

クワ輪斑病,とくに病原菌Gonato Phragmium mori の生活史と分類

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Zonate Leaf Spot of Mulberry, with Special Reference to the Life-Cycle and Taxonomy of Causal Fungus *Gonatophragmium mori*

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Abstract

The zonate leaf spot fungus newly found on mulberry, *Morus alba*, in Japan since 1978 was identified as *Gonatophragmium mori* (Sawada) Deighton (= *Spondylocladium mori* Sawada). Many new host plants, being 28 species belonging to 24 genera of 16 families, were recorded through the field surveys around mulberry plantations. In the overwintering experiments with naturally or artificially infected leaves on *Morus*, *Vitis* and *Broussonetia*, development of teleomorph, the perfect state was confirmed. Ascospores serve as the primary infection source in early summer. From the pathogenicity to *Morus* and *Vitis* with ascospores and conidia, and the identity of morphological characteristics of perithecial and anamorph, conidial states, the causal fungus was re-classified as *Acrospermum viticola* Ikata apud Ikata and Hitomi (1931) having the conidial state, *Gonatophragmium mori* (Sawada) Deighton (1969).

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Key words: *Acrospermum viticola*, *Gonatophragmium mori*, zonate leaf spot of mulberry, host range, life-cycle, taxonomy.

Introduction

Zonate leaf spot disease of mulberry, *Morus alba* L., was found by Sawada in Taiwan and its causal fungus was described as *Spondylocladium mori* Sawada (Sawada 1919)¹⁰⁾. In 1969, Deighton revised the fungus as *Gonatophragmium mori* (Sawada) Deighton and combined several other species with its synonyms, such as *Ormathodium fici* Time et Olive (1948)¹³⁾, *Dactylaria cvetkovicii* Muntañola (1957)⁷⁾, etc. (Deighton 1969)²⁾. According to him, *Gonatophragmium mori* causes large zonate leaf spots of many plants belonging to more than 15 families mainly in the tropics. No record of the disease has been found in Japan.

On the other hand, a zonate leaf spot disease of grape vines, *Vitis labrusca* L., has been reported from Okayama Prefecture, Japan, by Ikata and Hitomi (1931)⁶⁾. Causal fungus of the disease was newly described as *Acrospermum viticola* Ikata with its conidial state *Spondylocladium*, to which he did not give any specific epithet. According to their inoculation tests with conidia or ascospores, the fungus could infect only American varieties (*Vitis labrusca* L.) but not European varieties (*V. vinifera* L.) of grape vine.

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No report of the disease has been found since their report.

In September of 1978, an occurrence of the zonate leaf spot disease of mulberry was found at Nishitosa, Kôchi Prefecture, Japan, and the causal fungus was identified as *Gonatophragmium mori* (Sawada) Deighton (Takahashi *et al.* 1980)¹¹⁾. Thereafter, the disease was observed in mulberry fields throughout Kôchi Prefecture and in a part of Ehime, Kumamoto, Kagoshima and Miyazaki Prefectures (Teramine *et al.* 1985)¹²⁾. The present paper deals with the host range, life cycle and taxonomy of the fungus.

Host range

Surveys to find wild plants naturally infected with *Gonatophragmium mori* were conducted around mulberry fields in Kôchi Prefecture from 1980 to 1985. In total, 29 species belonging to 24 genera of 16 families were recorded as the host plants for the fungus during the survey (Table 1, Plate I-1~6). All of them except *Morus alba* are the new hosts for the fungus.

Table 1. Host plants of *Gonatophragmium mori* found in the field of Kôchi Prefecture

Family : Scientific name (Japanese name)	Severity of the disease ^{a)}
Acanthaceae :	
<i>Justicia procumbens</i> var. <i>leucantha</i> Honda (kitunenomago)	+
Amaranthaceae :	
<i>Amaranthus viridis</i> L. (aobiyu)	+
Anacardiaceae :	
<i>Rhus verniciflua</i> Stokes (urushi)	+
Chenopodiaceae :	
<i>Chenopodium album</i> var. <i>centrorubrum</i> Makino (akaza)	+
Commelinaceae :	
<i>Commelina communis</i> L. (tuyukusa)	+
Compositae :	
<i>Adenostemma lavenia</i> (L.) Kuntze (numadaikon)	+
<i>Aster ageratoides</i> var. <i>ovatus</i> (Franch. et Savat.) Nakai (nokongiku)	+
<i>Senecio vulgaris</i> L. (noborogiku)	+
Euphorbiaceae :	
<i>Acalypha australis</i> L. (enokigusa)	+
Leguminosae :	
<i>Amphicarphaea edgeworthii</i> var. <i>japonica</i> Olier (yabumame)	+
<i>Desmodium oxyphyllum</i> DC. (nusubito-hagi)	+
<i>Pueraria lobata</i> (Willd.) Ohwi (kuzu)	++
Menispermaceae :	
<i>Stephania japonica</i> (Thunb.) Miers (hasunohakazura)	+
Moraceae :	
<i>Broussonetia kazinoki</i> Sieb. (kôzo)	+
<i>B. papyrifera</i> (L.) Vent. (kazinoki)	+++
<i>Fatoua villosa</i> (Thunb.) Nakai (kuwakusa)	+++

<i>Ficus erecta</i> Thunb. (inubiwa)	≡
<i>Humulus japonica</i> Sieb. et Zucc. (kanamugura)	+
<i>Morus alba</i> L. (karayamaguwa)	≡
<i>M. bombycis</i> Koidz. (yamaguwa)	≡
<i>M. latifolia</i> Poir. (roguwa)	≡
Polygonaceae :	
<i>Polygonum cuspidatum</i> Sieb. et Zucc. (itadori)	+
Rosaceae :	
<i>Fragaria ananassa</i> Duch. (orandaitigo)	+
Ulmaceae :	
<i>Celtis sinensis</i> var. <i>japonica</i> (Planch.) Nakai (enoki)	≡
Urticaceae :	
<i>Boehmeria nippononivea</i> Koidz. (karamushi)	≡
<i>B. spicata</i> (Thunb.) Thunb. (koakaso)	+
<i>B. tricuspidata</i> (Hance) Makino (akaso)	+
Verbenaceae :	
<i>Premna japonica</i> Miq. (hamakusagi)	+
Vitaceae :	
<i>Ampelopsis brevipedunculata</i> (Maxim.) Trautv. (nobudô)	≡

a) ≡ : Severe, ≡ : Moderate, + : Slight

On the other hand, susceptibility of certain possible host plants was tested through the artificial inoculations with conidia of isolates Gm-1 (IFO-30967) from *Morus alba* and Gm-126 from *Ampelopsis brevipedunculata*, and with conidia on mulberry leaves. Among the inoculated plants the followings were confirmed to be highly susceptible: *Morus alba* (karayamaguwa), *M. bombycis* (yamaguwa), *M. latifolia* (roguwa), *Broussonetia kazinoki* (kôzo), *B. papyrifera* (kazinoki), *Cudrania cochinchinensis* var. *gerontogea* (kagatugayu), *C. tricuspidata* (hariguwa), *Ficus carica* (itiziku), *F. erecta* (inubiwa, Plate I-7), *F. pumila* (ôitabi), *Vitis labrusca* cv. Campbell Early (Plate I-8), Delaware (American grape). Whereas, *Edgeworthia papyrifera* (mitumata) and *V. vinifera* cv. Kôsyu (European grape), *V. vinifera* × *V. labrusca* cv. Kyohô were moderately resistant.

In the inoculation tests, infections occurred every time when spore suspensions including conidia or ascospores were sprayed on the lower leaf surface. It was confirmed under scanning electron microscope that germ-tubes of the fungus penetrated through stomata (Plate II-1). Incubation period was about 20 days at 20 C.

Life cycle

From the field observations, disease occurrence and conidial production were recorded during early summer through late autumn. As listed above, host plants of the fungus are annual herbs or deciduous woody plants. Therefore, periodical examinations of the fallen diseased leaves of mulberry were carried out from December to the next June, during 1982 to 1985 to clarify the mode of overwintering and primary infection source of the fungus. Conidia of the fungus on fallen diseased leaves disappear in a little while. In the next spring, many minute thorn-like sticks, white to pale yellowish brown

in color, appear on the residua of the fallen diseased leaves. Heads of those sticks containing perithecia became dark brown to blackish in the early summer, June to July. White viscous mass of asci and ascospores are oozed out from the tip of the stick having mature perithecium under humid conditions.

From these observations and from the inoculation tests with ascospores, it was concluded that ascospores of the fungus produced on the fallen overwintered leaves really serve as the primary infection source for disease development. Overwintering and formation of teleomorph of the fungus were repeatedly confirmed in each diseased material of *Morus*, *Vitis* and *Broussonetia* inoculated with two isolates from *Morus* (Gm-1) and from *Ampelopsis* (Gm-126). Life cycle of the fungus was summarized in Figure 1.

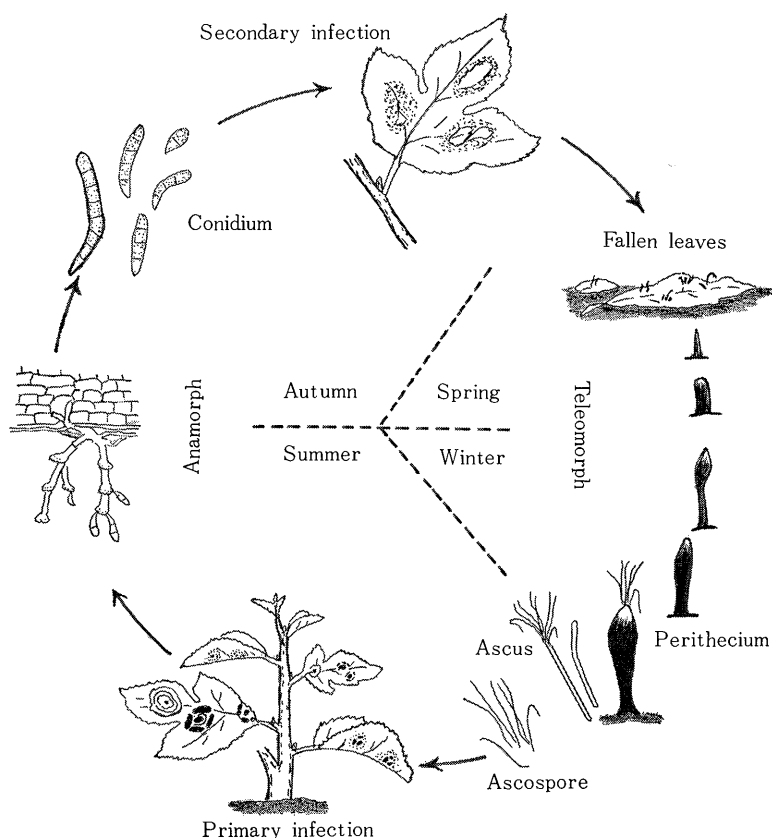


Fig. 1. Summarized life cycle of *Acrospermum viticola* Ikata.

Morphology

Anamorph: colonies effused on leaf surface, gray or olivaceous; mycelia partly superficial, immersed; conidiophores macronematous, mononematous, branched, flexuous, pale brown, thinwalled, smooth, with nodose swellings which often proliferate as short lateral branchlets, up to 500 μm long, 2–5 μm thick; conidiogenous cells polyblastic, sympodial, integrated, terminal and intercalary, cylindrical or clavate, denticulate; conidia

solitary, dry, acropleurogenous, cylindrical to clavate, often slightly curved, pale brown, thin-walled, smooth or occasionally with minute warts, $6-53 \times 2.5-7 \mu\text{m}$, with 1-8, usually 3 transverse septa (Plate II-2, 3).

Teleomorph: perithecia on the fallen overwintered leaves, at first scattered as small black dots, later as very conspicuous thorn-like appearance, free, superficial, lanceolate or clavate, somewhat compressed, black in color, $700-3,800 \mu\text{m}$ in height, $100-500 \mu\text{m}$ in diam.; asci bitunicate, hyaline, cylindrical, with round apex, $200-350 \times 2-3 \mu\text{m}$, 8-spored, without paraphyses; ascospores hyaline, very slender, long filamentous, non-septate, $110-250 \times 1-2 \mu\text{m}$ (Plate II-4-9).

Anamorph on living leaves of *Morus alba* L. (karayamaguwa): Nishitosa, Kôchi, September 25, 1978, by R. Komatsu (TNS-F-194618), Nakamura, Kôchi, September 26, 1984, by T. Teramine (TNS-F-198232), *Ampelopsis brevipedunculata* (Maxim.) Trautv. (nobudô): Umagi, Kôchi, September 18, 1983, by TT (TNS-F-198234): *Celtis sinensis* Pers. var. *japonica* (Planch.) Nakai (enoki): Kagami, Kôchi, September 26, 1984, by TT (TNS-F-198235). Other hosts are given in Table 1.

Teleomorph on fallen overwintered leaves of *Morus alba* (karayamaguwa): Tosayamada, Kôchi, June 23, 1983, by TT (TNS-F-198233).

Taxonomy

Anamorph of the fungus seems to belong to the genus *Gonatophragmium* Deighton²⁾ and teleomorph to the genus *Acrospermum* Tode ex Fries⁹⁾. Two species of *Gonatophragmium*, *G. mori* (Sawada) Deighton and *G. mangiferae* Mulder, have hitherto been known (Deighton 1969²⁾, Ellis 1971⁴⁾, 1976⁵⁾, Mulder 1973⁸⁾, Sawada 1919¹⁰⁾). Morphological characteristics of the anamorph of the present fungus are quite identical with those of these two species (Table 2). Symptoms caused by these fungi are also quite

Table 2. Dimensions of *Gonatophragmium*-state of mulberry zonate leaf spot fungus

Species	Host genus	Conidiophores(μm)	Conidia (μm)	Septa of conidia
<i>Gonatophragmium</i> sp.	<i>Morus</i>	25-500 $\times$ 2-5 (100-300 $\times$ 3-4)	8-53 $\times$ 2-7 (16-26 $\times$ 3.5-5)	1-8 a) (3)
<i>G. mori</i> (Sawada) Deighton	<i>Ampelopsis</i>	25-316 $\times$ 2-3.5	6-14 $\times$ 2.5-4.5	1-2 a)
	(many host)	180-500 $\times$ 3-4.5	9-45.5 $\times$ 3.5-5.5	1-7 b)
	<i>Morus</i>	180-270 $\times$ 3-4	13-24 $\times$ 3.5-4.5	3 c)
	<i>Ficus</i>	135-240 $\times$ 3-4	13.9-29.6 $\times$ 3.4-5.8	1-7 d)
	<i>Ficus</i>	117-240 $\times$ 3-4.5	13-30 $\times$ 4-5.5	1-5 e)
	<i>Phenax</i> , <i>Chamissoa</i> , <i>Cestrum</i>	400-500 $\times$ 3-5	19-37 $\times$ 4-6	3-5 f)
<i>G. mangiferae</i> Mulder	<i>Mangifera</i>	>100 $\times$ 3-4.5	17-36 $\times$ 4-6.8	1-3 g)
<i>Spondylocadium</i> sp.	<i>Vitis</i>	25-300 $\times$ 3-4	7.5-16.3 $\times$ 2-6	1-3 h)

a) The authors, b) Deighton (1969), c) Sawada (1919), d) Tims and Olive (1948),

e) Azmatullah Khan (1954), f) Muntañota (1957), g) Mulder (1973),

h) Ikata and Hitomi (1931)

similar to each other. Mulder (1973)⁸⁾ did not explain the basis distinguishing *Gonatophragmium mangiferae* from the older species *G. mori*. Therefore, the present fungus was identified with *Gonatophragmium mori* (Sawada) Deighton as already suggested (Takahashi *et al.* 1980)¹¹⁾.

On the other hand, four species of *Acrospermum* have been known, that is *A. compressum* Tode ex Fries, *A. gramineum* Libert, *A. gracile* Corda and *A. viticola* Ikata (Ikata and Hitomi 1931⁶⁾, Tonolo 1957¹⁴⁾). Among them, *Acrospermum gracile* clearly differs from the present fungus in its conical form of perithecial bodies and small sizes of asci. *A. compressum* and *A. gramineum* are also distinguished from the present fungus by their larger asci and ascospores, though the former species has similar lanceolate form of perithecia (Table 3). The present *Acrospermum* is quite similar to *A. viticola* in its

Table 3. Dimensions of *Acrospermum* having the lanceolate perithecia

Species	Host genus	Perithecium (mm)	Ascus (μ m)	Ascospore (μ m)
<i>Acrospermum</i> sp.	<i>Morus</i>	0.8-3.8 $\times$ 0.1-0.5	210-350 $\times$ 2.5-3	160-250 $\times$ 1-1.7 a)
	<i>Broussonetia</i> *	0.7-1.5 $\times$ 0.1-0.3	200-250 $\times$ 2-3	110-225 $\times$ 1-1.5 a)
	<i>Vitis</i> *	0.7-1.5 $\times$ 0.1-0.3	230-260 $\times$ 2-3	162-250 $\times$ 1-1.5 a)
<i>A. compressum</i> Tode ex Fries	<i>Urtica, Pisum,</i>	1-3	130-150 $\times$ 3-5	90-100 $\times$ 0.8-1 b)
	<i>Olea</i>			
	<i>Urtica</i>	2-3 $\times$ 0.2-0.4	-500 $\times$ 3-4	-500 $\times$ 0.5 c)
	<i>Quercus</i>	1.5-3 $\times$ 0.4-0.5	500-700 $\times$ 3-5	500-700 $\times$ 0.5-1 d)
	<i>Urtica</i>	3	200-500 $\times$ 4-6	100-400 $\times$ 1 e)
<i>A. viticola</i> Ikata	<i>Vitis</i>	0.9-2.1 $\times$ 0.2-0.4	225-413 $\times$ 2.5-3.5	152-280 $\times$ 1-2 f)

* Artificial inoculation of the isolate Gm-126 from *Ampelopsis brevipedunculata*.

a) The authors, b) Saccardo (1883), c) Webster (1956), d) Tonolo (1957),
e) Dennis (1968), f) Ikata and Hitomi (1931).

form of perithecial bodies, and sizes of asci and ascospores. Therefore, the present fungus was identified as *Acrospermum viticola* Ikata.

Taxonomic treatment is as follows:

***Acrospermum viticola* Ikata**, in Ikata and Hitomi, Ann. Phytopath. Soc. Japan 2 (4): 357-373, 1931.

Anamorph: *Gonatophragmium mori* (Sawada) Deighton, CMI, Mycol. Pap. 117: 13-20, 1969.

Synonyms: Refer to Deighton (1969)

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和 文 摘 要

高橋幸吉・寺峰 孜：クワ輪斑病，とくに病原菌 *Gonatophragmium mori* の生活史と分類

1978年，高橋ら（1980）が高知県で発見し，現在四国・九州地方にまん延しつつあるクワ輪斑病菌 *Gonatophragmium mori* (Sawada) Deighton 1969 の生活史を実験的ならびに自然条件下で明らかにした。本菌は夏～秋季の主に桑園周辺の調査で16科24属29種の草本および木本の落葉植物に寄生し，葉身に大きな輪帯状病斑を形成することを確かめた。このうち，カラヤマグワを除くほかの宿主は本菌の新しい宿主植物である。人工培地で形成させたクワおよびノブドウ分離菌株の分生子接種では，供試植物のクワ科4属10種，ブドウ科2属2種4品種，ジンチョウゲ科1属1種のすべてが感染した。本菌の宿主植物とその病徴，病原性，分生子世代および子のう世代の形態等分類学上の特徴から，*Gonatophragmium mori* の完全世代は *Acrospermum viticola* Ikata 1931 であると結論した。

Explanation of plates

Plate I

Figs. 1-6. Naturally diseased leaves caused by *Acrospermum viticola* Ikata.

Fig. 1 : *Morus alba* cv. Shinichinose.

Fig. 2 : *Broussonetia papyrifera*.

Fig. 3 : *Fatoua villosa*.

Fig. 4 : *Polygonum cuspidatum*.

Fig. 5 : *Celtis sinensis* var. *japonica*.

Fig. 6 : *Ampelopsis brevipedunculata*.

Figs. 7, 8. Symptoms caused by *A. viticola* isolate Gm-126 on certain inoculated test plants.

Fig. 7 : *Ficus erecta*

Fig. 8 : *Vitis labrusca* cv. Campbell Early.

Plate II

Fig. 1. Scanning electron micrograph of germ tube of *A. viticola* penetrated through stomata of *Morus alba*.

Fig. 2. Conidia from *A. viticola* isolate Gm-1, on 14 days old autoclaved mulberry leaf placed on water agar.

Fig. 3. Conidia and conidiophores of *A. viticola* on naturally infected mulberry leaves collected from Kôchi Prefecture.

Figs. 4-9. Teleomorph of *A. viticola* on naturally infected overwintered mulberry leaves.

Figs. 4, 5. : Young perithecia.

Fig. 6. : Matured perithecia.

Fig. 7. : Ascospores spouting from head of matured perithecia.

Fig. 8. : Ascus.

Fig. 9. : Ascospores.

Plate I

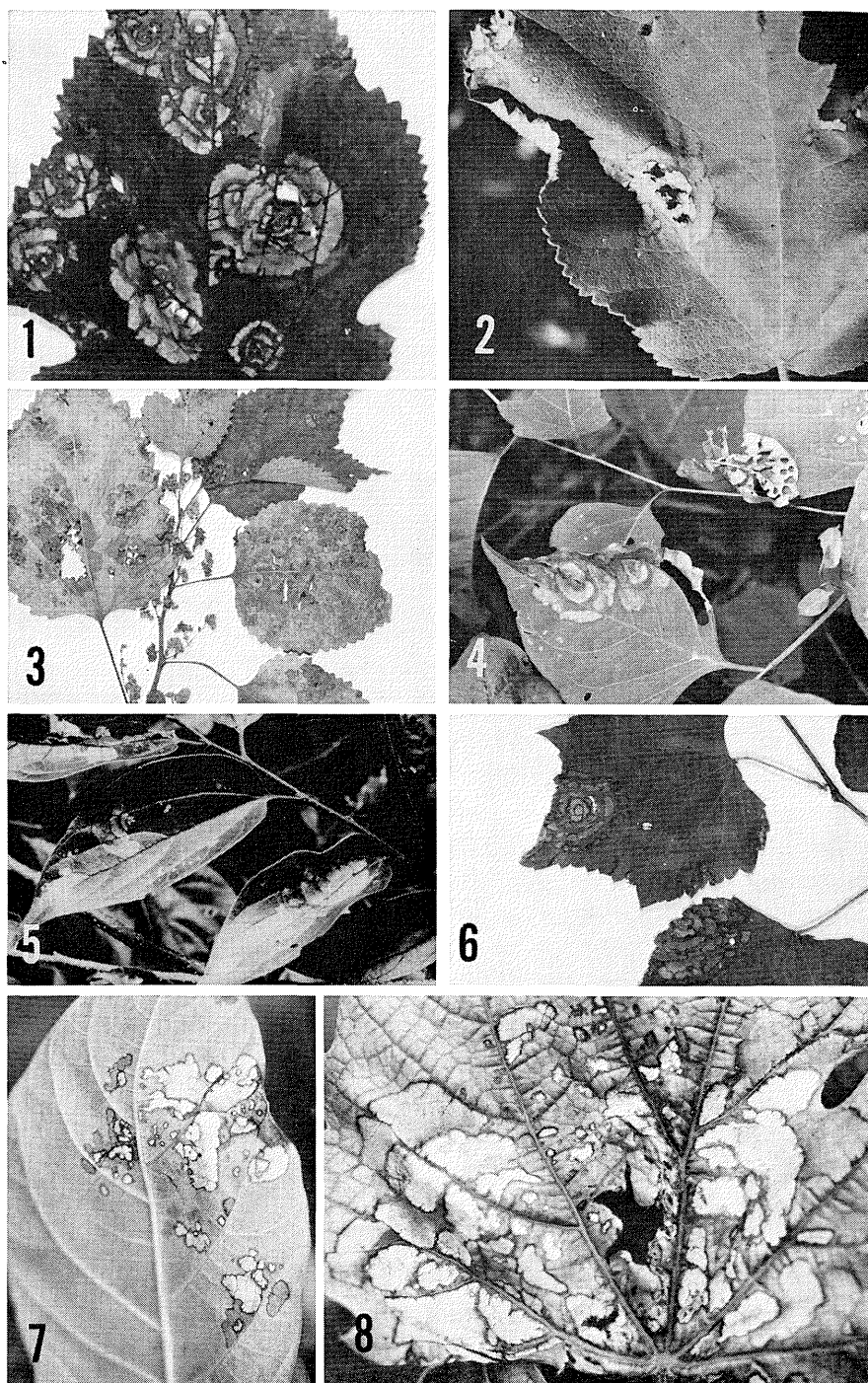


Plate II

