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Evolutionary Pattern and Taxonomy of Psyllid (Homoptera: Psylloidea) 1. On the Subfamily Spondyliaspidinae

Hee Cheon Park* and Keith R. Taylor[1]
(Department of Biology, Kyungpook National University, Daegu 702-701, Korea;
[1]Department of Entomology, ANIC, CSIRO, Canberra, Australia)

ABSTRACT

Burckhardt (1987) combined Aphalaridae and Spondyliaspididae into the Psyllidae, as there were no chracter sets which had clearly defined these three families. During the analysis on the character evolution of the psyllids from the world including Australia, there were a few different results for the taxonomy of the Spondyliaspidinae. 52 species and 28 genera in the Australian native psyllids were dissected to examine the taxonomic position of the subfamily Spondyliaspidinae. All of the dissected psyllids in the subfamily Spondyliaspidinae had one follicle in the male testes, but the subfamilies of the Psyllidae except Spondyliaspidinae were having two or more follicles.

By the characteristics with living on the *Eucalyptus* host plants recently evolved, having just one follicle which clearly defined it from other families and experienced an explosive specific diversification in the Gondwana region, it is reasonable to separate the subfamily Spondyliaspidinae from the family Psyllidae with two or more follicles.

Key words: Taxonomy, Follicle numbers, Male testes, Psyllidae, Spondyliaspidinae, Homoptera, Australia

* To whom correspondence should be addressed
Tel: 82-53-950-5351, Fax: 82-53-953-3066, E-mail: heecheon@knu.ac.kr

INTRODUCTION

Psyllids include about 2,500-3,000 species in the world, which suck sap from the plant phloem and transfer viruses to the host plants, making galls and lerps on the leaves and stems (Carver M., 1987, 1991).

During the last decade, psyllid specialists tried to develop a stable higher taxonomic system about the superfamily Psylloidea, they used morphological characters of the psyllids mostly from Northern hemisphere. There is still confusion and controversy about it.

Our taxonomic concern in this work focuses on the taxonomical position of the subfamily Spondyliaspidinae, occuring mostly on the Australian native plants on the genus *Eucalyptus* (Myrtaceae). This subfamily was merged in the family Psyllidae, along with the Aphalarinae by Burchkhard (1987).

White and Hodkinson (1985) tried a taxonomic revision based on the nymphal and morphological characters extracted from psyllid materials over the world including Subtropics and Southern hemisphere. They used variable numerical methods including the phenetic and cladistic methods for the taxonomic revision of this superfamily.

White and Hodkinson (1985) suggested that the ancestor of this group had originated in the Gondwana land, fed on Rutales, and evolved about 90-125 million years ago.

They insisted that Spondyliaspididae was closely related to Aphalaridae and Psyllidae, and after that, Burchkharsdt (1987) had combined the Spondyliaspididae and Aphalaridae into the family Psyllidae (Table 1).

It was used the number of follicles in the male testes of the psyllids to define this subfamily as a key character.

Table 1. The comparison between the taxonomic systems about the superfamily Psylloidea, especially the classification of Psyllidae and Spondyliaspidinae suggested by Burckhardt (1987)

White and Hodkinson (1985)	Burckhardt (1987)	Park and Taylor
Aphalaridae	Psyllidae = Aphalaridae	Spondyliaspididae
	=Spondyliaspididae	Psyllidae
Spondyliaspididae	Aphalarinae	Aphalarinae
Psyllidae	Rhinocolinae	(except Rhinocorinae)
Calophyidae	Apahlaroidinae	(Except other families)
Phacopteronidae	Diaphorinae	
Homotomidae	Aciziinae	
Carsidaridae	Ciriacraminae	
Triozidae	Psyllinae	
	Pachipsyllinae (1991)	
	Spondyliaspidinae	
	Calophyiidae	
	Triozidae	

MATERIALS AND METHODS

Living psyllids collected from the field were placed in the Carnoy's solution (Ethanol 3: Glacial acetic acid 1) or in 95% alcohol solution. Most of the Australian psyllid materials came from the Department of Entomology, ANIC, CSIRO, Canberra (Taylor deposition), and some specimens were from KNU (Park collection). The material dissection was conducted at the ANIC, CSIRO in Canberra, Australia.

Anatomical dissections of the male psyllids, following the removal of the abdomen, were done under the stereoscopic microscope and phase contrast microscope. And the specimen on the slide was stained with 2% lacto-aceto-orcein or aceto carmin. The result of the dissection was filmed using a microscopic camera to show the features of the extracted follicle.

RESULTS AND DISCUSSION

Presently, Australian psyllids include 276 species, 41 genera and 5 families, according to recent psyllid research (Taylor, 1996 unpublished data). We have examined 52 species belonging to 28 genera and 5 families, most of which were Australian proper psyllids and including nearly half of all Australian psyllid genera.

Burkhardt (1987) proposed a new and revised taxonomic system after treating psyllid materials including South America and Australia from the worldwide. Especially, he merged Spondyliaspididae and Aphalaridae into the Psyllidae with having a similar wing vein shape and aedeagus and on account of not to define these families in the external and morphological characters (Table 1).

However, by our long time study about the character evolution of the Psylloidea from Northern

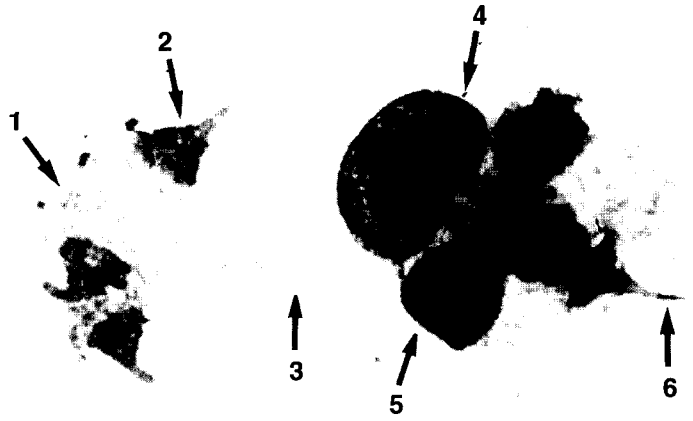

Fig. 1. Photogarph of the male reproductive system of psyllid stained in aceto carmin after dissection. 1, Testes; 2, Follicle; 3, Sperm duct; 4, Seminal vesicle; 5, Accessory gland; 6, Ejaculatory duct

Table 2. The numbers of genera dissected in the Australian native psyllids

Family	No. of genus (No. of dissected)	%
Spondyliaspidinae	26 (21)	63.4
Psyllidae	6 (3)	14.7
Carsidaridae	5 (2)	12.2
Phacopteronidae	1 (0)	2.4
Triozidae	3 (2)	7.3
Total	41 (28)	100.0

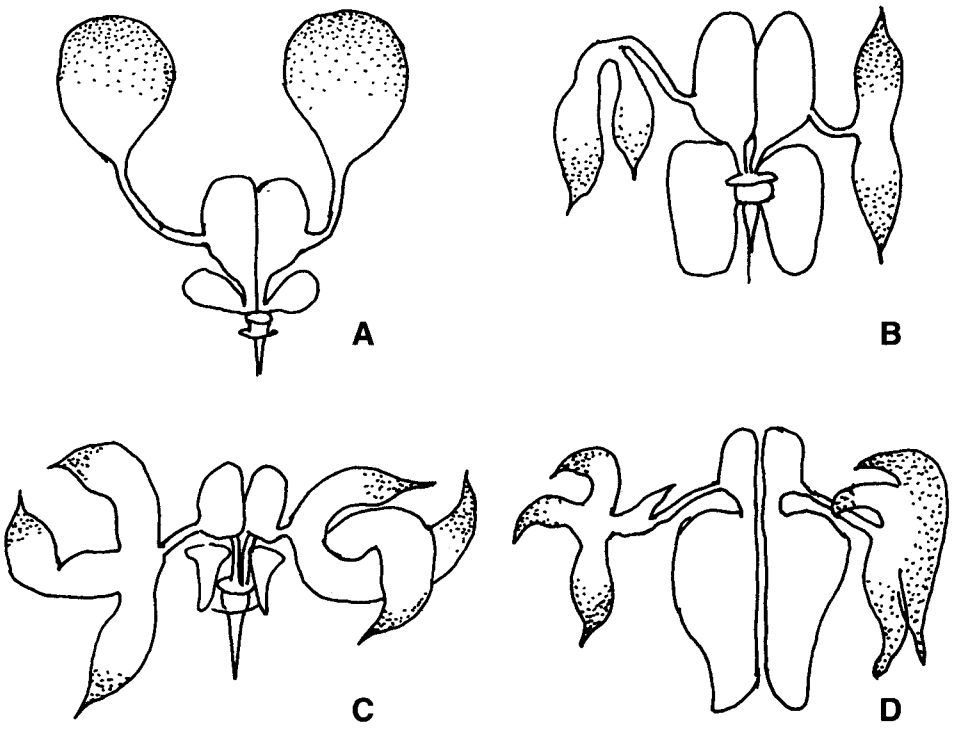

Fig. 2. The variations of follicle numbers of the male testes in the Australian psyllids. A, One follicle; B, Two follicles; C, Three follicles; D, Four follicles

hemisphere to Southern hemisphere, we found a few different results on the taxonomic characters. Especially in the case of the psyllids from Australia and Southern hemisphere, there showed a very different pattern in the character evolution.

First of all, we started a character analysis about the male testes, like a follicle and chromosome, with the Australian psyllid materials, which were a lot of native psyllid species belonging to the Spondyliaspinae. We could comment chromosome characters later.

The Australian psyllids *sensu* White and Hodkinson (1985) include 63.4% in the Spondyliaspidi-

Table 3. The genera, families and follicle numbers of the Australian native psyllids

	Genera	Family	Follicle no.
1.	*Acizzia* Heslop-Harrison	Psyllidae	4
2.	*Brachypsylla* Frogatt	Psyllidae	
3.	*Cacopsylla* Geoffroy	Psyllidae	
4.	*Ciriacremum* Enderlein	Psyllidae	
5.	*Epipsylla*	Psyllidae	1
6.	*Heteropsylla*	Psyllidae	2
7.	*Agelaeopsylla* Taylor	Spondyliaspididae	
8.	*Anoeconeossa* Taylor	Spondyliaspididae	1
9.	*Anomalopsylla* Tuthill	Spondyliaspididae	1
10.	*Australopsylla* Tuthill	Spondyliaspididae	1
11.	*Blastopsylla* Taylor	Spondyliaspididae	1
12.	*Blepharocosta* Taylor	Spondyliaspididae	
13.	*Cardiaspina* Crawford	Spondyliaspididae	1
14.	*Cometopsylla* Frogatt	Spondyliaspididae	1
15.	*Creiis* Scott	Spondyliaspididae	
16.	*Cryptoneossa*	Spondyliaspididae	1
17.	*Ctenarytaina* Ferris and Klyver	Spondyliaspididae	1
18.	*Dasypsylla* Frogatt	Spondyliaspididae	1
19.	*Eriopsylla* Frogatt	Spondyliaspididae	1
20.	*Eucalyptolyma* Frogatt	Spondyliaspididae	
21.	*Geijerolyma* Frogatt	Spondyliaspididae	
22.	*Glycaspis* Taylor	Spondyliaspididae	1
23.	*Hyalinaspis* Taylor	Spondyliaspididae	1
24.	*Kenmooreana* Taylor	Spondyliaspididae	1
25.	*Leptospermonastes* Taylor	Spondyliaspididae	1
26.	*Pachypsylla* Riley	Spondyliaspididae	
27.	*Phellopsylla* Taylor	Spondyliaspididae	1
28.	*Phyllolyma* Scott	Spondyliaspididae	1
29.	*Platyobria* Taylor	Spondyliaspididae	1
30.	*Scenitopsylla* Tuthill and Taylor	Spondyliaspididae	1
31.	*Spondyliaspis* Signoret	Spondyliaspididae	1
32.	*Syncarpiolyma* Frogatt	Spondyliaspididae	1
33.	*Aconopsylla* Tuthill and Taylor	Carsidaridae	
34.	*Carsidara* Walker	Carsidaridae	
35.	*Mesohomotoma* Kuwayama	Carsidaridae	
36.	*Mycopsylla* Frogatt	Carsidaridae	1
37.	*Protyora* Kieffer	Carsidaridae	1
38.	*Cecidopsylla* Kieffer	Phacopteronidae	
39.	*Aacanthocnema* Tuthill and Taylor	Triozidae	2
40.	*Schetotrioza* Tuthill and Taylor	Triozidae	1
41.	*Trioza* Feorster	Triozidae	2
	Total 41 genera		

dae, 14.7% in the Psyllidae, 12.2% in the Carsidaridae, 2.4% in the Phacopteronidae, and 7.3 % in Triozidae in the generic numbers (Table 2), and the family Spondyliaspididae included about 170 species (61.6%) of the 276 known species and 26 of the 41 genera from Australia (Taylor, 1996).

This family was very well adapted to the Australian continental flora, and especially the main native host plants, *Eucalyptus* spp. (Osborne, 1990).

Among the psyllid families living in the Australian region, the family Spondyliaspididae was an explosively diversified group (Yang and Mitter, 1993).

We have dissected 28 genera of 41 psyllid genera occuring in Australia, and we found that all of the 21 genera dissected from the Australian native family, especially, the Spondyliaspidinae, had exclusively one follicle in each side of the male testes (Fig. 2).

Although a few genera of the Carsidaridae and Rhinocorinae of the Aphararidae had one follicle, most of genera in the families except Spondyliaspidinae showed two to four follicles in each side of the testes. it need more detail taxonomical analysis on the genera of the Rhinocorinae in the Psyllidae *sensu* Burchhardt (1987) and Carsidaridae having one follicle.

Glowacka *et al.* (1995) have presented the follicle numbers and chromosome features of about 132 species of psyllids. There were two groups, the first few group having one follicle in the Carsidaridae, and the Rhinocorinae and genus *Ctenalytaina* in the Euphyllurinae of the Aphalaridae, presently, genus *Ctenalytaina* belongs to the Spondyliaspidinae. Carsidaridae (Yen, 1980) with one follicle originated in the Gondwana region, and the Rhinocorinae maybe had come from the Mediterranean area not far from Gondwana land. The second group had two or more follicles and included most of Laurasian elements of the psyllids. Right now, two follicles were found in most psyllid species in the world as well as most families, except a few groups such as the Spondyliaspidinae.

Glowacka *et al.* (1995) did not give an explanation for the origin of the single follicle character. They thought that two follicles in the testes of the psyllids was derived character in the polarity and that one follicle would be a primitive character. Maybe, their suggestion, which the character with two follicle would be a synapomorphic character in the psyllid could be applicable in the case of the

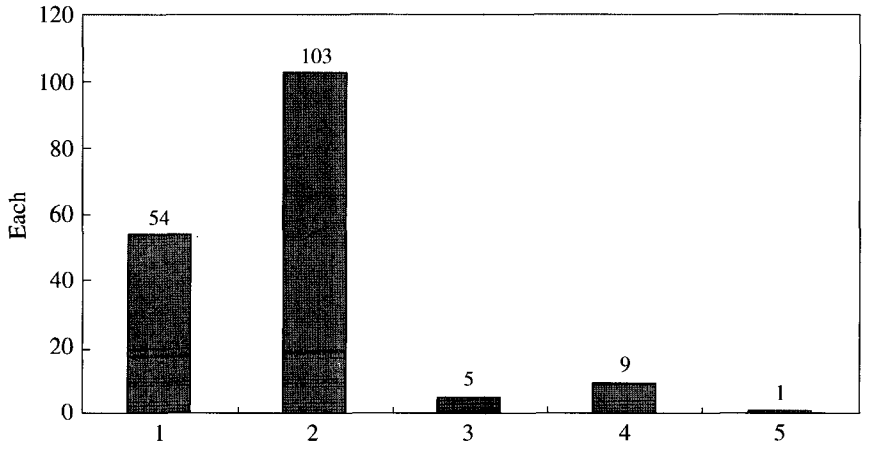

Fig. 3. Follicle numbers in the male testes of the Psyllids.

Laurasian psyllids (Fig. 3). We thought they did not treat a lot of Gondwana psyllid materials from Australia, Africa and South America.

Among the 172 species examined including the Gondwana species with an Australo-African psyllid dissected in this work for the polarity analysis and biogeographical distribution of the follicle number in the character evolution of psyllid, two or more follicles were found in the Psyllidae and Aphalaridae containing 103 species, which shows a primitive character state.

And one follicle in the male testes of the psyllid was found in all of the species belonging to the Spondyliaspidinae and few species of two genera in the Carsidaridae from Australia and it seemed a derived character state originated by the recent diversification on the Australian native plants.

The anatomical result on the male testes of the Spondyliaspidinae showed that the family Psyllidae did not appear to keep the definition of the Psyllidae *sensu* Burchhardt (1987), and this should be divided into the Spondyliaspididae and Psyllidae.

We could summarize that the one follicle character of the male testes among the psyllids was recently derived character state originated in the Gondwana region, in particularly the Australia, and this character has experienced an explosive evolution on the Australian native host plants, and recently this character is going on dispersing from the Southern hemisphere to the Northern hemishere.

With these three important characters of the Spondyliaspidinae, which are arising on the native host plants in the Australia, having one follicle clearly defined this group from the Psyllidae and being of the main distribution in the Gondwana region, it is reasonable to seperate the subfamily Spondyliaspidinae with one follicle from the family Psyllidae *sensu* Burchhardt (1987) with two or more follicles and re-erect this psyllid group to the family position in the Psylloidea.

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나무이의 계통분류 및 진화적 패턴 (나무이상과: 동시목)
1. 호주나무이아과를 중심으로

박 희 천 · Keith L. Taylor[1]
(경북대학교 생물학과; [1]호주 CSIRO 국립곤충연구센터)

요 약

Burckhardt (1987)는 분명하게 과들을 구분해 주는 형질이 없기 때문에 날개 및 생식기의 기본구조가 비슷한 Aphalaridae (모나무이과)와 Spondyliaspididae (호주나무이과)를 Psyllidae (나무이과)의 아과로 통합하였다. 나무이를 대상으로 형질의 기울기와 진화패턴을 분석하기 위해, 호주를 포함한 전세계의 나무이를 분석하면서 호주나무이아과에 관하여 Burckhardt와는 다른 결과를 얻었다.

특히 호주나무이아과에 대한 분류학적 위치를 검토하기 위해 호주전역에서 채집된 28속 52종의 호주산나무이의 정소를 해부한 결과, 나무이의 정소 소포수 형질은 변이가 1-4개까지 나타났으며, 특히 Spondyliaspidinae (호주나무이아과)는 정소소포수가 공통적으로 1개였다.

호주나무이아과가 최근 신생대에 진화한 *Eucalyptus* 식물군을 기주로 하고, Gondwana 지역에서 폭발적인 종분화를 하였으며, 이 아과의 속 과 종 모두가 1개의 정소 소포수를 공통적으로 가진다는 점에서 호주나무이아과는 나무이과에서 독립된 호주나무이과로 분리하여야 한다.