Differential Production of the Phytotoxins Thaxtomin A and Concanamycins A and B by Potato Common Scab-causing *Streptomyces* spp.

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**Key words:*** *Streptomyces scabies*, *Streptomyces acidiscabies*, common scab, phytotoxin, thaxtomin, concanamycin.

The causal organism of potato scab first described as *Oospora scabies* by Thaxter in 1892 was renamed *Streptomyces scabies* in 1948, but this name was not authorized because the original strain had not been preserved. Revival of the name *S. scabies* was proposed by Lambert and Loria7) in 1989, *S. scabies* being characterized by smooth grey spores borne in spiral chains. At that time, they proposed another pathogenic species, *S. acidiscabies*, which has flexuous spore chains and can grow at pH 4.0\(^9\).

Several *Streptomyces* species cause potato scab. Tashiro et al.16) examined various species isolated from lesions on potato tubers and sugar beet roots that cause common scab on potato. Based on spore chain morphology (spiral (SI) or rectiflexible (RF) spore chain) and DNA homology, the pathogens were divided into four distinct groups: SI type from potato, RF type from potato, SI type from sugar beet, and RF type from sugar beet. Strains with the same spore chain morphology but from different hosts showed low DNA homology values.

Tanii14) classified the strains that induce potato scab in Hokkaido into four groups based on a combination of spore chain morphology (SI or RF) and pigment productivity (+ or -). Tanaka13) examined the serological properties and DNA homologies of the strains in these four groups and concluded that all the SI type strains were classifiable as *S. scabies*. He identified the SI type strains lacking melanin productivity as *S. scabies* subsp. *achromogenes*, according to Elesawy and Szabo\(^9\). Because the serological properties of RF type strains without pigment production differed from those of *S. acidiscabies*, he proposed a new species, *S. turgidiscabies*. The RF type strains with pigment productivity were not identified because of the limited number of strains collected.

Symptoms of potato scab are classified into four groups; common, deep, tumulus, and superficial (russet) scab\(^17\). The cause of the variety of these disease symptoms, however, is a matter of controversy.

The phytotoxins produced by *S. scabies* were isolated by King et al.5) and named thaxtomins A and B. We confirmed that a Japanese strain isolated from a potato scab, deposited as *S. scabies* IFO 13768, also produces thaxtomin A\(^11\). We also identified other phytotoxins; concanamycins A and B\(^11\).

Phytotoxin production was examined in five strains (S-851, S-131, S-51, S-12 and S-15) that have distinct DNA homologies\(^16\) and in two type strains (*S. scabies* JCM 7914 (=ATCC 49173\(^7\)) and *S. acidiscabies* JCM 7913 (= ATCC 49003\(^8\))). Each strain was cultured, and the resulting material treated as reported previously\(^11\), yielding a 10% MeOH-CHCl\(_3\) fraction from a silica gel column. This fraction was used in the HPLC analysis (Develosil ODS-5, 30% aq. CH\(_3\)CN, UV 220 nm) to examine thaxtomin production. For concanamycin analysis, it was further purified in a silica gel column using an EtOAc-n-hexane solvent system. The concanamycins A and B eluted in the 90% EtOAc-n-hexane fraction were verified by HPLC (Develosil ODS-5, 70% aq. CH\(_3\)CN, UV 245 nm).

Phytotoxin production findings are shown in Table 1. All the strains isolated from potato, with one exception (S-131), produced thaxtomin A, and the RF type strains tended to produce more thaxtomin A than the SI type strains. King et al.\(^6\) reported a positive correlation between the pathogenicity of *S. scabies* isolates and their ability to produce thaxtomin. Our findings that most of the strains tested produced thaxtomin A support this correlation.

Concanamycins A and B were produced only by SI type strains S-851 and S-131 isolated from potato. *S. scabies* strains S-51, S-12, S-15, and S-851 produced thaxtomin A and concanamycins A and B. The RF type strains S-851 and S-131 isolated from potato produced thaxtomin A and concanamycins A and B.

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Table 1. Production of thaxtomin A and concanamycins A and B in relation to the taxonomy of pathogenic *Streptomyces*

<table>
<thead>
<tr>
<th>Strain</th>
<th>Source</th>
<th>Spore chain morphology</th>
<th>Geographic origin</th>
<th>Production of phytotoxin (μg/ml medium)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Thaxtomin A</td>
</tr>
<tr>
<td>S-851</td>
<td>Potato</td>
<td>Spiral</td>
<td>Saga, Japan</td>
<td>0.39</td>
</tr>
<tr>
<td>S-131</td>
<td>do.</td>
<td>do.</td>
<td>do.</td>
<td>nd</td>
</tr>
<tr>
<td><em>S. scabies</em> JCM 7914</td>
<td>do.</td>
<td>do.</td>
<td>USA</td>
<td>2.50</td>
</tr>
<tr>
<td>(= ATCC 49173)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-51</td>
<td>do.</td>
<td>Rectiflexible</td>
<td>Saga, Japan</td>
<td>5.24</td>
</tr>
<tr>
<td><em>S. acidiscabies</em> JCM 7913 (= ATCC 49003)</td>
<td>do.</td>
<td>do.</td>
<td>USA</td>
<td>5.31</td>
</tr>
<tr>
<td>S-12</td>
<td>Sugar beet</td>
<td>Spiral</td>
<td>Hokkaido, Japan</td>
<td>0.24</td>
</tr>
<tr>
<td>S-15</td>
<td>do.</td>
<td>Rectiflexible</td>
<td>do.</td>
<td>1.45</td>
</tr>
</tbody>
</table>

a) The DNA homology between S-851 and S-131 was 86%, whereas the homologies of the other two-strain combinations of S-851, S-131, S-51, S-12 and S-15 were less than 40% (see Ref. 15).
b) nd: not detected (less than 0.03 μg/ml for thaxtomin A, less than 0.002 μg/ml for concanamycins A and B).

*S. scabies* JCM 7914 also produced both thaxtomin A and concanamycins A and B. RF type strains S-51 and *S. acidiscabies* JCM 7913 did not produce any concanamycin. The morphological and physiological properties of S-851 or S-131 and those of JCM 7914 and of S-51 and JCM 7913 were similar. If S-851 and S-131 are identified as *S. scabies* and S-51 as *S. acidiscabies*, then the pattern of toxin production coincides with the taxonomy. The DNA homologies between these strains are interesting.

Because S-131 showed pathogenicity in the inoculation test at isolation, the lack of thaxtomin production by this strain suggests two possibilities: S-131 lost this ability due to prolonged preservation and/or repeated subculture, or concanamycin itself also induces common scab symptoms.

Tashiro speculated that different potato scab symptoms are caused by different organisms: SI type strains induce common scab and RF type strains superficial or tumulus scab. In contrast, Loria *et al.* argued that the type of symptom depends on the thaxtomin A concentration in the lesion. Our findings that SI type strains produce both thaxtomin and concanamycins and that RF type strains produce only thaxtomin support the Tashiro's speculation.

To clarify whether concanamycins participate in the induction of scab symptoms, efforts are being made to mass-produce concanamycins A and B and to determine whether their effects on potato tubers are independent of or synergistic with thaxtomin A. The production of thaxtomin and concanamycins at various types of potato tuber lesions also needs to be examined.

The two strains isolated from sugar beet roots that induce scab symptoms on potato produced only thaxtomin A. S-12 is remarkably similar to *S. scabies* in taxonomic characteristics such as melanin production, smooth surface spores, spiral spore chains, physiological properties, and pathogenicity to potato, but it has only 30-40% DNA homology with S-851 and S-131. This low DNA homology may explain the lack of concanamycin production by S-12. S-12 was isolated from the pitted and S-15 from the mound type symptoms of sugar beet scab. S-15 induced mound type symptoms, whereas S-12 induced both pitted and mound type symptoms on sugar beet. If the difference in symptoms is due to the kinds of toxin produced, S-12, S-15, or both, may produce phytotoxin(s) other than thaxtomin and concanamycins.

The study reported here was concerned with one or two strains in each taxonomic group. New species, *S. turgidiscabies*, *S. caviscabies*, and *S. ipomoeae*, that were not included in our experiments, have recently been reported. Investigation of more strains in each taxonomic group and of a wider range of species is needed to confirm the foregoing speculations.

**Literature cited**


和文摘要

夏目雅裕・山田晃子・田代暢増・安部 浩：ジャガイモ病の病原菌に由来する植物毒素thaxtomin Aとconcanamycin AおよびBの生成性の相違

ジャガイモ病は病原菌と病徵の多様性が報告されているが、病原菌の分類やその病徵との関連は未だ明らかにされていない。我々はジャガイモ病の1菌株がthaxtomin Aの他にconcanamycin AおよびBを生産することを見いだした。そこで、そうなる菌の分類と生産する毒素との間に関連があるのではないかと考え、DNA モノリーが調べられているジャガイモ病菌5菌株と *Streptomyces scabies* および* S. acidiscabies* の標準菌株2菌株計7菌株について、thaxtomin Aとconcanamycins AおよびBの生成性を調べた。その結果、thaxtomin Aは7菌株中6菌株で生産が認められ、その生産性は胞子鎖がspiral型の菌株よりもrectiflexible型の菌株の方が高い傾向にあった。一方、concanamycinsはジャガイモから分離されたspiral型の胞子鎖を有する2菌株と*S. scabies* でのみ生産が確認された。concanamycinsのジャガイモ塊茎に対する作用は現在検討中であるが、thaxtomin Aのみを生産する菌種と、thaxtomin Aとconcanamycins AおよびBを生産する菌種が存在することは、そうなる病徵のタイプが感染した病原菌の種類によって決まる可能性を示唆していると考えられる。

(Received January 28, 1998; Accepted March 26, 1998)