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spores are apt to show somewhat smaller and rounder in size and shape when they are examined one or more days after the fungi are collected, since the fungi may discharge the spores continuously and freely as long as the pilei do not dry out or rot. Investigators should bear in mind these facts if they try to identify a fungus of this group.

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STUDIES ON THE DOWNY MILDEWS OF CRUCIFEROUS VEGETABLES IN JAPAN I

BY

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Many kinds of cruciferous vegetables useful to the daily life of the Japanese are widely cultivated throughout the territory of Japan. Most of them belong to the genus *Brassica* or *Raphanus*, and are commonly subject to the attack of a *Peronospora* fungus known formerly as *Peronospora parasitica* (PERS.) FR., but lately often designated as *Peronospora brassicae* GM.

It seems to be inferable from the recent investigation of GÄUMANN⁽³⁾ that the fungus parasitic on these cruciferous vegetables might comprise various strains different in pathogenicity. To ascertain this assumption, some inoculation experiments have been carried out, and the results so far obtained are tentatively presented in this paper.

Materials and Methods

Affected leaves of various cruciferous vegetables found in the neighbourhood of Gifu Agricultural College were collected, as a rule, towards evening, washed in running water, and each kept in a moist satchel in the laboratory. In this way, an abundance of fresh conidia were easily available on the following morning. The seeds used in these experiments were all gotten at a seed store in Gifu. They were sown and grown in ordinary porcelain pots.

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Spore suspension was inoculated by means of an atomizer, and the plants inoculated were kept in moist chambers for 30-48 hours.

Experimental Results

- (a) Experiments with the Downy Mildew of *Raphanus sativus*, L.
var. *raphanistroides*, MAK.

Experiment I

On April 13, 1928, the downy mildew of Sima-Daikon, a cultural form of *Raphanus sativus*, var. *raphanistroides* collected at Rokken, was inoculated on 30-day-old* plants of various cultural forms of *Brassica* and *Raphanus*. The reactions of the plants to the fungus are briefly tabulated in Table I.

Table I. Reaction of various cultural forms of *Raphanus* and *Brassica* to the downy mildew of Sima-Daikon.

Plants inoculated		Formation of conidia
Species	Cultural forms	
<i>Raphanus sativus</i> , L. var. <i>raphanistroides</i> , MK.	Sima-Daikon	+++
<i>Raphanus sativus</i> , L.	White Icicle	+++
<i>Brassica pekinensis</i> , RUPR.	Aburana	++
	Tirimen-Sirona	+
<i>Brassica chinensis</i> , L.	Sina-Sirokuki-Taina	+
<i>Brassica juncea</i> , COSS.	Ôba-Takana	+
<i>Brassica Rapa</i> , L.	Syôgoin-Kabu	+
	Komatuna	++
<i>Brassica oleracea</i> , L. var. <i>capitata</i> , L.	Succession	-
<i>Brassica oleracea</i> , L. var. <i>botrytis</i> , L.	Late Giant	-
<i>Brassica oleracea</i> , L. var. <i>gemmifera</i> , ZENKER.	Exhibition	-
<i>Brassica oleracea</i> , L. var. <i>bullata</i> , DC.	Drumhead Savoy	-

"+" means positive in conidial formation, while "-" negative.

* This means 30 days after sowing.

Experiment 2

On October 23, 1933, the downy mildew of Miyasige-Daikon, a cultural form of *Raphanus sativus*, var. *raphanistroides* collected at Naka, was inoculated on ten-day-old seedlings of the same host and of Taina, a cultural form of *Brassica chinensis*. Conidia were abundantly produced on the former, but none on the latter.

Experiment 3

On November 18, 1933, the downy mildew of Miyasige-Daikon collected at Sinkanô, was inoculated on 30-day-old plants of the same host and Taina. The results were exactly the same as in Experiment 2.

Experiment 4

On December 4, 1933, the downy mildew of Miyasige-Daikon collected at Sinkanô, was inoculated on various cultural forms of *Raphanus* and *Brassica*. The plants inoculated were 25 days old. The reactions are shown in Table 2.

Table 2. Reaction of various cultural forms of *Raphanus* and *Brassica* to the downy mildew of Miyasige-Daikon.

Plants inoculated		Formation of conidia
Species	Cultural forms	
<i>Raphanus sativus</i> , L. var. <i>raphanistroides</i> , M.K.	Miyasige-Daikon	+++
	Sirimaru-Daikon	+++
	Minowase-Daikon	+++
	Sirokubi-Hôryô-Daikon	+++
<i>Raphanus sativus</i> , L.	Hatuka-Daikon	++
<i>Brassica Rapa</i> , L.	Komatuna	+++
	Tennoji-Kabu	—
<i>Brassica pekinensis</i> , RUPR.	Tirimen-Sirona	++
	Sirokuki-Santôna	—
<i>Brassica chinensis</i> , L.	Hirosimana	—
	Yukisiro-Taina	—
<i>Brassica oleracea</i> , L. var. <i>capitata</i> , L.	Tamana	—

As seen from the results tabulated above, the downy mildew of *Raphanus sativus*, var. *raphanistroides*, so far as the present investigation is concerned, is very pathogenic to all cultural forms of *Raphanus* as well as to certain cultural forms of *Brassica pekinensis*, and *B. Rapa*; not or slightly pathogenic to most of the cultural forms of *Brassica pekinensis*, *B. chinensis*, *B. Rapa*, and *B. juncea*, and not pathogenic to the varieties of *Brassica oleracea*.

(b) Experiments with the Downy Mildew of *Brassica pekinensis* L.

Experiment 5

On May 5, 1928, the downy mildew of Aburana, a cultural form of *Brassica pekinensis* collected at Inuyama, was inoculated on 10-day-old seedlings of Sima-Daikon and Aburana. Conidia were produced on both kinds of plants. But, the amount of the conidia was found to be less on the former than on the latter.

Experiment 6

On November 16, 1933, the downy mildew of Sirona, a cultural form of *Brassica pekinensis* collected in the experimental farm of our college, was inoculated on the seedlings of Miyasige-Daikon and Taina, both being 11 day old. No conidia were produced on Miyasige-Daikon, but they were produced on Taina.

Experiments 7-8

On December 1, 1933, the downy mildew of Santôna, a cultural form of *Brassica pekinensis* collected in the experimental farm of our college, was inoculated on various cultural forms of *Raphanus* and *Brassica*. The plants were 22 days old, when inoculated (Exp. 7).

On the next day, the downy mildew of Sirona collected in the experimental farm of our college, was also inoculated on another series of the same cultural forms as used in Experiment 7. The plants were 23 days old in this case (Exp. 8). The reactions of the plants to the fungus in both experiments are shown together in Table 3.

Table 3. Reaction of various cultural forms of *Raphanus* and *Brassica* to the downy mildews of Santôna and of Sirona

Plants inoculated		Formation of conidia	
Species	Cultural forms	Exp. 7	Exp. 8
<i>Raphanus sativus</i> , L. var. <i>raphanistrôides</i> , MK.	Miyasige-Daikon	—	—
	Sirimaru-Daikon	—	—
	Minowase-Daikon	—	—
	Sirokubi-Hôryô-Daikon	—	—
<i>Raphanus sativus</i> , L.	Hatuka-Jaikon	—	—
<i>Brassica Rapa</i> , L.	Komatuna	+++	+++
	Tennoji-Kabu	+++	+++
<i>Brassica pekinensis</i> , RUPR.	Tirimen-Sirona	+++	+++
	Sirokubi-Santôna	+++	+
<i>Brassica chinensis</i> , L.	Hirosimana	+++	+
	Yukisiro-Taina	+++	+
<i>Brassica oleracea</i> , L. var. <i>capitata</i> , L.	Tamana	—	—

The results of Experiments 5-8 indicate clearly that the downy mildew of *Brassica pekinensis*, with the exception of Aburana, cannot attack the cultural forms of *Raphanus* tested, showing that the fungus on *Brassica pekinensis* is quite different in pathogenicity from that on *Raphanus*. The results are also somewhat suggestive to indicate that the fungus on Aburana, Sirona, and Santôna, respectively, might be different pathogenically. However, further study is necessary for a determination of this point.

(c) Experiments with the Downy Mildew of *Brassica chinensis*, L.

Experiment 9

On November 16, 1933, the downy mildew of Taina, a cultural form of *Brassica chinensis*, L. collected from the experimental farm of our college, was inoculated on the seedlings of Miyasige-Daikon and Taina, when both were 11 days old. Abundant conidia were produced on Taina, but none on Miyasige-Daikon.

Experiment 10

On December 6, 1933, the downy mildew of Taina collected from the experimental garden of the Phytopathological Division, was inoculated on various

cultural forms of *Raphanus* and *Brassica*, when the plants were 27 days of age. The reactions are shown in Table 4.

Table 4. Reaction of various cultural forms of *Raphanus* and *Brassica* to the downy mildew of *Taina*

Plants inoculated		Formation of conidia
Species	Cultural forms	
<i>Raphanus sativus</i> , var. <i>raphanistroides</i> , Mk.	Miyasige-Daikon	—
	Sirimaru-Daikon	—
	Minowase-Daikon	—
	Sirokubi-Hōryō-Daikon	—
<i>Raphanus sativus</i> , L.	Hatuka-Daikon	—
<i>Brassica Rapa</i> , L.	Komatuna	+++
<i>Brassica pekinensis</i> , L.	Tirimen-Sirona	+++
	Sirokubi-Santōna	+++
<i>Brassica chinensis</i> , RUPR.	Hirosimana	++
	Yukisiro-Taina	+++
<i>Brassica oleracea</i> , L. var. <i>capitata</i> , L.	Tamana	—

The results of Experiments 9-10 indicate that the fungus on *Taina* (*Brassica chinensis*) is distinguishable in pathogenicity from that on *Raphanus*, but seems to be closely related to that on Santōna (See Expt. 7).

(d) Experiments with the Downy Mildew of *Brassica Rapa*, L.

Experiment 11

On November 22, 1933, the downy mildew of Kurona, possibly a cultural form of *Brassica Rapa*, L. collected in Saraki-Mura, was inoculated on

- (1) 17-day-old plants of Sirona,
- (2) 13-day-old plants of Tennoji-Kabu, and
- (3) 40-day-old plants of Miyasige-Daikon and Taina.

Abundant conida were formed on Sirona and Tennoji-Kabu, but none on Miyasige-Daikon and Taina.

Experiment 12

On December 1, 1933, the downy mildew of Kurona collected in the experimental farm of our college, was inoculated on various cultural forms of

Raphanus and *Brassica*. The plants were 22 days old, when inoculated. Table 5 represents the reactions of the plants to the fungus.

Table 5. Reaction of various cultural forms of *Raphanus* and *Brassica* to the downy mildew of Kurona

Plants inoculated		Formation of conidia
Species	Cultural forms	
<i>Raphanus sativus</i> , L. var. <i>raphanistroides</i> , MK.	Minowase-Daikon	—
	Sirimaru-Daikon	—
	Miyasige-Daikon	—
	Sirokubi-IHōryō-Daikon	—
<i>Raphanus sativus</i> , L.	Hatuka-Daikon	—
<i>Brassica Rapa</i> , L.	Komatuna	+++
	Tennoji-Kabu	+
<i>Brassica pekinensis</i> , RUPR.	Tirimen-Sirona	+
	Sirokuki-Santōna	+
<i>Brassica chinensis</i> , L.	Hirosimana	+
	Yukisiro Taina	+
<i>Brassica oleracea</i> , L. var. <i>capitata</i> , L.	Tamana	—

The results of these experiments also indicate that the fungus on *Brassica Rapa* is evidently different from that on *Raphanus*.

It is noticeable that the downy mildew of *Brassica pekinensis*, *B. chinensis*, and *B. Rapa*, respectively, is closely related, since it has a similar range of susceptible hosts. However, there are some differences in the grade of production of conidia, and it remains to be determined, whether these differences are significant from the standpoint of physiological specialization, or are merely explained by the influence of environmental factors.

Considerations

In 1926, GÄUMANN⁽³⁾ reported that *Peronospora brassicae* GM. is sub-divided into three biologic forms, namely:

(1) f. sp. *brassicae*, the principal hosts of which are *Brassica oleracea*, L., *Br. Napus*, L., *Br. Rapa*, L., *Br. nigra* (L.) KOCH, *Br. juncea* (L.) COSS., *Br. Tournefortii*, GOUAN and *Br. fruticulosa*, CHR. It is able to produce sub-infections

on *Sinapis arvensis*, L., *Sin. alba*, L., *Raphanus Raphanistrum*, L., *R. sativus*, L., and *Eruca sativa*, L.

(2) f. sp. *sinapidis*, the principal hosts of which are *Sinapis arvensis*, L., and *S. alba*. It is able to produce sub-infections on all the above-mentioned species of *Brassica*, with the exception of *Br. Rapa* and *Br. juncea*, and both species of *Raphanus*, with occasional conidiophore formation on *Br. oleracea*.

(3) f. sp. *raphani*, the principal hosts of which are *Raphanus Raphanistrum*, L. and *R. sativus*, L. It is able to produce sub-infections on all the above-mentioned species of *Brassica* (except *Br. fruticulosa*), as well as on both species of *Sinapis*, with occasional conidiophore formation on *Br. oleracea* and *Br. Napus*.

In 1933, SAWADA⁽⁴⁾ described the *Peronospora* on *Brassica chinensis* under the name of *Peronospora Brassicae*, GM., also the *Peronospora* on *Raphanus sativus*, L. as *Peronospora Brassicae*, GM. f. sp. *Raphani*, SAW., without mentioning GÄUMANN's publication stated above.

According to SAWADA, H. KUROSAWA formerly proved by inoculation experiments that (1) the fungus on Taina, a cultural form of *Brassica chinensis*, L., is capable of infecting Sirona-group (*Brassica pekinensis*), Tamana-group (*Br. oleracea*), Kabu-group (*Br. Rapa*), and Karasina-group (*Br. juncea*), but is unable to infect Daikon-group (*Raphanus sativus*); (2) on the other hand the fungus on *Raphanus* infects readily many cultural forms of *Raphanus*, but very rarely many forms of *Brassica*, with the exception of *Br. oleracea* which is rather susceptible; (3) the fungus on *Br. oleracea* is unable to infect *Raphanus*, although it is capable of infecting all the cultural forms of *Brassica*.

If GÄUMANN's results in inoculation experiments with the fungus from *Brassica oleracea* are compared with those reported by SAWADA, it is perceived that there is a general coincidence between the two. The same is also the case with the results of the experiments on the fungus from *Raphanus sativus*, suggesting that f. sp. *Raphani* SAW. is a synonym of f. sp. *raphani* GM.

As has been already stated, the results of the present investigation are sufficient to show that the fungus on *Raphanus sativus* is distinguishable pathogenically from that on *Brassica*. However, it seems quite questionable, whether or not the fungus on *Raphanus* or *Brassica* is uniform pathogenically. The fungus on *Raphanus* studied by the present writers has appeared to be more pathogenic on species of *Brassica* than that studied by GÄUMANN. The behaviour of the fungus on *Brassica Rapa* has been also found to be somewhat different from that reported by the latter. Still more, the results of the present experiments with the downy mildew from various cultural forms of *Brassica* have suggested that the fungus on *Brassica* might not be uniform, since there have been found some differences in the reactions of the same plants to each strain

of the fungus. If proper differential hosts are chosen, and inoculations are made under controlled conditions, the problem under consideration may be proved to be more complex than hitherto considered.

Biometrical studies have shown that the conidia of the fungus on *Raphanus sativus* are considerably smaller than those on *Brassica*. This is mainly in accordance with the descriptions given by SAWADA. Further study is now in progress.

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