# Turnip Mosaic Virus Strains in Cruciferous Crops in Japan

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## Introduction

Several kinds of viruses such as turnip mosaic virus (TuMV), cauliflower mosaic virus, cucumber mosaic virus, broad bean wilt virus and beet western yellows virus have been reported to occur in cruciferous crops in Japan. Out of these viruses, TuMV is most predominant and geographically widespread in Japan. TuMV is therefore recognized to be the most important virus in growing cruciferous crops, including Japanese radish, Chinese cabbage, cabbage and turnip, due to its serious cause for significant yield losses. The virus has a wide host range, many of which are overwintering hosts. It is readily transmissible by many species of aphids, and no effective control of the vectors with insecticides has been developed. In the circumstance, varietal resistance is considered the only effective means of control, and studies on TuMV-resistant varieties and breeding materials have been initiated in several countries.

It is well known that there are different strains of TuMV. Yoshii differentiated TuMV isolates into two strain groups according to their different infectivities to *Brassica oleracea* subsp. *capitata* (cabbage) and *Nicotiana glutinosa*[7]. The strain that produced mild symptoms on cabbage and *N. glutinosa* was named ordinary strain, and the other that produced severe necrotic ring symptom on cabbage and rather severe mosaic on *N. glutinosa* was named cabbage strain. It was reported that all the Japanese isolates of that virus belonged to the ordinary strain[7]. Provvidenti obtained many isolates of TuMV from cruciferous crops in New York State, and divided them into four strains after screening 46 Chinese cabbage cultivars of Japanese and Chinese origins based on their resistance to TuMV[3]. On the basis of the Provvidenti's TuMV strain differentials, Green and Deng identified five strains of TuMV from cruciferous crops in Taiwan[1]. In addition to the four strains of the virus described in the United States, they isolated a fifth strain that was capable of systemically infecting a multi-resistant Chinese cabbage variety.

Differentiation of the TuMV strains based on the reactions to three kinds of cruciferous plants such as Japanese radish, cabbage and Chinese cabbage was conducted. The purposes of this differentiation were to determine the presence and prevalence of TuMV strains infecting cruciferous vegetables commercially grown in Japan, and to make those strains available for the development of stable yielding and disease-resistant cruciferous varieties in the breeding program.

## Materials and methods

Infected leaves of field-grown Japanese radish (*Raphanus sativus* L.), Chinese cabbage (*B. campestris* subsp. *pekinensis* L.), cabbage (*B. oleracea* subsp. *capitata* L.), broccoli (*B. oleracea* subsp. *italica* L.), turnip (*B. campestris* subsp. *rapifera* L.), horseradish (*Armoracia rusticana* G.) and *Brassica* × *napus* Hort. were collected during

1983–1985 from the major cruciferous vegetable-growing areas of Japan. Each isolate of TuMV passed through three successive single local lesion transfers on *N. tabacum* L. 'Bright Yellow'. All isolates were maintained in turnip plants. Finally, 47 isolates of TuMV, comprising 22 from Japanese radish, nine from Chinese cabbage, seven from cabbage, three from broccoli, four from turnip, one from *Brassica* × *napus* Hort. and one from horseradish, were chosen for strain differentiation. In the strain differentiation, five out of the 11 cultivars of Japanese radish, six out of the 11 cultivars of cabbage and six out of the 17 cultivars of Chinese cabbage were chosen on the basis of their abilities to differentiate the strains. Inocula were prepared by grinding infected turnip leaves with 0.1 M phosphate buffer at pH 7.0. Ten plants of each cultivar, previously dusted with Carborundum, were mechanically inoculated with each TuMV isolate. After inoculation, all plants were kept under observation for 4 weeks and checked regarding the presence of the virus by back-inoculation to *Chenopodium amaranticolor*. Inoculated plants that did not show any symptoms and also that were found to be free of viral infection were rated as highly resistant or immune. Plants in which virus infection remained confined to the inoculated leaves were classified as resistant. Those which exhibited moderate to severe systemic symptoms were considered susceptible.

Seeds of Japanese cultivars were provided by various companies in Japan. Plant introductions (PI) from China were kindly supplied by Provvidenti, B., New York State Agricultural Experiment Station, New York, USA.

## Results

### 1) *Classification of TuMV isolates based on reactions to Japanese radish cultivars*

Eleven cultivars of *Raphanus sativus* were used for differentiation of TuMV isolates, out of which five cultivars were found to be useful. Two cultivars, i.e. Eberesuto and Nerima-chunaga, had low resistance to TuMV infection, and Risou showed moderate resistance. Two cultivars, i.e. Natsumino-wase No. 1 and Tosai, were well known for their high resistance to TuMV infection. The 47 isolates of TuMV which had been chosen for strain differentiation were divided into three groups according to their different reactions to five cultivars of the Japanese radish (Table 1). TuMV isolates of Group Ir systemically infected all five cultivars and those of Group IIr could not systemically infected both or either of the resistant cultivars Tosai and Natsumino-wase No. 1. TuMV isolates of Group IIIr generally induced local infections without subsequent systemic infection on all the cultivars under testing.

**Table 1. Three groups of TuMV isolates on *Raphanus sativus* cultivars selected for differentiation**

| Cultivar | Reactions[a)] | | |
|---|---|---|---|
| | Ir | IIr | IIIr |
| Eberesuto (T)[b)] | S | S | R(S) |
| Nerima-chunaga (Sh) | S | S | R |
| Risou (M) | S | S | R |
| Tosai (I) | S | R(S) | R |
| Natsumino-wase No. 1(T) | S | R(S) | R |

a): S; Susceptible (virus present in inoculated and noninoculated leaves), R; Resistant (virus confined to the inoculated leaves), ( ); Rare case

b): Name of company that supplied seeds. T; Takii Seed Co., Sh; Shibuya Seed Co., M; Matsunaga Seed Co., I; Ikeda Seed Co., N; Nozaki Seed Co., S; Sakata Seed Co.

Out of the 22 TuMV isolates from Japanese radish tested, a majority of them belonged to Group Ir. However, all the isolates from cabbage, broccoli and *Brassica* × *napus* Hort. belonged to Group IIIr. Out of the nine isolates from Chinese cabbage tested, 5 and 4 belonged to Group IIr and IIIr, respectively. Two isolates from turnip and horseradish belonged to Group IIr.

### 2) *Classification of TuMV isolates based on reactions to cabbage cultivars*

The above 47 isolates were subjected to

**Table 2. Three groups of TuMV isolates on *Brassica oleracea* subsp. *capitata* cultivars selected for differentiation**

| Cultivar | Reactions[a] | | |
|---|---|---|---|
| | Ic | IIc | IIIc |
| Shikidori (T)[b] | S | S | S |
| 60-Days (T) | S | S | R |
| No. 2 (N) | S | S | R |
| Haruhikari No. 1 (T) | S | S | R |
| Hamakaze (T) | S | R | R |
| Fukamidori (T) | S | R | R |

a), b): Same as Table 1.

**Table 3. Five groups of TuMV isolates on *Brassica campestris* subsp. *pekinensis* cultivars selected for differentiation**

| Cultivar | Reactions[a] | | | | |
|---|---|---|---|---|---|
| | Ip | IIp | IIIp | IVp | Vp |
| PI 418957 | S | R | I | R | I |
| PI 419105 | S | S | R | R | S |
| PI 419106 | S | S | I | R | S |
| Crusader (T)[b] | S | S | S | R | S |
| WR 75-Days (T) | S | S | S | R | I |
| Tropical Delight (S) | S | S | S | S | I |

a), b): Same as Table 1. I: Immunity.

further classification according to their different reactions to *B. oleracea* subsp. *capitata* cultivars. Among the 11 of cabbage cultivars that had different resistance to TuMV, six cultivars, i.e. Shikidori, 60-Days, No. 2, Haruhikari No. 1, Hamakaze and Fukamidori were found to be useful. Based on these differential cultivars, the TuMV isolates could be divided again into three groups (Table 2).

The isolates from cabbage, broccoli and *Brassica* × *napus* Hort. infected all of the six cultivars systemically, accordingly they were designated as Group Ic. Nine isolates from Chinese cabbage were divided into two groups, consisting of 5 isolates belonging to Group Ic and 4 isolates to Group IIc. The isolates of Group IIc systemically infected the following four cabbage cultivars; Shikidori, 60-Days, No. 2 and Haruhikari No. 1. The isolates of Group IIIc could not induce any systemic infection on five cultivars with an exception of Shikidori. Twenty-two TuMV isolates from Japanese radish were divided into three groups; three isolates belonged to Group Ic, 16 to Group IIc, and three to Group IIIc. Those in Group IIIc were isolated only from Japanese radish. Out of the four turnip isolates tested, three belonged to Group IIc and one to Group Ic.

### *3) Classification of TuMV isolates based on reactions to Chinese cabbage cultivars*

The 47 TuMV isolates above were further classified on the basis of reactions to a group of cultivars of *B. campestris* subsp. *pekinensis*. Eleven cultivars of the Chinese cabbage from Japan were preliminarily tested for classification of TuMV isolates, which did not manifest any distinct differences among their reactions to those cultivars. Six Chinese cabbage cultivars, including PI 418957, PI 419105, PI 419106, Crusader, WR 75-Days and Tropical Delight used by Provvidenti[2], were also chosen for the strain differentiation in this experiment, resulting in five groups of the TuMV isolates (Table 3). The isolates of Group Ip systemically infected all the six cultivars, while those of Group IIp could not induce systemic infection only on PI 418957. The isolates of Group IVp induced chlorotic local lesions without subsequent systemic infection on five cultivars except for Tropical Deilght. Those isolates classified in Group IIIp or Group Vp could not infect PI 418957. The former infected systemically both WR 75-Days and Tropical Delight, but the latter could not.

Among the 22 isolates from Japanese radish which were divided into four groups, half of them belonged to Group Vp and seven isolates to Group IIp. Nine isolates from Chinese cabbage were classified to Groups Ip through IIIp, while a majority of the isolates from cabbage and broccoli belonged only to Group IIp. Some of the isolates in Group Ip were found in Japanese radish, Chinese cabbage, cabbage and broccoli. The TuMV isolates in Groups IVp or Vp were detected only on Japanese radish. The isolates of Group IIIp

were detected on Chinese cabbage, horseradish and turnip. However, the isolates of Group IIp were frequently found on various kinds of cruciferous crops.

*4) Strain differentiation*

Based on the combined results obtained from the above-stated classification tests on Japanese radish, cabbage and Chinese cabbage, the 47 TuMV isolates were divided into nine strain groups (Table 4). The distribution of TuMV strains among the cruciferous crops under testing is shown in Table 5. The TuMV isolates from Japanese radish are divided into six strain groups. In this connection, it is noticeable that those isolates included in strain groups F, G and I are found on Japanese radish only. On the contrary, the isolates of strain groups C and D are found not on Japanese radish but often on Chinese cabbage, cabbage and broccoli. The isolates both from cabbage and broccoli are divided into two strain groups C and D, the latter containing most of the isolates.

**Table 4. Strain differentiation based on combination of each reactions to test plants**

| Strain | Group on plant | | |
|---|---|---|---|
| | Cabbage | Japanese radish | Chinese cabbage |
| A | Ic | Ir | IIp |
| B | Ic | IIr | Ip |
| C | Ic | IIIr | Ip |
| D | Ic | IIIr | IIp |
| E | IIc | Ir | IIp |
| F | IIc | Ir | IVp |
| G | IIc | Ir | Vp |
| H | IIc | IIr | IIIp |
| I | IIIc | Ir | Vp |

## Conclusion

Provvidenti[3] classified TuMV isolates on the basis of differential host reaction to a selected group of *B. campestris* subsp. *pekinensis* cultivars, and divided the isolates into four strain groups. The TuMV isolates from Taiwan were also classified into five strain groups on the same basis of Provvidenti's strain differentials[1,2]. Walkey and Pink[6] recently demonstrated that the level of resistance in white cabbage cultivars to TuMV infection was somewhat virus-strain dependent. They indicated that some cultivars showed a high level of resistance with little or no symptoms, while others were seriously infected with a company of severe necrotic symptoms. It is well known that Japanese radish cultivars considerably vary in their responses to TuMV infection[5]. It was also reported that some cultivars such as Natsumino-wase No. 1 and Tosai were highly resistant to TuMV infection without any clear mosaic symptoms even if they were infected[4].

The present study attempted to differentiate the TuMV isolates collected from cruciferous crops in Japan on the basis of differential host reactions to a selected group of *R. sativus* cultivars, *B. oleracea* subsp. *capitata* cultivars

**Table 5. Presence of turnip mosaic virus (TuMV) strains on cruciferous plants in Japan**

| Source plant | No. of isolates collected | TuMV strain[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H | I |
| Japanese radish | 22 | 2 | 1 | 0 | 0 | 5 | 3 | 8 | 0 | 3 |
| Chinese cabbage | 9 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 4 | 0 |
| Cabbage | 7 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 0 |
| Broccoli | 3 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| *Brassica* × *napus* Hort. | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Horseradish | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Turnip | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 |

a): Number of isolates belonging to each strain group.

and *B. campestris* subsp. *pekinensis* cultivars. It is concluded that the isolates studied represent nine strain groups of TuMV. Out of these groups, isolates of the strain A and B groups induce systemic infection on various cruciferous plants. For example, the strain A isolates systemically infected all the cultivars of Japanese radish and cabbage tested. In addition, they infected a majority of the Chinese cabbage cultivars except for PI 418957, which is reported to be a multiresistant line to TuMV infection. However, any isolate of the strain A could not be isolated from field-grown cabbage and Chinese cabbage. The isolates of the strain B group that were isolated from susceptible cultivars of Japanese radish and Chinese cabbage systemically infected all the cultivars of cabbage and Chinese cabbage, but they did not induce systemic infection on one or two highly resistant cultivars of Japanese radish. On the other hand, the H strain isolates infected systemically a rather smaller number of the test plants of cabbage, Japanese radish and Chinese cabbage compared with the other strain isolates. From these results, the above two strain groups, i.e. A and B, will be useful as inoculum sources for breeding cruciferous crop cultivars with high TuMV resistance.

On the basis of host range, disease symptoms and locality, Yoshii[7] differentiated the TuMV isolates tested into two strain groups, comprising the cabbage strain group and the ordinary strain group. He indicated that the isolates of the ordinary strain had developed in Japan, while the cabbage strains had not. In the present study, the isolates of both C and D strain groups infected cabbage, broccoli and cauliflower that contain a C genome, and they occasionally produced necrotic ring spots on the outer leaves of cabbage. It seems however that those isolates are different from the cabbage strain group, since various cabbage cultivars showed severely infected mosaic symptoms with necrosis in case where they were infected by the cabbage strain. From these results, it is concluded that the isolates of both C and D strains which were identified in this study may be distinguished from the ordinary and the cabbage strain groups. They are tentatively designated as the mild cabbage strain of TuMV, accordingly.

## References


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