Life Cycle and Host Specificity of *Tanysphyrus* (*Tanysphyroides*) *major* Roelofs (Coleoptera : Curculionidae), a Possible Candidate Agent for the Biological Control of *Monochoria vaginalis* var. *plantaginea*

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물달개비의 생물학적 방제인자 물달개비바구미의 생활사 및 기주특이성

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ABSTRACT *Monochoria vaginalis* var. *plantaginea* (Pontederiaceae) is one of the most problematic weed in the rice field in Korea. *Tanysphyrus* (*Tanysphyroides*) *major* was selected as a potential biological control agent for *M. vaginalis*. Continuous rearing of *T.* (*T.*) *major* was carried out from 2006 to 2007, and its morphological characteristics and ecological characteristics were investigated. This species has a single generation per year, over-wintering as an adult stage. The emergence of adults starts in later June and last until September. These observations indicate that *T.* (*T.*) *major* takes 22±0.7 days to develop from egg to adulthood. Host specificity test showed that finally selected this species was suitable candidates for the biological control of *M. vaginalis* var. *plantaginea* since it showed negative host specificity against major 60 test crops.

Key words: biological weed control; host specificity test; *Monochoria vaginalis* var. *plantaginea*; *Tanysphyrus* (*Tanysphyroides*) *major*.

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INTRODUCTION

Monochoria vaginalis var. *plantaginea* is an aquatic summer annual herb with emersed leaves, to 50 cm tall. Propagation is by seeds. It is a serious weed of rice fields in much of eastern and southeastern Asia. A high population density of *M. vaginalis* var. *plantaginea* can reduce rice yield by up to 82%. Sixty individual plants per square meter caused a reduction in rice yield of up to 35%. It is well known that has become a problematic weeds in Korean rice fields. With its ability to germinate at any season, it is hard to control this weed by herbicide application alone. Also it is become known as the herbicide resistance weed.

Alternative ways to control this weed was studied since 2006, and the potential insect agent for the biological control was selected for further tests.

Tanysphyrus (*Tanysphyroides*) *major* is first recorded insect from Korea (Park *et al.*, 2006, 2007a, b).

This experiment was conducted to get basic data for biological control of *M. vaginalis* var. *plantaginea.* Basic life cycle of the weevil were observed for the consecutive generations to find out the continuous rearing method of weevil population. Also the preliminary host specificity test showed a promising result of this species as a biological control agent of *M. vaginalis* var. *plantaginea.*

MATERIALS AND METHODS

Field observations

Field sites of *Monochoria vaginalis* var. *plantaginea* in Korea were surveyed during the period from June 2006 to October 2007 for the presence of damage from weevil. Other *Monochoria* species - *M. korsakowii* - were also surveyed at a number of localities at the same time. Other species of Pontederiaceae, including the above-mentioned species, growing in association with *Monochoria* spp. in rice field (i.e., in link canal), were also examined for the presence of *T.* (*T.*) *major*.

Life cycle

Stems containing *T.* (*T.*) *major* larvae were collected at Gyeonggi and Gangwon provinces of South Korea. Infested stems were placed in emergence cages (35 cm×35 cm×30 cm) in the quarantine laboratory. Newly emerged adults were removed and placed in large cages (42 cm×32 cm×30 cm) on potted *M. vaginalis* var. *plantaginea* plants in the laboratory under natural light, at temperatures ranging from 25 to 28℃.

The eggs laid in stems by female weevil were transferred to petri dishes (∅100×40 mm), with circular paper sheets spread over their the bottom, for an egg development study. The weevil larvae obtained were used to determine larval stages and were reared singly in petri dishes (∅100×40 mm) and provided with fresh stems. Stems were changed every one day. The observations pertaining to obvious morphological changes and molting were recorded. The same procedure for the pupal period was applied.

All experiments were conducted in a quarantine laboratory under natural light, with temperatures ranging from 25 to 28℃ with a 12L : 12D cycle and 40～60% relative humidity. Observations were recorded daily on *T.* (*T.*) *major***.** Each treatment had 20 replicates.

Host specificity Tests (No-Choice and Choice Test)

Host choice is entirely determined by adults *T.* (*T.*) *major* because larval development is completed within the plant chosen by the female. Two types

Table 1. Plants used to evaluate the host specificity of *Tanysphyrus* (*Tanysphyroides*) *major*.

Taxonomic grouping[a]	Common name[b]	Habitat and uses[a]
Potamogetonaceae		
Potamogeton distinctus	Round leaf pondweed	Wetland and rice field
Potamogeton octandrus		Wetland, canal bank and rice field
Potamogeton alpinus		Wetland, pond
Potamogeton perfoliatus		Wetland, pond
Ruppia maritima	Wigeon grass	Brackish water zone
Zannichellia palustris var. *indica*		Lake and brackish water zone
Potamogeton crispus	Curled pondweed	Pond
Lemnaceae		
Spirodela polyrhiza	Giant duckweed	Wetland and rice field
Lemna paucicostata	Duckweed	Wetland and rice field : medicine and enjoyment
Wolffia arrhiza	Rootless duckweed	Rice field
Haloragaceae		
Myriophyllum verticillatum	Milfoil, water persicaria	Wetland, pond and rice field
Juncaceae		
Juncus gracillimus		Wetland
Juncus effusus var. *decipiens*	Soft rush	Wetland and rice field : medicine, enjoyment and industrial
Juncus brachyspathus		Mountain wetland
Marsileaceae		
Marsilea quadrifolia	Water clover, nardo	Rice field and pond : food and enjoyment
Commelinaceae		
Commelina communis	Dayflower	Farmland, field, orchard and waterside : medicine
Polygonaceae		
Persicaria amphibia	Water smartweed	Wetland, rice field and waterside
Polygonum thunbergii		Wetland, rice field and waterside : medicine
Trapaceae		
Trapa japonica	Water chestnut	Wetland, rice field and pond : food and medicine
Pontederiaceae		
Monochoria korsakowii	Korsakow monochoria	Rice field : enjoyment
Monochoria vaginalis var. *plantaginea*	Monochoria	Rice field : enjoyment
Eichhornia crassipes	Waterhyacinth	Wetland and lake : enjoyment
Ranunculaceae		
Ranunculus kazusensis	Chyousenbaikamo	Wetland and rice field
Ranunculus sceleratus	Celery leaf butter	Wetland and rice field
Gramineae		
Leersia japonica		Wetland and around a rice field
Leersia sayanuka	Rice cut grass	Wetland and cultivated land
Zizania latifolia	Manchurian wild rice	Wetland and rice field : food and medicine
Phragmites australis	Common reed	Wetlanf and pond
Phragmites japonica		Wetland and watercourse
Oryza sativa	Rice	Rice field : cultivated food

Table 1. Continued.

Taxonomic grouping[a]	Common name[b]	Habitat and uses[a]
Typhaceae		
Typha orientalis	Common cattail	Wetland and pond
Typha anguststa	Southern cattail	Wetland and pond
Iridaceae		
Iris pseudacorus	Yellow lris	Wetland and pond : enjoyment
Cyperaceae		
Eleocharis kuroguwai	Water chesnut	Rice field
Eleocharis acicularis	Slender spikeruch	Rice field and wetland
Eleocharis congesta	Spikerush	Rice field, field and pond : enjoyment
Eleocharis mamillata var. *cyclocarpa*	Creeping spikerush	Wetland
Scirpus planiculmis	Sea clubrush	Wetland and reclaimed land
Scirpus fluviatilis	River bulrush	Wetland, rice field and reclaimed land
Scirpus juncoides	Bulrush	Wetland and rice field
Scirpus nipponicus		Rice field
Scirpus tabernaemontani		Rice field and pond
Umbelliferae		
Oenanthe javanica	Dropwort	Rice field and wetland : cultivated food and medicine
Salviniaceae		
Salvinia auriculata	Karibaweed	Rice field and wetland
Nymphaeaceae		
Brasenia schreberi	Purple wendock	Wetland and pond
Nuphar japonicum		Wetland and pond : enjoyment and medicine
Nymphaea tetragona	Water lily	Wetland and pond : enjoyment and medicine
Nymphaea minima		Wetland and pond : enjoyment
Nelumbo nucifera	Lotus, east indian lotus	Wetland and pond : cultivated food, enjoyment and medicine
Gentianaceae		
Nymphoides peltata	Yellow water gentian	Wetland and pond
Nymphoides indica	Water gentian	Wetland and pond
Araceae		
Acorus calamus var. *angustatus*	Iris, sweet flag, calamus	Wetland and pond
Colocasia antiquorum var. *esculenta*	Elephant's ear	Wetland : cultivated food
Alismataceae		
Alisma canaliculatum	Water plantain	Wetland and rice field
Alisma orientale	Oriental water plantain	Wetland and rice field
Caldesia parnassifolia		Wetland and rice field
Sagittaria pygmaea	Arrowhead	Rice field
Sagittaria aginashi		Rice field
Sagittaria trifolia		Rice field
Scrophulariaceae		
Lindernia procumbens	False pimpernel	Rice field and field

[a]Taxonomy, habitat and uses from Yang *et.al.* (2004), UADA-NRCS (2202) and http : // www.nature.go.kr
[b]Common names from the Yoon (1994).

of host-specificity tests were undertaken with adult *T.* (*T.*) *major*, short-term with no-choice and choice tests. The aim of the short term with no-choice tests was to determine the degree to which adults would feed and lay eggs in test plants and also to examine the survival of early instar larvae on plants where eggs were laid. In the choice tests, adult *T.* (*T.*) *major* were able to choose between the target and test plant species for adult feeding and oviposition. In all tests, *M. vaginalis* var. *plantaginea*, the main target weed, was used as the control. The plant test list of 60 species was compiled to achieve representation of the water plants in Korea. Leaves in a petri dish (∅100×40 mm) of a suitable size, lined with paper. Unfed adults were placed on the leaf. The petri dishes were sealed with wax tape to prevent desiccation of the plant material and escape of the adults. The adults were observed daily for survival and signs of feeding. Each replicate consisted of one leaf (or part if leaves were very large, or more than one if leaves were small) with six adults. Each trial was replicated three times.

For each choice test, six weevils were released in petri dish (∅150×40 mm) containing moist filter paper and leaves or sections of leaves from *M. vaginalis* var. *plantaginea* and one plant species. The same methods were used for no-choice test. Leaves were scored positive or negative for feeding after 7-10 days. Adults choice tests were not replicated.

RESULTS AND DISCUSSIONS

Field observations

Weevil larvae and/or adults was collected in the rice field or in link canal on *Monochoria* spp. Of the native species surveyed in the rice field or in link canal, *T.* (*T.*) *major* was found only on *Monochoria* spp.

Life cycle

Egg (Fig. 1A). Eggs were whitish, ovoid and measure 0.6 mm. They were laid singly in holes excavated by rostrum of the female in the stem of *M. vaginalis*. The eggs hatched after 4～5 days. The egg period was 4.3±0.5 days (Fig. 2).

Larva (Fig. 1B-D). Larvae were uniformly yellowish with a light brown head capsule. They were molted two times with instars closely resembling each other. The presence of exuviae and head capsule size was used to differentiate between instars. The larvae in the stem tunneled towards the bottom part of the plant. As the plants grows, leaves containing feeding larvae were displaced towards the outer edge of the rosette (Table 3). Consequently, last instar larvae often occur in older leaves from where they sometimes migrate back into the younger leaves. Fig. 2 depicts that the larval period (days) for first, second and third instars of *T.* (*T.*) *major* were recorded 3.2±0.4, 3.4±0.5 and 3.4±0.5, respectively.

Pupa (Fig. 1E). The mature larva makes a cavity into stem or root to pupate (Table 3). Fig. 2 shows that the pupal period was 8.9±0.7 days. Adult (Fig. 1F). Adults emerged from the pupal skin, by splitting it transversely and longitudinally on the ecdysial sutures in the thoracic region. The newly emerged beetles were white in color for first few minutes then slowly changed through brown to dark gray.

This species has a single generation per year, overwintering as an adults inside soil. The adults appear during the last week of June to the later September. The oviposition period starts in early July. These observations indicate that *T.* (*T.*) *major* takes 22.0±0.7 days to develop from egg to adulthood. The distribution of the species in Korea, Japan, China, Sakhalin, KunashiriI. and Java.

Table 2. Host specificity of *Tanysphyrus* (*Tanysphyroides*) *major* as indicated by choice and no-choice tests conducted in Korea.

Test Plants	Adult[a]			
	No-choice		Choice	
	F	O	F	O
Potamogetonaceae				
Potamogeton distinctus	-	-	-	-
Potamogeton octandrus	-	-	-	-
Potamogeton alpinus	-	-	-	-
Potamogeton perfoliatus	-	-	-	-
Ruppia rostellata	-	-	-	-
Zannichellia palustris var. *indica*	-	-	-	-
Potamogeton crispus	-	-	-	-
Lemnaceae				
Spirodela polyrhiza	+++	-	+	-
Lemna paucicostata	+++	-	+	-
Wolffia arrhiza	-	-	-	-
Haloragaceae				
Myriophyllum verticillatum	-	-	-	-
Juncaceae				
Juncus gracillimus	-	-	-	-
Juncus effusus var. *decipiens*	-	-	-	-
Juncus brachyspathus	-	-	-	-
Marsileaceae				
Marsilea quadrifolia				
Commelinaceae				
Commelina communis	-	-	-	-
Polygonaceae				
Persicaria amphibia	-	-	-	-
Polygonum thunbergii	-	-	-	-
Trapaceae				
Trapa japonica	-	-	-	-
Pontederiaceae				
Monochoria korsakowii	+++	++	++	+
Monochoria vaginalis var. *plantaginea*	++++	++++	++++	++++
Eichhornia crassipes	+++	-	+	-
Ranunculaceae				
Ranunculus kazusensis	-	-	-	-
Ranunculus sceleratus	-	-	-	-
Gramineae				
Leersia japonica	-	-	-	-
Leersia sayanuka	-	-	-	-
Zizania latifolia	-	-	-	-
Phragmites australis	-	-	-	-
Phragmites japonica	-	-	-	-
Oryza sativa	-	-	-	-

Table 2. Continued.

Test Plants	Adult[a]			
	No-choice		Choice	
	F	O	F	O
Typhaceae				
Typha orientalis	-	-	-	-
Typha angustifolia	-	-	-	-
Iridaceae				
Iris pseudacorus	-	-	-	-
Cyperaceae				
Eleocharis kuroguwai	-	-	-	-
Eleocharis acicularis	-	-	-	-
Eleocharis congesta	-	-	-	-
Eleocharis mamillata var. *cyclocarpa*	-	-	-	-
Scirpus planiculmis	-	-	-	-
Scirpus fluviatilis	-	-	-	-
Scirpus juncoide	-	-	-	-
Scirpus nipponicus	-	-	-	-
Scirpus tabernaemontani	-	-	-	-
Umbelliferae				
Oenanthe javanica	-	-	-	-
Salviniaceae				
Salvinia natans	-	-	-	-
Nymphaeaceae				
Brasenia schreberi	-	-	-	-
Nuphar japonicum	-	-	-	-
Nymphaea tetragona var. angusta	-	-	-	-
Nymphaea minima	-	-	-	-
Nelumbo nucifera	-	-	-	-
Gentianaceae				
Nymphoides peltata	-	-	-	-
Nymphoides indica	-	-	-	-
Araceae				
Acorus calamus var. *angustatus*	-	-	-	-
Colocasia antiquorum var. *esculenta*	-	-	-	-
Alismataceae				
Alisma canaliculatum	-	-	-	
Alisma orientale	-	-	-	
Caldesia parnassifolia	-	-	-	
Sagittaria pygmaea	-	-	-	
Sagittaria aginashi	-	-	-	
Sagittaria trifolia	-	-	-	
Scrophulariaceae				
Lindernia procumbens	-	-	-	-

[a]No-choice and choice teats conducted with six adults *T.* (*T.*) *major* and detached leaves in petri dishes. F, feeding; O, oviposition. Results scored as either "+" for positive or "-" for negative.

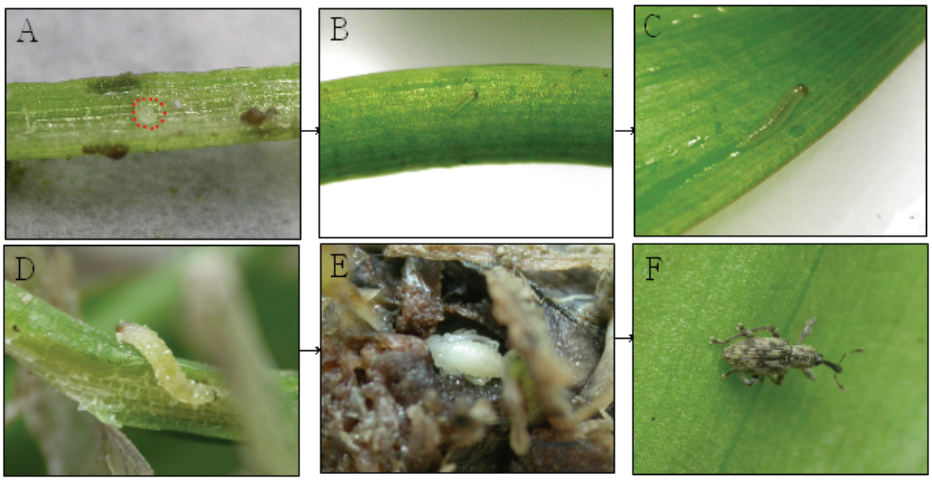

Fig. 1. Life cycle of *Tanysphyrus* (*Tanysphyroides*) *major*.
A. egg; B. 1st instar larva; C. 2nd instar larva;
D. 3rd instar larva; E. pupa; F. adult.

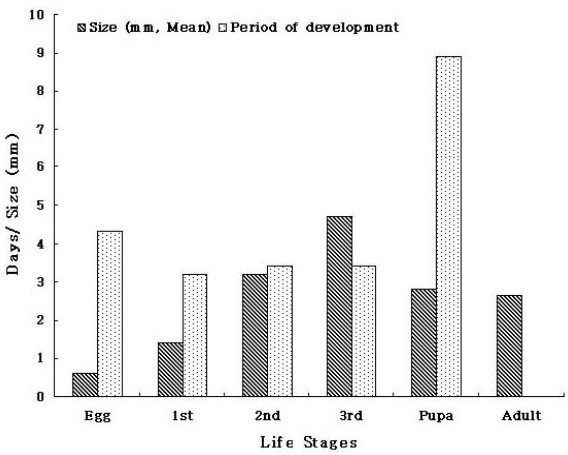

Fig. 2. Morphological characters and period of development of *Tanysphyrus* (*Tanysphyroides*) *major*.

Table 3. Damage region of *Monochoria vaginalis* by developmental stage of *Tanysphyrus* (*Tanysphyroides*) *major*.

Taxa	Damage region
Egg	Stem
1st instar larva	Stem
2nd instar larva	Leaf, Stem, Root
3rd instar larva	Leaf, Stem, Root, Seed
Pupa	Stem, Root
Adult	Leaf, Stem, Flower, Seed

Host-specificity Tests

Feeding by adult *T.* (*T.*) *major* was insignificant, but was greatest on plants from the genus *Monochoria* with negligible or no feeding on other species (Table 1, 2). Larvae were only able to feed and develop in plants of *Monochoria* spp. Minimal adult feeding occurred on only a plant species other than *Monochoria* spp. (Table 2). Although adults lived for several days on some other plant species, they were not oviposition.

요 약

물달개비는 한국의 논에서 문제되는 난방제 잡초 중의 하나이다. 물달개비의 생물학적 방제 인자로 물달개비바구미를 선발하였다. 생물학적 방제에 이용하기 위해 2006년과 2007년 계대사육을 실시하여 형태적, 생태적 특징을 조사하였다. 이 종은 1년에 한세대만 경과하며 성충으로 월동하고, 성충은 6월 하순부터 9월 하순까지 발생한다. 물달개비바구미는 알에서 성충까지 22±0.7일이 소요된다. 주요 농작물과 수생식물 60종을 대상으로 기주특이성을 조사 결과 물달개비의 생물학적 방제 곤충으로서의 가능성을 보였다.

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