 24.33%, respectively. The cvs. 'Elsanta', 'Florence', 'Selva' and 'Alfa Centauri' were more susceptible, the mean values of disease index were 30.5, 29.16, 32.0 and 33.83%, respectively. In control combinations the values of disease index were low and ranged from 1.5% for 'Senga Sengana' in 2012 to 7.0% for cv. 'Camarosa' in 2014 (tab. 2).



Phot. 3. Anthracnose symptoms on petioles (photo B. Hetman)

The isolation of fungi from inoculated plants confirmed the presence of *C. acutatum* in plant tissues. The highest number of *C. acutatum* colonies was isolated from the plants of cv. 'Camarosa' and the lowest one from 'Senga Sengana'. Other potentially pathogenic fungi: *Botrytis cinerea*, *Cylindrocarpon destructans* and *Fusarium oxysporum* might be the secondary colonizers (fig. 1).



Phot. 4. Acervuli and spores of *Colletotrichum acutatum* (photo M. Wróbel)

Table 1. Disease index (%) for the plants inoculated with *C. acutatum*

Cultivar	2012	2013	2014	Mean
Honeoye	15.50 d * B*	21.50 d* B*	32.50 c* A*	23.16 c*
Camarosa	33.00 a C	45.00 a B	62.00 a A	46.66 a
Elsanta	20.50 bc C	28.50 b B	42.50 b A	30.50 b
Darselect	18.50 cd B	20.00 d B	34.50 c A	24.33 bc
Florence	19.50 cd C	27.00 bc B	41.00 b A	29.16 bc
Senga Sengana	8.00 e A	9.50 e A	11.50 d A	9.66 d
Selva	22.50 bc C	30.00 b B	43.50 b A	32.00 b
Alfa Centauri	24.00 b C	32.50 b B	45.00 b A	33.83 b
Mean	20.18 B	26.75 B	39.06 A	–

* – values designated with the same letters (a, b, c...) do not significantly differ in columns $p \leq 0.05$ (test Tukeya)

* – values designated with the same letters (A, B, C) do not significantly differ in row $p \leq 0.05$ (test Tukeya)

Table 2. Disease index (%) for the control plants

Cultivar	2012	2013	2014	Mean
Honeoye	2.50 a* A*	3.00 ab* A*	3.50 b* A*	3.00 bc*
Camarosa	2.50 a C	5.00 a B	7.00 a A	4.83 a
Elsanta	3.00 a B	5.00 a A	5.50 ab A	4.50 ab
Darselect	2.00 a B	3.50 ab A	4.50 b A	3.33 abc
Florence	2.00 a A	2.50 b A	3.00 bc A	2.50 c
Senga Sengana	1.50 a B	2.00 b AB	3.50 b A	2.33 c
Selva	2.50 a B	4.00 ab A	5.00 ab A	3.83 abc
Alfa Centauri	3.00 a B	4.00 ab AB	4.50 b A	3.83 abc
Mean	2.37 B	3.62 AB	4.56 A	–

For explanations, see Table 1

The yield from inoculated with the pathogen cultivars was evaluated in 2012–2014. There were the differences between the cultivars and the years of investigations. Total yield of fruits for all tested cultivars in 2012 was much lower than in next years due to the first year of cultivation. The yield of healthy fruits from the plants inoculated with *C. acutatum* was much lower than the yield from the control plants (tabs 3, 4). The highest yield of healthy fruits from the inoculated plants was noticed for cvs. ‘Darselect’ and ‘Senga Sengana’ and the lowest one for cvs. ‘Camarosa’, ‘Selva’ and ‘Alfa Centauri’ (tab. 3).

Table 3. Fruit yield (kg/m²) from the combinations with *C. acutatum* inoculation

Cultivar	Healthy				Diseased				Deformed				Total			
	2012	2013	2014	mean 2012– 2014	2012	2013	2014	mean 2012– 2014	2012	2013	2014	mean 2012– 2014	2012	2013	2014	mean 2012– 2014
Honeoye	0.600cd	3.062b	2.850c	2.170c	0.450bc	0.775c	1.437d	0.887d	0.050a	0.550a	0.200b	0.266a	1.100d	4.387a	4.487b	3.324b
Camarosa	0.550d	1.012g	0.612h	0.724g	0.275d	0.562e	0.700h	0.512g	0.025a	0.200d	0.150c	0.125de	0.850e	1.775g	1.462g	1.362f
Elsanta	0.850b	2.187c	2.325d	1.787d	0.650a	0.875b	1.925b	1.150a	0.100b	0.425b	0.150c	0.225b	1.600bc	3.487c	4.400bc	3.162c
Darselect	1.025a	3.112a	3.025b	2.387a	0.625a	0.925a	2.150a	1.233b	0.125b	0.225c	0.200b	0.183c	1.775ab	4.262b	5.375a	3.804a
Florence	1.125a	1.930d	1.850e	1.635e	0.625a	0.887b	1.550c	1.020c	0.125c	0.150e	0.250a	0.175c	1.875a	2.967d	3.650d	2.830d
Senga Sengana	1.125a	1.912e	3.575a	2.204b	0.225d	0.737d	0.775g	0.579f	0.050d	0.100f	0.200b	0.116e	1.400c	2.750e	4.550b	2.900d
Selva	0.625cd	1.375f	0.775f	0.925f	0.375c	0.162g	1.262e	0.599f	0.100d	0.050g	0.250a	0.133d	1.100d	1.587h	2.287e	1.658e
Alfa Centauri	0.725bc	1.362f	0.712g	0.933f	0.475b	0.517f	0.887f	0.626e	0.075e	0.200d	0.125d	0.133d	1.275cd	2.080f	1.724f	1.693e

* – values designated with the same letters (a,b,c..) do not significantly differ in columns $p \leq 0.05$ (test Tukeya)

Table 4. Fruit yield (kg/m²) from the control combinations

Cultivar	Healthy				Diseased				Deformed				Total			
	2012	2013	2014	mean 2012– 2014	2012	2013	2014	mean 2012– 2014	2012	2013	2014	mean 2012– 2014	2012	2013	2014	mean 2012– 2014
Honeoye	1.125d	4.200a	4.400b	3.241b	0.025e	0.150a	0.125d	0.100d	0.050c	0.175a	0.125b	0.116a	1.200e	4.525a	4.650b	3.458b
Camarosa	1.050d	2.250e	2.000d	1.766e	0.025e	0.070c	0.050e	0.048e	0.037c	0.100c	0.075c	0.070d	1.112f	2.420e	2.125d	1.885f
Elsanta	1.475b	3.500b	4.375b	3.116c	0.225a	0.050d	0.200c	0.158b	0.050c	0.125b	0.125b	0.100b	1.750b	3.675b	4.700b	3.375c
Darselect	1.700a	4.225a	4.875a	3.600a	0.100d	0.120b	0.375a	0.198a	0.100a	0.125b	0.125b	0.116a	1.900a	4.470a	5.375a	3.915a
Florence	1.550ab	3.125c	3.375c	2.683d	0.200b	–	0.225b	0.141bc	0.050c	–	0.200a	0.083c	1.800b	3.125c	3.800c	2.908e
Senga Sengana	1.300c	2.800d	4.200b	2.766d	0.125c	0.050d	0.375a	0.183a	0.075b	0.050d	0.125b	0.083c	1.500c	2.900d	4.700b	3.033d
Selva	1.025d	1.700f	1.800d	1.508g	0.125c	0.020e	0.225b	0.123cd	0.100a	–	0.075c	0.058e	1.250e	1.720g	2.100d	1.690h
Alfa Centauri	1.125d	2.250e	1.550e	1.641f	0.125c	0.050d	0.200c	0.125c	0.100a	–	0.050d	0.050f	1.350d	2.300f	1.800e	1.816g

For explantions, see Table 3

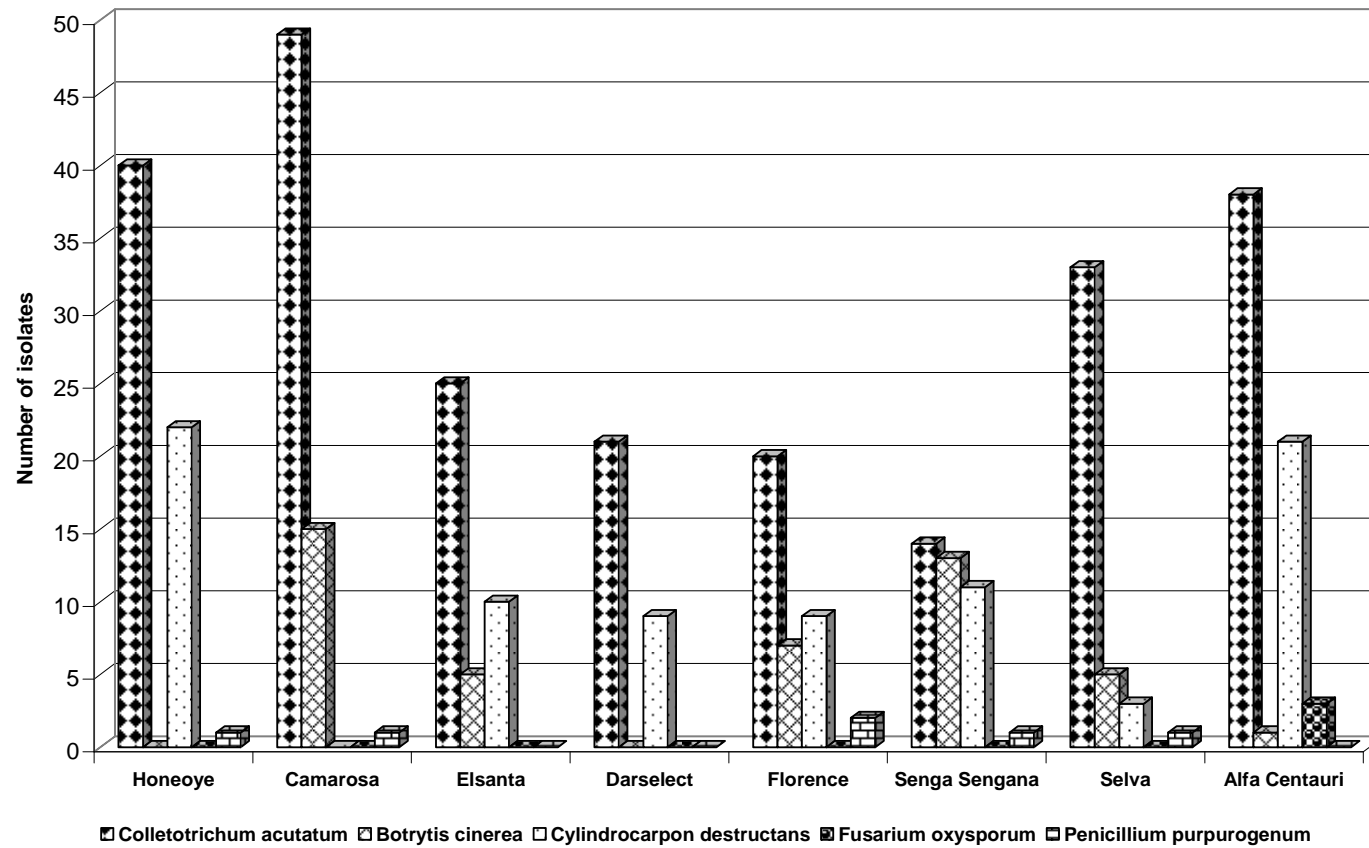


Fig. 1. Fungi isolated from strawberry plants inoculated with *Colletotrichum acutatum*

DISCUSSION

The observations of disease symptoms on strawberry plants, such as dark brown lesions and irregular spots on petioles, confirmed the reports of other authors. On petioles and stolons appeared dark brown lesions and on leaves irregular spots. Also on green fruits brown, hard lesions were observed. Ripe fruits showed sunken lesions with pink-coloured spores. Such symptoms were observed also by Smith [2008] during her research in southeastern USA. The investigations showed that primary infections by *C. acutatum* happened more often due to infected strawberry transplants than due to diseased fruits or other hosts. Smith [2002] also stated that the living mulches such as wheat, rye, rye grass grown between rows and organic mulches (wheat straw, pine needles) reduced the disease spread comparing to plastic mulch. Also Freeman et al. [2001] regards mother strawberry plants as the primary inoculum source, on which the pathogen proliferates and then spreads to daughter plants in the nursery and eventually to production fields through the transplants. Apart from that there are additional sources of infection, such as other plants susceptible to the pathogen, among them some weeds.

Our experiments with an artificial inoculation with the mixture of *C. acutatum* isolates showed different pathogenicity to the tested cultivars. In our research cv. 'Camarosa' was the most susceptible what was proved by the highest disease index and the highest yield of fruits with anthracnose symptoms. According to Chandler et al. [2006] this cultivar was also susceptible, showing the lower number of leaves, smaller fruits and the reduced plant height. In their study the yield of 'Camarosa' infected with the pathogen was reduced by 22.41%. In our experiments one of the cultivars of moderate susceptibility was 'Elsanta'. Denoyes-Rothan et al. [1999] stated that this cultivar and cv. 'Honeoye' were susceptible. In our study cv. 'Honeoye' showed rather low susceptibility. Embamy and Abd-Ellatif [2013] proved that both 'Tamar' and 'Yael' cultivars were susceptible to anthracnose. In many countries the studies revealed some resistant cultivars. Among them are 'Sequoia' [Denoyes-Rothan et al. 1999], 'Chandler' and 'Pelican' [Hammerschlag et al. 2006, Smith 2008, Smith et al. 1998].

Using of resistant to *C. acutatum* cultivars is more favorable than chemical control of the disease. The fungicides have a negative effect on the environment and human health and also many isolates of pathogen have been found resistant to some chemicals [Hammerschlag et al. 2006]. *In vitro* screening can be used to evaluate strawberry germplasms for the resistance to *C. acutatum* [Smith 2008]. The testing of cultivars and genotypes for the resistance to this pathogen is very important not only for the producers but also for breeding programs.

CONCLUSIONS

1. All tested cultivars showed different susceptibility to *Colletotrichum acutatum*.
2. All of them showed the disease symptoms but the significant differences in the disease index and the yield of healthy fruit were observed.
3. The most susceptible cultivar proved to be 'Camarosa'.
4. Cv. 'Senga Sengana' was the most resistant to the anthracnose.

5. The cultivars 'Honeoye' and 'Darselect' seemed to be more susceptible to the pathogen than 'Senga Sengana' but less than other cultivars.

6. The germplasms of the least susceptible cultivars might be used in breeding programs for strawberry cultivars resistant to anthracnose.

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**PODATNOŚĆ ODMIAN TRUSKAWKI NA *Colletotrichum acutatum*
J.H. SIMMONDS**

Streszczenie. Badaniami prowadzonymi przez trzy lata objęto osiem odmian truskawki uprawianych w tunelu foliowym. Rośliny inokulowano mieszaniną izolatów *Colletotrichum acutatum* uzyskanych z chorych roślin truskawki. Wszystkie testowane odmiany okazały się podatne na porażenie, ale w różnym stopniu. Najbardziej podatną odmianą okazała się ‘Camarosa’ (najwyższy indeks porażenia i najniższy plon owoców). Odmiana ‘Senga Sengana’ była najbardziej odporna.

Słowa kluczowe: antraknoza, *Fragaria ananassa*, odporność

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