

# ラッキョウ乾腐病とその病原菌 *Fusarium oxysporum* Schl. f. sp. *allii* n.f.

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## ***Fusarium* Basal Rot of *Allium bakeri* Regel and its Causal Fungus, *Fusarium oxysporum* Schl. f. sp. *allii* n. f.**

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松尾卓見\*・遠山 明\*\*・伊阪実人\*\*\*: ラッキョウ乾腐病とその病原菌  
*Fusarium oxysporum* Schl. f. sp. *allii* n. f.

### **Abstract**

The outbreak and symptom of *Fusarium* basal rot of *Allium bakeri* Regel and the result of taxonomic study of its causal fungus were described. A new forma specialis, *Fusarium oxysporum* Schl. f. sp. *allii*, was proposed for the fungus on the morphological and cultural characters and the specialized pathogenicity to *Allium bakeri* Regel.

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### **Introduction**

The bulb rot of Baker's garlic, *Allium bakeri* Regel, by *Fusarium* was first reported by Watanabe and Wakaida<sup>15)</sup> from Tochigi Prefecture in 1955. According to the description, this bulb rot was superficial and not so severe as the *Fusarium* basal rot treated in this paper. In 1956, Doke<sup>3)</sup> reported the bulb rot of Baker's garlic cultivated in sand dunes of Tottori Prefecture, the causal fungus of which was regarded as *Fusarium*. Matuo, Sakurai and Doke<sup>10)</sup> identified the 5 isolates as *Fusarium mouillifolme* Sheld. (3 isolates) and *Fusarium oxysporum* Schl. (2 isolates). Long-term inoculation tests (from autumn to spring) to Baker's garlic were conducted and these fusaria were accepted to be pathogenic to the bulb of Baker's garlic though their virulence was weak. The pathogenicity of the above 2 isolates of *F. oxysporum*, however, seemed not to be specific to Baker's garlic and was regarded to be inferior to that of *F. oxysporum* f. sp. *tulipae* or *F. oxysporum* f. sp. *gladioli* to the Baker's garlic, which was tested in the same experiments.<sup>10)</sup>

Since 1975, *Fusarium oxysporum* which causes a destructive disease of Baker's garlic was reported by Tooyama *et al.*<sup>14,13)</sup> from Tottori Prefecture, and also by Isaka *et al.*<sup>5,7,8)</sup> from Fukui Prefecture. These isolates of *F. oxysporum* from both prefectures proved to be quite similar in their pathogenicity to Baker's garlic, and to be a new forma specialis of the species.

In this paper, the outbreak and symptom of the disease, *Fusarium* basal rot of Baker's garlic, and the characteristic of the new causal fungus are described, and its new forma specialis is presented. The outline of this paper was read in 1977.<sup>11)</sup> We would like to express our thanks to Dr. W. C. Snyder, Professor Emeritus of Univ. of California, who reviewed this manuscript and gave his kind advice.

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### Outbreak and symptom of the disease

In sand dunes of Tottori and Fukui Prefectures, Baker's garlic has been cultivated in large areas since about 1948. It was also reported before 1969 that fusaria were isolated from the rotted bulb of Baker's garlic in sand dunes of two prefectures by Doke,<sup>3)</sup> Isaka and Kawakubo,<sup>6)</sup> and Katsura *et al.*<sup>9)</sup> Doke's isolates were not strong pathogens as we explained in the introduction of this paper. Isaka and Kawakubo<sup>6)</sup> and Katsura *et al.*<sup>9)</sup> suggested that the fusaria were the secondary invaders after the white tip disease by *Phytophthora porri* Foister. We do not know the exact year when the severely virulent *F. oxysporum*, first reported by Tooyama and Yumoto<sup>14)</sup> from Tottori Prefecture and by Isaka<sup>5)</sup> from Fukui Prefecture, appeared in sand dunes of both prefectures, but it is assumed that the year was about 1969 or 1970. At any rate, it is true that this *Fusarium* basal rot has been one of the most important diseases of Baker's garlic in both prefectures since about 1971.

Seed bulbs of Baker's garlic are planted in the fields of sand dunes from the latter part of July to the first part of September, and are harvested in the latter part of May to the middle part of June of next year. The *Fusarium* basal rot appears most vigorously in autumn, especially 20 to 40 days after sprouting of seed bulbs, and then in May to June before harvest and the successive non-harvested seed bulb fields. The autumn outbreak of this disease seems to originate mostly from the seed bulbs accompanying the causal fungus. The first symptom appears in outer leaves which lose the vitality and wilt, and then the new leaves wither from their tops, and all leaves die. The bulbs of these diseased plants rot from the basal parts of scales adjoining to the disk in water-soaked appearance. The lesion spreads to the all parts of bulbs causing light yellow—brown colored dry rot which results in a mummy appearance, but the bulbs often show soft rot in case of wet conditions. Sometimes white or light rouge mycelia appear on the surface of bulbs. Vertical sections of the bulbs show that even inner young scales of the bulb are discoloring to light yellow—brown and decaying. The disks change fragile and the roots rot off. The advancement of the disease is very speedy, and sometimes almost all plants in a field die 30 to 40 days after planting.

In the outbreak of the disease in May to June before harvest, the blades wilt and hang limply, the vascular bundles of the bulbs discolor, and are followed by the decay of the bulbs and the roots. In non-harvested field for seed bulbs, the sleeping seed bulbs often decay by this disease, and various bacteria, the bulb mite, the seed maggot and the onion maggot are often observed on the decaying bulbs. Certain bacteria were reported to cause soft rot of Baker's garlic, but many bacteria there are regarded to functionate as secondary invaders. A bulb mite, *Rhizoglyphus echinopus* Fumonze *et* Robin, seems to serve as a vector of *Fusarium* basal rot of Baker's garlic as it is a first and secondary invader to the bulbs. The seed maggot and the onion maggot, observed in Fukui Prefecture, seem to be secondary invaders of the diseased bulbs.

### Morphological and cultural characters of the causal fungus and its species name

The same *Fusarium* fungus was isolated easily from the discolored bulbs of the *Fusarium* basal rot by the usual method. It produces microconidia and macroconidia abundantly on culture media. Microconidia hyaline, elliptic, long elliptic or ovoid, formed phialidic in aggregation on short, simple conidiophores arising laterally on the hyphae. Macroconidia hyaline, sickle formed, slightly curved, foot cell generally obscure, 1-4 septate, formed phialidic. Chlamydospores spheric or elliptic, hyaline, light brown, surface smooth, single or in chain, terminal or intercalary, formed on

hypha. The figures and the measurements of microconidia and macroconidia are shown in Plate (c) and Table 1. The fungus grows well on ordinary media. The aerial mycelium is white, and the culture stroma on the media is white or light brown, often shows blue and purple stains. These characters of the causal fungus agree with those of *Fusarium oxysporum* Schl. emend. Snyder et Hansen.<sup>12)</sup>

Table 1. Measurements of microconidia and macroconidia of *Allium bakeri* isolates on PSA

| Isolate | Place formed   | Septum number <sup>a)</sup> | Size range of conidium ( $\mu$ m) (mean value) |                                               |                                               |
|---------|----------------|-----------------------------|------------------------------------------------|-----------------------------------------------|-----------------------------------------------|
|         |                |                             | 0-sept.                                        | 1-sept.                                       | 3-sept.                                       |
| T-1     | On hyphae      | 0 1 2                       | 5-14 $\times$ 2.0-4.0<br>(8.1 $\times$ 2.9)    | 12-20 $\times$ 2.5-4.0<br>(16.0 $\times$ 3.2) | —                                             |
| T-2     | On hyphae      | 0 1 2 3 4                   | 6-12 $\times$ 2.0-3.5<br>(8.3 $\times$ 2.7)    | 8-16 $\times$ 3.0-5.0<br>(11.5 $\times$ 3.3)  | 20-36 $\times$ 3.5-5.0<br>(30.0 $\times$ 4.1) |
| T-3     | On hyphae      | 0 1 2                       | 5-14 $\times$ 2.0-3.5<br>(8.2 $\times$ 2.5)    | 12-20 $\times$ 2.5-3.0<br>(14.3 $\times$ 2.8) | —                                             |
| T-4     | On hyphae      | 0 1 2 3                     | 5-10 $\times$ 2.0-3.0<br>(7.9 $\times$ 2.4)    | 12-18 $\times$ 3.0-4.0<br>(14.5 $\times$ 3.5) | 24-38 $\times$ 3.0-4.5<br>(30.0 $\times$ 3.7) |
| F-1     | On sporodochia | 0 1 2 3 4                   | 6-14 $\times$ 2.0-3.5<br>(9.5 $\times$ 2.6)    | 14-16 $\times$ 2.5-3.0<br>(15.0 $\times$ 2.8) | 32-44 $\times$ 3.0-4.5<br>(37.0 $\times$ 3.7) |

a) Numbers in gothics indicate predominant septum number of macroconidia.

### Pathogenicity and forma specialis of the fungus

Four formae speciales of *Fusarium oxysporum* Schl. ; f. sp. *cepae* (Hanzawa) Snyder et Hans.,<sup>12)</sup> f. sp. *lilii* Imle,<sup>4)</sup> f. sp. *asparagi* Cohen<sup>2)</sup> and f. sp. *tulipae* Apt,<sup>1)</sup> were proposed relating to Liliaceae plant. We intended to make clear the pathogenicity of *Allium bakeri* isolates of *F. oxysporum* paying special attention to the comparison with these 4 formae speciales. Among them, *F. oxysporum* f. sp. *lilii* Imle has not occurred in Japan. We tried in vain to get the isolate from U. S. A., so we were obliged to conduct only one sided inoculation tests in the pathogenicity test of *Allium bakeri* isolates to lily.

**Inoculation experiments to *Allium bakeri*** The inoculation experiments with *Allium bakeri* isolates of *F. oxysporum* to *Allium bakeri* were carried out from the middle and latter parts of August to the first and middle parts of September successfully by two methods. The first method is the disk inoculation test, in which the base of the disk of bulbs was injured slightly by a knife and a bit of mycelium was put on the injury, and the bulbs were kept at 25C in Petri dish in wet condition for 5 days and then in dry condition for 14 days. The second method is the usual pot inoculation test, in which uninjured seed bulbs were planted in steam-sterilized soil of pots (5 seed bulbs for a 12 cm diameter pot) mingled with inocula (5g bran culture for a pot) and were kept for about 20 days in a glasshouse. The results demonstrated, as shown in Table 2, that this fungus has a strong virulence to *Allium bakeri*, though *F. oxysporum* f. sp. *cepae*, f. sp. *tulipae*, f. sp. *asparagi*, f. sp. *gladioli* and f. sp. *narcissi* are scarcely pathogenic to *Allium bakeri*. Many other formae speciales of *F. oxysporum* ; f. sp. *callistephi*, *lactucae*, *arctii*, *niveum*, *melonis*, *cucumerinum*, *luffae*, *lagenariae*, *sesami*, *lycopersici* (J1, 2, 3), *melongenae*, *batatas*, *apii*, *cyclaminis*, *vasinfectum*, *lini*, *tracheiphylum*, *phaseoli*, *fabae*, *lupini*, *medicaginis*, *pisi* (race 1,2), *fragariae*, *conglutinans*, *raphani*, *nelumbicola*, *dianthi*, *spinaciae*, *pini*, were tested in the same way and proved to be non or scarcely pathogenic to *Allium bakeri*. In these inoculation experiments, cul-

Table 2. Results of inoculation experiments with *Allium bakeri* isolates and various formae speciales of *F. oxysporum* to *Allium bakeri* (Cultivar : Rakuda)

| Test fungus                  | Disk inoculation   |                |                 | Pot inoculation    |                |              |                  |
|------------------------------|--------------------|----------------|-----------------|--------------------|----------------|--------------|------------------|
|                              | Bulb No.<br>tested | Healthy<br>No. | Diseased<br>No. | Bulb No.<br>tested | Healthy<br>No. | Diseased No. |                  |
|                              |                    |                |                 |                    |                | +            | ++ <sup>a)</sup> |
| <i>Allium bakeri</i> isolate |                    |                |                 |                    |                |              |                  |
| T-3                          | 20                 | 1              | 19              | 28                 | 0              | 3            | 25               |
| T-4                          | 20                 | 0              | 20              | 28                 | 0              | 7            | 21               |
| F-1                          | 20                 | 0              | 20              | 28                 | 2              | 6            | 20               |
| <i>f. sp. cepae</i>          |                    |                |                 |                    |                |              |                  |
| OFA                          | 21                 | 21             | 0               | 21                 | 20             | 0            | 1 <sup>b)</sup>  |
| OFB                          | 21                 | 21             | 0               | 21                 | 19             | 0            | 2                |
| OFC                          | 21                 | 20             | 1               | 21                 | 20             | 1            | 0                |
| <i>f. sp. tulipae</i>        |                    |                |                 |                    |                |              |                  |
| SUF 347                      | 20                 | 20             | 0               | 28                 | 27             | 0            | 1                |
| SUF 351                      | 20                 | 19             | 1               | 28                 | 23             | 3            | 2                |
| <i>f. sp. asparagi</i>       |                    |                |                 |                    |                |              |                  |
| SUF 844                      | 20                 | 20             | 0               | 28                 | 26             | 1            | 1                |
| SUF 1226                     | 20                 | 20             | 0               | 28                 | 26             | 0            | 2                |
| <i>f. sp. gladioli</i>       |                    |                |                 |                    |                |              |                  |
| SUF 405                      | 20                 | 19             | 1               | 28                 | 22             | 4            | 2                |
| SUF 467                      | 20                 | 20             | 0               | 28                 | 26             | 2            | 0                |
| <i>f. sp. narcissi</i>       |                    |                |                 |                    |                |              |                  |
| SUF 202                      | 20                 | 20             | 0               | 28                 | 28             | 0            | 0                |
| Control                      | 25                 | 25             | 0               | 30                 | 28             | 2            | 0                |

a) For rating marks, refer to Plate (D).

b) Most diseased bulbs in various *f. sp.* plots seemed to be caused by the contamination of *Allium bakeri* isolates.

tivar 'Rakuda' of *Allium bakeri* was used. 'Rakuda' is native cultivar in Tottori Prefecture and more susceptible to *Fusarium* basal rot than new cultivar 'Tama-rakkyo' as shown in Table 3. The results in Table 3 were obtained by the following method. Seed bulbs of each cultivar were dipped in spore suspension (spore density : 50 to 60 in a field of vision of 400 × microscope) for 15 hr and dried for 4 days and planted in soil (Aug. 31). Percentage of diseased plants was investigated 42 days after planting (Oct. 12).

**Inoculation experiments to various plants** On the other hand, the pathogenicity

Table 3. Results of inoculation experiment with an *Allium bakeri* isolate to seed bulbs of some cultivars of *Allium bakeri*

| Cultivar                    | Bulb No. tested | % diseased |
|-----------------------------|-----------------|------------|
| Rakuda (Fukube native line) | 119             | 85.7       |
| Kuzuryu                     | 118             | 98.3       |
| Eshalot                     | 108             | 79.6       |
| Tamarakkyo                  | 105             | 22.0       |
| Tamarakkyo (Hojo-line)      | 101             | 11.0       |

of *Allium bakeri* isolates of *F. oxysporum* to differential plants of forma specialis, especially onion (*Allium cepa* L.), tulip (*Tulipa gesneriana* L.), asparagus (*Asparagus officinalis* L.), lily (*Lilium longiflorum* Thunb.), gladiolus (*Gladiolus grandavensis* Van Houtt.), narcissus (*Narcissus Tazetta* L.) was tested by the usual seed bulb or seed (in case of asparagus) inoculation experiments. Seed bulbs or seeds of these plants were planted in steam-sterilized soil of pots mingled with inocula in September or October and were kept in a glasshouse till May of next year. Seed inoculation test (from May to June) of Welsh onion (*Allium fistulosum* L.) was added to this tests. In these inoculation tests, the pathogenicity of standard formae speciales of *F. oxysporum* except f. sp. *lilii*; f. sp. *cepa*, f. sp. *tulipae*, f. sp. *asparagi*, f. sp. *gladioli* and f. sp. *narcissi*, was tested to respective hosts as control.

Table 4. Results of inoculation experiments with *Allium bakeri* isolates and standard formae speciales of *F. oxysporum* to various plants

| Test plant<br>(cultivar)           | Isolate from <i>A. bakeri</i> |                    |                 | Standard f. sp. of <i>F. oxysporum</i> |                    |                 |
|------------------------------------|-------------------------------|--------------------|-----------------|----------------------------------------|--------------------|-----------------|
|                                    | Isolate                       | Bulb No.<br>tested | Diseased<br>No. | Test fungus                            | Bulb No.<br>tested | Diseased<br>No. |
| Onion<br>(Senshu-chuko)            | T-3                           | 30                 | 2               | f. sp. <i>cepa</i>                     |                    |                 |
|                                    | T-4                           | 28                 | 0               | Kamikawa A                             | 20                 | 12              |
|                                    | F-1                           | 28                 | 2               | Kamikawa B                             | 20                 | 9               |
|                                    | Control <sup>a)</sup>         | 30                 | 1               | Tottori 11                             | 29                 | 11              |
| Welsh onion<br>(Kujonegi)          | T-3                           | 22                 | 1               | f. sp. <i>cepa</i>                     |                    |                 |
|                                    | T-4                           | 22                 | 2               | Tottori 11                             | 25                 | 14              |
|                                    | F-1                           | 22                 | 0               |                                        |                    |                 |
|                                    | Control                       | 22                 | 1               |                                        |                    |                 |
| Tulip<br>(Apeldoorn)               | T-3                           | 8                  | 0               | f. sp. <i>tulipae</i>                  |                    |                 |
|                                    | T-4                           | 11                 | 1               | SUF 351                                | 10                 | 10              |
|                                    | F-1                           | 9                  | 0               |                                        |                    |                 |
|                                    | Control                       | 20                 | 1               |                                        |                    |                 |
| Asparagus<br>(Merry<br>Washington) | T-3                           | 20                 | 0               | f. sp. <i>asparagi</i>                 |                    |                 |
|                                    | T-4                           | 20                 | 0               | SUF 1226                               | 19                 | 18              |
|                                    | F-1                           | 20                 | 1               |                                        |                    |                 |
|                                    | Control                       | 20                 | 0               |                                        |                    |                 |
| Lily<br>(Teppo-yuri)               | T-3                           | 20                 | 0               |                                        |                    |                 |
|                                    | T-4                           | 20                 | 0               |                                        |                    |                 |
|                                    | F-1                           | 20                 | 0               |                                        |                    |                 |
|                                    | Control                       | 20                 | 0               |                                        |                    |                 |
| Gladiolus<br>(Hector)              | T-3                           | 12                 | 1               | f. sp. <i>gladioli</i>                 |                    |                 |
|                                    | T-4                           | 12                 | 0               | SUF 405                                | 12                 | 6               |
|                                    | F-1                           | 12                 | 0               |                                        |                    |                 |
|                                    | Control                       | 12                 | 1               |                                        |                    |                 |
| Narcissus<br>(Orange glow)         | T-3                           | 12                 | 0               | f. sp. <i>narcissi</i>                 |                    |                 |
|                                    | T-4                           | 12                 | 2               | SUF 202                                | 12                 | 8               |
|                                    | Control                       | 12                 | 0               |                                        |                    |                 |

a) Non-inoculated plot.

The results of these inoculation tests demonstrated, as shown in Table 4, that *Allium bakeri* isolates were non or scarcely pathogenic to these plants including *Lilium longiflorum* Thunb., though *F. oxysporum* f. sp. *cepa*, f. sp. *tulipae*, f. sp. *asparagi*, f. sp. *gladioli*, f. sp. *narcissi* showed the virulence to their respective hosts. In addition, the pathogenicity of *Allium bakeri* isolates to aster (Shirobana-dairin), great burdock (Tokiwa-dainaga), watermelon (Nishō-red), melon (Prince), cucumber (Sūyō), dishcloth gourd (Futo-hechima), bottle gourd (Sakigake), sesame (Shirogoma), tomato (Fukuju No. 2), eggplant (Honnaga), sweet potato (Kokei No. 14), cowpea (Sanjaku-sasage), kidney bean (Kizaya-kuro-sando), broad bean (unknown), pea (Shirohime), strawberry (Hokō-wase) and spinach (Yugiri) was tested by the usual seedling or young shoot test. The results showed that *Allium bakeri* isolates are not pathogenic to these plants too.

On the results of the above cross-inoculations between *Allium bakeri* isolate and various formae speciales of *F. oxysporum*, we propose a new forma specialis for this *Allium bakeri* isolate as follows.

*Fusarium oxysporum* Schl. f. sp. *allii* Matuo, Tooyama et Isaka

Hab. in vivis *Allium bakeri* Regel, cetera ut in typo.

The type culture is deposited in Lab. Phytopathology and Mycology, Ueda, Nagano-ken, Japan, which was isolated from the bulb of *Allium bakeri* suffered from *Fusarium* basal rot.

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## 和 文 摘 要

ラッキョウ乾腐病とその病原菌 *Fusarium oxysporum* f. sp. *allii* n. f.

松尾卓見・遠山 明・伊阪実人

鳥取県及び福井県の砂丘のラッキョウに、数年前から病原性の強い *Fusarium oxysporum* Schl. が寄生し、顕著な疾病（乾腐病）を起こすことがわかった。本病の発生状況や病徴を記載し、従来ラッキョウ鱗茎から分離された病原性の弱い *Fusarium* 菌との区別について記述した。本病原菌はラッキョウに著しい病原性を示すが、これまで提案されたユリ科に関係ある *F. oxysporum* の4分化型中の3分化型, f. sp. *cepa* (Hanzawa) Snyd. et Hans., f. sp. *tulipae* Apt, f. sp. *asparagi* Cohen (f. sp. *lilii* Imle は入手不能) 及び f. sp. *gladioli*, f. sp. *narcissi* その他29分化型はラッキョウ苗に対し全くまたは殆んど病原性を示さなかった。一方、ラッキョウ菌は、ユリを含むタマネギ、チューリップ、アスパラガスなどのユリ科植物、及びグラジオラス、スイセン其他多数の植物に対し病原性を示さなかった。このように本菌はラッキョウに対する病原性に特異性が認められたので、*Fusarium oxysporum* Schl. f. sp. *allii* Matuo, Tooyama et Isaka なる新分化型名を与えた。

## Explanation of plate

- A Diseased bulbs (*Fusarium* basal rot) of *Allium bakeri*, naturally occurred. Left 2 bulbs are diseased severely, and right one is slightly diseased.
- B A diseased bulb vertically sectioned. The disk is completely rotted.
- C Macroconidia and microconidia of *F. oxysporum* f. sp. *allii*.
- D Results of pot inoculation experiment. Left bulbs—severely diseased (++), middle bulbs—slightly diseased (+), right ones—healthy (control).

